INTERNATIONAL

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

This standard is issued under the fixed designation C660; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 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 Terminology C286). 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 porcelain enameling. All of the listed recommendations are based on experiences with gray iron casting and enameling.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

A48/A48M Specification for Gray Iron Castings

A74 Specification for Cast Iron Soil Pipe and Fittings

A126 Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings

A278/A278M Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650 °F (350 °C)

C286 Terminology Relating to Porcelain Enamel and Ceramic-Metal Systems

## 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

[1] These practices are under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and are the direct responsibility of Subcommittee B08.12 on Materials for Porcelain Enamel and Ceramic-Metal Systems.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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 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 A48/A48M 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 A126, would be selected. Other appropriate Specifications would be A74 and A278/A278M, 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 × S, 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.