



Cast Aluminum Alloys

1 Scope

This material specification applies to aluminum alloys for cast parts for automotive and other allied industries. Aluminum casting alloys are specified by chemical composition and thermal treatment. This standard governs only the chemical composition of parts made with aluminum 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.

1.1 Material Description. Most metallic elements readily alloy with aluminum, but only a few are used in commercial aluminum based alloys. Principle alloying elements include Si, Cu and Mg. Additional elements such as Mn, Na, Sr and Ti serve as supplementary alloying additions for improving material properties and casting characteristics. Other elements appear as impurities, which can affect alloy cost and product properties.

1.2 Symbols. Not applicable

1.3 Applicability. Aluminum castings are widely used in automotive applications. Typical applications and alloy selection criteria for major subsystems are given in Table A1 in Appendix A.

1.4 Remarks. Appendix B, Table B1 is a guide of GMW5 alloys and global industry standards such as; ISO 3522, ISO 209 and key European, Asian and American standards and is presented for reference only. GMW5 requirements may differ from those in other specifications. Global referenced alloys are not interchangeable with their GMW5 counterpart.

2 References

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

2.1 External Standards/Specifications.

ASTM E34	ASTM E1251	ISO 3522	ISO 9916
ASTM E88	GB/T 7999	ISO 6506	
ASTM E406	ISO 209	ISO 6892	
ASTM E607	ISO 2092	ISO 9915	

2.2 GM Standards/Specifications.

GMW3059

3 Requirements

3.1 Chemical Requirements. Suppliers shall deliver castings that conform to chemical composition limits shown in Tables 1 thru 4 and, if applicable, Table 5. Tables 1 through 4 contain base composition limits for GMW5 alloys; Table 5 contains restricted composition limits applicable when option "Class A" is included in the specification callout (see 3.1.2). Exceptions to GMW5 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 documents.

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 E34, ASTM E406, ASTM E607, ASTM E1251, GB/T 7999, or equivalent.

3.1.1.1 Analysis of Parts. For resolving disputes and auditing chemical composition, parts shall be sampled and analyzed by wet chemical methods per ASTM E88 and ASTM E34, 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 supersede 3.1.1 and 3.1.1.1 due to potential error caused by segregation, incompatibility with master samples, or oxidative alloy element loss.

3.1.2 Optional Callout for Class A Restricted Composition. For critical components (e.g., certain cylinder heads and blocks) a code may be added to the alloy callout to restrict chemical composition ranges of Si, Cu, Mg, Fe, Mn and Zn, which affect strength, castability and porosity. The Class A designation shall require these elements be restricted to the range, maximum or minimum listed in Table 5.

3.1.2.1 Selection and Documentation of Si, Cu and Mg Ranges for Class A Restricted Composition. Supplier and purchaser (Design Responsible Engineer or delegate) shall select, agree on and document, prior to delivery of castings, limits on Si, Cu and Mg that shall be controlled in production; the selected maximum and minimum of these three elements shall lie within larger ranges listed for Tables 1 thru 4 base compositions. The restricted ranges that are chosen for these elements shall be documented in the GM engineering drawing and other equivalent part specification documents.

Table 1: Base Chemical Composition for GMW5 Alloy Series – Specialty Alloys
(If included in callout, Class A Restricted Composition supersedes limits on Si, Cu, Mg, Mn, Fe and Zn)

Element ^{Note 1}	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Pb	Sn	Ti	Other, each	Other, total
Al99.7 ^{Note 2}	Note 2	Note 2	—	Note 2	—	Note 2	—	0.05 max	—	—	Note 3	0.03 max	0.10 ^{Note 2}
Cu5Mg0.4Mn	0.05 max	0.20 max	4.2 to 5.0	0.20 to 0.50	0.15 to 0.55	—	0.05 max	0.10 max	—	—	0.10 max	0.05 max	0.15 max
Si7MnMg ^{Note 3, Note 4}	6.0 to 8.0	0.25 max	—	0.30 to 0.60	0.10 to 0.60	—	—	—	—	—	0.15 max	0.05 max	0.15 max
Si8MnMg ^{Note 5}	7.5 to 8.5	0.20 max	0.20 max	0.30 to 0.60	0.20 to 0.30	—	—	—	—	—	—	0.05 max	0.15 max
Si10MnMg ^{Note 6}	9.5 to 11.5	0.15 max	0.03 max	0.50 to 0.80	0.10 to 0.50	—	—	0.07 max	—	—	0.04 to 0.15	0.03 max	0.10 max
Si10MnMgA ^{Note 3, Note 4}	9.5 to 11.5	0.25 max	—	0.30 to 0.70	0.10 to 0.60	—	—	—	—	—	0.10 max	0.05 max	0.15 max
Si10Cu1MnMg ^{Note 3, Note 7}	8.5 to 11.0	0.20 max	0.80 to 1.5	0.30 to 0.80	0.40 max	—	—	0.07 max	—	—	0.20 max	0.05 max	0.20 max
Si11Cu3MnMg ^{Note 8}	10.5 to 12.0	0.55 max	2.25 to 3.25	0.75 max	0.25 to 0.55	—	—	1.0 max	—	—	0.15 max	0.05 max	—
Si12Cu1Mg1Ni1	11.0 to 13.0	0.8 max	0.8 to 1.3	0.15 max	0.7 to 1.3	0.10 max	0.8 to 1.5	0.15 max	0.05 max	0.05 max	0.20 max	—	0.50 max
Si12Cu1Ni1Mg	11.0 to 13.0	0.8 max	0.8 to 1.8	0.40 max	0.25 to 0.55	—	0.8 to 1.3	0.50 max	—	—	0.20 max	0.05 max	—

Note 1: Composition limits in % by weight. Remainder of each alloy is Al.

Note 2: Additional limits not included in "Other" for Al99.7: Fe/Si ratio = 1.5 min, Mn+Cr+Ti+V = 0.025 max, Al=99.70 min (i.e., Fe+Si+Mn+Cr+Zn+Ti+V+other, total = 0.30 max).

Note 3: For GMW5 2016 release alloy Mg0.6Si0.5 was removed for non-use and new alloys added include; Si7MnMg, Si10MnMgA and Si10Cu1MnMg.

Note 4: Additional limits not included in "Other" for Si7MnMg and Si10MnMgA – Sr: 0.010 to 0.030.

Note 5: Additional limits not included in "Other" for Si8MnMg – Sr: 0.010 to 0.020.

Note 6: Additional limits not included in "Other" for Si10MnMg – Sr: 0.035 max

Note 7: Additional limits not included in "Other" for Si10Cu1MnMg – Sr: 0.010 to 0.050, P: 0.005 max

Note 8: Additional limits not included in "Other" for Si11Cu3MnMg – Mn/Fe ratio: 1.1 min, Sr: 0.008 to 0.025, Ca: 0.04 max, P: 0.04 max

max = maximum; **min** = minimum

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Table 2: Base Chemical Composition for GMW5 Alloy Series – (Al) Si Mg

(If included in callout, Class A Restricted Composition supersedes limits on Si, Cu, Mg, Mn, Fe and Zn)

Element Note 1	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Pb	Sn	Ti	Other, each	Other, total
Si7Mg	6.5 to 7.5	0.20 max	0.10 max	0.10 max	0.25 to 0.45	–	0.05 max	0.10 max	–	–	0.20 max	0.05 max	0.15 max
Si7Mg0.5	6.5 to 7.5	0.15 max	0.05 max	0.03 max	0.45 to 0.60	–	–	0.05 max	–	–	0.20 max	0.05 max	0.15 max
Si7Mg(Fe)	6.5 to 7.5	0.60 max	0.20 max	0.60 max	0.20 to 0.40	–	0.05 max	0.30 max	0.05 max	0.05 max	0.20 max	0.05 max	0.15 max
Si7Cu0.5Mg Note 2	6.5 to 7.5	0.20 max	0.40 to 0.60	0.10 max	0.25 to 0.45	–	0.05 max	0.10 max	–	–	0.20 max	0.05 max	0.15 max
Si9Mg	9.0 to 10.0	0.19 max	0.05 max	0.10 max	0.25 to 0.45	–	–	0.07 max	–	–	0.15 max	0.03 max	0.10 max
Si10Mg Note 3	9.0 to 11.0	0.60 max	0.10 max	0.60 max	0.15 to 0.40	–	0.05 max	0.10 max	0.05 max	0.05 max	0.20 max	–	0.50 max

Note 1: Composition limits in % by weight. Remainder of each alloy is Al.**Note 2:** New alloy for 2016 release of GMW5.**Note 3:** In Table 2 only Si10Mg is affected by Class A requirements. Class A should not be used on the other alloys.**max** = maximum**Table 3: Base Chemical Composition for GMW5 Alloy Series (Fe ≤ 1%) – (Al) Si Cu, (Al) Si Cu Mg**

(If included in callout, Class A Restricted Composition supersedes limits on Si, Cu, Mg, Mn, Fe and Zn)

Element Note 1	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Pb	Sn	Ti	Other, each	Other, total
Si6Cu3	5.0 to 7.0	1.0 max	2.0 to 4.0	0.50 max	0.50 max	0.20 max	0.35 max	1.0 max	0.20 max	0.10 max	0.20 max	0.05 max	0.15 max
Si6Cu4Mg	5.0 to 7.5	1.0 max	3.0 to 5.0	0.10 to 0.60	0.10 to 0.50	–	0.30 max	2.0 max	0.30 max	0.10 max	0.15 max	0.05 max	0.15 max
Si7Cu3Mg Note 2	6.5 to 8.0	0.8 max	3.0 to 4.0	0.20 to 0.50	0.30 to 0.60	–	0.30 max	0.8 max	0.15 max	0.10 max	0.25 max	0.05 max	0.25 max
Si9Cu1Mg	9.0 to 10.0	0.30 max	0.8 to 1.3	0.10 max	0.25 to 0.5	–	0.10 max	0.10 max	–	0.05 max	0.15 max	0.05 max	0.40 max
Si9Cu3	8.0 to 11.0	0.8 max	2.0 to 3.5	0.10 to 0.50	0.50 max	–	0.30 max	1.2 max	0.20 max	0.10 max	0.15 max	–	0.50 max
Si9Cu3(Fe)	7.0 to 10.0	1.0 max	2.0 to 4.0	0.50 max	0.50 max	0.20 max	0.35 max	1.0 max	0.20 max	0.10 max	0.20 max	–	–
Si12Cu	11.0 to 13.5	0.9 max	1.2 max	0.50 max	0.30 max	–	0.30 max	0.50 max	0.20 max	0.10 max	0.20 max	–	0.50 max

Note 1: Composition limits in % by weight. Remainder of each alloy is Al.**Note 2:** Additional limits not included in "Other" for Si7Cu3Mg – Sr: 0.010 max, Ca: 0.015 max, Na: 0.30 max**max** = maximum

Table 4: Base Chemical Composition for GMW5 Alloy Series (Fe > 1%) – (Al)SiCuMgFe

(If included in callout, Class A Restricted Composition supersedes limits on Si, Cu, Mg, Mn, Fe and Zn)

Element ^{Note 1}	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Pb	Sn	Ti	Other, each	Other, total
Si8Cu3Fe	7.5 to 9.5	1.3 max	2.5 to 4.0	0.6 max	0.30 max	–	0.50 max	1.2 max	0.30 max	0.20 max	0.20 max	–	0.50 max
Si8Cu3Fe1(Zn)	7.5 to 9.5	1.3 max	3.0 to 4.0	0.5 max	0.10 max	–	0.50 max	3.0 max	–	0.35 max	–	–	0.50 max
Si9Cu3Fe1 ^{Note 2}	8.0 to 11.0	1.3 max	2.0 to 3.5	0.10 to 0.50	0.50 max	–	0.30 max	1.2 max	0.20 max	0.10 max	0.15 max	–	0.50 max
Si10Cu2Fe1	9.5 to 11.5	1.3 max	2.0 to 3.0	0.50 max	0.10 max	–	0.30 max	3.0 max	–	0.15 max	–	–	0.50 max
Si10Cu4Fe1	9.0 to 10.0	1.3 max	3.0 to 4.0	0.50 max	0.13 max	0.15 max	0.50 max	3.0 max	0.15 max	0.15 max	0.20 max	–	0.50 max
Si11Cu3Fe1	9.6 to 12.0	1.3 max	1.5 to 3.5	0.50 max	0.30 max	–	0.50 max	1.0 max	0.20 max	0.20 max	0.30 max	–	–
Si17Cu4Fe1 ^{Note 3}	16.0 to 18.0	1.3 max	4.0 to 5.0	0.50 max	0.45 to 0.65	–	0.10 max	1.5 max	–	–	0.20 max	0.10 max	0.20 max

Note 1: Composition limits in % by weight. Remainder of each alloy is Al.**Note 2:** Si9Cu3Fe1 is the high pressure die casting version of Si9Cu3 in Table 3.**Note 3:** Composition limits revised to be identical to Aluminum Association B390.0 limits.**max** = maximum**Table 5: Class A Restricted Composition** ^{Note 1}
(Only Applicable if Included in Callout)

Element	Casting Process ^{Note 2}	Restricted Composition ^{Note 3, Note 4}
Si	All processes	Range: 1.0
Cu	All processes	Range: 1.0
Mg	All processes	Range: 0.20
Fe	L, S, X	Max: 0.60
	P	Max: 0.80
	D, Q, R	Max: 1.3
Mn/Fe Ratio and Mn ^{Note 5}	L, S, X	Min Mn/Fe: 0.60 Max Mn: 0.50
	P	Min Mn/Fe: 0.60 Max Mn: 0.60
	D, Q, R	none
Zn	All processes	1.0 max

Note 1: Composition limits in % by weight.**Note 2:** See Table 6 for a description of process codes.**Note 3:** Range is the difference between agreed upon maximum and minimum, and shall lie within Tables 1 thru 4 base composition limits.**Note 4:** Class A limits shall not supersede Tables 1 thru 4 base composition limits that are more restrictive.**Note 5:** Minimum Mn shall be controlled as Mn/Fe ratio and thus depends on the actual Fe content of each lot.**Max** and **Min** indicate limits that supersede those in Tables 1 thru 4.**max** = maximum; **min** = minimum

3.1.2.2 Where Base Composition Limits are More Restrictive than Class A. In some GMW5 alloys, the base composition limits for one or more elements are more restrictive than those for Class A (e.g., Fe content for Si10MnMg in Table 1). When this occurs, the base composition limits as listed in Tables 1 thru 4 shall take precedence. (i.e., for Class A the more restrictive limits of Tables 1 thru 5 shall apply). **Note:** Most base composition limits of (Al)SiMg alloys in Table 2 are more restrictive than Class A limits.

3.1.2.3 Class A Coding and Examples of Usage. The convention for coding Class A restricted composition is given in Section 8. Appendix C illustrates usage.

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 above 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 aluminum product: percent porosity, largest pore size, dendrite arm spacing, maximum constituent particle size, platelet section length of Fe-rich intermetallic phases. Usage of grain refinement and silicon modification must be disclosed in the process control plan or equivalent document, and any change is subject to Production Part Approval Process (PPAP) requirements. For hypereutectic alloys, primary silicon size, distribution and the presence of surface depletion zones may be specified. 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. By agreement between supplier and purchaser (Design Responsible Engineer or delegate) electrical conductivity requirements may be specified on the GM engineering drawing and other equivalent part specification documents. Typical physical properties associated with each alloy grade are shown in Appendix D, Table D1.

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 casting, permanent mold, high pressure die casting, high pressure vacuum die casting and lost foam processes.

4.1.1 Process Coding. Table 6 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 7 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).

4.3 Post Processing. Post processing of castings may include the traditional steps of trimming, grinding, and blast cleaning. Castings shall not be welded or straightened except with the permission of the purchaser (Design Responsible Engineer or delegate).

4.4 Inspection. Visual inspection, dimensional or non-destructive evaluation such as radiography or radioscopy to ISO 9915, liquid penetrant inspection per ISO 9916 and pressure tightness may be specified.