



Compacted Graphite Iron

1 Scope

This material specification applies to grades of compacted graphite iron castings used in automotive and allied industries. Compacted graphite iron (CGI) is also known as vermicular graphite iron. This specification specifies mechanical properties from test bars machined from separately cast test samples. Mechanical properties may also be specified from test bars machined from specific control locations in product castings. Microstructure features shall only be evaluated at specific control locations in the product castings. Criteria for separately cast test samples and/or control locations for mechanical property and metallographic criteria shall be agreed to by the purchaser and supplier.

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Material Description. Compacted graphite iron is similar to nodular cast iron in chemistry except for a lower magnesium or cerium content. Unlike nodular iron, compacted graphite iron exhibits an as-cast structure containing graphite predominantly in the form of short thick flakes with rounded extremities and undulating surfaces. The development of graphite during solidification is sensitive to chemistry, inoculation and solidification rate. Thin sections may contain greater amounts of nodular graphite and be more susceptible to shrink than thick sections. Susceptibility to flake graphite also increases as time elapses after the final chemistry adjustment or final inoculation. Hence, chemistry, inoculation and pouring practice shall be balanced to meet required properties and microstructures. A thin skin of flake graphite can be expected at the as-cast surfaces, but elsewhere flake graphite is unacceptable in CGI components. The matrix can be made predominantly pearlitic or ferritic or a combination as required. Increasing the pearlite content of the matrix is typically achieved by alloying with a combination of manganese, copper, and tin. Mechanical properties of CGI are intermediate to gray iron and nodular iron, notably, modulus of elasticity, tensile and fatigue strengths, thermal conductivity, damping capacity and machinability.

Table 1: Material Identification

GMW Grades ^{Note 1}	Minimum Tensile Strength of Test Pieces Machined from Separately Cast Test Samples in N/mm ²
GMW7M-IR-C-CG300	300
GMW7M-IR-C-CG350	350
GMW7M-IR-C-CG400	400
GMW7M-IR-C-CG450	450

Note 1: See Section 8 for explanation.

1.2 Symbols. Not applicable.

1.3 Applicability. Compacted graphite irons with a predominately pearlitic matrix are applicable to flywheels (CG400) and engine cylinder blocks and heads (CG450). CGI with a predominantly ferritic matrix (CG300) is applicable to exhaust manifolds. (See Table 1.)

2 References

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

2.1 External Standards/Specifications.

ASTM E322	ISO 945	ISO 6506
ASTM E1019	ISO 1083	ISO 16112

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 are all interrelated, thus the chemical compositions shown in Table 2 are typical and shall be considered secondary to the mechanical properties. If a mandatory composition is required, the composition shall be agreed upon between the supplier and the purchaser and this shall be stated on the engineering drawing.

3.1.1.1 The composition listed in Table 2 reflects finished castings. Spectrographic analyses shall be taken from chilled samples. When using optical emission spectroscopy to analyze a finished casting for chemical composition, a piece of the casting shall be remelted and cast as a chilled spectrographic disk.

3.1.1.2 Spectrographic analysis of chemistry shall be measured in accordance with procedures, master samples and calibration per ASTM E322.

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.

Table 2: Typical Chemical Composition in Percent by Mass

Element	Unit	All Grades
Carbon	% by mass	3.4 to 3.9
Silicon		2.0 to 3.2
Manganese		0.60 max.
Sulfur		0.02 max.
Titanium ^{Note 1}		0.015 max.
Magnesium/Cerium		As required
Copper		1.20 max.
Chromium		0.08% max.
Tin		0.10% max.
Phosphorus		0.05 max.

max. = maximum

Note 1: Treatment processes using titanium are not allowed; the residual titanium level from charge materials is 0.015% max.

3.1.2 Mechanical Requirements. The minimum mechanical properties associated with each grade are listed in Table 3 for separately cast bars. Mechanical property testing locations on the casting, particularly hardness testing, shall be by agreement between the purchaser and the supplier. The agreed upon test locations on the casting shall be noted on the drawing. Since the microstructure and, hence, the mechanical properties can vary between different section thicknesses of the casting, correlations between castings and separately cast test samples shall be determined and documented. With a batch treatment process, the test samples shall be cast at the end of the treatment batch. The validity of tests and applicability of any retests shall be in accordance with ISO 1083. The final sampling plan shall be agreed upon by the purchaser and the supplier.

3.1.2.1 Hardness. Brinell hardness shall be taken in accordance with ISO 6506. The material hardness requirements described in Table 3 shall be met on both test samples and the castings they represent. To prepare

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as-cast surfaces for the load impression, grind or machine to a representative depth of ≈ 1.5 mm 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 supplier and customer. The purchaser and supplier may also agree to locations for hardness checks on machined surfaces or core hardness.

3.1.2.2 Tensile Strength. The tensile properties in Table 3 apply to test pieces that are machined from separately cast test samples as described in ISO 16112. The separately cast test samples represent the quality of the metal from which the castings are poured.

3.1.2.2.1 The separately cast samples shall be poured into baked, green sand, or chemically bonded molds made of a siliceous sand aggregate that is similar to the aggregate used in production molds. The samples shall cool to $+480$ °C or until a fully gray color is observed. At this time, the sample can be removed from the mold and allowed to air cool.

3.1.2.2.2 Tensile properties may be specified from test pieces machined from the actual castings and/or special test coupons that are cast integral with the product castings. These properties may vary from those machined from separately cast samples because of cooling rate and section size variations.

Table 3: Mechanical Properties (Separately Cast Test Bars)

Property	Unit ^{Note 1}	CG300	CG350	CG400	CG450
Minimum tensile strength	N/mm ²	300	350	400	450
Minimum yield strength	N/mm ²	210	245	280	315
Minimum elongation	%	2.0	1.5	1.0	1.0
Hardness	HB	140 to 210	160 to 220	180 to 240	200 to 250

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

3.1.2.2.3 For heat treated CGI, separately cast 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 separately cast test piece represent an invalid test, thus the data shall be discarded. The viewing of such discontinuities shall be done without the use of any magnifying device. Allowable porosity, shrink or other discontinuities within a test piece machined from a casting will be allowed so long as the test specimen breaks within its gauge length.

3.1.2.3 Yield Strength. The yield strength shall be determined by the 0.2% offset method during the course of the tensile test (see paragraph 3.1.2.2). Other methods may be used by mutual consent of the purchaser and supplier.

3.1.2.4 Percent Elongation. The percent elongation calculation will be based on the ISO 1083 standard in which the original gage length is 5 times that of the gauge diameter. (Note that the ASTM English units standard calls for the original gage length to be 4 times that of the diameter.) The percent elongation is determined as part of the tensile test (see 3.1.2.2). An extensometer shall be used until specimen failure to measure the plastic elongation accurately.

3.1.3 Physical Requirements. Typical values for physical properties are shown in Table A1 of Appendix A. These properties have been gathered from text books and are for reference only. They are not derived from GM laboratory testing.

3.1.4 Additional Requirements.

3.1.4.1 Microstructure Requirements. The graphite form and matrix phases will vary within the casting due to variations in section size and will further vary between castings due to fading of treatment and inoculant alloys. Hence, microstructure samples should be taken from the last metal poured within each treated batch. The first metal poured from a treated batch may also be monitored to guard against high nodularity caused by excessive treatment alloy addition. The control locations on the casting shall be identified on the engineering drawing after agreement between the purchaser and supplier is reached. When analyzing specimens for microstructure, at least five fields of view shall be inspected at the specific control location. Microstructures are not to be read