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MAGNESIUM WROUGHT ALLOYS

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

1. *Scope*—This SAE Standard covers the most common magnesium alloys used in wrought forms, and lists chemical composition and minimum mechanical properties for the various forms. A general indication of the usage of the various materials is also provided.

1.1 Introduction—Magnesium wrought alloys are produced and fabricated by all the common production methods such as rolling, extrusion, and forging. Forms available are sheet, plate, wire, rod, bar, shapes, tubes, forgings, and impact extrusions. Magnesium alloys can be formed by bending, drawing, spinning, and pressing. The work is generally done hot except for simple operations. When done hot, magnesium alloys have exceptional workability. The temperature used varies from 300–750°F (149–399°C), depending on operation, alloy, and condition. All of the wrought alloys can be joined by adhesive bonding, spot welding, riveting, and bolting. Most of them are readily fusion welded and some do not require stress relief after welding. As with the cast alloys, all wrought alloys machine readily.

The temper designations used for wrought magnesium are similar to those used for aluminum alloys. Temper designations are covered by ASTM B 296-67 (1972), Recommended Practice for Temper Designations of Magnesium Alloys, Cast and Wrought. Mechanical properties are obtained by standard ASTM procedures. The tensile and compressive yield strength is taken at an offset of 0.2% from the initial modulus line.

Table 1 lists similar ASTM, AMS, Military, and Federal specifications covering the SAE wrought alloys in this SAE Standard.

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TABLE 1—SIMILAR SPECIFICATIONS OF MAGNESIUM WROUGHT ALLOYS

Alloy Designation						
UNS	ASTM and SAE	Old SAE	Form	ASTM	AMS	Military or Federal
M11311	AZ31B	510	Sheet and plate	B90	4375, 4376, 4377	QQ-M-44
			Bar, rod, shapes	B107	—	QQ-M-31
			Tube	B107	—	WW-T-825
			Forgings	B91	—	QQ-M-40
M11610	AZ61A	520	Bar, rod, shapes	B107	4350	QQ-M-31
			Tube	B107	4350	WW-T-825
			Wire (welding rod)	—	—	Mil-R-6944
			Forgings	B91	4358(1)	QQ-M-40
M11800	AZ80A	523	Bar, rod, shapes	B107	—	QQ-M-31
			Forgings	B91	4360(1)	QQ-M-40
M14141	LA141A		Sheet and plate	B90	—	—
M13310	HK31A	507	Sheet and plate	B90	4384, 4385	Mil-M-26075
M13210	HM21A		Sheet and plate	B90	4383, 4390	Mil-M-8917
			Forgings	—	4363	QQ-M-40
M13312	HM31A		Bar, rod, shapes	—	4388, 4389	Mil-M-8916
M15100	M1A	522	Bar, rod, shapes	B107	—	QQ-M-31
			Forgings	—	—	QQ-M-40
M16100	ZE10A	534	Sheet and plate	B90	—	Mil-M-46037
M16400	ZK40A		Bar, rod, shapes	B107	—	—
M16600	ZK60A	524	Bar, rod, shapes	B107	4352	QQ-M-31
			Tube	B107	4352	WW-T-825
			Forgings	B91	4362	QQ-M-40

1. Noncurrent specifications.

2. *References*

2.1 Applicable Publications—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

2.1.1 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

ASTM B 90-70—Specification for Magnesium-Alloy Sheet and Plate
ASTM B 107-70—Specification for Magnesium-Alloy Extruded Bars, Rods, Shapes, Tubes, and Wire
ASTM B 296—Recommended Practice for Temper Designations of Magnesium Alloys, Cast and Wrought

3. *Sheet And Plate:*

3.1 Introduction—Magnesium alloy sheet is rolled to a thickness of 0.006-0.249 in (0.15-6.32 mm). Plate is 0.250 in (6.35 mm) or over in thickness. Dimensional tolerances used are the same as for aluminum alloys and are given in the current issue of ASTM B 90-70.

Magnesium sheet and plate is flattened thermally and can be obtained commercially, with smaller flatness tolerances than for most other metals. One grade of specially flattened plate is used extensively as tooling plate. The annealed condition (–0) is used for maximum formability and ductility. The cold rolled and partially annealed condition (–H24) has better strength and less ductility than the –0 temper. Tensile properties of the sheet and alloys covered by this standard are given in Table 3 and the chemical composition limits are given in Table 2.

TABLE 2—COMPOSITION OF WROUGHT MAGNESIUM ALLOYS

Alloy Designation			Elements, weight %												
UNS	ASTM and SAE	Old SAE	Al	Mn min	Zn	Zr	Rare Earths	Th	Ca, max	Cu, max	Fe, max	Na, max	Ni, max	Si, max	Total Other Elements, max
M11311	AZ31B	510	2.5–3.5	0.20	0.6–1.4	—	—	—	0.04	0.05	0.005	—	0.005	0.10	0.30
M11610	AZ61A	520	5.8–7.2	0.15	0.40–1.5	—	—	—	—	0.05	0.005	—	0.005	0.10	0.30
M11800	AZ80A	523	7.8–9.2	0.12	0.20–0.8	—	—	—	—	0.05	0.005	—	0.005	0.10	0.30
M13310	HK31A	507	—	—	0.30 max	0.40–1.0	—	2.5–4.0	—	0.10	—	—	0.01	—	0.30
M13210	HM21A	—	—	0.45–1.1	—	—	—	1.5–2.5	—	—	—	—	—	—	0.30
M13312	HM31A	—	—	1.2	—	—	—	2.5–3.5	—	—	—	—	—	—	0.30
M14141[1]	LA141A	—	1.0–1.5	0.15	—	—	—	—	—	0.04	0.005	0.005	0.005	0.10	0.30
M15100	M1A	522	—	1.2	—	—	—	—	0.30	0.05	—	—	0.01	0.10	0.30
M16100	ZE10A	534	—	—	1.0–1.5	—	0.12–0.22[2]	—	—	—	—	—	—	—	0.30
M16400	ZK40A	—	—	—	3.5–4.5	0.45 min	—	—	—	—	—	—	—	—	0.30
M16600	ZK60A	524	—	—	4.8–6.2	0.45 min	—	—	—	—	—	—	—	—	0.30

1. LA141 contains 13–15% LI.
2. Rare earth elements are in the form of mischmetal.

TABLE 3—MINIMUM MECHANICAL PROPERTIES OF MAGNESIUM ALLOY SHEET AND PLATE

Alloy Designation UNS	ASTM and SAE	Old SAE	Temper	Thickness in (mm)	Tensile Strength psi (MPa)	Yield Strength 0.2% Offset, psi (MPa)	Elongation in 2 in (50.8 mm), %
M11311	AZ31B	510	–0	0.016–0.250 (0.41–12.70)	32 000 (221)(1)	—	12
				0.251–2.000 (12.73–50.80)	32 000 (221)(1)	—	10
				2.001–3.000 (50.83–76.20)	32 000 (221)(1)	—	9
			–H24	0.016–0.249 (0.41–6.32)	39 000 (269)	29 000 (200)	6
				–0.374 (6.35–9.50)	38 000 (262)	26 000 (179)	8
				–0.500 (9.52–12.70)	37 000 (255)	24 000 (165)	8
				0.501–1.000 (12.73–25.40)	36 000 (248)	22 900 (152)	8
				1.001–2.000 (25.43–50.80)	34 000 (234)	20 000 (138)	8
				2.001–3.000 (50.83–76.20)	34 000 (234)	18 000 (124)	8
			–H26	0.250–0.374 (6.35–9.50)	39 000 (269)	27 000 (186)	6
				–0.500 (9.52–12.70)	38 000 (262)	26 000 (179)	6
				0.501–0.750 (12.73–19.05)	37 000 (255)	25 000 (172)	6
				0.751–1.000 (19.08–25.40)	37 000 (255)	23 000 (159)	6
				1.001–1.500 (25.43–38.10)	35 000 (241)	22 000 (152)	6
				1.501–2.000 (38.13–50.80)	35 000 (241)	21 000 (145)	6
M13310	HK31A	507	–0	0.016–0.250 (0.41–6.35)	30 000 (207)(2)	—	12
				0.251–0.500 (6.38–12.70)	30 000 (207)	16 000 (110)	12
				0.501–1.000 (12.73–25.40)	30 000 (207)	15 000 (103)	12
				1.001–3.000 (25.43–76.20)	29 000 (200)	14 000 (97)	12
			–H24	0.016–0.125 (0.41–3.18)	34 000 (234)	26 000 (179)	4
				0.126–0.250 (3.20–6.35)	34 000 (234)	24 000 (165)	4
				0.251–1.000 (6.38–25.40)	34 000 (234)	23 000 (159)	4
				1.001–3.000 (25.43–76.20)	33 000 (228)	23 000 (159)	4
M13210	HM21A		–T8	0.016–0.250 (0.41–6.35)	33 000 (228)	18 000 (124)	6
				0.251–0.500 (6.38–12.70)	32 000 (221)	21 000 (145)	6
				0.501–3.000 (12.73–76.20)	30 000 (207)	21 000 (145)	6
M14141	LA141A		–T7	0.010–0.090 (0.25–2.29)	19 000 (131)	15 000 (103)	10
				0.091–0.250 (2.31–6.35)	19 000 (131)	14 000 (97)	10
				0.251–2.000 (6.38–50.80)	18 000 (124)	13 000 (90)	10
M16100	ZE10A	534	-0	0.016–0.060 (0.41–1.52)	30 000 (207)	18 000 (124)	15
				0.061–0.250 (1.55–6.35)	30 000 (207)	15 000 (103)	15
				0.251–0.500 (6.38–12.70)	29 000 (200)	12 000 (83)	12
			–H24	0.016–0.125 (0.41–3.18)	36 000 (248)	25 000 (172)	4
				0.126–0.188 (3.20–4.78)	34 000 (234)	22 000 (152)	4
				0.189–0.250 (4.80–6.35)	31 000 (214)	20 000 (138)	4

1. Maximum tensile strength shall be 40 000 psi (276 MPa).
2. Maximum tensile strength shall be 38 000 psi (262 MPa).

3.2 General Data—Alloy M11311 is the most commonly used of the sheet alloys and is available in either the annealed (–0) or cold rolled and partially annealed (–H24 and –H26) conditions. M11311 alloy can be formed and welded readily. It has found widespread use. Applications most familiar in the automotive field would be its use in truck bodies, ramps, and dockboards and the various places such as patterns, jigs, and fixtures in which tooling plate has been used.

M16100 is not as strong as M11311. It has good formability and excellent weldability and does not require stress relieving after welding. It is used in place of M11311 primarily in tanks and large structures where stress relieving would be a problem. It is available in either the annealed (–0) or cold rolled and partially annealed (–H24) conditions.

M13310 was developed primarily for elevated temperature use in the 300–700 °F (149–371 °C) range. It is more costly than M11311 and M16100. M13310 alloy has excellent weldability and good formability. It is available in either the annealed (–0) or cold rolled and partially annealed (–H24) conditions. It has been used primarily in aircraft and missiles. M13210 was also developed for elevated temperature use in aircraft, missiles, and electronics.

M14141, containing 14% Li, is the only magnesium alloy with a body-centered cubic rather than hexagonal-close-packed crystal structure. It was developed as a very ductile and highly formable alloy.

4. Extrusions

4.1 Introduction—Magnesium alloys in general are extruded to size without subsequent drawing operations. Some sizing or shaving has been used to get better tolerances than can be obtained by extrusion. Wire, rod, bar, tubes, and special shaped sections are produced as extrusions. Dimensional tolerances on the various forms are given in the current issue of ASTM B 107-70.

Magnesium alloys produced as extrusions are available in the as-extruded (–F) condition. In some alloys an increase in strength is obtained by artificial aging to the extruded and aged (–T5) condition. Minimum mechanical properties of the SAE extrusion alloys are shown in Table 4. The chemical composition of the SAE alloys used for extrusions is given in Table 2.

TABLE 4—MINIMUM MECHANICAL PROPERTIES OF MAGNESIUM ALLOY EXTRUSIONS

Alloy Designation							Minimum Properties		
UNS	ASTM and SAE	Old SAE	Temper	Form	Dia or Thickness, in (mm)	Cross Sectional Area, in^2 (cm^2)	Tensile Strength, psi (MPa)	Yield Strength 0.2% Offset, psi (MPa)	Elongation in 2 in (50.8 mm), %
M11311	AZ31B	510	–F	Bars, rods, shapes	0.249 (6.32) and under	All	35 000 (241)	21 000 (145)	7
					0.250–1.499 (6.35–38.07)	All	35 000 (241)	22 000 (152)	7
					1.500–2.499 (38.10–63.47)	All	34 000 (234)	22 000 (152)	7
					2.500–4.999 (63.50–126.97)	All	32 000 (221)	20 000 (138)	7
				Hollow shapes	All	All	32 000 (221)	16 000 (110)	8
				Tubes	0.028–0.250 (0.71–6.35)	6.000 (38.71) and under	32 000 (221)	16 000 (110)	8
					0.251–2.499 (6.38–63.47)	6.000 (38.71) and under	32 000 (221)	16 000 (110)	4
M11610	AZ61A	520	–F	Bars, rods, shapes	0.249 (6.32) and under	All	38 000 (262)	21 000 (145)	8
					0.250–2.499 (6.35–63.47)	All	39 000 (269)	24 000 (165)	9
					2.500–4.999 (63.50–126.97)	All	40 000 (276)	22 000 (152)	7
				Hollow shapes	All	All	36 000 (248)	16 000 (110)	7
				Tubes	0.028–0.750 (0.71–19.05)	6.000 (38.71) and under	36 000 (248)	16 000 (110)	7

TABLE 4—MINIMUM MECHANICAL PROPERTIES OF MAGNESIUM ALLOY EXTRUSIONS (CONTINUED)

Alloy Designation				Form	Dia or Thickness, in (mm)	Cross Sectional Area, in^2 (cm^2)	Minimum Properties		
UNS	ASTM and SAE	Old SAE	Temper				Tensile Strength, psi (MPa)	Yield Strength 0.2% Offset, psi (MPa)	Elongation in 2 in (50.8 mm), %
M11800	AZ80A	523	–F	Bars, rods, shapes	0.249 (6.32) and under	All	43 000 (296)	28 000 (193)	9
					0.250–1.499 (6.35–38.07)	All	43 000 (296)	28 000 (193)	8
					1.500–2.499 (38.10–63.47)	All	43 000 (296)	28 000 (193)	6
					2.500–4.999 (63.50–126.97)	All	42 000 (290)	27 000 (186)	4
			–T5	Bars, rods, shapes	0.249 (6.32) and under	All	47 000 (324)	30 000 (207)	4
					0.250–2.499 (6.35–63.47)	All	48 000 (331)	33 000 (228)	4
					2.500–4.999 (63.50–126.97)	All	45 000 (310)	30 000 (207)	2
M13312	HM31A		–T5	Bars, rods, shapes	Under 1.000 (25.40)	All	37 000 (255)	26 000 (179)	4
					1.000–3.999 (25.40–101.57)	All	37 000 (255)	26 000 (179)	4
M15100	M1A	522	–F	Bars, rods, shapes	0.249 (6.32) and under	All	30 000 (207)	—(1)	2
					0.250–1.499 (6.35–38.07)	All	32 000 (221)	—(1)	3
					1.500–4.999 (38.10–126.97)	All	29 000 (200)	—(1)	2
				Hollow shapes	All	All	28 000 (193)	—(1)	2
				Tubes	0.028–0.750 (0.71–19.05)	6.000 (38.71) and under	28 000 (193)	—(1)	2
M16400	ZK40A		–T5	Bars, rods, shapes, and wires	All	4.999 (32.25) and under	40 000 (276)	37 000 (255)	4
				Hollow shapes	All	All	40 000 (276)	37 000 (255)	4
				Tubes	0.062–0.500 (1.57–12.70)	3.000 (19.35) and under	40 000 (276)	36 000 (248)	4
M16600	ZK60A	523	–F	Bars, rods, shapes	All	4.999 (32.25) and under	43 000 (296)	31 000 (214)	4
				Hollow shapes	All	All	40 000 (276)	28 000 (193)	5
				Tubes	0.028–0.750 (0.71–19.05)	3.000 (19.35) and under	40 000 (276)	28 000 (193)	5
		524	–T5	Bars, rods, shapes	All	4.999 (32.25) and under	45 000 (310)	36 000 (248)	4
				Hollow shapes	All	All	46 000 (317)	38 000 (262)	4
				Tubes	0.028–0.250 (0.71–6.35)	3.000 (19.35) and under	46 000 (317)	38 000 (262)	4

1. Not required.

4.2 General Data—M11311, M11610, and M11800 contain aluminum and zinc as the principal alloying elements. M11311-F has moderate strength, good ductility, and good weldability. It is used where maximum strength is not a requirement. M11610-F has slightly better strength than M11311 but less than M11800. It has been supplanted to a large degree by the higher strength alloys, although still widely used as welding wire. M11800 has the highest strength of these three alloys. Low ductility has caused it to be replaced largely by M16600. Alloy M11800 is not as weldable as M11311 and M11610, which have excellent welding characteristics. M11311 has been used in truck bodies, ramps, and docks, and with tooling plate in making jigs and fixtures.

M15100 has excellent weldability and good corrosion resistance. It is a low strength alloy with good ductility. It has been replaced for most applications by M11311.

M16600 combines high strength with good ductility and toughness. However, it has limited weldability. M16600 costs more than M11311, M16610, M11800, and M15100. It has been used primarily in military applications and aircraft. M13312 alloy was developed for use at elevated temperatures in the range of 300–800°F (149–427°C). M16400 possesses high yield strength and has better extrusion characteristics than M16610.

5. Forgings

5.1 Introduction—Magnesium alloys are available as both hammer forgings and press forgings. The stronger alloys are too tender at hot working temperature to stand the shock of hammer forging and must be worked slowly under hydraulic presses. They may be forged sometimes to advantage by first pressing to shape and finishing on the hammer.

Die equipment built for aluminum alloy forgings can, in many cases, be used without change for producing magnesium alloy hammer forgings. This also applies to small die forgings made by pressing. Large press forgings comparable in size to an aircraft radial motor crankcase require special equipment and can usually be supplied only as oversize die forgings. Compared with an aluminum forging, magnesium press forgings frequently require an extra blocking die.

Forgings subject to shock, vibration, or repeated stresses must be carefully designed and carefully machined to avoid notches, sharp corners, tool marks, and other stress raisers. Minimum machining radius is 0.040 in (1.02 mm), and all sharp corners and feather edges must be broken. Magnesium alloy forgings may have marked directional properties, especially with regard to yield strength in tension and in compression. For this reason, it is advisable for user to consult with manufacturer on design of forgings.

5.2 General Data—M11311, M11610, M11800, M13210, and M16600 alloys are used principally as press forgings. M11311 and M11610 are used where moderately high strength and good ductility are desired. Alloys M11800 and M16600 are used where greater strength is required. M13210 alloy was developed for use at temperatures of 300–800°F (149–427°C). The chemical composition of the SAE alloys used for forgings is given in Table 2.

5.3 Mechanical Properties—The properties for forgings are those obtained from tensile test specimens taken with the longitudinal axis of the specimen parallel to the direction of maximum flow of the metal or from separately forged coupons. Minimum properties of magnesium alloy forgings are given in Table 5.