Alloy Data

The cross reference designations shown are for alloy specifications according to widely recognized sources. References apply to the metal in the die cast condition and should not be confused with similar specifications for metal ingot. A "—" in a column indicates that the specific alloy is not registered by the given source.

1 Die Casting Alloy Cross Reference Designations

Aluminum Alloy Specifications

Comm'l	UNS	ANSI AA	Former ASTM B85	SAE J452	Federal QQ-A-591Ⓑ	DINⒼ 1725	JIS H5302
360	A03600	360.0	SG100B	—	Ⓑ		
A360Ⓐ	A13600	A360.0	SG100A	309	Ⓑ	233	ADC3
380	A03800	380.0	SC84B	308	Ⓑ		
A380Ⓐ	A13800	A380.0	SC84A	306	Ⓑ	226AⒺ	ADC10 ⒸⒹ
383	A03830	383.0	SC102	383	Ⓑ	226AⒺ	ADC12 ⒸⒹ
384	A03840	384.0	SC114A	303	Ⓑ		ADC12 ⒸⒹ
A384Ⓐ	—	A384.0	—	—	Ⓑ		ADC12 ⒸⒹ
390	A23900	B390.0	SC174B	—	Ⓑ		
13	A04130	413.0	S12B	—	Ⓑ		
A13Ⓐ	A14130	A413.0	S12A	305	Ⓑ	231DⒻ	ADC1Ⓒ
43	A34430	C443.0	S5C	304	Ⓑ		
218	A05180	518.0	G8A	—	Ⓑ	341	

Ⓐ Similar to preceding entry with slight variations in minor constituents. Ⓑ The Federal specification for aluminum alloy die castings uses the Aluminum Association designations for individual alloys. Military designations superseded by Federal specifications. Ⓒ Japanese specifications allow 0.3 magnesium maximum. Ⓓ Japanese specifications allow 1.0 zinc maximum. Ⓔ DIN 1725 spec allows 1.2 max zinc and up to 0.5 max magnesium. Ⓕ DIN 1725 spec allows 0.3 max magnesium. Ⓖ Alloy compositions shown in DIN 1725 tend to be "primary based" and have low impurity limits making it difficult to correlate directly to U.S. alloys.

***Note:** Some of these standards are obsolete but included here for historical purposes. For closest cross-reference refer to the tables of foreign alloy designations and chemical constituencies at the end of this section.*

Aluminum Metal Matrix Composite Alloy Specifications

Duralcan USA	UNS	AA
F3D.10S-F		380/SiC/10p
F3D.20S-F		380/SiC/20p
F3N.10S-F		360/SiC/10p
F3N.20S-F		360/SiC/20p

Table Symbols

UNS — Unified Numbering System

ANSI — American National Standards Institute

ASTM — American Society for Testing and Materials

AA — Aluminum Association

SAE — Society of Automotive Engineers

FED — Federal Specifications

MIL — Military Specifications

JIS — Japanese Industrial Standard

DIN — German Industrial Standard

Copper Alloy Specifications			
Comm'l	UNS	ASTM B176	SAE J461/
857	C85700	—	—
858	C85800	Z30A	J462
865	C86500	—	—
878	C87800	ZS144A	J462
997	C99700	—	—
997.5	C99750	—	—

Magnesium Alloy Specifications						
Comm'l	UNS	ASTM B93 & B94	Former SAE J465B	Federal	DIN 1729	JIS H2222 & H5303
AZ91B	M11912	AZ91B	501A	QQ-M38	3.5912.05	MDI1B
AZ91D	M11916	AZ91D	—	—	—	MDI1D
AZ81	—	—	—	—	—	—
AM60A	M10600	AM60A	—	—	3.5662.05	MDI2A
AM60B	M10602	AM60B	—	—	—	MDI2B
AM50	—	—	—	—	—	—
AE42	—	—	—	—	—	—
AS41A	M10410	AS41A	—	—	3.5470.05	MDI3A
AS41B	M10412	AS41B	—	—	—	—
AM20	—	—	—	—	—	—

Zinc and ZA Alloy Specifications						
Comm'l	UNS	ASTM B86	Former SAE J469	Federal QQ-Z-363a	DIN	JIS
2	Z35541	AC43A	921	AC43A	1743	
3	Z33520	AG40A	903	AG40A	1743	ZDC-2
5	Z355310	AC41A	925	AC41A	1743	ZDC-1
7	Z33523	AG40B	—	AG40B		
ZA-8	Z35636	—	—	—		
ZA-12	Z35631	—	—	—		
ZA-27	Z35841	—	—	—		

Table Symbols

UNS — Unified Numbering System

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DIN — German Industrial Standard

2 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 390 (ANSI/AA B390.0) was developed for automotive engine blocks. Its resistance to wear is excellent; its ductility is low. It is used for die cast valve bodies and compressor housings in pistons.

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.

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 plating. 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: **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**
Nominal Comp:	Mg 0.5 Si 9.5	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 Comp.											
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	0.10	0.10	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	0.5	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. Sources: ASTM B85-92a; Aluminum Association.*

* *Two other aluminum alloys, 361 & 369, are being utilized in limited applications where vibration and wear are of concern. Contact your alloy producer for more information.*

Alloy Data: Aluminum Die Casting Alloy Properties

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**	**390***	**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	44	46	46	47	45	48	46	43	42	33	45
(MPa)	(300)	(320)	(320)	(320)	(310)	(330)	(320)	(300)	(290)	(230)	(310)
Yield Strength Ⓐ											
ksi	25	24	23	23	22	24	36	21	19	14	28
(MPa)	(170)	(170)	(160)	(160)	(150)	(170)	(250)	(140)	(130)	(100)	(190)
Elongation											
% in 2 in. (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	28	26	28	27	—	29	—	25	25	19	29
(MPa)	(190)	(180)	(190)	(190)		(200)		(170)	(170)	(130)	(200)
Impact Strength											
ft-lb	—	—	3	—	3 Ⓓ	—	—	—	—	—	7
(J)			(4)		(4)						(9)
Fatigue Strength Ⓒ											
ksi	20	18	20	20	21	20	20	19	19	17	20
(MPa)	(140)	(120)	(140)	(140)	(145)	(140)	(140)	(130)	(130)	(120)	(140)
Young's Modulus											
psi x 10^6	10.3	10.3	10.3	10.3	10.3	—	11.8	10.3	—	10.3	—
(GPa)	(71)	(71)	(71)	(71)	(71)		(81.3)	(71)		(71)	
Physical Properties											
Density											
lb/in^3	0.095	0.095	0.099	0.098	0.099	0.102	0.098	0.096	0.096	0.097	0.093
(g/cm^3)	(2.63)	(2.63)	(2.74)	(2.71)	(2.74)	(2.82)	(2.73)	(2.66)	(2.66)	(2.69)	(2.57)
Melting Range											
°F	1035-1105	1035-1105	1000-1100	1000-1100	960-1080	960-1080	950-1200	1065-1080	1065-1080	1065-1170	995-1150
(°C)	(557-596)	(557-596)	(540-595)	(540-595)	(516-582)	(516-582)	(510-650)	(574-582)	(574-582)	(574-632)	(535-621)
Specific Heat											
BTU/lb °F	0.230	0.230	0.230	0.230	0.230	—	—	0.230	0.230	0.230	—
(J/kg °C)	(963)	(963)	(963)	(963)	(963)	—	—	(963)	(963)	(963)	—
Coefficient of Thermal Expansion											
µ in./in./°F	11.6	11.6	12.2	12.1	11.7	11.6	10.0	11.3	11.9	12.2	13.4
(µ m/m°K)	(21.0)	(21.0)	(22.0)	(21.8)	(21.1)	(21.0)	(18.0)	(20.4)	(21.6)	(22.0)	(24.1)
Thermal Conductivity											
BTU/ft hr °F	65.3	65.3	55.6	55.6	55.6	55.6	77.4	70.1	70.1	82.2	55.6
(W/m °K)	(113)	(113)	(96.2)	(96.2)	(96.2)	(96.2)	(134)	(121)	(121)	(142)	(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.

** Two other aluminum alloys, 361 & 369, are being utilized in limited applications where vibration and wear are of concern. Contact your alloy producer for more information.*

More info can be obtained from Microstructure and Properties of Aluminum Die Casting Alloys Book, NADCA Publication # 215

Alloy Data: Aluminum Die Casting Alloy Characteristics

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:	**360**	**A360**	**380**	**A380**	**383**	**384**	**390***	**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**
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	1
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. Generally aluminum die castings are unsuitable for light color anodizing where pleasing appearance is required. Ⓘ Rated on combined resistance of coating and base alloy to corrosion. Ⓙ Rating based on tensile and yield strengths at temperatures up to 500°F (260°C), after 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. 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.*

5 Selecting Magnesium Alloys

Magnesium (Mg) has a specific gravity of 1.74 g/cc, making it the lightest commonly used structural metal.

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

Alloy AZ91D and AZ81 offer the highest strength of the commercial magnesium die casting alloys.

Alloy AZ91D is the most widely-used magnesium die casting alloy. It is a high-purity alloy with excellent corrosion resistance, excellent castability, and excellent strength. Corrosion resistance is achieved by enforcing strict limits on three metallic impurities: iron, copper and nickel.

AZ81 use is minimal since its properties are very close to those of AZ91D. Alloys AM60B, AM50A and AM20 are used in applications requiring good elongation, toughness and impact resistance combined with reasonably good strength and excellent corrosion resistance. Ductility increases at the expense of castability and strength, as aluminum content decreases. Therefore, the alloy with the highest aluminum content that will meet the application requirements should be chosen.

Alloys AS41B and AE42 are used in applications requiring improved elevated temperature strength and creep resistance combined with excellent ductility and corrosion resistance. The properties of AS41B make it a good choice for crankcases of air-cooled automotive engines.

Among the more common applications of magnesium alloys can be found the following: auto parts such as transfer cases, cam covers, steering columns, brake and clutch pedal brackets, clutch housings, seat frames, and dash board supports. Non-automotive products would include chain saws, portable tools, drills and grinders, vacuum cleaners, lawn mowers, household mix-ers, floor polishers and scrubbers, blood pressure testing machines, slide and movie projectors, cameras, radar indicators, tape recorders, sports equipment, dictating machines, calculators, postage meters, computers, telecommunications equipment, fractional horsepower motors, carpenter and mason levels, sewing machines, solar cells, snowmobiles and luggage.

Machining

The magnesium alloys exhibit the best machinability of any group of commercially used metal alloys. Special precautions must routinely be taken when machining or grinding magnesium castings.

Surface Treatment Systems

Decorative finishes can be applied to magnesium die castings by painting, chromate and phosphate coatings, as well as plating. Magnesium castings can be effectively plated by applying an initial immersion zinc coating, followed by conventional copper-nickel-chromium plating procedure generally used for plating zinc metal/alloys.

Magnesium underbody auto parts, exposed to severe environmental conditions, are now used with no special coatings or protection. Other Mg die castings, such as computer parts, are often given a chemical treatment. This treatment or coating protects against tarnishing or slight surface corrosion which can occur on unprotected magnesium die castings during storage in moist atmospheres. Painting and anodizing further serve as an environmental corrosion barrier.

Improved wear resistance can be provided to magnesium die castings with hard anodizing or hard chrome plating.

A detailed discussion of finishing methods for magnesium die castings can be found in ***Product Design For Die Casting***.

Alloy Data: Magnesium Die Casting Alloy Composition

Table A-3-10 Chemical Composition: Mg Alloys

All single values are maximum composition percentages unless otherwise stated

	Magnesium Die Casting Alloys						
Commercial:	**AZ91D**Ⓐ	**AZ81**Ⓑ	**AM60B**Ⓐ	**AM50A**Ⓐ	**AM20**Ⓑ	**AE42**Ⓑ	**AS41B**Ⓐ
Nominal Comp:	Al 9.0 Zn 0.7 Mn 0.2	Al 8.0 Zn 0.7 Mn 0.22	Al 6.0 Mn 0.3	Al 5.0 Mn 0.35	Al 2.0 Mn 0.55	Al 4.0 RE 2.4 Mn 0.3	Al 4.0 Si 1.0 Mn 0.37
Detailed Comp.							
Aluminum Al	8.3-9.7	7.0-8.5	5.5-6.5	4.4-5.4	1.7-2.2	3.4-4.6	3.5-5.0
Zinc Zn	0.35-1.0	0.3-1.0	0.22 max	0.22 max	0.1 max	0.22 max	0.12 max
Manganese Mn	0.15-0.50Ⓒ	0.17 min	0.24-0.6Ⓒ	0.26-0.6Ⓒ	0.5 min	0.25Ⓓ	0.35-0.7Ⓒ
Silicon Si	0.10 max	0.05 max	0.10 max	0.10 max	0.10 max	—	0.5-1.5
Iron Fe	0.005Ⓒ	0.004 max	0.005Ⓒ	0.004Ⓒ	0.004 max	0.005Ⓓ	0.0035Ⓒ
Copper, Max Cu	0.030	0.015	0.010	0.010	0.008	0.05	0.02
Nickel, Max Ni	0.002	0.001	0.002	0.002	0.001	0.005	0.002
Rare Earth, Total RE	—	—	—	—	—	1.8-3.0	—
Others Each	0.02	0.01	0.02	0.02	0.01	0.02	0.02
Magnesium Mg	Balance	Balance	Balance	Balance	Balance	Balance	Balance

Ⓐ ASTM B94-94, based on die cast part. Ⓑ Commercial producer specifications, based on ingot. Source: International Magnesium Association. Ⓒ In alloys AS41B, AM50A, AM60B and AZ91D, if either the minimum manganese limit or the maximum iron limit is not met, then the iron/manganese ratio shall not exceed 0.010, 0.015, 0.021 and 0.032, respectively. Ⓓ In alloy AE42, if either the minimum manganese limit or the maximum iron limit is exceeded, then the permissible iron ot manganese ration shall not exceed 0.020. Source: ASTM B94-94, International Magnesium Assn.

NADCA

A-3-11-03

Standard

Alloy Data: Magnesium Die Casting Alloy Properties

Table A-3-11 Typical Material Properties: Mg Alloys

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

	Magnesium Die Casting Alloys						
Commercial:	**AZ91D**	**AZ81**	**AM60B**	**A50A**	**AM20**	**AE42**	**AS41B**
Mechanical Properties							
Ultimate Tensile Strength Ⓑ							
ksi	34	32	32	32	27	33	31
(MPa)	(230)	(220)	(220)	(220)	(185)	(225)	(215)
Yield Strength ⒺⒷ							
ksi	23	21	19	18	15	20	20
(MPa)	(160)	(150)	(130)	(120)	(105)	(140)	(140)
Compressive Yield Strength Ⓗ							
ksi	24	N/A	19	N/A	N/A	N/A	20
(MPa)	(165)		(130)				(140)
Elongation Ⓑ							
% in 2 in. (51mm)	3	3	6-8	6-10	8-12	8-10	6
Hardness Ⓕ							
BHN	75	72	62	57	47	57	75
Shear Strength Ⓑ							
ksi	20	20	N/A	N/A	N/A	N/A	N/A
(MPa)	(140)	(140)					
Impact Strength Ⓓ							
ft-lb	1.6	N/A	4.5	7.0	N/A	4.3	3.0
(J)	(2.2)		(6.1)	(9.5)		(5.8)	(4.1)
Fatigue Strength Ⓐ							
ksi	10	10	10	10	10	N/A	N/A
(MPa)	(70)	(70)	(70)	(70)	(70)		
Latent Heat of Fusion							
Btu/lb	160	160	160	160	160	160	160
(kJ/kg)	(373)	(373)	(373)	(373)	(373)	(373)	(373)
Young's Modulus Ⓑ							
psi x 10^6	6.5	6.5	6.5	6.5	6.5	6.5	6.5
(GPa)	(45)	(45)	(45)	(45)	(45)	(45)	(45)
Physical Properties							
Density Ⓑ							
lb/in^3	0.066	0.065	0.065	0.064	0.063	0.064	0.064
(g/cm^3)	(1.81)	(1.80)	(1.79)	(1.78)	(1.76)	(1.78)	(1.78)
Melting Range							
°F	875-1105	915-1130	1005-1140	1010-1150	1145-1190	1050-1150	1050-1150
(°C)	(470-595)	(490-610)	(540-615)	(543-620)	(618-643)	(565-620)	(565-620)
Specific Heat Ⓑ							
BTU/lb °F	0.25	0.25	0.25	0.25	0.24	0.24 Ⓖ	0.24
(J/kg °C)	(1050)	(1050)	(1050)	(1050)	(1000)	(1000)	(1000)
Coefficient of Thermal Expansion Ⓑ							
µ in./in./°F	13.8	13.8	14.2	14.4	14.4	14.5 Ⓖ	14.5
(µ m/m°K)	(25.0)	(25.0)	(25.6)	(26.0)	(26.0)	(26.1)	(26.1)
Thermal Conductivity							
BTU/ft hr °F	41.8 Ⓒ	30 Ⓑ	36 Ⓑ	36 Ⓑ	35 Ⓑ	40 ⒷⒼ	40 Ⓑ
(W/m °K)	(72)	(51)	(62)	(62)	(60)	(68)	(68)
Electrical Resistivity Ⓑ							
µ Ω in.	35.8	33.0	31.8	31.8	N/A	N/A	N/A
(µ Ω cm)	(14.1)	(13.0)	(12.5)	(12.5)			
Poisson's Ratio	0.35	0.35	0.35	0.35	0.35	0.35	0.35

n/a = data not available Ⓐ Rotating Beam fatigue test according to DIN 50113. Stress corresponding to a lifetime of 5 x 10^7 cycles. Higher values have been reported. These are conservative values. Soundness of samples has great effect on fatigue properties resulting in disagreement among data sources. Ⓑ At 68°F (20°C). Ⓒ At 212-572°F (100-300°C). Ⓓ ASTM E 23 unnotched 0.25 in. die cast bar. Ⓔ 0.2% offset. Ⓕ Average hardness based on scattered data. Ⓖ Estimated. Ⓗ 0.1% offset. Ⓘ Casting conditions may significantly affect mold shrinkage. Source: International Magnesium Assn.

Alloy Data: Magnesium Die Casting Alloy Characteristics

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 a magnesium 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-3-12 Die Casting and Other Characteristics: Mg Alloys (1 = most desirable, 5 = least desirable)

	Magnesium Die Casting Alloys						
Commercial:	**AZ91D**	**AZ81**	**AM60B**	**AM50A**	**AM20**	**AE42**	**AS41B**
Resistance to Cold Defects(A)	2	2	3(G)	3(G)	5(G)	4(G)	4(G)
Pressure Tightness	2	2	1(G)	1(G)	1(G)	1(G)	1(G)
Resistance to Hot Cracking(B)	2	2	2(G)	2(G)	1(G)	2(G)	1(G)
Machining Ease & Quality(C)	1	1	1(G)	1(G)	1(G)	1(G)	1(G)
Electroplating Ease & Quality(D)	2	2	2(G)	2(G)	2(G)	—	2(G)
Surface Treatment(E)	2	2	1(G)	1(G)	1(G)	1(G)	1(G)
Die-Filling Capacity	1	1	2	2	4	2	2
Anti-Soldering to the Die	1	1	1	1	1	2	1
Corrosion Resistance	1	1	1	1	2	1	2
Polishing Ease & Quality	2	2	2	2	4	3	3
Chemical Oxide Protective Coating	2	2	1	1	1	1	1
Strength at Elevated Temp.(F)	4	4	3	3	5	1	2

(A) The ability of alloy to resist formation of cold defects; for example, cold shuts, cold cracks, non-fill "woody" areas, swirls, etc. (B) Ability of alloy to withstand stresses from contraction while cooling through the hot-short or brittle temperature range. (C) Composite rating based on ease of cutting, chip characteristics, quality of finish and tool life. (D) Ability of the die casting to take and hold an electroplate applied by present standard methods. (E) Ability of castings to be cleaned in standard pickle solutions and to be conditioned for pest paint adhesion. (F) Rating based on resistance to creep at elevated temperatures. (G) Rating based upon limited experience, giving guidance only. Sources: ASTM B94-92, International Magnesium Assn.

6 Selecting Zinc and ZA Alloys

Zinc (Zn) alloy die castings offer a broad range of excellent physical and mechanical properties, castability, and finishing characteristics. Thinner sections can be die cast in zinc alloy than in any of the commonly used die casting alloys.

Zinc alloy generally allows for greater variation in section design and for the maintenance of closer dimensional tolerances. The impact strength of zinc components is higher than other die casting alloys, with the exception of brass. Due to the lower pressures and temperatures under which zinc alloy is die cast, die life is significantly lengthened and die maintenance minimized.

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

The zinc alloys include the traditional Zamak (acronym for zinc, aluminum, magnesium and copper) group, Nos. 2, 3, 5, and 7, and the relatively new high-aluminum or ZA® alloy group, ZA-8, ZA-12 and ZA-27.

The Zamak alloys all contain nominally 4% aluminum and a small amount of magnesium to improve strength and hardness and to protect castings from intergranular corrosion. These alloys all use the rapid-cycling hot-chamber process which allows maximum casting speed.

Miniature zinc die castings can be produced at high volume using special hot-chamber die casting machines that yield castings which are flash-free, with zero draft and very close tolerances, requiring no secondary trimming or machining.

Zinc No. 3 is the most widely used zinc alloy in North America, offering the best combination of mechanical properties, castability, and economics. It can produce castings with intricate detail and excellent surface finish at high production rates. The other alloys in the Zamak group are slightly more expensive and are used only where their specific properties are required

Alloys 2 and 5 have a higher copper content, which further strengthens wear resistance, but at the expense of dimensional and property stability. No. 5 offers higher creep resistance and somewhat lower ductility and is often preferred whenever these qualities are required. No. 7 is a special high-purity alloy which has somewhat better fluidity and allows thinner walls to be cast.

The ZA alloys contain substantially more aluminum than the Zamak group, with the numerical designation representing the ZA alloy's approximate percent Al content.

The higher aluminum and copper content of the ZA alloys give them several distinct advantages over the traditional zinc alloys, Including higher strength, superior wear resistance, superior creep resistance and lower densities.

ZA-8, with a nominal aluminum content of 8.4%, is the only ZA alloy that can be cast by the faster hot-chamber process. It has the highest strength of any hot-chamber zinc alloy, and the highest creep strength of any zinc alloy.

ZA-12, with a nominal aluminum content of 11%, has properties that fall midway in the ZA group. ZA-27, with a nominal aluminum content of 27%, has the highest melting point, the highest strength, and the lowest density of the ZA alloys.

Machining Characteristics

The machining characteristics of the Zamak and ZA alloys are considered very good. High-quality surface finishes and good productivity are achieved when routine guidelines for machining zinc are followed.

Surface Treatment Systems

In many applications, zinc alloy die castings are used without any applied surface finish or treatment.

Differences in the polishing, electroplating, anodizing and chemical coating characteristics of the Zamak and ZA alloys can be noted in table A-3-15.

Painting, chromating, phosphate coating and chrome plating can be used for decorative finishes. Painting, chromating, anodizing, and iridite coatings can be used as corrosion barriers. Hard chrome plating can be used to improve wear resistance, with the exception of ZA-27.

The bright chrome plating characteristics of the Zamak alloys and ZA-8 make these alloys a prevailing choice for hardware applications.

A detailed discussion of finishing methods for zinc die castings can be found in ***Product Design for Die Casting***.

Table A-3-13 Chemical Composition: Zn and ZA Alloys
All single values are maximum composition percentages unless otherwise stated

	Zamak Die Casting Alloys				ZA Die Casting Alloys		
Commercial: **ASTM:**	**No. 2**	**No. 3** **AG-40A**	**No. 5** **AG-41A**	**No. 7** **AG-40B**	**ZA-8**	**ZA-12**	**ZA-27**
Nominal Comp:	Al 4.0 Mg 0.035 Cu 3.0	Al 4.0 Mg 0.035	Al 4.0 Mg 0.055 Cu 1.0	Al 4.0 Mg 0.013 Cu 0.013	Al 8.4 Mg 0.023 Cu 1.0	Al 11.0 Mg 0.023 Cu 0.88	Al 27.0 Mg 0.015 Cu 2.25
Detailed Comp.							
Aluminum Al	3.5-4.3	3.5-4.3	3.5-4.3	3.5-4.3	8.0-8.8	10.5-11.5	25.0-28.0
Magnesium Mg	0.02-0.05	0.02-0.05Ⓐ	0.03-0.08	0.005-0.020	0.015-0.030	0.015-0.030	0.010-0.020
Copper Cu	2.5-3.0	0.25 maxⒷ	0.75-1.25	0.25 max	0.8-1.3	0.5-1.2	2.0-2.5
Iron Fe (max)	0.10	0.10	0.10	0.075	0.075	0.075	0.075
Lead Pb (max)	0.005	0.005	0.005	0.003	0.006	0.006	0.006
Cadmium Cd (max)	0.004	0.004	0.004	0.002	0.006	0.006	0.006
Tin Sn (max)	0.003	0.003	0.003	0.001	0.003	0.003	0.003
Nickel Ni	—	—	—	0.005-0.020	—	—	—
Zinc Zn	Balance	Balance	Balance	Balance	Balance	Balance	Balance

Ⓐ The magnesium may be as low as 0.015 percent provided that the lead, cadmium and tin do not exceed 0.003, 0.003 and 0.001 percent, respectively. Ⓑ For the majority of commercial applications, a copper content in the range of 0.25-0.75 percent will not adversely affect the serviceability of die castings and should not serve as a basis for rejection. Sources: ASTM B86 and ASTM B791.

Alloy Data: Zinc and ZA Die Casting Alloy Properties

Table A-3-14 Typical Material Properties: Zn and ZA Alloys
Typical values based on "as-cast" characteristics for separately die cast specimens, not specimens cut from production die castings.

	Zamak Die Casting Alloys				ZA Die Casting Alloys		
Commercial:	**No. 2**	**No. 3 AG-40A**	**No. 5 AC-41A**	**No. 7 AG-40B**	**ZA-8**	**ZA-12**	**ZA-27**
Mechanical Properties							
Ultimate Tensile Strength							
As-Cast ksi (MPa)	52 (359)	41 (283)	48 (328)	41 (283)	54 (372)	59 (400)	62 (426)
Aged ksi (MPa)	48 (331)	35 (241)	39 (269)	41 (283)	43 (297)	45 (310)	52 (359)
Yield Strength Ⓐ							
As-Cast ksi (MPa)	41 (283)	32 (221)	39 (269)	32 (221)	41-43 (283-296)	45-48 (310-331)	52-55 (359-379)
Aged ksi (MPa)					32 (224)	35 (245)	46 (322)
Compressive Yield Strength Ⓑ							
As-Cast ksi (MPa)	93 (641)	60 (414) Ⓒ	87 (600)Ⓒ	60 (414) Ⓒ	37 (252)	39 (269)	52 (358)
Aged ksi (MPa)	93 (641)	60 (414)	87 (600)	60 (414)	25 (172)	27 (186)	37 (255)
Elongation							
As-Cast % in 2 in. (51mm)	7	10	7	13	6-10	4-7	2.0-3.5
Aged % in 2 in. (51mm)	2	16	13	18	20	10	3
Hardness Ⓓ							
As-Cast BHN	100	82	91	80	100-106	95-105	116-122
Aged BHN	98	72	80	67	91	91	100
Shear Strength							
As-Cast ksi (MPa)	46 (317)	31 (214)	38 (262)	31 (214)	40 (275)	43 (296)	47 (325)
Aged ksi (MPa)	46 (317)	31 (214)	38 (262)	31 (214)	33 (228)	34 (234)	37 (255)
Impact Strength							
As-Cast ft-lb	35	43 Ⓔ	48 Ⓔ	43 Ⓔ	24-35Ⓔ	15-27Ⓔ	7-12 Ⓔ
Aged ft-lb	5	41	40	41	13	14	3.5
(J)	(47.5)	(58)	(65)	(58)	(32-48)	(20-37)	(9-16)
Fatigue Strength Ⓕ							
As-Cast ksi (MPa)	8.5 (58.6)	6.9 (47.6)	8.2 (56.5)	6.9 (47.6)	15 (103)	—	21 (145)
Aged ksi (MPa)	8.5 (58.6)	6.9 (47.6)	8.2 (56.5)	6.8 (46.9)	15 (103)	—	21 (145)
Young's Modulus							
psi x 10^6 (GPa)	Ⓖ	Ⓖ	Ⓖ	Ⓖ	12.4 (85.5)	12 (83)	11.3 (77.9)
Physical Properties							
Density							
lb/in^3	0.24	0.24	0.24	0.24	0.227	0.218	0.181
(g/cm^3)	(6.6)	(6.6)	(6.7)	(6.6)	(6.3)	(6.03)	(5.00)
Melting Range							
°F	715-734	718-728	717-727	718-728	707-759	710-810	708-903
(°C)	(379-390)	(381-387)	(380-386)	(381-387)	(375-404)	(377-432)	(372-484)
Specific Heat							
BTU/lb °F	0.10	0.10	0.10	0.10	0.104	0.107	0.125
(J/kg °C)	(419)	(419)	(419)	(419)	(435)	(450)	(525)
Coefficient of Thermal Expansion							
μ in./in./°F x 10^{-6}	15.4	15.2	15.2	15.2	12.9	13.4	14.4
(μ m/m°K)	(27.8)	(27.4)	(27.4)	(27.4)	(23.2)	(24.1)	(26.0)
Thermal Conductivity							
BTU/ft hr °F	60.5	65.3	62.9	65.3	66.3	67.1	72.5
(W/m °K)	(104.7)	(113)	(109)	(113)	(115)	(116)	(122.5)
Electrical Conductivity							
μ Ω in.	25.0	27.0	26.0	27.0	27.7	28.3	29.7
Poisson's Ratio	0.30	0.30	0.30	0.30	0.30	0.30	0.30

Ⓐ 0.2% offset, strain rate sensitive, values obtained at a strain rate of 0.125/min (12.5% per minute). Ⓑ 0.1% offset. Ⓒ Compressive strength. Ⓓ 500 kg load, 10 mm ball. Ⓔ ASTM E 23 unnotched 0.25 in. die cast bar. Ⓕ Rotary Bend 5 x 10^8 cycles. Ⓖ Varies with stress level; applicable only for shor-duration loads. Use 10^7 as a first approximation. Source: International Lead Zinc Research Organization.

Alloy Data: Zinc and ZA Die Casting Alloy Characteristics

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 a zinc 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 zinc alloy being considered are clear.

Table A-3-15 Die Casting and Other Characteristics: Zn and ZA Alloys (1 = most desirable, 5 = least desirable)

	Zamak Die Casting Alloys				ZA Die Casting Alloys		
Commercial: **ASTM:**	**No. 2**	**No. 3** **AG-40A**	**No. 5** **AC-41A**	**No. 7** **AG-40B**	**ZA-8**	**ZA-12**	**ZA-27**
Resistance to Hot CrackingⒷ	1	1	2	1	2	3	4
Pressure Tightness	3	1	2	1	3	3	4
Casting Ease	1	1	1	1	2	3	3
Part Complexity	1	1	1	1	2	3	3
Dimensional Accuracy	1	1	1	1	2	2	3
Dimensional Stability	4	2	2	1	2	3	4
Corrosion Resistance	2	3	3	2	2	2	1
Resistance to Cold DefectsⒶ	2	2	2	1	2	3	4
Machining Ease & QualityⒸ	1	1	1	1	2	3	4
Polishing Ease & Quality	2	1	1	1	2	3	4
Electroplating Ease & QualityⒹ	1	1	1	1	1	2	3
Anodizing (Protection)	1	1	1	1	1	2	2
Chemical Coating (Protection)	1	1	1	1	2	3	3

Ⓐ The ability of alloy to resist formation of cold defects; for example, cold shuts, cold cracks, non-fill "woody" areas, swirls, etc. Ⓑ Ability of alloy to withstand stresses from contraction while cooling through the hot-short or brittle temperature range. Ⓒ Composite rating based on ease of cutting, chip characteristics, quality of finish and tool life. Ⓓ Ability of the die casting to take and hold an electroplate applied by present standard methods. Source: International Lead Zinc Research Organization.

8 Quick Guide to Alloy Family Selection

	Aluminum	Magnesium	Zinc	Zinc-Aluminum
Cost	Lowest cost per unit volume.	Can compete with aluminum if thinner wall sections are used. Faster hot-chamber process possible on smaller parts.	Effective production of miniature parts. Significant long-term tooling cost savings (tooling lasts 3-5 times longer than aluminum).	
Weight	Second lowest in density next to magnesium.	Lowest density.	Heaviest of die cast alloys, but castable with thinner walls than aluminum, which can offset the weight disadvantage.	Weight reduction as compared with the Zinc family of alloys.
Structural Properties	Highest Modulus of Elasticity	Highest strength-to-weight ration, best vibration dampening characteristics.	Highest ductility and impact strength.	Highest tensile and yield strength.
Surface Finish & Coatings	Good choice for coating processes that require high temperatures.	Good as-cast surface finishes can be achieved.	Best as-cast surface finish readily accepts electro-coatings and decorative finishes.	
Wear Resistance	*	*	*	Best as-cast wear resist.
Corrosion Resistance	*	*	*	*
Machinability	Good	Best machinability in terms of tool-life, achievable finish, low cutting forces and energy consumption.	Good	Good
Thermal Properties, Conductive, & Electromagnetic Shielding	Best choice for heat transfer. Good electrical conductivity	Electro-magnetic shielding	Best electrical conductor. Good heat transfer	

Wear and corrosion resistance can be improved in all alloys through surface treatments and coatings.

8 Quick Guide to Alloy Family Selection

ANSI ASTM or AA Number	Former Designation	UNS Universal No. System	SAE	Old ASTM	QQ-A-371c.	Canada	United Kingdom	Japan	Germany	ISO
360	360	AO3601	309	SG100B	360	—	LM2	JISH 530Z ADC3	—	—
A360	A360	AO3602	309	SG100A	360	—	—	—	GD-AlSi10Mg	Al-Si10Mg
380	380	AO3801	306.308	SC84A-B	380	143	LM24	JISH 5302 ADC10	—	—
A380	A380	AO3802	306.308	SC84-A	380	—	—	—	GD-AlSi8Cu3	Al-Si8Cu3Fe
383	383	AO3831	306.308	—	—	—	—	—	—	—
384	384	AO3841	303	SC114A	384	A143	LM26	JISH 5302 ADC12	—	—
A384	A384	AO3842	303	SC114A	384	—	—	—	—	—
390	—	AO3902	—	—	—	—	LM28	—	—	—
B390	—	AO3901	—	—	—	—	—	—	—	—
413	13	AO4131	305	S12A.B	13	162	LM6	JISH 5302 ADC1	—	—
A413	A13	A14132	305	S12A	13	—	—	—	—	—
443	43	AO4431	35	S5B	43	123	LM18	—	—	—
518	218	AO5181	—	—	218.	340	—	—	—	—

INTERNATIONAL ALUMINUM ALLOY COMPOSITIONS												
JAPAN												
	Cu	**Mg**	**Si**	**Fe**	**Mn**	**Ni**	**Zn**	**Pb**	**Sn**	**Ti**	**Each**	**Total**
JIS H 5302 ADC1	1.0	0.3	11.0-13.0	1.3	0.3	0.5	0.5	-	0.1	-	-	-
JIS H 5302 ADC3	.6	.4-.6	9.0-10.0	1.3	.3	.5	.5	-	.1	-	-	-
JIS H 5302 ADC10	2.0-4.0	.3	7.5-9.5	1.3	.5	.5	1.0	-	.3	-	-	-
JIS H 5302 ADC12	1.5-3.5	.3	9.6-12.0	1.3	.5	.5	1.0	-	.3	-	-	-
UNITED KINGDOM												
B.S.1490	**Cu**	**Mg**	**Si**	**Fe**	**Mn**	**Ni**	**Zn**	**Pb**	**Sn**	**Ti**	**Others**	
LM2	0.7-2.5	0.30	9.0-11.5	1.0	0.5	0.5	2.0	0.3	0.2	0.2	-	
LM6	0.1	0.10	10.0-13.0	0.6	0.5	0.1	0.1	0.1	0.05	0.2	-	
LM18	0.1	0.10	4.5-6.0	0.6	0.5	0.1	0.1	0.1	0.05	0.2	-	
LM24	3.0-4.0	0.30	7.5-9.5	1.3	0.5	0.5	3.0	0.3	0.2	0.2	-	
LM26	2.0-4.0	0.5-1.5	8.5-10.5	1.2	0.5	1.0	1.0	0.2	0.1	0.2	-	
GERMANY												
	Cu	**Mg**	**Si**	**Fe**	**Mn**	**Ni**	**Zn**	**Pb**	**Sn**	**Ti**	**Each**	**Total**
GD-Al-Si8Cu3	2.0-3.5	0-.3	7.5-9.5	1.3	.2-.5	0.3	0.7	0.2	0.1	0.15	0.05	0.15
GD-Al-Si10Mg	0.10	.20-.50	9.0-11.0	1.0	0-0.4	-	0.1	-	-	0.15	0.05	0.15
ISO												
	Cu	**Mg**	**Si**	**Fe**	**Mn**	**Ni**	**Zn**	**Pb**	**Sn**	**Ti**	**Each**	
AL-Si8Cu3Fe	2.5-4.0	0.3 max	7.5-9.5	1.3 max	0.6 max	0.5 max	1.2 max	0.3 max	0.2 max	0.2 max	0.5 max	
Al-Si10Mg	0.1 max	01.5-0.40	9.0-11.0	0.6 max	0.6 max	0.05 max	0.1 max	0.05 max	0.05 max	0.2 max	-	

CROSS REFERENCE OF EQUIVALENT MAGNESIUM ALLOY SPECIFICATIONS AND DESIGNATIONS		
U.S. ASTM	**ISO16220**	**EN-1753/1997**
AX91D	MgAl9Znl	AZ9I
AM60B	MgAl6Mn	AM60
AM50A	MgAl5Mn	AM50
AM20	MgAl2Mn	AM20
AS21	MgAl2Si	AS21
AS41B	MgAl4Si	AS41

INTERNATIONAL MAGNESIUM ALLOY COMPOSITIONS									
U.S. ASTM	**% Al**	**% Zn**	**% Mn**	**% Si**	**% Fe**	**% Cu**	**% Ni**	**0 Each**	**Fe/Mn Max.**
AZ91D	8.3-9.7	0.35-1.0	0.15-0.50	0.10	0.005	0.030	0.002	0.01	0.032***
AM60B	5.5-6.5	0.22	0.24-0.6	0.10	0.005	0.010	0.002	0.02	0.021**
AM50A	4.4-5.4	0.22	0.26-0.6	0.10	0.004	0.010	0.002	0.02	0.015**
AM20	—	—	—	—	—	—	—	—	—
AS21	—	—	—	—	—	—	—	—	—
AS41B	3.5-5.0	0.12	0.35-0.7	0.50-1.5	0.0035	0.02	0.002	0.02	0.010**
ISO 16220									
MgAl9ZnI	8.3-9.7	0.35-1.0	0.15-0.50	0.10	0.005	0.030	0.002	0.01	0.032**
MgAl6Mn	5.5-6.5	0.2	0.24-0.60	0.10	0.005	0.010	0.002	0.01	0.021*
MgAl5Mn	4.4-5.5	0.2	0.26-0.60	0.10	0.004	0.010	0.002	0.01	0.015*
MgAl2Mn	1.6-2.6	0.2	0.33-0.70	0.10	0.004	0.010	0.002	0.01	0.012*
MgAl2Si	1.8-2.6	0.2	0.18-0.70	0.7-1.2	0.004	0.01	0.002	0.01	0.022*
MgAl4Si	3.5-5.0	0.2	0.18-0.70	0.5-1.5a	0.004	0.010	0.002	0.01	0.022*
EN-1753/1997									
AZ91	8.3-9.7	0.35-1.0	min. 0.1	0.10	0.005	0.030	0.002	0.01	—
AM60	5.5-6.5	0.2	min. 0.1	0.10	0.005	0.010	0.002	0.01	—
AM50	4.4-5.5	0.2	min. 0.1	0.10	0.005	0.010	0.002	0.01	—
AM20	1.6-2.6	0.2	min. 0.1	0.10	0.005	0.010	0.002	0.01	—
AS21	1.8-2.6	0.2	min. 0.1	0.7-1.2	0.005	0.010	0.002	0.01	—
AS41	3.5-5.0	0.2	min. 0.1	0.50-1.5	0.005	0.010	0.002	0.01	—

CROSS REFERENCE OF EQUIVALENT ZINC ALLOY SPECIFICATIONS AND DESIGNATIONS								
U.S. Commercial	**ASTM**	**SAE**	**Canada**	**United Kingdom**	**Japan**	**Germany**	**ISO**	**EN**
# 3	AG40A	903	AG40	A	Class 2	Z400	ZnAl4	ZNAl4P
# 5	AC41A	905	—	B	Class 1	Z410	ZnAl4Cu1	ZnAl4Cu1P

INTERNATIONAL ZINC ALLOY COMPOSITIONS									
EN 12844	**% Al**	**% Cu**	**% Mg**	**% Pb**	**% Cd**	**% Sn**	**% Fe**	**% Ni**	**% Si**
ZnAl4-P	3.7-4.3	0.1	0.025-0.06	0.005	0.005	0.002	0.05	0.02	0.03
ZnAl4Cu1-P	3.7-4.3	0.7-1.3	0.4-0.6	0.005	0.005	0.002	0.05	0.02	0.03