Alloy Data

2 Aluminum Alloys

Selecting Aluminum Alloys

Aluminum (Al) die casting alloys have a specific gravity of approximately 2.7 g/cc, placing them among the lightweight structural metals. The majority of die castings produced worldwide are made from aluminum alloys.

Six major elements constitute the die cast aluminum alloy system: silicon, copper, magnesium, iron, manganese, and zinc. Each element affects the alloy both independently and interactively.

This aluminum alloy subsection presents guideline tables for chemical composition, typical properties, and die casting, machining and finishing characteristics for 11 aluminum die casting alloys. This data can be used in combination with design engineering tolerancing guidelines for aluminum die casting and can be compared with the guidelines for other alloys in this section and in the design engineering section.

Alloy A380 (ANSI/AA A380.0) is by far the most widely cast of the aluminum die casting alloys, offering the best combination of material properties and ease of production. It may be specified for most product applications. Some of the uses of this alloy include electronic and communications equipment, automotive components, engine brackets, transmission and gear cases, appliances, lawn mower housings, furniture components, hand and power tools.

Alloy 383 (ANSI/AA 383.0) and alloy 384 (ANSI/AA 384.0) are alternatives to A380 for intricate components requiring improved die filling characteristics. Alloy 383 offers improved resistance to hot cracking (strength at elevated temperatures).

Alloy A360 (ANSI/AA A360.0) offers higher corrosion resistance, superior strength at elevated temperatures, and somewhat better ductility, but is more difficult to cast.

While not in wide use and difficult to cast, alloy 43 (ANSI/AA C443.0) offers the highest ductility in the aluminum family. It is moderate in corrosion resistance and often can be used in marine grade applications.

Alloy A13 (ANSI/AA A413.0) offers excellent pressure tightness, making it a good choice for hydraulic cylinders and pressure vessels. Its casting characteristics make it useful for intricate components.

Alloy B390 (ANSI/AA B390.0) was developed for automotive engine blocks. Its resistance to wear is excellent but, its ductility is low. It is used for die cast valve bodies and sleeve-less piston housings.

Alloy 218 (ANSI/AA 518.0) provides the best combination of strength, ductility, corrosion resistance and finishing qualities, but it is more difficult to die cast.

* Different sets of properties can be achieved with alternate processes (such as high vacuum, squeeze, and semi-solid casting) and alternate alloys (such as A356, Aural 2 or 356, and Silafont 36). Information on these processes and alloys can be found in the Product Specification Standards for Die castings produced by Semi-Solid and Squeeze Cast Processes (NADCA Publication #403) and the High Integrity Die Castings book (NADCA Publication #404).

Machining Characteristics

Machining characteristics vary somewhat among the commercially available aluminum die casting alloys, but the entire group is superior to iron, steel and titanium. The rapid solidification rate associated with the die casting process makes die casting alloys somewhat superior to wrought and gravity cast alloys of similar chemical composition.

Alloy A380 has better than average machining characteristics. Alloy 218, with magnesium the major alloying element, exhibits among the best machinability. Alloy 390, with the highest silicon content and free silicon constituent, exhibits the lowest.

Surface Treatment Systems

Surface treatment systems are applied to aluminum die castings to provide a decorative finish, to form a protective barrier against environmental exposure, and to improve resistance to wear.

Decorative finishes can be applied to aluminum die castings through painting, powder coat finishing, polishing, epoxy finishing, and electro-chemical processing. Aluminum can be plated by applying an initial immersion zinc coating, followed by conventional copper-nickel-chromium plating procedure similar to that used for plating zinc metal/alloys.

Protection against environmental corrosion for aluminum die castings is achieved through painting, anodizing, chromating, and iridite coatings.

Improved wear resistance can be achieved with aluminum die castings by hard anodizing.

Where a part design does not allow the production of a pressure-tight die casting through control of porosity by gate and overflow die design, the location of ejector pins, and the reconfiguration of hard-to-cast features, impregnation of aluminum die castings can be used. Systems employing anaerobics and methacrylates are employed to produce sealed, pressure-tight castings with smooth surfaces. A detailed discussion of finishing methods for aluminum die castings can be found in *Product Design For Die Casting*.

Table A-3-1 Chemical Composition: Al Alloys
All single values are maximum composition percentages unless otherwise stated.

	Aluminum Die Casting Alloys Ⓐ Ⓔ										
Commercial:	360	A360	380 Ⓑ	A380 Ⓑ	383	384 Ⓑ	B390*	13	A13	43	218
ANSI/AA	360.0	A360.0	380.0	A380.0	383.0	384.0	B390.0	413.0	A413.0	C443.0	518.0
Nominal Comp:	Mg 0.5 Si 9.0	Mg 0.5 Si 9.5	Cu 3.5 Si 8.5	Cu 3.5 Si 8.5	Cu 2.5 Si 10.5	Cu 3.8 Si 11.0	Cu 4.5 Si 17.0	Si 12.0	Si 12.0	Si 5.0	Mg 8.0
Detailed Composition											
Silicon Si	9.0-10.0	9.0-10.0	7.5-9.5	7.5-9.5	9.5-11.5	10.5-12.0	16.0-18.0	11.0-13.0	11.0-13.0	4.5-6.0	0.35
Iron Fe	2.0	1.3	2.0	1.3	1.3	1.3	1.3	2.0	1.3	2.0	1.8
Copper Cu	0.6	0.6	3.0-4.0	3.0-4.0	2.0-3.0	3.0-4.5	4.0-5.0	1.0	1.0	0.6	0.25
Magnesium Mg	0.4-0.6	0.4-0.6	0.30 Ⓕ	0.30 Ⓕ	0.10	0.10	0.45-0.65	0.10	0.10	0.10	7.5-8.5
Manganese Mn	0.35	0.35	0.50	0.50	0.50	0.50	0.50	0.35	0.35	0.35	0.35
Nickel Ni	0.50	0.50	0.50	0.50	0.30	0.50	0.10	0.50	0.50	0.50	0.15
Zinc Zn	0.50	0.50	3.0	3.0	3.0	3.0	1.5	0.50	0.50	0.50	0.15
Tin Sn	0.15	0.15	0.35	0.35	0.15	0.35	—	0.15	0.15	0.15	0.15
Titanium Ti	—	—	—	—	—	—	0.10	—	—	—	—
Others Each	—	—	—	—	—	—	0.10	—	—	—	—
Total Others Ⓒ	0.25	0.25	0.50	0.50	0.50	0.50	0.20	0.25	0.25	0.25	0.25
Aluminum Al	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance

Ⓐ Analysis shall ordinarily be made only for the elements mentioned in this table. If, however, the presence of other elements is suspected, or indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements are not present in excess of specified limits. Ⓑ With respect to mechanical properties, alloys A380.0, 383.0 and 384.0 are substantially interchangeable. Ⓒ For RoHS (the European Union's Directive on Restriction of Hazardous Substances) compliance, certification of chemical analysis is required to ensure that the "total others" category does not exceed the following weight percent limits: 0.01% cadmium, 0.4% lead, and 0.1% mercury. Hexavalent chromium does not exist in the alloys and therefore meets the 0.1% limit. Ⓓ Notched Charpy. Sources: ASTM B85-92a; ASM; SAE; Wabash Alloys. Ⓔ Registration for REACH (the European Union's Directive on Registration, Evaluation, and Authorization of Chemicals) is not required for die castings, even if coated, since die castings are considered articles. Notification may be required if some contained substances in the die casting or coating exceed the 0.1% total weight of the article level and are listed as SVHC (substances of very high concern). Ⓕ NADCA allows 0.30 maximum magnesium as opposed to 0.10. A380 with 0.30 magnesium has been registered with the Aluminum Association as E380 and 383 with 0.30 magnesium as B383.

** Two other aluminum alloys, 361 and 369, are being utilized in limited applications where vibration and wear are of concern. There are also other heat treatable specialty alloys available for structural applications, such as the Silafonts and AA365, and high ductility, high strength alloys such as Mercalloy and K-Alloy. Contact your alloy producer for more information. Sources: ASTM B85-92a; Aluminum Association.*

Alloy Data

Table A-3-2 Typical Material Properties: Al Alloys

Typical values based on "as-cast" characteristics for separately die cast specimens, not specimens cut from production die castings.

	Aluminum Die Casting Alloys										
Commercial:	360	A360	380	A380 Ⓔ Ⓕ	383 Ⓔ	384	B390*	13	A13	43	218
ANSI/AA	360.0	A360.0	380.0	A380.0	383.0	384.0	B390.0	413.0	A413.0	C443.0	518.0
Mechanical Properties											
Ultimate Tensile Strength ksi (MPa)	44 (303)	46 (317)	46 (317)	47 (324)	45 (310)	48 (331)	46 (317)	43 (296)	42 (290)	33 (228)	45 (310)
Yield Strength Ⓐ ksi (MPa)	25 (172)	24 (165)	23 (159)	23 (159)	22 (152)	24 (165)	36 (248)	21 (145)	19 (131)	14 (97)	28 (193)
Elongation % in 2in. (51mm)	2.5	3.5	3.5	3.5	3.5	2.5	<1	2.5	3.5	9.0	5.0
Hardness Ⓑ BHN	75	75	80	80	75	85	120	80	80	65	80
Shear Strength ksi (MPa)	28 (193)	26 (179)	28 (193)	27 (186)	—	29 (200)	—	25 (172)	25 (172)	19 (131)	29 (200)
Impact Strength ft-lb (J)	—	—	3 (4)	—	3 Ⓓ (4)	—	—	—	—	—	7 (9)
Fatigue Strength Ⓒ ksi (MPa)	20 (138)	18 (124)	20 (138)	20 (138)	21 (145)	20 (138)	20 (138)	19 (131)	19 (131)	17 (117)	20 (138)
Young's Modulus psi x 10^6 (GPa)	10.3 (71)	10.3 (71)	10.3 (71)	10.3 (71)	10.3 (71)	—	11.8 (81)	10.3 (71)	—	10.3 (71)	—
Physical Properties											
Density lb/in^3 (g/cm^3)	0.095 (2.63)	0.095 (2.63)	0.099 (2.74)	0.098 (2.71)	0.099 (2.74)	0.102 (2.82)	0.098 (2.71)	0.096 (2.66)	0.096 (2.66)	0.097 (2.69)	0.093 (2.57)
Melting Range °F (°C)	1035-1105 (557-596)	1035-1105 (557-596)	1000-1100 (540-595)	1000-1100 (540-595)	960-1080 (516-582)	960-1080 (516-582)	950-1200 (510-650)	1065-1080 (574-582)	1065-1080 (574-582)	1065-1170 (574-632)	995-1150 (535-621)
Specific Heat BTU/lb °F (J/kg °C)	0.230 (963)	0.230 (963)	0.230 (963)	0.230 (963)	0.230 (963)	—	—	0.230 (963)	0.230 (963)	0.230 (963)	—
Coefficient of Thermal Expansion μ in/in°F (μ m/m°K)	11.6 (21.0)	11.6 (21.0)	12.2 (22.0)	12.1 (21.8)	11.7 (21.1)	11.6 (21.0)	10.0 (18.0)	11.3 (20.4)	11.9 (21.6)	12.2 (22.0)	13.4 (24.1)
Thermal Conductivity BTU/ft hr°F (W/m °K)	65.3 (113)	65.3 (113)	55.6 (96.2)	55.6 (96.2)	55.6 (96.2)	55.6 (96.2)	77.4 (134)	70.1 (121)	70.1 (121)	82.2 (142)	55.6 (96.2)
Electrical Conductivity % IACS	30	29	27	23	23	22	27	31	31	37	24
Poisson's Ratio	0.33	0.33	0.33	0.33	0.33	—	—	—	—	0.33	—

Ⓐ 0.2% offset. Ⓑ 500 kg load, 10mm ball. Ⓒ Rotary Bend 5 x 10^8 cycles. Ⓓ Notched Charpy. Sources: ASTM B85-92a; ASM; SAE; Wabash Alloys. Ⓔ A 0.3% Mg version of A380 and 383 have been registered with the Aluminum Association as E380 and B383. Ⓕ Higher levels of Mg and the addition of Sr to alloy A380 have shown positive results. The limited data on pages 3-7 – 3-11 shows the effect.

** Two other aluminum alloys, 361 and 369, are being utilized in limited applications where vibration and wear are of concern. There are also other heat treatable specialty alloys and processes available for structural applications, such as the Silafonts and AA365 (Aural 2), and high ductility, high strength alloys such as Mercalloy and K-Alloy. Contact your alloy producer for more information. More information can also be obtained from Microstructures and Properties of Aluminum Die Casting Alloys Book, NADCA Publication #215 and the High Integrity Aluminum Die Casting Book, NADCA Publication #307.*

Alloy Data

Die casting alloy selection requires evaluation not only of physical and mechanical properties, and chemical composition, but also of inherent alloy characteristics and their effect on die casting production as well as possible machining and final surface finishing.

This table includes selected die casting and other special characteristics which are usually considered in selecting an aluminum alloy for a specific application.

The characteristics are rated from (1) to (5), (1) being the most desirable and (5) being the least. In applying these ratings, it should be noted that all the alloys have sufficiently good characteristics to be accepted by users and producers of die castings. A rating of (5) in one or more categories would not rule out an alloy if other attributes are particularly favorable, but ratings of (5) may present manufacturing difficulties.

The benefits of consulting a custom die caster experienced in casting the aluminum alloy being considered are clear.

Table A-3-3 Die Casting And Other Characteristics: Al Alloys
(1 = most desirable, 5 = least desirable)

	Aluminum Die Casting Alloys										
Commercial: ANSI/AA	360 360.0	A360 A360.0	380 380.0	A380 A380.0	383 383.0	384 384.0	390* B390.0	13 413.0	A13 A413.0	43 C443.0	218 518.0
Resistance to Hot Cracking Ⓐ	1	1	2	2	1	2	4	1	1	3	5
Pressure Tightness	2	2	2	2	2	2	4	1	1	3	5
Die-Filling Capacity Ⓑ	3	3	2	2	1	1	1	1	1	4	5
Anti-Soldering to the Die Ⓒ	2	2	1	1	2	2	2	1	1	4	5
Corrosion Resistance Ⓓ	2	2	4	4	3	5	3	2	2	2	1
Machining Ease & Quality Ⓔ	3	3	3	3	2	3	5	4	4	5	3
Polishing Ease & Quality Ⓕ	3	3	3	3	3	3	5	5	5	4	1
Electroplating Ease & Quality Ⓖ	2	2	1	1	1	2	3	3	3	2	5
Anodizing (Appearance) Ⓗ	3	3	3	3	3	4	5	5	5	2	1
Chemical Oxide Protective Coating Ⓘ	3	3	4	4	4	5	5	3	3	2	1
Strength at Elevated Temp. Ⓙ	1	1	3	3	2	2	3	3	3	5	4

Ⓐ *Ability of alloy to withstand stresses from contraction while cooling through hot-short or brittle temperature ranges.* Ⓑ *Ability of molten alloy to flow readily in die and fill thin sections.* Ⓒ *Ability of molten alloy to flow without sticking to the die surfaces. Ratings given for anti-soldering are based on nominal iron compositions of approximately 1%.* Ⓓ *Based on resistance of alloy in standard type salt spray test.* Ⓔ *Composite rating based on ease of cutting, chip characteristics, quality of finish, and tool life.* Ⓕ *Composite rating based on ease and speed of polishing and quality of finish provided by typical polishing procedure.* Ⓖ *Ability of the die casting to take and hold an electroplate applied by present standard methods.* Ⓗ *Rated on lightness of color, brightness, and uniformity of clear anodized coating applied in sulphuric acid electrolyte.* Ⓘ *Rated on combined resistance of coating and prolonged heating at testing temperature. Sources: ASTM B85-92a; ASM; SAE*

** Two other aluminum alloys, 361 & 369, are being utilized in limited applications where vibration and wear are of concern. There are also other heat treatable specialty alloys available for structural applications, such as the Silafonts and AA365, and high ductility, high strength alloys such as Mercalloy and K-Alloy. Contact your alloy producer for more information.*

Note: *Die castings are not usually solution heat treated. Low-temperature aging treatments may be used for stress relief or dimensional stability. A T2 or T5 temper may be given to improve properties. Because of the severe chill rate and ultra-fine grain size in die castings, their "as-cast" structure approaches that of the solution heat-treated condition. T4 and T5 temper results in properties quite similar to those which might be obtained if given a full T6 temper. Die castings are not generally gas or arc welded or brazed.*

Additional A380 Alloy Tensile Data
(Data is from separately cast specimines in the naturally aged condition)

Alloys	Tensile ksi (MPa)	Yield ksi (MPa)	Elong %
A380 at 0.09% Mg	45.5 (243)	23.8 (135)	2.6
A380 with 0.26% Mg	47.0 (201)	26.6 (183)	2.8
A380 with 0.33% Mg + 0.035% Sr*	45.7 (177)	28.5 (196)	2.4

** Identified as AMC380* in research being conducted by WPI and funded by DoD/DLA. The values in this table are the average mean values and are provided to indicate the effect of a higher magnesium content and additional strontium. The properties shown do not represent design minimums and should be used for reference only.*