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Magnesium Casting Alloys

RATIONALE

The technical report covers technology, products, or processes which are mature and not likely to change in the foreseeable future.

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1. **Scope**—This document has not changed other than to put it into the new SAE Technical Standards Board Format

This SAE Standard covers the most commonly used magnesium alloys suitable for casting by the various commercial processes. The chemical composition limits and minimum mechanical properties are shown. Over the years, magnesium alloys have been identified by many numbering systems, as shown in Table 1. Presently, SAE is recommending the use of the UNS numbering system to identify those materials. Other equally important characteristics such as surface finish and dimensional tolerances are not covered in this standard.

- 1.1 **Sources of Magnesium**—Sources of Magnesium—Magnesium is the third most abundant structural element in the earth's crust, and considered inexhaustible. Common sources are sea water, natural brines, magnesite, and dolomite. Three methods of extraction are used in the United States. One method involves treating sea water with a source of alkalinity to precipitate the magnesium as hydroxide, mixing with hydrochloric acid to produce hydrated magnesium chloride, and then partially drying. The hydrous magnesium chloride is reduced electrolytically to produce magnesium metal and a mixture of chlorine and hydrochloric acid. A second method produces co-products magnesium metal and pure chlorine in the electrolytic cell by the reduction of anhydrous magnesium chloride or by the chlorination of MgO. The anhydrous cell feed results from the complete dehydration of natural brines. Another method of extraction, which is also used in the United States and in other countries, is by thermal reduction of magnesium oxide by ferrosilicon. Most of the magnesium ingot sold is of 99.80% purity. Grades of magnesium of 99.90, 99.95, and 99.98% purity are also available. The higher purity grades are used mostly in nuclear applications and for reduction purposes.

TABLE 1—PHYSICAL PROPERTIES AND CHARACTERISTICS OF MAGNESIUM SAND-CASTING ALLOYS

Alloy Designation			Approximate Melting Range, °F (°C)		Pattern Shrinkage Allowance in/ft (mm/m) ⁽³⁾	Foundry Characteristics ⁽¹⁾				Cast-ability	Other Characteristics					
UNS	ASTM and SAE	Old SAE	Non-Equilibrium Solidus ⁽²⁾	Liquidus		Pressure Tightness	Fluidity ⁽⁴⁾	Micro-porosity Tendency ⁽⁵⁾	Normally Heat Treated		Machining ⁽⁶⁾	Electro-plating ⁽⁷⁾	Surface Treatment ⁽⁸⁾	Suit-ability to Brazing ⁽⁹⁾	Suit-ability to Welding ⁽¹⁰⁾	
M10100 ⁽¹¹⁾	AM100A	502	810 (432)	867 (464)	1100 (593)	5/32 (13.0)	2	1	2	Yes	2	1	2	2	No	1
M11630	AZ63A	50	685 (363)	850 (454)	1130 (610)	5/32 (13.0)	3	1	3	Yes	3	1	1	1	No	3
M11810 ⁽¹¹⁾	AZ81A	505	790 (421)	882 (472)	1115 (602)	5/32 (13.0)	2	1	2	Yes	1	1	2	2	No	1
M11914 ⁽¹¹⁾	AZ91C	504	785 (418)	875 (468)	1105 (596)	5/32 (13.0)	2	1	2	Yes	1	1	2	2	No	2
M11920 ⁽¹¹⁾	AZ92A	500	770 (410)	830 (443)	1100 (593)	5/32 (13.0)	2	1	2	Yes	2	1	2	2	No	2
M12330 ⁽¹²⁾	EZ33A	506	— —	1010 (543)	1189 (643)	3/16 (15.5)	1	2	1	Yes	1	1	1	1	No	1
M13310 ⁽¹¹⁾	HK31A	507	— —	1092 (589)	1204 (651)	7/32 (18.0)	1	2	1	Yes	1	1	1	1	— ⁽¹³⁾	1
M13320 ⁽¹¹⁾	HZ32A	—	— —	1026 (552)	1198 (648)	3/16 (15.5)	1	2	1	Yes	1	1	—	2	— ⁽¹³⁾	2
M18010 ⁽¹⁴⁾	K1A	—	— —	— —	1205 (652)	3/16 (15.5)	2	2	2	No	2	1	3	2	— ⁽¹³⁾	1
M18210	QH21A	—	— —	1004 (539)	1184 (640)	3/16 (15.5)	2	2	2	Yes	1	1	2	1	No	—
M18220 ⁽¹¹⁾	QE22A	—	— —	1020 (549)	1190 (643)	5/32 (13.0)	2	2	2	Yes	1	1	2	1	— ⁽¹³⁾	1
M16410 ⁽¹⁴⁾	ZE41A	—	— —	950 (510)	1184 (640)	3/16 (15.5)	— ⁽¹³⁾	2	2	Yes	1	1	1	1	No	2
M16630 ⁽¹⁴⁾	ZE63A	—	— —	510 (266)	950 (510)	3/16 (15.5)	1	2	1	Yes	1	1	— ⁽¹³⁾	1	No	1
M16620	ZH62A	508	— —	— —	1169 (632)	5/32 (13.0)	2	2	2	Yes	2	1	1	1	No	— ⁽¹³⁾
M16510	ZK51A	509	— —	1020 (549)	1185 (641)	5/32 (13.0)	3	2	3	Yes	3	1	2	2	No	3
M16610	ZK61A	513	— —	985 (529)	1175 (635)	5/32 (13.0)	3	2	3	Yes	3	1	2	1	No	3

1. Rating of 1 indicates best of group; 3 indicates poorest of group.

2. As measured on metal solidified under normal casting conditions.

3. Allowance for average castings. Shrinkage requirements will vary with intricacy of design and dimensions. (1 in/ft x 8.333 = % Shrinkage.)

4. Ability of liquid alloy to flow readily in mold and fill thin sections.

5. Based on radiographic evidence.

6. Composite rating based on ease of cutting, chip characteristics, quality of finish, and tool life. Ratings, in the case of heat-treatable alloys, based on —T6 type temper. Other tempers, particularly the annealed temper, may have lower ratings.

7. Ability of casting to take and hold an electroplate applied by present standard methods.

8. Ability of castings to be cleaned in standard pickle solutions and to be conditioned for best paint adhesion.

9. Refers to suitability of alloy to withstand brazing temperature without excessive distortion or melting.

10. Based on ability of material to be fusion welded with filler rod of same alloy.

11. Properties applicable for permanent mold and investment castings.

12. Properties applicable for permanent mold castings also.

13. Inexperience with these alloys under wide production conditions makes it undesirable to supply ratings at this time.

14. Properties applicable for investment castings also.

- 1.2 Castings**—Magnesium alloys are cast by all casting methods, the most common being pressure die casting, investment casting, sand casting, and permanent mold casting. Many alloys are available for use as sand, investment, and permanent mold castings to give the desired end use and production characteristics. Most of these are not suitable for use in the pressure die casting process. Most of the alloys used for sand, investment, and permanent mold castings may be heat treated to increase strength or improve stability. Die castings, while in the same composition range as some of the sand castings, are not heat treated because of undesirable effects such as grain growth and blistering. Magnesium alloy sand, investment, and permanent mold castings are generally sold in the solution heat treated (T4) condition for best ductility. Artificial aging after solution heat treatment (T6) increases the yield strength considerably but decreases the ductility. Many times an artificial age (T5) from the as-cast condition (F) is sufficient to give the desired strength and stability.
- 1.3 Alloying Elements**—Common alloying elements used in magnesium alloys are aluminum, manganese, rare earths, silicon, silver, thorium, zinc, and zirconium. Alloys are stronger than the pure metal, but have lower electrical and thermal conductivities. Certain of the alloys respond to heat treatment with an increase in strength and hardness. Most commercial alloys are stable at room temperature. Certain alloying elements such as the rare earths and thorium improve the high temperature strength of magnesium alloys.
- 1.4 Alloy Nomenclature**—A designation system for magnesium alloys used commercially and described in ASTM B 275, Recommended Practice for Codification of Light Metals and Alloys, Cast and Wrought, was adopted by SAE in 1971. The initial letters represent the major alloying elements with the following numerals representing the nominal percent by weight of each element. The final letter is assigned arbitrarily.
- 1.5 Temper Designation**—The same temper designation system is used for both aluminum-base and magnesium-base alloys. It is described in detail under the aluminum alloy section of this book and in ASTM B 296, Recommended Practice for Temper Designation of Magnesium Alloys, Cast and Wrought.
- 1.6 Finishing and Coating**—Bare magnesium is suitable for some applications. Protective finishes may be required to prevent tarnishing or for protection from corrosion in humid industrial or marine atmospheres. It is subject to galvanic attack when coupled to most other metals, and such connections should be adequately protected if moisture will be present. Magnesium can be finished by plating and painting for either protection or decoration.
- 1.7 Testing**—Magnesium alloys are tested like other metals using standard ASTM methods. The tensile and compressive yield strengths are defined as the stress at which the stress-strain curve deviates 0.2% from the initial modulus line.

2. References

- 2.1 Applicable Publications**—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the latest revision of SAE publications shall apply.

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

ASTM B 275—Recommended Practice for Codification of Light Metals and Alloys, Cast and Wrought

ASTM B 296—Recommended Practice for Temper Designation of Magnesium Alloys, Cast and Wrought

ASTM B 557—Method of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products