GM WORLDWIDE ENGINEERING STANDARDS	**Material Specification**	**GMW10**

Nodular Cast Iron

1 Scope

This material specification covers castings made of nodular iron, also known as spheroidal or ductile iron, as used in automotive and allied industries. This specification describes the material properties, not specific casting properties, based on data obtained from separately cast Y-block test samples. Any specific requirements for the whole or a critical section of a casting shall be identified on the engineering drawing.

1.1 Material Description (see Table 1 and Table A1 in Appendix A). Nodular iron is a cast iron with an as-cast structure containing graphite of a spheroidal or nodular shape. These irons are produced commercially by treating molten iron of appropriate base metal composition with magnesium. The presence of the graphite in the truly spheroidal condition results in a significant improvement of ductility.

Table 1: Material Description

GMW Grades Note 1	Minimum Tensile Strength of Test Pieces Machined from Separately Cast Test Samples in N/mm^2
GMW10M-IR-C-N350A-22	350
GMW10M-IR-C-N400A-18	400
GMW10M-IR-C-N400-15	400
GMW10M-IR-C-N450-12	450
GMW10M-IR-C-N450-10	450
GMW10M-IR-C-N500-7	500
GMW10M-IR-C-N550-6	550
GMW10M-IR-C-N550-3	550
GMW10M-IR-C-N600-3	600
GMW10M-IR-C-N700-2	700
GMW10M-IR-C-N700M-2	700
GMW10M-IR-C-N800M-2	800
GMW10M-IR-C-N700-8	700

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

1.2 Symbols. Not applicable.

1.3 Applicability. Nodular cast iron is used for those applications which require high strength, toughness and high resistance to wear, thermal shock and scaling. Typical applications include crankshafts, camshafts, knuckles, control arms, motor mounts and differential carriers.

2 References

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

2.1 External Standards/Specifications.

ASTM A536	ASTM E1010	ASTM E1999	ISO 945	ISO 6506
ASTM E8	ASTM E1019	ISO 148	ISO 1083	ISO 6892

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2.2 GM Standards/Specifications.

GMW3059 GMW16547

2.3 Additional References.

TMC003 Material Safety Data Sheet guidance documents (available at www.gmsupplypower.com).

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 Table 2 and Table 3 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 purchaser and the supplier and is to be stated on the engineering drawing.

Even though the chemistry is typical, it is expected that a narrower range of composition limits be set up to achieve the desired mechanical properties during Prototype/Production Part Approval Process (PPAP) stages and adhered to during regular production so as consistent parts are received through the life of the program. The supplier, prior to delivery of castings, shall document in the GM engineering drawing or other equivalent part specification documents, the limits on chemical composition that will be controlled in production.

3.1.1.1 The compositions listed in Table 2 and Table 3 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 remelted 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 in accordance with standard procedures, master samples and calibration per ASTM E1019.

Table 2: Typical Chemical Composition - As-cast Grades

Element	Grade Note 1, Note 2					
	N400-15	N450-12	N450-10	N500-7	N550-6	N550-3
Carbon	3.30 to 3.90	3.30 to 3.90	3.30 to 3.90	3.30 to 3.90	3.30 to 3.90	3.30 to 3.90
Silicon	1.80 to 2.70	1.80 to 2.70	1.80 to 2.70	1.80 to 2.70	1.80 to 2.70	1.80 to 2.70
Manganese	0.40 max.	0.70 max.	0.70 max.	0.70 max.	0.20 to 1.00	0.20 to 1.00
Copper	0.30 max.	0.50 max.	0.50 max.	0.70 max.	0.70 max.	0.70 max.
Sulfur	0.02 max.	0.02 max.	0.02 max.	0.02 max.	0.02 max.	0.02 max.
Phosphorus	0.05 max.	0.05 max.	0.05 max.	0.05 max.	0.05 max.	0.05 max.
Chromium	0.10 max.	0.10 max.	0.10 max.	0.10 max.	0.10 max.	0.10 max.
Magnesium	0.03 to 0.05	0.03 to 0.05	0.03 to 0.05	0.03 to 0.05	0.03 to 0.05	0.03 to 0.05

Note 1: Chemical composition in weight percent.
Note 2: Max. = Maximum.

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Table 2: Typical Chemical Composition - As-cast Grades (continued) and Heat Treated Grades

Element	Grade Note 1, Note 2				
	N600-3	N700-2	N700M-2	N800M-2	N700-8
Carbon	3.30 to 3.90	3.30 to 3.90	3.30 to 3.90	3.30 to 3.90	3.35 to 3.65
Silicon	1.80 to 2.70	1.80 to 2.70	1.80 to 2.70	1.80 to 2.70	2.30 to 3.00
Manganese	0.20 to 1.00	0.20 to 1.00	0.20 to 1.00	0.20 to 1.00	0.15 to 0.40
Copper	0.70 max.	0.70 max.	0.70 max.	0.70 max.	0.50 to 1.10
Sulfur	0.02 max.	0.02 max.	0.02 max.	0.02 max.	0.01 max.
Phosphorus	0.05 max.	0.05 max.	0.05 max.	0.05 max.	0.03 max.
Chromium	0.10 max.	0.10 max.	0.10 max.	0.10 max.	0.10 max.
Magnesium	0.03 to 0.05	0.03 to 0.05	0.03 to 0.05	0.03 to 0.05	0.025 to 0.040

Note 1: Chemical composition in weight percent.
Note 2: Max. = Maximum.

Table 3: Typical Chemical Composition - Annealed Grades

Element	Grade Note 1, Note 2	
	N350A-22	N400A-18
Carbon	3.30 to 3.90	3.30 to 3.90
Silicon	1.80 to 2.70	1.80 to 2.70
Manganese	0.60 max.	0.60 max.
Copper	0.30 max.	0.30 max.
Sulfur	0.02 max.	0.02 max.
Phosphorus	0.05 max.	0.05 max.
Chromium	0.10 max.	0.10 max.
Magnesium	0.03 to 0.05	0.03 to 0.05

Note 1: Chemical composition in weight percent.
Note 2: Max. = Maximum.

3.1.2 Mechanical Requirements. The specific mechanical properties associated with each grade are listed in Tables 4a and 4b. The mechanical properties are the primary requirements in grading and classifying nodular irons for use as automotive castings. Mechanical properties are obtained from test pieces that are machined from separately cast Y-shaped test samples, described in ISO 1083 standard, or test samples that are cast in a production mold (co-cast). The Y-shaped test samples shall be cast at the end of the treatment batch. 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 1083.

3.1.2.1 Hardness. Brinell hardness shall be taken in accordance with ISO 6506. The material hardness requirements described in Tables 4a and 4b shall be met on both the test piece and its represented castings. Since casting hardness will vary throughout the part due to differences in section size and cooling rates, the specific test location(s) on the casting shall have agreement between the purchaser and the supplier and shall be identified on the engineering drawing. To prepare the casting for the load impression, ≈ 1.5 mm of stock shall be removed from the surface to reach a representative structure of the casting. 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.

The hardness indicated in the table has a wider range. It is expected that a narrower range of hardness limits be set up during prototype/PPAP stages and adhered to during regular production, so as consistent parts are received through the life of the program. The supplier, prior to delivery of castings, shall document in the GM engineering drawing or other equivalent part specification documents, the limits on hardness that will be controlled in production at a specific location. The parts must have been validated at both end of the hardness ranges set up for production and documented.

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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 4a and 4b. Test pieces shall be machined from test samples which can be separately cast test samples (Y-block) or test samples that are cast in a production mold (co-cast). The test pieces shall comply with the dimensions described in ISO 1083 standard and shall follow the test procedure in ISO 6892. The separately cast test samples represent the quality of the material and melt from which the casting is poured. The manufacturer shall maintain sufficient controls and documentation to assure the purchaser that properties determined from separately cast or co-cast test samples are representative of the castings shipped.

3.1.2.2.1 The separately cast test samples (Y-blocks) 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 samples can be removed from the mold and allowed to air cool.

3.1.2.2.2 For safety critical applications, it is a standard practice to specify tensile strength properties for test pieces machined from the actual castings. The properties of the pieces machined from the castings may vary from those machined from separately cast samples because of cooling rate and section size variations. When using test pieces machined from the casting, the location and specific tensile strength requirements shall be identified on the engineering drawing. If test samples are used to qualify castings for specific product requirements, a correlation study between separately/co-cast and test pieces machined from castings shall be completed. When the mechanical properties of test pieces machined from castings are different from the grade values (from separately cast test bars) specified in Tables 4a and 4b, the casting property values from the successfully validated lot shall be indicated in GM engineering drawings and will become the controlling values for production.

3.1.2.2.3 If the nodularizing treatment is carried out in the mold (in-mold method), the separately cast test samples (Y-blocks or test samples) may be cast directly onto the casting using a feeder gate or cast separately in the mold such as to receive the same treated iron as the casting. The separately cast Y-block that is poured in a production mold shall meet the dimensions shown in ISO 1083. When space in a production mold is not available for a Y-block, a separately cast test sample in the mold (co-cast) may be used if it has a minimum diameter of 25 mm and a minimum length of 225 mm.

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

3.1.2.2.5 Porosity, shrink or other discontinuities within a test piece represent an invalid test, thus the data shall be discarded.

Table 4a: Mechanical Properties of Nodular Iron Grades

Property	Unit Note 1	Grade					
		N350A-22	N400A-18	N400-15	N450-12	N450-10	N500-7
Minimum Tensile Strength Note 2	N/mm^2	350	400	400	450	450	500
Minimum Yield Strength Note 2, Note 3	N/mm^2	220	250	250	310	290	320
Minimum Elongation Note 2	%	22	18	15	12	10	7
Hardness Note 4	HBW	110 to 150	120 to 170	130 to 180	160 to 210	160 to 210	170 to 230
Mean/Minimum V- Notched Bar Impact Energy							
at (+20 ± 3) °C	J	17/14	14/11	---	---	---	---
at (-20 ± 3) °C	J	---	12/9	---	---	---	---
at (-40 ± 3) °C	J	12/9	---	---	---	---	---
Minimum Un-notched Bar Impact Energy							
at (-30 ± 3) °C	J	70	70	---	---	---	---

Note 1: Conversions: 1 N/mm^2 = 145 psi; 1 N/mm^2 = 1 MPa.
Note 2: Mechanical property data is based on 12.7 mm test pieces machined from Type II Y-shaped separately cast test samples.
Note 3: Yield strength is determined at a 0.2% offset.
Note 4: Hardness values represent the hardness of both the test piece and the casting.

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