



Pressure Die Cast Magnesium Alloys

1 Scope

1.1 Material Description. This material specification applies to magnesium alloys for cast parts for automotive and other allied industries. This standard governs only the chemical composition of parts made with magnesium alloys that represent common materials for identical product requirements across GM worldwide. Casting processes, thermal treatments, casting quality, microstructure, and mechanical properties are discussed, but are not controlled by this standard. Many metallic elements readily alloy with magnesium, but only a few are used in commercial magnesium based alloys. Principle alloying elements include aluminum (Al), zinc (Zn), manganese (Mn), silicon (Si), and rare earth (RE) elements.

1.2 Symbols. Not applicable.

1.3 Applicability. Magnesium castings are widely used in automotive applications. Typical applications and alloy selection criteria for major subsystems are given in Appendix A, Table A1. Also see Appendix C.

2 References

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

2.1 External Standards/Specifications.

ASTM B954-07	ISO 2092	ISO 6892
ASTM E88	ISO 6506	

2.2 GM Standards/Specifications.

GMW3059

2.3 Additional References.

- ASM Handbook available at <http://www.asminternational.org/>.
- Safety and Industrial Hygiene (S&IH) Technical Standard (TS), S&IH TS 3.4-160-02

3 Requirements

3.1 Chemical Requirements. Suppliers shall deliver castings that conform to chemical composition limits shown in Table 1. Exceptions to GMW3028 composition requirements require agreement from purchaser (Design Responsible Engineer or delegate), and shall be explicitly documented on the GM engineering drawing and other equivalent part specification document.

Table 1: Base Chemical Composition for GMW3028 Alloy Series

Element Note 1	Al	Zn	Mn	Si	Fe	Cu	Ni	RE Note 2	Fe/Mn Note 3	RE/Al	Other, Each	Other, Total
Al9Zn1	8.3 to 9.7	0.35 to1.0	0.15 to 0.50	0.10 maximum	0.005 maximum	0.030 maximum	0.001 maximum	-	0.032 maximum	-	0.01 maximum	0.15 maximum
Al5Mn	4.4 to 5.5	0.20 maximum	0.26 to 0.60	0.10 maximum	0.005 maximum	0.010 maximum	0.001 maximum	-	0.015 maximum	-	0.01 maximum	0.15 maximum
Al6Mn	5.5 to 6.5	0.20 maximum	0.24 to 0.60	0.10 maximum	0.005 maximum	0.010 maximum	0.001 maximum	-	-	-	0.01 maximum	0.15 maximum

Element Note 1	Al	Zn	Mn	Si	Fe	Cu	Ni	RE Note 2	Fe/Mn Note 3	RE/Al	Other, Each	Other, Total
Al4Si	3.5 to 5.0	0.20 maximum	0.1 to 0.70	0.50 maximum	0.005 maximum	0.010 maximum	0.001 maximum	-	0.010 maximum	-	0.01 maximum	0.15 maximum
Al4RE2	3.40 to 4.60	0.20 maximum	0.10 to 0.50	0.050 maximum	0.004 maximum	0.008 maximum	0.001 maximum	2.0 to 3.0	0.020 maximum	-	-	0.15 maximum
Al4RE4	3.60 to 4.40	0.20 maximum	0.18 to 0.50	0.050 maximum	0.004 maximum	0.008 maximum	0.001 maximum	3.6 to 4.6	0.020 maximum	0.90 minimum	0.01 maximum	0.15 maximum

Note 1: Composition limits in percent by weight, remainder of each alloy is Mg.

Note 2: Total Rare Earth (TRE) additions are principally a mixture of Cerium, Lanthanum, Neodymium and Praseodymium with the following ranges: **Ce:** 60% to 70%, **La:** 30% to 40%, **Nd + Pr** < 1.0%.

Note 3: If either the minimum manganese or maximum iron limit is not met, then the iron/manganese shall not exceed the given values.

3.1.1 Chemical Analysis. The casting producer shall control chemical composition with samples taken from the melt prior to casting and solidified in a metallic die. Chemistry shall be measured in accordance with procedures, master samples, and calibration per ASTM B954-07; or equivalent.

3.1.1.1 Disputes. If there is a dispute concerning chemistry, parts shall be sampled and analyzed by wet chemical methods per ASTM E88, or equivalent. Samples shall be excised (e.g., drilled) from multiple locations in the part to minimize segregation effects; these may be mixed together and analyzed, or individually analyzed; if individual samples are analyzed, results shall be averaged.

3.1.1.2 Other Chemical Analysis Methods. Alternatively, parts or remelted and cast sections of parts may be analyzed spectrographically. Such analysis shall not supercede 3.1.1 and 3.1.1.1 due to potential error caused by segregation, incompatibility with master samples, or oxidative alloy element loss.

3.2 Casting Requirements. Castings furnished shall be free from cold laps, misruns, hot tears, cracks, macroporosity, shrinkage, dross, mold material and lubricants, entrapped air, and any other discontinuities, all to an extent that would be detrimental to machinability, appearance, or performance. These discontinuities, plus surface roughness, casting cleanliness, and weight of retained material, may have maximum allowable limits specified. For any of the preceding casting requirements, a measurement system shall be agreed upon by supplier and purchaser (Design Responsible Engineer or delegate).

3.3 Microstructure Requirements. The following microstructural features may be specified in identified regions of a cast magnesium product: percent porosity, largest pore size, and dendrite arm spacing. Usage of grain refinement must be disclosed in the process control plan or equivalent document, and any change is subject to Production Part Approval Process (PPAP) requirements. Limits on macro-segregation of alloying elements may be imposed. If microstructure features are specified, a measurement system shall be agreed upon by the supplier and purchaser (Design Responsible Engineer or delegate).

3.4 Mechanical Properties. This specification does not govern mechanical properties. Mechanical properties are significantly influenced by alloy composition and casting process parameters, such as molten metal handling practice, casting process, and thermal history. Properties of test specimens excised from castings will differ from cast-to-shape test bars due to differences in solidification conditions and thermal history. Therefore, any specific property required from a particular casting or section of a casting shall be called out separately on the GM engineering drawing and other equivalent part specification documents.

3.4.1 Specification of Mechanical Properties. By agreement between supplier and purchaser (Design Responsible Engineer or delegate) hardness and mechanical property requirements may be specified on the GM engineering drawing and other equivalent part specification documents. Unless otherwise specified, testing shall be done in accordance with ISO 6506 for hardness and ISO 6892 for tensile properties. The supplier and purchaser (Design Responsible Engineer or delegate) shall agree on a sampling plan.

3.5 Physical Properties. This specification does not govern physical properties. Typical physical properties associated with each alloy grade are shown in Appendix B, Table B1.

3.6 All materials supplied to this standard must comply with GMW3059, Restricted and Reportable Substances, including the requirement to obtain a GM-approved International Material Data System (IMDS) submission.

4 Manufacturing Process

The selection of the casting process shall be a joint agreement between the supplier and purchaser (Design Responsible Engineer or delegate).

4.1 Casting. Castings are made by sand castings, permanent mold, high pressure die castings, and high pressure vacuum die casting (hot and cold chamber) and thixomolding processes.

4.1.1 Process Coding. Table 2 lists and defines codes that shall be included in the alloy callout per Section 8.

4.2 Temper (Heat Treatment). A temper designation from Table 3 shall be appended in the alloy callout per Section 8 except when specifying ingot. Tempers comprise combinations of solution and aging treatments, the latter at room temperature (natural aging) or elevated temperature (artificial aging). The temper designation does not explicitly control the heat treatment process (temperature, times, cooling rates, etc.) Heat treatment parameters must be selected to meet separate requirements (e.g., tensile properties, or stability) and are subject to agreement between supplier and purchaser (Design Responsible Engineer or delegate).

Table 2: Coding and Descriptions for Processes Used in Magnesium Casting

Code	Process	Description
S	Sand Casting	Bonded sand mold (e.g., green sand and chemically bonded sand) with cavity filling accomplished by gravity or low pressure method. A variant of the process uses vacuum to hold mold shape. A variant combining chemically bonded sand and large chills is known as the precision sand process.
P	Permanent Mold	Known as die casting outside North America. Metal mold with cavity filling by gravity or low pressure method. A variant, semi-permanent mold, refers to the use of bonded sand cores inserted into the metal mold cavity to create internal cavities.
D	Die Casting	Known as high-pressure die casting outside North America. Metal mold with cavity filling at high injection speed under high pressure and turbulence. A variant, vacuum die casting, uses vacuum to draw metal into the mold at intermediate fill rate.
R	Semi-Solid Metal Casting	Metal mold with cavity filling at low injection speed under high pressure. Semi-solid metal is produced by reheating billet cast with a spheroidized dendritic structure, or by stirring metal until it is partially solidified, the latter known as rheocasting.
T	Thixomolding	Chipped magnesium is fed into a barrel and screw in which the feed stock is heated to a semi-solid or fully molten state. The Mg alloy slurry in the barrel is injected into the mold cavity similar to plastic injection.
X	Unspecified, or other	The X code shall be used for any process that does not represent one of the category codes provided in Table 2, this could include investment, plaster, and centrifugal casting, and ingot.

Table 3: Definition of Temper (Heat Treatment) Designations

Temper	Description
F	As-cast (as-fabricated). Applies to products processed without ostensive thermal treatment.
T4	Solution heat-treated and naturally aged.
T5	Cooled from an elevated temperature process and precipitation-treated (artificially aged).
T6	Solution heat-treated, quenched and precipitation-treated (artificially aged).
T7	Solution heat-treated, quenched and stabilized (artificially over aged).