

Automotive Gray Iron Castings — SAE J431 AUG79

SAE Standard
Completely Revised August 1979

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Report of the Iron and Steel Division, approved January 1935, completely revised by the Iron and Steel Technical Committee August 1979.

1. **Scope**—This standard covers the hardness and microstructural requirements for gray iron sand mold castings used in automotive and allied industries. The chemical requirements for alloy gray iron automotive camshafts are included in the standard under *casting for special application with controlled composition and microstructure*. The Appendix provides general information on application of gray iron in automotive castings and chemical composition to meet hardness, microstructural, and other properties needed for particular service conditions. The mechanical properties in the Appendix are provided for design purposes.

Note: This document was rewritten in June 1970. The materials described by the grade numbers are different than in the former writing.

2. **Grades**—The specified grades, hardness ranges, and metallurgical description are shown in Tables 1 and 2 and in Sections 5 and 6.

TABLE 1—GRADES OF GRAY IRON

Grade	Casting Hardness Range at Specified Locations	Description
G1800	187 HB max or as agreed (4.4 BID max)	Ferritic-pearlitic
G2500	170–229 HB or as agreed (4.6–4.0 BID)	Pearlitic-ferritic
G3000	187–241 HB or as agreed (4.4–3.9 BID)	Pearlitic
G3500	207–255 HB or as agreed (4.2–3.8 BID)	Pearlitic
G4000	217–269 HB or as agreed (4.1–3.7 BID)	Pearlitic

Note: Brinell impression diameter (BID) is the diameter in millimeters (mm) of the impression of a 10 mm ball at 3000 kg load.

TABLE 2—BRAKE DRUMS AND CLUTCH PLATES FOR SPECIAL SERVICE

Grade	C % min	Casting Hardness at Specified Locations	Microstructure	
			Graphite ^b	Matrix ^c
G2500a	3.40	170–229 HB or as agreed (4.6–4.0 BID)	Type VII A, distribution size 2–4	Lamellar pearlite. Ferrite if present not to exceed 15%
G3500b	3.40 ^a	207–255 HB or as agreed (4.2–3.8 BID)	Type VII A, distribution size 3–5	Lamellar pearlite. Ferrite or carbide if present not to exceed 5%
G3500c	3.50 ^b	207–255 HB or as agreed (4.2–3.8 BID)	Type VII A, distribution size 3–5	Lamellar pearlite. Ferrite or carbide if present not to exceed 5%

^aGrades G3500b and G3500c normally require alloying to obtain the specified hardness at the high carbon levels specified.

^bSee ASTM A 247, Recommended Practice for Evaluating the Microstructure of Graphite in Iron Castings.

^cSee ASTM E 562, Determining Volume Fraction by Systematic Manual Point Count.

Note: Brinell impression diameter (BID) is the diameter in millimeters (mm) of the impression of a 10 mm ball at 3000 kg load.

3. **Hardness**

3.1 The area or areas on the casting where hardness is to be checked shall be established by agreement between supplier and purchaser.

3.2 The foundry shall exercise the necessary controls and inspection techniques to insure compliance with the specified hardness range. Brinell hardness shall be determined according to ASTM E 10, Test for Brinell Hardness of Metallic Materials, after sufficient material has been

removed from the casting surface to insure representative hardness readings. The 10 mm ball and 3000 kg load shall be used unless otherwise agreed upon.

4. **Heat Treatment**

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

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

5. **Microstructure**

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

5.2 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 ASTM A 247, Recommended Practice for Evaluating the Microstructure of Graphite in Iron Castings.

5.3 Unless otherwise specified, the matrix microstructure of castings covered by this standard shall be substantially free of primary cementite and/or massive steadite. Castings in grades G1800 and G2500 may have a matrix of ferrite and/or pearlite. Grades G3000, G3500, and G4000 shall be substantially pearlitic in matrix structure.

6. **Casting for Special Application with Controlled Composition and Microstructure**

6.1 **Heavy Duty Brake Drums and Clutch Plates**

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

6.2 **Alloy Gray Iron Automotive Camshafts**

6.2.1 These castings are considered as special cases.

6.2.2 Grade Designation—G4000d.

6.2.3 **Chemical Composition**—Alloy gray iron camshafts shall contain alloys within the following range or as agreed upon by supplier and purchaser:

Chromium	0.85–1.50%
Molybdenum	0.40–0.60%
Nickel	As agreed

6.2.4 **Casting Hardness**—241–321 HB determined on a bearing surface or as agreed by supplier and purchaser.

6.2.5 **Microstructure**—Extending 45 deg on both sides of the centerline of the cam nose and to a minimum depth of 1/8 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, 4–7 flake size according to ASTM A 247, Recommended Practice for Evaluating the Microstructure of Graphite in Gray Iron Castings. 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.

6.2.6 **Selective Hardening**—The cam areas of camshaft castings 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 by supplier and purchaser.

7. **Quality Assurance**—Sampling plans are a matter of agreement between supplier and purchaser. The supplier shall employ adequate equipment and controls to insure that parts conform to agreed upon requirements.

8. **General**

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

8.2 Minor imperfections usually not associated with the structural functioning may occur in castings. These imperfections often are repairable; however, repairs should be made only in areas and by methods approved by the purchaser.

8.3 Additional casting requirements such as vendor identification, other casting information, and special testing, may be agreed upon by purchaser and supplier. These should appear as product specifications on the casting or part drawing.

The φ symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

APPENDIX—GRAY IRON

(A material description and not a part of the standard)

A1. Definition—Gray iron is 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.

A2. Chemical Composition—The ranges in composition generally employed in producing the various grades of most automotive gray iron castings are shown in Table A-1. The composition ranges for such special applications as heavy duty brake drums and clutch plates and camshafts are shown in Table A-3 and Table A-5, respectively. The contents of certain elements for these applications are critical in terms of service requirements and the ranges are specified in the standard.

A2.1 The specific composition range for a given grade may vary according to the prevailing or governing section size of the castings being produced.

A2.2 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.

A3. Microstructure

A3.1 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 A-1—TYPICAL BASE COMPOSITIONS, %

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

^aTypical value.

^bCE = % C + 1/3% Si.

TABLE A-2—TYPICAL MECHANICAL PROPERTIES FOR DESIGN PURPOSES^a

Grade	Hardness Range	Tensile Strength, min, psi (MPa)	Transverse Strength ^b , min, lb (kN)	Deflection ^b , min, in (mm)
G1800	187 HB max (4.4 BID, min)	18 000 (124)	1720 (7.65)	0.14 (3.6)
G2500	170–229 HB (4.6–4.0 BID)	25 000 (173)	2000 (8.90)	0.17 (4.3)
G3000	187–241 HB (4.4–3.9 BID)	30 000 (207)	2200 (9.79)	0.20 (5.1)
G3500	207–255 HB (4.2–3.8 BID)	35 000 (241)	2450 (10.90)	0.24 (6.1)
G4000	217–269 HB (4.1–3.7 BID)	40 000 (276)	2600 (11.56)	0.27 (6.9)

^aThe reported mechanical properties were determined on separately cast 1.2 in D (30 mm D) test bars and may vary throughout the casting depending on composition and cooling rate. Heavy wall (slowly cooled) castings may exhibit lower properties.

^bSee ASTM A 438, Transverse Testing of Gray Cast Iron, for information concerning the B transverse test bar and the transverse test.

Note: Brinell impression diameter (BID) is the diameter in millimeters (mm) of the impression of a 10 mm ball at 3000 kg load.

TABLE A-3—TYPICAL BASE COMPOSITION OF BRAKE DRUMS AND CLUTCH PLATES FOR SPECIAL SERVICE, %

Grade	Carbon ^a	Silicon ^b	Manganese ^b	Sulfur ^c	Phosphorus, max
G2500a	3.40 min	1.60–2.10	0.60–0.90	0.12	0.15
G3500b	3.40 min	1.30–1.80	0.60–0.90	0.12	0.15
G3500c	3.50 min	1.30–1.80	0.60–0.90	0.12	0.15

Alloy may be added as required.

^aMandatory.

^bAs required.

^cTypical value.

TABLE A-4—MECHANICAL PROPERTIES FOR DESIGN PURPOSES FOR BRAKE DRUMS, CLUTCH PLATES, AND SPECIAL SERVICE^a

Grade	Hardness Range	Tensile Strength, min, psi (MPa)	Transverse Strength ^b , min, lb (kN)	Deflection ^b , min, in (mm)
G2500a	170–229 HB (4.6–4.0 BID)	25 000 (173)	2000 (8.90)	0.17 (4.3)
	207–255 HB (4.2–3.8 BID)	35 000 (241)	2400 (10.68)	0.24 (6.1)
G3500c	207–255 HB (4.2–3.8 BID)	35 000 (241)	2400 (10.68)	0.24 (6.1)

^aThe reported mechanical properties were determined on separately cast 1.2 in D (30 mm D) test bars and may vary throughout the casting depending on composition and cooling rate. Heavy wall (slowly cooled) castings may exhibit lower properties.

^bSee ASTM A 438, Transverse Testing of Gray Cast Iron, for information concerning the B transverse test bar and the transverse test.

Note: Brinell impression diameter (BID) is the diameter in millimeters (mm) of the impression of a 10 mm ball at 3000 kg load.

TABLE A-5—TYPICAL 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	0.85–1.50
Molybdenum	0.40–0.60
Nickel	0.20–0.45 optional
Copper	Residual

A3.2 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.

A3.3 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.

A3.4 Alloying with nickel, chromium, molybdenum, tin, copper, or other alloys usually promotes a more stable pearlitic structure and is often