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Standard Specification for Automotive Gray Iron Castings[1]

This standard is issued under the fixed designation A159; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.
This specification replaces Federal specification AA-I-653A.

1. Scope

1.1 This specification applies to gray iron castings, cast in sand molds, used in the products of the automobile, truck, tractor, and allied industries.

1.2 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 The following documents of the issue in effect on the date of material procurement form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*[2]
A247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings
E10 Test Method for Brinell Hardness of Metallic Materials
2.3 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage[3]
2.4 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[3]

3. Grades

3.1 The specified grades, hardness ranges, and metallurgical description are shown in Table 1 and Table 2 and in Section 9.

4. Ordering Information

4.1 Orders for materials under this specification shall include the following information:
4.1.1 ASTM designation,
4.1.2 Grade designation of gray iron required (3.1),
4.1.3 If special heat treatment is required (see Section 6),
4.1.4 If special microstructure requirements are needed (see Section 7),
4.1.5 Surface where hardness test is to be performed (see 9.4),
4.1.6 Depth and surface hardness of case required (see 9.6),
4.1.7 Inspection lot and sampling plan required (see Section 10),
4.1.8 If additional requirements are needed (see 11.3), and
4.1.9 Whether special packaging and marking is required (see Section 12).

5. Hardness

5.1 The foundry shall exercise the necessary controls and inspection techniques to ensure compliance with the specified hardness range, Brinell hardness shall be determined in accordance with Test Method E10, after sufficient material has been removed from the casting surface to ensure representative hardness readings. The 10-mm ball and 3000-kg load shall be used unless otherwise agreed upon. The area or areas on the casting where hardness is to be checked shall be established by agreement between supplier and purchaser and shall be shown on the drawing.

6. Heat Treatment

6.1 Unless otherwise specified, castings of Grades G1800 and G2500 may be annealed in order to meet the desired hardness range.

6.2 Appropriate heat treatment for removal of residual stresses, or to improve machinability or wear resistance may be specified by agreement between supplier and purchaser.

7. Microstructure

7.1 The microstructure shall consist of flake graphite in a matrix of ferrite or pearlite or mixtures thereof.

7.2 As graphite size and shape somewhat affect hardness-strength ratio and other properties, the type size and distribution of the graphite flakes at a designated location on the casting may be specified by agreement between supplier and purchaser in accordance with Method A247.

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[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Grey and White Iron Castings.

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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.

[3] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

TABLE 1 Grades of Gray Iron

Grade	Casting Hardness Range	Description
G1800	HB 187 max 4.4 BID min or as agreed[A]	ferritic-pearlitic
G2500	HB 170-229 4.6–4.0 BID or as agreed[A]	pearlitic-ferritic
G3000	HB 187-241 4.4–3.9 BID or as agreed[A]	pearlitic
G3500	HB 207-255 4.2–3.8 BID or as agreed[A]	pearlitic
G4000	HB 217-269 4.1–3.7 BID or as agreed[A]	pearlitic

[A]Brinell impression diameter (BID) is the diameter in millimetres of the impression of a 10 mm ball at 3000-kg load.

7.3 Unless otherwise specified, the matrix microstructure of castings covered by this specification shall be substantially free of primary cementite. Castings in Grades G1800 and G2500 may have a matrix of ferrite or pearlite or both. Grades G3000, G3500, and G4000 shall be substantially pearlite in matrix structure.

8. Heavy-Duty Brake Drums and Clutch Plates

8.1 These castings are considered as special cases and are covered in Table 2.

9. Alloy Gray Iron Automotive Camshafts

9.1 These castings are considered as special cases.

9.2 *Grade Designation*—G4000d.

9.3 *Chemistry*—Alloy gray iron camshafts shall contain alloys within the following range or as agreed upon between supplier and purchaser.

Chromium	0.85–1.25 %
Molybdenum	0.40–0.60 %
Nickel	as agreed

9.4 *Casting Hardness*—HB 241-321 determined on a bearing surface as agreed by supplier and purchaser.

9.5 *Microstructure*—Extending 45° on both sides of the centerline of the cam nose and to a minimum depth of ⅛ in. (3.2 mm), the surface shall consist of primary carbides (of acicular or cellular form or a mixture thereof) and graphite in a fine pearlitic matrix. The graphite shall be Type VII A and E distribution, 4 to 7 flake size in accordance with Method A247. The amount of primary carbides and location at which the structure is checked shall be a matter of agreement between the supplier and the purchaser.

9.6 *Selective Hardening*—The cam areas of camshaft casting are usually selectively hardened by flame or induction hardening by the supplier. The depth and surface hardness of the hardened case shall be as agreed upon between supplier and purchaser.

10. Quality Assurance Provisions

10.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and tests requirements specified in this specification. Except as otherwise specified in the contract or purchase order, the producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspection and tests set for in this specification where such inspections are deemed necessary to assure that material conform to prescribed requirements.

10.2 *Lot*—For the purpose of inspection, lot and sampling plans shall be agreed upon between the purchaser and the producer.

11. General

11.1 Castings furnished to this specification shall be representative of good foundry practice and shall conform to dimensions and tolerances specified on the casting drawing.

11.2 Minor imperfections usually not associated with the structural function may occur in castings. These are often repairable but repairs shall be made only where allowed by the purchaser and only by approved methods.

11.3 Additional casting requirements may be agreed upon by purchaser and supplier. These should appear as product specifications on the casting or part drawing.

12. Preparation for Delivery

12.1 Unless otherwise specified in the contract or purchase order, castings shall be cleaned, preserved, and packaged in accordance with supplier's standard commercial practice.

12.2 *Government Procurement*—When specified for Government procurement, castings shall be marked for shipment in accordance with MIL-STD-129 for military procurement and Fed. Std. No. 123 for civil agency procurement.

TABLE 2 Brake Drums and Clutch Plates for Special Service

Grade	Carbon min, %[A]	Casting Hardness	Microstructure	
			Graphite	Matrix
G2500a	3.40	HB 170-229 4.6–4.0 BID or as agreed	Type VII, size 2–4[B] A distribution	lamellar pearlite ferrite if present not to exceed 15%
G3500b	3.40[C]	HB 207-255 4.2–3.8 BID or as agreed	Type VII, size 3–5[B] A distribution	lamellar pearlite ferrite or carbide if present not to exceed 5%
G3500c	3.50[C]	HB 207-255 4.2–3.8 BID or as agreed	Type VII, size 3–5[B] A distribution	lamellar pearlite ferrite or carbide, if present not to exceed 5%

[A]The chemical analysis for total carbon shall be made on chilled pencil-type specimens or from thin wafers approximately 1/32 in. (0.8 mm) thick cut from test coupons. Drillings are not reliable because of the probable loss of graphite.
[B]See Method A247.
[C]Grades G 3500b and G 3500c normally require alloying to obtain the specified hardness at the high carbon levels specified.

APPENDIX

(Nonmandatory Information)

X1. GRAY IRON

X1.1 Definition

X1.1.1 *gray iron*—a cast iron in which the graphite is present as flakes instead of temper carbon nodules as in malleable iron or small spherulites as in ductile iron.

X1.2 Chemical Composition

X1.2.1 The ranges in composition generally employed in producing the various grades of most automotive gray iron castings are shown in Table X1.1. The composition ranges for such special applications as heavy duty brake drums and clutch plates and camshafts are shown in Table X1.2 and Table X1.3, respectively. The contents of certain elements for these applications are critical in terms of service requirements and the ranges are specified in the standard.

X1.2.2 The specific composition range for a given grade may vary according to the prevailing or governing section of the castings being produced.

X1.2.3 Alloying elements such as chromium, copper, nickel, tin, molybdenum, or other elements may be employed to meet the specified hardness or microstructural requirements or to provide the properties needed for particular service conditions.

TABLE X1.2 Usual Composition of Brake Drums and Clutch Plates for Special Service

Chemical Composition, %	Grade G2500a	Grade G3500b	Grade G3500c
Carbon, total (mandatory)	3.40 min	3.40 min	3.50 min
Silicon (as required)	1.60–2.10	1.30–1.80	1.30–1.80
Manganese (as required)	0.60–0.90	0.60–0.90	0.60–0.90
Sulfur, max	0.12	0.12	0.12
Phosphorus, max	0.15	0.15	0.15
Alloys	as required	as required	as required

TABLE X1.3 Usual Chemical Composition of Alloy Gray Iron Automotive Camshafts

	Grade G4000d, %
Total carbon	3.10–3.60
Silicon	1.95–2.40
Manganese	0.60–0.90
Phosphorus	0.10 max
Sulfur	0.15 max
Chromium	0.85–1.25
Molybdenum	0.40–0.60
Nickel	0.20–0.45 optional
Copper	residual

X1.3 Microstructure

X1.3.1 The microstructure of the various grades of gray iron are generally a mixture of flake graphite in a matrix of ferrite, pearlite, or tempered pearlite. The relative amounts of each of these constituents depends on the analysis of the iron, casting design, and foundry techniques as they affect solidification and subsequent cooling rate and heat treatments if any.

TABLE X1.1 Typical Base Compositions, %

Grade	Carbon	Silicon	Manganese	Sulfur, max	Phosphorus, max	Approximate Carbon Equivalent
G1800	3.40–3.70	2.30–2.80	0.50–0.80	0.15	0.25	4.25–4.5
G2500	3.20–3.50	2.00–2.40	0.60–0.90	0.15	0.20	4.0–4.25
G3000	3.10–3.40	1.90–2.30	0.60–0.90	0.15	0.15	3.9–4.15
G3500	3.00–3.30	1.80–2.20	0.60–0.90	0.15	0.12	3.7–3.9
G4000	3.00–3.30	1.80–2.10	0.70–1.00	0.15	0.10	3.7–3.9 (usually alloyed)

X1.3.2 The distribution and size of graphite flakes like the matrix structure of gray iron depends greatly on the solidification rate and cooling rate of the casting. If a section solidifies very rapidly an appreciable amount of carbide causing a mottled fracture or chilled corners can be present. If a section cools slowly, as in a massive heavy-section casting, an appreciable amount of ferrite may be present. In like manner, light sections will contain small graphite flakes while graphite will form in much larger flakes if the same iron is poured into a heavy casting.

X1.3.3 For these reasons the strength and hardness of gray iron are greatly influenced by the rate of cooling during and after solidification, the design and nature of the mold and the casting, and by other factors such as inoculation practice in addition to the composition of the iron.

X1.3.4 Alloying with nickel, chromium, molybdenum, tin, copper or other alloys usually promotes a more stable pearlitic structure and is often done to obtain increased hardness, strength, and wear resistance especially in heavy sections subjected to severe service.

X1.3.5 Alloying is sometimes used to obtain structures containing a controlled percentage of carbides as in camshaft or valve lifter castings.

X1.3.6 Primary carbides or pearlite or both, can be decomposed by appropriate heat treatment. Gray irons of suitable composition and structure can be hardened by liquid quenching or by flame or induction selective hardening.

X1.4 Mechanical Properties

X1.4.1 The mechanical properties listed in Table X1.4 can be used for design purposes. However, the suitability of a particular grade for an intended application is best determined by laboratory or service tests. Typical mechanical properties for such specialized applications as heavy-duty brake drums and clutch plates are shown in Table X1.5.

X1.5 Application of Gray Iron in Automotive Castings (see Table X1.6)

X1.5.1 The graphite flakes in gray iron give this metal many desirable properties. These include excellent machinability, high thermal conductivity, vibration dampening properties, and resistance to wear or scuffing. Due to its low freezing temperature for a ferrous alloy, high fluidity, and low shrinkage properties it is more readily cast in complex shapes than other ferrous metals.

X1.5.2 Gray iron castings of the lower-strength Grades G1800 and G2500 are characterized by excellent machinability, high damping capacity, low modulus of elasticity, and comparative ease of manufacture. When higher strength is obtained by a reduction in the carbon or carbon equivalent, castings are more difficult to machine, have lower damping capacity, higher modulus of elasticity, and may be more difficult to manufacture.

TABLE X1.5 Typical Mechanical Properties

Mechanical Properties	Grade G2500a	Grade G3500b	Grade G3500c
Tensile strength, min:			
psi	25 000	35 000	35 000
kgf/mm^2	17.5	24.5	24.5
Transverse strength, min:			
lb	2000	2400	2400
kg	910	1090	1090
Deflection, min:			
in.	0.17	0.24	0.24
mm	4.3	6.1	6.1
Hardness, HB	170–229	207–255	207–255
Brinell indention diameter, mm	4.6–4.0	4.2–3.8	4.2–3.8

TABLE X1.6 Typical Applications of Gray Iron for Automotive Castings

Grade	General Data
G1800	Miscellaneous soft iron castings (as cast or annealed) in which strength is not of primary consideration. Exhaust manifolds may be made of this grade of iron, alloyed or unalloyed. These may be annealed castings for exhaust manifolds in order to avoid growth and cracking due to heat.
G2500	Small cylinder blocks, cylinder heads, air cooled cylinders, pistons, clutch plates, oil pump bodies, transmission cases, gear boxes, clutch housings, and light-duty brake drums.
G3000	Automobile and diesel cylinder blocks, cylinder heads, flywheels, differential carries castings, pistons, medium-duty brake drums, and clutch plates.
G3500	Diesel engine blocks, truck and tractor cylinder blocks and heads, heavy flywheels, tractor transmission cases, and heavy gear boxes.
G4000	Diesel engine castings, liners, cylinders, and pistons.

TABLE X1.4 Mechanical Properties for Design Purposes

Grade	Hardness Range[A]	Tensile Strength, min, psi (kgf/mm^2)	Transverse Strength, min, lb (kg)[B]	Deflection, min, in. (mm)[B]
G1800	HB 143-187 5.0–4.4 BID	18 000 (14)	1720 (780)	0.14 (3.6)
G2500	HB 170-229 4.6–4.0 BID	25 000 (17.5)	2000 (910)	0.17 (4.3)
G3000	HB 187-241 4.4–3.9 BID	30 000 (21)	2200 (1000)	0.20 (5.1)
G3500	HB 207-255 4.2–3.8 BID	35 000 (24.5)	2450 (1090)	0.24 (6.1)
G4000	HB 217-269 4.1–3.7 BID	40 000 (28)	2600 (1180)	0.27 (6.9)

[A]Brinell impression diameter (BID) is the diameter in millimetres of the impression of a 10-mm ball at 3000-kg load.
[B]See Method A438 for information concerning the B transverse test bar and the transverse test.

X1.6 Special Applications of Gray Iron

X1.6.1 *Heavy-Duty Brake Drums and Clutch Plates*—Automotive brake drums and clutch plates for heavy-duty service are considered as special cases. Typical chemical analyses and mechanical properties are listed in Table X1.2 and Table X1.5. Heavy-duty irons for such service require high carbon contents for resistance to thermal shock and to minimize heat checking. To maintain strength levels specified for Grades G3500b and G3500c normally requires alloying due to their high carbon contents.

X1.6.2 *Microstructure*—See Table 2 for microstructure requirements.

X1.6.3 *Suggested Usage*—Following are suggested grades for brake drums and clutch plates according to types of service:

Grade	Suggested Usage
G2500a	Brake drums and clutch plates for moderate service requirements, where high carbon iron is desired to minimize heat checking (see Section 8).
G3500b	Brake drums and clutch plates for heavy-duty service where both resistance to heat checking and higher strength are definite requirements (see Section 8).
G3500c	Extra-heavy-duty service brake drums (see Section 8).

X1.7 Automotive Camshafts

X1.7.1 Alloy gray iron automotive camshafts are also considered as special cases. The chemical composition of such castings is usually within the range given in Table X1.3 but may be modified by mutual agreement.

X1.7.2 In casting hardenable iron from camshafts, the aim is to obtain a suitable microstructure in critical locations of the casting and balance the composition to obtain response to induction or flame-hardening treatment. These depend not only on the chemistry of the iron but even more on the cross section of the casting and details of melting practice. In making a given casting, it is recognized that the foundry will find it necessary to adjust the chemistry to narrower limits within the range of analysis in Table X1.3.

X1.7.3 As the performance of an automotive camshaft is determined by the microstructure and hardness, producers do not normally use tensile or transverse tests for quality control purposes. Camshaft iron with chemistry as given in Table X1.3 would be expected to have the following minimum mechanical properties.

Tensile strength, min:	
psi	40 000
kgf/mm^2	28
Transverse strength, min:	
lb	2600
kg	1180
Deflection, min:	
in.	0.27
mm	6.9
Hardness, HB	241–321
BID	3.9–3.4

X1.7.4 *Microstructure*— See 9.5 for microstructure requirements for Grade G4000d alloy cast iron camshafts.

X1.8 Additional Information

X1.8.1 Additional information concerning gray iron castings, their properties and uses can be obtained from the following sources:

(*1*) *Metals Handbook,* 8th Edition, Vols 1, 2, and 5, published by the American Society for Metals, Metals Park, Ohio.

(*2*) *Cast Metals Handbook* published by the American Found rymen's Society, Des Plaines, Ill.

(*3*) Gray & Ductile Iron Castings Handbook (1971) published by Gray and Ductile Iron Founders Society, Cleveland, Ohio.

(*4*) *Physical and Engineering Properties of Cast Iron,* Angus, British Cast Iron Research Association (1960), Alve- church, Birmingham, England.

(*5*) *Engineering Data on Gray Cast Irons,* G. N. J. Gilbert British Cast Iron Research Association (1968), Alve church, Birmingham, England.

(*6*) *Gray, Ductile and Malleable, Iron Castings Current Capabilities. ASTM STP 455,* (1969).