



Gray Cast Iron

1 Scope

This material specification applies to those grades of gray iron castings intended for a wide range of automotive applications. This standard describes the material properties, not specific casting properties, based on data obtained from separately cast test samples. Any specific property required from a particular casting or section of that casting shall be identified on the engineering drawing.

1.1 Material Description. Gray iron is a cast iron in which the free graphite, in the form of flakes, precipitates throughout the metallic matrix. It is the graphite flakes which account for the excellent machinability, wear resistance, damping capacity, low shrinkage characteristics and generally higher thermal conductivity.

Table 1: Material Identification

GMW Grade Note 1	Minimum Tensile Strength Machined from Separately Cast Test Samples in N/mm²
GMW4M-IR-C-G125	125
GMW4M-IR-C-G150	150
GMW4M-IR-C-G200	200
GMW4M-IR-C-G225	225
GMW4M-IR-C-G250	250
GMW4M-IR-C-G300	300

Note 1: See Section 8 for explanation of coding system.

1.2 Symbols. Not applicable.

1.3 Applicability. Gray cast iron is a low-cost material with good hardness, strength, and rigidity. It has excellent castability for complex designs and demonstrates exceptional dampening capacity and thermal shock resistance. The gray cast iron characteristics lend themselves to a wide variety of applications which include cylinder blocks and heads, cylinder liners, bearing caps, camshafts, manifolds, pump bodies and housings, and valve bodies.

1.4 Remarks. This specification has resulted in the consolidation of several similar GM North America specifications. Appendix A, Table A1 depicts the GMNA deleted standards and the applicable global replacement grades. Also listed in Appendix A, Table A1 are specialty grades required for special purpose castings. Appendix B, Table B1 shows the relationship between the new global grades, their tensile strengths, the superseded GM regional grades and the corresponding International Standard grade.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ASTM A48	ASTM E1019	ISO 185	ISO 6506
ASTM E1010	ASTM E1999	ISO 945	ISO 6892

2.2 GM Standards/Specifications.

GMW3059

3 Requirements

3.1 Requirements on Delivery.

3.1.1 Chemical Requirements. The chemical composition, section size, and casting cooling rate all affect the tensile strength thus the chemical compositions shown in Tables 2, 3, and 4 are typical and shall be considered secondary to the mechanical properties. For special purpose casting grades listed in Table 5, the chemical composition is mandatory.

3.1.1.1 The compositions listed in the tables reflect those of finished castings. When using optical emission spectroscopy to analyze a finished casting for chemical composition, a piece of the casting shall be re-melted so a chilled sample is obtained. All spectrographic analysis shall be taken from a chilled sample.

3.1.1.2 Spectrometric analysis of chemistry shall be measured in accordance with procedures, master samples, and calibration per ASTM E1010 and ASTM E1999.

Carbon levels shall be measured using either thermal analysis or C and S analyzer, and shall be measured in accordance with procedures, master samples, and calibration per ASTM E1019.

3.1.2 Mechanical Requirements. The specific mechanical properties associated with each grade are listed in Tables 2, 3, 4, and 5. The mechanical properties are measured from separately cast 30 mm diameter test samples that are poured from the same material as the castings which they represent. Properties of test pieces machined from castings will vary from those determined by the separately cast test samples due to differences in solidification and cooling rate of the individual castings. When specified in product drawings, samples should be excised from parts for testing. Table 2 describes general purpose gray iron. Tables 3, 4, and 5 describe special purpose gray irons which are identified by the grade, when appropriate, followed by the special purpose (SP-XN) identification number, "N". If the unique grade number is itself preceded by a letter, "X", this letter denotes a part or material family of special purpose irons, i.e., "L" = cylinder liners (Table 4), "C" = carbide iron (Table 5). The mechanical properties are the primary requirements in grading and classifying gray irons for use as automotive castings except for special wear resistant castings such as camshafts and valve lifters. The mechanical properties shall meet or exceed the minimum product requirements. The final sampling plan shall have agreement between the purchaser and the supplier. The validity of tests and applicability of any retests shall be in accordance with ISO 185.

3.1.2.1 Hardness. Brinell hardness shall be taken in accordance with ISO 6506. The material hardness requirements described in Tables 2, 3, 4, and 5 shall be met on both the test sample and its represented castings. Casting hardness will vary throughout the part due to differences in section size and cooling rates. Appendix C, Table C1 shows the anticipated Brinell hardness for different thicknesses of the same casting. The specific test location(s) on the casting shall be identified on the engineering drawing after agreement is reached between purchaser and the supplier. To prepare the casting for the load impression, a representative depth of 1.5 mm shall be removed from the surface. Other hardness methods, such as cast surface penetrators, can be used if these methods are validated against ISO 6506 and are agreed upon by purchaser and supplier.

3.1.2.1.1 In unusual cases where the specified hardness and tensile strength cannot be met simultaneously, a revised hardness range shall be established by agreement between the purchaser and supplier. The tensile strength will take precedence over hardness.

3.1.2.2 Tensile Strength. Test samples, that are poured from the same material as the castings which they represent shall conform to the tensile strength property requirements listed in Tables 2, 3, and 5. Tensile strength data shall be obtained from 20 mm diameter test pieces machined from separately cast test samples (30 mm diameter). The standard dimensions and testing procedure for test samples and machined test pieces are described in the ISO 185 and ISO 6892 specifications. The separately cast test samples represent the quality of the material and melt from which the casting is poured. A separately cast "B" test sample conforming to ASTM A48 is equivalent to the ISO test sample and may also be used. The manufacturer shall maintain sufficient controls and documentation to assure the purchaser that properties determined from separately cast test samples are representative of the castings shipped.

- Exception: For special purpose gray cast iron cylinder liners (Table 4), tensile strength shall be determined from a test piece excised from the wall of unmachined castings.

3.1.2.2.1 The separately cast test samples shall be poured vertically into dried, baked, green sand or chemically bonded molds made of a siliceous aggregate that is similar to the aggregate used in production molds. The coupons shall cool to +480 °C or until a fully gray color is observed in the riser. At this time the sample can be removed from the mold and allowed to air cool. Any changes from this procedure shall require an agreement between the purchaser and the supplier.

3.1.2.2.2 Tensile strength properties may be specified for test pieces machined from the actual casting. The properties of the pieces machined from the castings may vary from those machined from separately cast test samples because of cooling rate and section size variations. Appendix D, Table D1 shows anticipated minimum tensile strengths for test pieces produced from castings of varying section thickness. When using test pieces machined from the casting, the location of the machined test specimen and its specific tensile strength requirements shall be identified on the engineering drawing. The specified tensile strength requirements shall be determined by a statistically significant sampling of test pieces that were machined from castings.

3.1.2.2.3 For heat treated gray iron, the test samples shall be poured following the same procedure as the as-cast tensile samples. These test samples shall accompany the represented castings through the heat treatment process before being machined and tested.

3.1.2.2.4 Porosity, shrink or other discontinuities within a test piece represents an invalid test, thus the data shall be discarded. The viewing of such discontinuities shall be done without the use of any magnifying device.

3.1.2.2.5 If a test specimen fails to meet a specific tensile requirement for an unknown reason, two (2) more retests can be run from the same material. If both retest pieces pass the tensile requirement, the material will be deemed acceptable.

Table 2: General Purpose Gray Cast Iron

	Grade					
	G125	G150 Note 1	G200 Note 1	G225 Note 1	G250 Note 1	G300
Mandatory Mechanical Properties Note 2						
Minimum Tensile Strength (MPa) Note 3	125	150	200	225	250	300
Brinell Hardness Note 4 (HBW)	126 to 179	143 to 207	170 to 229	179 to 241	187 to 255	207 to 262
BHD (mmHB) Note 5	4.5 to 5.3	4.2 to 5.0	4.0 to 4.6	3.9 to 4.5	3.8 to 4.4	3.7 to 4.2
Typical Matrix Microstructure						
Matrix	Predominantly Ferritic	Predominantly Ferritic	Pearlitic, Ferritic	Pearlitic, Ferritic	Pearlitic, Ferritic	Predominantly Pearlitic
Typical Chemical Composition Note 6						

	Grade					
	G125	G150 ^{Note 1}	G200 ^{Note 1}	G225 ^{Note 1}	G250 ^{Note 1}	G300
Carbon	3.35 to 3.65	3.30 to 3.60	3.15 to 3.55	3.15 to 3.50	3.10 to 3.45	3.00 to 3.45
Silicon	2.30 to 2.75	2.30 to 2.75	2.10 to 2.65	2.00 to 2.65	1.85 to 2.60	1.85 to 2.50
Manganese	0.30 to 0.60	0.30 to 0.70	0.45 to 0.90	0.45 to 0.90	0.45 to 0.90	0.60 to 0.90
Copper	0.20 maximum.	0.20 maximum.	0.40 maximum.	0.60 maximum.	0.80 maximum.	0.80 maximum.
Sulfur	0.16 maximum.	0.16 maximum	0.16 maximum.	0.16 maximum.	0.16 maximum.	0.16 maximum.
Phosphorus	0.10 maximum.	0.10 maximum.	0.10 maximum.	0.10 maximum.	0.10 maximum.	0.10 maximum.
Chromium	0.20 maximum.	0.30 maximum.	0.20 to 0.40	0.60 maximum.	0.80 maximum.	0.80 maximum.
Typical Application						
	Pump body		Brake drum	Cylinder block	Cylinder head ^{Note 7}	Bearing cap
	Transmission cover		Intake manifold		Cylinder block	
	Water pump			Pump housing	Bearing cap	
	Valve body					

Note 1: When annealed to G125 hardness range, these grades are acceptable as G125. The supplier shall, however, notify the purchaser when such substitutions are made.

Note 2: Mechanical property data represented in this chart is based on test pieces machined from separately cast 30 mm diameter test samples.

Note 3: Conversions: 1 N/mm² = 145 psi; 1 N/mm² = 1 MPa.

Note 4: Brinell Hardness values represent the hardness of both the test sample and the casting.

Note 5: Brinell Hardness Diameter (BHD) values shown use a 10 mm ball and a 3000 kg load.

Note 6: Chemical composition in weight percent.

Note 7: For heads not requiring localized valve seat hardening.

Table 3: Special Purpose Gray Cast Iron

	Grade				
	G175SP-1 ^{Note 1}	G185SP-1 ^{Note 2}	G250SP-1 ^{Note 3}	G275SP-1	GSP-1
Mandatory Mechanical Properties					
Minimum Tensile Strength (MPa) ^{Note 4}	175	185	250	275	-
Hardness HBW	163 to 207	149 to 197	187 to 255	187 to 285	-
BHD (mm) ^{Note 5}	4.2 to 4.7	4.3 to 4.9	3.8 to 4.4	3.6 to 4.4	-
Rockwell Hardness B (HRB)					95 to 106 ^{Note 6}
Typical Microstructure					
Matrix	Ferritic	Pearlitic	Ferritic/	Pearlitic	Pearlitic

	Grade				
	G175SP-1 Note 1	G185SP-1 Note 2	G250SP-1 Note 3	G275SP-1	GSP-1
			Pearlitic		
Typical Chemical Composition Note 7					
Carbon	3.45 to 3.65	3.80 to 4.00	3.10 to 3.45	3.15 to 3.55	3.60 to 3.90
Silicon	2.45 to 2.65	2.70 to 2.90	1.85 to 2.60	2.15 to 2.55	2.60 to 3.10
Manganese	0.60 to 1.00	0.35 to 0.50	0.45 to 0.90	0.50 to 0.60	0.50 to 0.80
Copper	0.30 maximum.	0.30 to 0.45	0.60 maximum.	0.30 maximum.	0.30 maximum.
Sulfur	0.16 maximum.	0.16 maximum.	0.16 maximum.	0.16 maximum.	0.10 maximum.
Phosphorus	0.35 maximum.	0.10 maximum	0.10 maximum.	0.10 maximum.	0.35 to 0.55
Chromium	0.10 maximum.	0.10 maximum.	Note 3	0.25 maximum.	0.10 maximum.
Molybdenum	0.08 maximum.	0.08 maximum.	0.08 maximum.	0.40 to 0.60	0.08 maximum.
Typical Application					
	Master cylinder	Pump Body	Cylinder head	Bearing cap	Piston ring

Note 1: This specification is for gray iron cast into permanent metal molds. To eliminate surface chill for machining, castings shall be given an annealing treatment at +900 °C for 1h minimum.

Note 2: This specification covers an electrically melted grade of gray iron cast into light-section parts by the Vacuum Assisted Casting Process. Tensile strength properties shall be determined from specially shaped test samples that are machined to a 6.35 mm diameter with a 25.4 mm gauge section. A minimum of finish stock to permit test sample clean up shall be used.

Note 3: Intended for cylinder heads requiring subsequent localized hardening of the valve seats. The chromium composition shall be 0.25% to 0.50% and the total chromium and copper content shall be 0.50% minimum.

Note 4: Conversions: 1 N/mm² = 145 psi; 1 N/mm² = 1 MPa.

Note 5: Brinell Hardness Diameter (BHD) values shown use a 10 mm ball and a 3000 kg load.

Note 6: Represents a Rockwell B hardness.

Note 7: Chemical composition in weight percent.

Table 4: Special Purpose Gray Cast Iron for Cylinder Liners

	Grade			
	G250SP-L1	G250SP-L2	G250SP-L3	G300SP-L4
Process	Static – Low Phosphorus	Centrifugal – Low Phosphorus	Centrifugal – Medium Phosphorus	Centrifugal – Low Phosphorus
Mandatory Mechanical Properties				
Minimum Tensile Strength Note 1 (MPa) Note 2	250	250	250	300
Hardness Rockwell HRB Note 3	92 to 101	95 to 106	95 to 106	
Hardness HBW Note 4	192 to 248	207 to 285	207 to 285	230 to 270
Typical Microstructure Note 5				
Matrix Note 6	Pearlitic	Pearlitic	Pearlitic	Pearlitic

	Grade			
	G250SP-L1	G250SP-L2	G250SP-L3	G300SP-L4
	Static – Low Phosphorus	Centrifugal – Low Phosphorus	Centrifugal – Medium Phosphorus	Centrifugal – Low Phosphorus
Typical Chemical Composition ^{Note 7}				
Maximum Carbon Equivalent ^{Note 8}	4.15	4.30	4.40	4.35
Carbon	3.10 to 3.40	3.20 to 3.50	3.20 to 3.50	3.00 to 3.50
Silicon	1.80 to 2.50	2.00 to 2.50	2.00 to 2.50	2.00 to 2.40
Manganese	0.50 to 0.90	0.50 to 0.90	0.50 to 0.90	0.60 to 0.80
Copper	0.50 to 1.50	0.50 to 1.50	0.20 to 0.60	0.45 maximum.
Sulfur	0.06 to 0.15	0.06 to 0.15	0.06 to 0.15	0.08 maximum.
Phosphorus	0.25 maximum.	0.25 maximum.	0.40 to 0.60	0.15 maximum.
Chromium	0.20 to 0.50	0.20 to 0.50	0.20 to 0.40	0.20 to 0.40
Molybdenum	-	-	-	0.50 to 0.90

Note 1: The tensile strength shall be determined from a test piece taken from the wall of the liner below the flange as shown on the drawing for a given part number.

Note 2: Conversions: 1 N/mm² = 145 psi; 1 N/mm² = 1 MPa.

Note 3: The Rockwell hardness measurement shall use a 100 kg load and a 1.6 mm (¹/₁₆ in) ball. The average of three (3) readings shall be taken at the top (deckface) of the finished liner.

Note 4: The alternate hardness method is the Brinell hardness which is measured at a point corresponding to the top (deckface) of the finished cylinder bore. Test is per ISO 6506 with a load to ball ratio of 3000/10 kg/mm, 750/5 kg/mm or 187.5/2.5 kg/mm as the section size dictates.

Note 5: The graphite structure shall be analyzed at the final machined bore wall surface at the top ring reversal area as shown on the drawing for each specific part number. Graphite flakes shall be at 50% minimum Type A and size four (4) to seven (7) per ISO 945 with the remainder being Types B, D, or E. Type C graphite is not allowed, nor is coarse, thick graphite of any type (refer to acceptable and unacceptable photomicrographs (Figure 1 and Figure 2) that illustrate the graphite microstructures in the unetched condition).

Note 6: For low phosphorus grades, the matrix shall contain 95% minimum lamellar pearlite at the final machined bore wall surface. Up to a combined total of 5% maximum ferrite, carbide and steadite is allowed with such constituents being finely dispersed and not in the form of massive particles or a continuous network. For medium phosphorus grades, the matrix shall consist of 85% minimum lamellar pearlite with (5% to 10%) steadite in the form of a fine network. Ferrite up to 10% maximum and carbide to of 5% maximum are allowed, both of which shall be finely dispersed.

Note 7: Chemical composition in weight percent.

Note 8: The maximum carbon equivalent composition is a mandatory requirement for cylinder liners. All other elements shall be considered as a typical requirement and secondary to microstructure and hardness. Carbon equivalent, CE = C% + (Si% + P%)/3.