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Automotive Gray Iron Castings — SAE J431c

**SAE STANDARD
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SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
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Report of Iron and Steel Division approved January 1935 and last revised by Iron and Steel Technical Committee January 1975.

1. SCOPE-This SAE Standard applied to gray iron castings cast in sand molds in the products of the automobile, truck, tractor, and allied industries, NOTE: This document was rewritten in January 1975. 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 paragraph 7.

3. HARDNESS

3.1 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. 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.

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 specification shall be substantially free of primary cementite. Castings in grades G1800 and G2500 may have a matrix of ferrite and/or pearlite. Grades G3000, G3500, and G4000 shall be substantially pearlite 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 CAM-SHAFTS

6.2.1 These castings are considered as special cases.

6.2.2 *Grade Designation*-G4000d.

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

Chromium Molybdenum Nickel	0.85-1.25% 0.40-0.60% As agreed
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6.2.4 *Casting Hardness*-241-321 Bhn determined on a bearing surface 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. 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.

TABLE 1 - GRADES OF GRAY IRON

Grade	Casting Hardness Range ^a	Description
G1800	187 Bhn max 4.4 BID max or as agreed	Ferritic-pearlitic
G2500	170-229 Bhn 4.6-4.0 BID or as agreed	Pearlitic-ferritic
G3000	187-241 Bhn 4.4-3.9 BID or as agreed	Pearlitic
G3500	207-255 Bhn 4.2-3.8 BID or as agreed	Pearlitic
G4000	217-269 Bhn 4.1-3.7 BID or as agreed	Pearlitic

^a 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	Microstructure	
			Graphite ^b	Matrix
G2500a	3.40	170-229 Bhn 4.6-4.0 BID or as agreed	Type A, distribution size 2-4	Lamellar pearlite. Ferrite if present not to exceed 15%
G3500b	3.40 ^a	207-255 Bhn 4.2-3.8 BID or as agreed	Type A, distribution size 3-5	Lamellar pearlite. Ferrite or carbide if present not to exceed 5%
G3500c	3.50 ^a	207-255 Bhn 4.2-3.8 BID or as agreed	Type A, distribution size 3-5	Lamellar pearlite. Ferrite or carbide if present not to exceed 5%

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

^b See ASTM A247, Recommended Practice for Evaluating the Microstructure of Graphite in Iron Castings.

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 are often repairable but repairs should be made only where allowed by the purchaser and only by approved methods.

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

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.

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 done to obtain increased hardness, strength, and wear resistance, especially in heavy sections subjected to severe service.

A3.5 Alloying is sometimes used to obtain structures containing a controlled percentage of carbides, as in camshaft or valve lifter castings.

A3.6 Primary carbides and/or pearlite 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.

A4. MECHANICAL PROPERTIES—The mechanical properties listed in Table A-2 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 A-4

A5. APPLICATIONS OF GRAY IRON IN AUTOMOTIVE CASTINGS

A5.1. 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.

TABLE A-1 - TYPICAL BASE COMPOSITIONS, %

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

TABLE A-2 - MECHANICAL PROPERTIES FOR DESIGN PURPOSES

Grade	Hardness Range ^a	Tensile Strength, min, psi (MP)	Transverse Strength, min, lb(kg)	Deflection, min, in. (mm)
G1800	143-187 Bhn max 5.0 - 4.4 BID, min	18,000 (118)	1720 (780)	0.14 (3.6)
G2500	170-229 Bhn 4.6 - 4.0 BID	25,000 (173)	2000 (910)	0.17 (4.3)
G3000	187-241 Bhn 4.4 - 3.9 BID	30,000 (207)	2200 (1000)	0.20 (5.1)
G3500	207-255 Bhn 4.2 - 3.8 BID	35,000 (241)	2450 (1110)	0.24 (6.1)
G4000	217-269 Bhn 4.1 - 3.7 BID	40,000 (276)	2600 (1180)	0.27 (6.9)

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

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

TABLE A-3- USUAL CHEMICAL COMPOSITION OF BRAKE DRUMS AND CLUTCH PLATES FOR SPECIAL SERVICE %

Element	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 A-4 - TYPICAL MECHANICAL PROPERTIES

Mechanical Properties	Grade G2500a	Grade G3500b	Grade G3500c
Tensile strength, min psi MPa	25,000 173	35,000 241	35,000 241
Transverse strength, min lb kg	2000 910	2400 1090	2400 1090
Deflection, min in. mm	0.17 4.3	0.24 6.1	0.24 6.1
Hardness, Bhn BID	170-229 4.6 - 4.0	207-255 4.2 - 3.8	207-255 4.2 - 3.8

TABLE A-5 - 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 - 1.50
Molybdenum	0.40 - 0.60
Nickel	0.20 0.45 optional
Copper	Residual

A5.2. 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 re-

duction in the carbon or carbon equivalent, castings are more difficult to machine, have lower damping capacity and higher modulus of elasticity, and may be more difficult to manufacture.

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 casting for exhaust manifolds in order to avoid growth cracking due to heat.
G2500	Small cylinder blocks, cylinder heads, aircooled 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 carrier 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, heavy gear boxes.
G4000	Diesel engine castings, liners, cylinders, and pistons.

A6. SPECIAL APPLICATION OF GRAY IRON

A6.1. 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 A-3 and A-4. 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.

Grade	Suggested Usage
G2500a	Brake drums and clutch plates for moderate service requirements, where high carbon iron is desired to minimize heat checking. (See paragraph 6.)
G3500b	Brake drums and clutch plates for moderate service where both resistance to heat checking and higher strength are definite requirements. (See paragraph 6.)
G3500c	Extra heavy duty service brake drums (See paragraph 6.)

A6.2. MICROSTRUCTURE-See Table 2 for microstructure requirements.

A6.3. SUGGESTIVE USAGE-Following are suggested grades for brake drums and clutch plates according to types of service.

A7. AUTOMOTIVE CAMSHAFTS

A7.1. 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 A-5 but may be modified by mutual agreement.

A7.2. In casting hardenable iron for 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 narrow limits within the range of analysis in Table A-5.

A7.3 As the performance of an automotive camshaft is determined by the microstructure and hardness, producers do not normally use tensile or transverse test for quality control purposes. Camshaft iron with chemistry as given in Table A5 would be expected to have the following minimum mechanical properties:

Tensile Strength, min psi kgf/mm ²	40,000 28
Transverse Strength, min lb kg	2600 1180
Deflection, min in mm	0.27 0.27 6.9
Hardness, Bhn BID	241-321 3.9 - 3.4

A7.4 Microstructure-See SAE J431 for microstructure requirements for Grade G4000d alloy cast iron camshafts.

A8. ADDITIONAL INFORMATION-Additional information concerning gray iron castings, their properties and uses can be obtained from

1. Metals Handbook, Vol 1, 8th Edition. American Society of Metals, Metals Park, Ohio

2. Cast Metals Handbook. American Foundrymen's Society, Des Plaines Ill.