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SURFACE VEHICLE STANDARD

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MAGNESIUM CASTING ALLOYS

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 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.

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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]	Solidus	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	—[13]	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)	532 (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 lastest 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

3. *Sand Castings*

3.1 General—Sand castings are used when a small number of castings are required or the casting is large or complicated. In many cases, sand cores are used with permanent mold castings. Dimensional tolerances, on the whole, are greater for sand castings than for permanent mold castings and the surface is not as smooth.

In the design of patterns, a shrinkage factor of 5/32 in/ft (13 mm/m) is generally used, but this may be reduced to 1/8 in/ft (10 mm/m) or less if free shrinkage is restrained by bosses, internal cores, or grates and risers. Walls as thin as 0.150 in (3.80 mm) can be readily made in large size castings. Thinner walls are possible for smaller areas. For example, a 0.120 in (3.05 mm) thick wall can be cast covering an area o f about 1 ft^2 (0.1 m^2).

In order to obtain the best results from castings, the foundry should be consulted on the design of the casting, choice of alloy, heat treatment, and properties attainable. The selection of the alloy and heat treatment is governed by the characteristics desired in the casting and the limitations of the casting process. Considerations of cost and secondary characteristics such as finishing, welding, and pressure tightness may be the deciding factor on which alloy to use.

3.2 Physical Properties and Characteristics

3.2.1 PURE MAGNESIUM—Magnesium is extremely light with the common alloys having a specific gravity of about 1.8 compared to 2.7 for aluminum. The heavier structural metals like iron, copper, and zinc are approximately four times as heavy as magnesium. Magnesium melts at 1202 °F (650 °C). The coefficient of thermal expansion between 68–212 °F (20–100 °C) is approximately 0.0000145/°F (0.0000261/°C) and is slightly higher than for aluminum, 0.000013/°F (0.000023/°C), and over twice that of steel. The thermal and electrical conductivities of magnesium are relatively high and some alloys approach values comparable to aluminum alloys. The modulus of elasticity is approximately 6 500 000 psi (45 GPa). The pure metal is not used for structural applications, but a number of alloys have been developed with good strength-to-weight ratios.

3.2.2 ALLOYS—The physical properties and characteristics of the most commonly used alloys for sand casting are compared in Table 1, which was compiled by the American Foundrymen's Society.

Approximately the same ratings shown in Table 1 would apply for the same alloys when used for permanent mold and investment castings, although not all sand casting alloys are suitable for use in permanent molds.

3.3 Composition and Its Effects—The compositions of magnesium casting alloys are given in Table 2.

TABLE 2—COMPOSITION OF MAGNESIUM CASTING ALLOYS

Alloy Designation			Elements, wt. %									
UNS	ASTM and SAE	Old SAE	Al	Mn, min	Zn	Th	Rare Earths	Zr	Cu, max	Ni, max	Si, max	Total Other Elements, max
M10600	AM60A	—	5.5–6.5	0.13	0.22	—	—	—	0.35	0.03	0.50	—
M10100	AM100A	502	9.3–10.7	0.10	0.30 max	—	—	—	0.10	0.01	0.30	0.30
M10410	AS41A	—	3.7–4.8	0.22–0.48	0.10 max	—	—	—	0.04	0.01	0.60–1.4	0.30
M11630	AZ63A	50	5.3–6.7	0.15	2.5–3.5	—	—	—	0.25	0.01	0.30	0.30
M11810	AZ81A	505	7.0–8.1	0.13	0.40–1.0	—	—	—	0.10	0.01	0.30	0.30
M11910	AZ91A	501	8.3–9.7	0.13	0.35–1.0	—	—	—	0.10	0.03	0.50	0.30
M11912	AZ91B	501A	8.3–9.7	0.13	0.35–1.0	—	—	—	0.35	0.03	0.50	0.30
M11914	AZ91C	504	8.1–9.3	0.13	0.4–1.0	—	—	—	0.10	0.01	0.30	0.30
M11920	AZ92A	500	8.3–9.7	0.10	1.6–2.4	—	—	—	0.25	0.01	0.30	0.30
M12330	EZ33A	506	—	—	2.0–3.1	—	2.5–4.0	0.50–1.0	0.10	0.01	—	0.30
M13310	HK31A	507	—	—	0.30 max	2.5–4.0	—	0.40–1.0	0.10	0.01	—	0.30
M13320	HZ32A	—	—	—	1.7–2.5	2.5–4.0	0.10 max	0.50–1.0	0.10	0.01	—	0.30
M18010	K1A	—	—	—	—	—	—	0.40–1.0	—	—	—	0.30
M18210	QH21A [1]	—	—	—	0.2 max	0.6–1.6 [2]	0.6–1.5 [3]	0.40–1.0	0.10	0.01	—	0.30
M18220	QE22A[1]	—	—	—	—	—	1.8–2.5 [4]	0.40–1.0	0.10	0.01	—	0.30
M16410	ZE41A	—	—	0.15 max	3.5–5.0	—	0.75–1.75	0.40–1.0	0.10	0.01	—	0.30
M16630	ZE63A	—	—	—	5.5–6.0	—	2.1–3.0	0.40–1.0	0.10	0.01	—	0.30
M16620	ZH62A	508	—	—	5.2–6.2	1.4–2.2	—	0.50–1.0	0.10	0.01	—	0.30
M16510	ZK51A	509	—	—	3.6–5.5	—	—	0.50–1.0	0.10	0.01	—	0.30
M16610	ZK61A	513	—	—	5.5–6.5	—	—	0.6–1.0	0.10	0.01	—	0.30

1. Silver content in M18220 shall be 2.0–3.0.
2. Th and didymium total is 1.5–2.4%.
3. Rare earth elements are in the form of didymium with not less than 70% neodymium and the remainder substantially praseodymium.
4. Rare earth elements in M18220 are in the form of didymium; in alloys M16410 and M16630, in the form of mischmetal.

Alloys M10100, M11630, M11810, M11914, and M11920 are used for most commercial applications. With the exception of M10100, which is a binary magnesium-aluminum alloy, they contain aluminum and zinc as alloying elements. This alloy family is used where moderately high strength at room temperature is desired. These alloys generally have good castability and are the lowest in cost of the commercial alloys. Individual differences in strength, ductility, and pressure tightness exist in this family of alloys. M11630 has the best toughness but has a tendency to microporosity in complex designs. M11920 has the highest tensile yield strength of the Mg-Al-Zn alloys. It has been used extensively in aircraft engines. M10100 has good castability and pressure tightness. Alloys M11914 and M11810 have better pressure tightness than M11630 and have good weldability. Both M11914 and M11810 have been used extensively in aircraft and racing car wheels. The upper operating limit for the Mg-Al-Zn casting alloys is generally considered to be about 300 °F (149 °C).

A second series of alloys is based upon the Mg-Zn-Zr alloy system. These alloys are also generally used at service temperatures below 300 °F (149 °C), although the addition of rare earth metals (alloy M16410) and thorium (alloy M16620) somewhat improves their ability to withstand exposure to more elevated temperatures. Alloys M16410 and M16620 have improved foundry characteristics and weldability over M16510 and M16610. Alloy M16610-T6 has a high strength-to-weight ratio compared to most commercial casting alloys, but shows less favorable foundry characteristics. Alloy M16630-T6 has a high strength-to-weight ratio, is readily castable, and shows little or no tendency to microporosity. It is designed to take advantage of a new principle of heat treatment involving the inward diffusion of hydrogen and formation of hydrides. M18010 is a low-strength casting alloy intended for applications requiring exceptionally good damping characteristics.

A third group of alloys is based on the Mg-Re-Zr system. These alloys are used in applications for operation at temperatures up to 550 °F (288 °C) where tensile or creep strength is a requirement. Alloy M12330 also is excellent where pressure tightness is a requirement. It rates second to M18010 in damping capacity.

The fourth group of alloys consists of Mg-Th-Zr alloys with or without zinc, which find applications in parts operating at temperatures up to 650 °F (343 °C). Alloy M18210 has the best short-time strength properties up to 400 °F (205 °C) of all magnesium alloys.

3.4 Mechanical Properties—The mechanical properties given in Table 3 are those obtained from separately cast test specimens. These test specimens are cast and heat treated under conditions that duplicate, as closely as possible, the conditions under which the castings they represent are made. The test bars are not machined except to fit the grips of the testing machine.

TABLE 3—MINIMUM MECHANICAL PROPERTIES OF SEPARATELY CAST TEST BARS MAGNESIUM SAND CASTING ALLOYS[1]

Alloy or Temper Designation				Ultimate Tensile Strength		Yield Strength 0.2% Offset		Elongation in 2 in (50.8 mm), %
UNS	ASTM and SAE	Temper		psi	MPa	psi	MPa	
M10100	AM100A	F	As-cast	20 000	138	—[2]	—[2]	—[2]
		–T4	Solution heat treated	34 000	234	—[2]	—[2]	6
		–T6	Solution heat treated and artificially aged	35 000	241	17 000	117	—[2]
M11630	AZ63A	F	As-cast	26 000	179	11 000	76	4
		–T4	Solution heat treated	34 000	234	11 000	76	7
		–T5	Artificially aged only	26 000	179	12 000	83	2
		–T6	Solution heat treated and artificially aged	34 000	234	16 000	110	3
M11810	AZ81A	–T4	Solution heat treated	34 000	234	11 000	76	7
M11914	AZ91C	F	As-cast	23 000	159	11 000	76	—[2]
		–T4	Solution heat treated	34 000	234	11 000	76	7
		–T5	Artificially aged only	23 000	159	12 000	83	2
		–T6	Solution heat treated and artificially aged	34 000	234	16 000	110	3
M11920	AZ92A	F	As-cast	23 000	159	11 000	76	—[2]
		–T4	Solution heat treated	34 000	234	11 000	76	6
		–T5	Artificially aged only	23 000	159	12 000	83	—[2]
		–T6	Solution heat treated and artificially aged	34 000	234	18 000	124	1
M12330	EZ33A	–T5	Artificially aged only	20 000	138	14 000	97	2
M13310	HK31A	–T6	Solution heat treated and artificially aged	27 000	186	13 000	90	4
M13320	HZ32A	–T5	Artificially aged only	27 000	186	13 000	90	4
M18010	K1A	F	As-cast	24 000	165	6 000	41	14
M18210	QH21A	–T6	Solution heat treated and artificially aged	35 000	241	27 000	186	2
M18220	QE22A	–T6	Solution heat and artificially aged	35 000	241	25 000	172	2
M16410	ZE41A	–T5	Artificially aged only	29 000	200	19 500	134	2.5
M16630	ZE63A	–T6	Solution heat treated and artificially aged	40 000	276	27 000	186	5
M16620	ZH62A	–T5	Artificially aged only	35 000	241	22 000	152	5
M16510	ZK51A	–T5	Artificially aged only	34 000	234	20 000	138	5
M16610	ZK61A	–T6	Solution heat treated and artificially aged	40 000	276	26 000	179	5

1. Alloy suitable for permanent mold and/or investment castings should meet these properties.
2. Not required.

The mechanical properties of test specimens machined from castings will depend upon the type and size of casting and the location from which the specimen is taken. Specimens from thin sections or heavily chilled sections may have properties comparable to or superior to those from separately cast test specimens. Specimens from sections near gates and risers generally have lower properties. Separately cast test bars serve as a control on the metal quality and the heat treating process, if such are used. Minimum properties of test specimens cut from castings are generally guaranteed on the basis of an average of not less than three specimens each from the thickest, the thinnest, and an average cross-section. Minimum mechanical properties for designated areas are sometimes specified.

The concept of premium quality castings has been introduced by research workers and the foundry industry. The most important feature of premium quality is higher integrity of the product, and the reliability of properties in designated areas of each and every single casting. Table 4 shows the minimum requirements for mechanical properties in designated and other areas of premium quality castings.

4. ***Permanent Mold Castings***—Any of the alloys listed in Table 3 as sand casting alloys can be used for permanent mold castings. Cracking tendencies limit the usefulness of many of the alloys since they cannot be cast in large sizes or complicated shapes. Permanent mold castings are used for economy of production when the number of pieces required justifies the increased mold cost. Permanent mold casting permits the production of more uniform castings, with closer dimensional tolerances and superior surface finish than with sand casting. The minimum wall thickness that it is possible to obtain is somewhat greater on permanent mold castings than for sand castings because of the chilling effect of the mold. However, thicknesses down to 0.150 in (3.80 mm) covering large areas may sometimes be cast. Thinner walls can be cast covering smaller areas. Complex parts which cannot be made entirely as a permanent mold casting, can often be produced in semi-permanent molds using sand cores. The characteristics of the various magnesium base alloys are typical of the alloy, whether cast in sand, investment, or permanent molds. Some of the characteristics, such as hot shortness, limit the usefulness of some of the alloys to such an extent that they are seldom used for permanent mold castings. In the Mg-Al-Zn alloy group, M11920, M10100, M11914, and M11810 are most commonly used as permanent mold castings. M12330, M13310, and M18220 alloys can be cast in permanent molds quite readily.

The minimum properties of separately cast test bars and test specimens cut from castings are generally the same for a given alloy, whether cast in sand or permanent molds. The same minimum mechanical properties are used for both sand and permanent mold casting of the same alloy. Hence, those shown in Table 3 for sand castings are used for permanent mold castings. Applications for permanent mold castings are the same as for sand castings. Producibility, cost, surface, and tolerances should be considered in deciding the process to be used.

TABLE 4—MINIMUM MECHANICAL PROPERTIES OF TEST SPECIMENS FROM DESIGNATED AREAS OF PREMIUM QUALITY CASTINGS OF MAGNESIUM ALLOYS (ACCORDING TO SPECIFICATIONS IN MIL-M-46062)

Alloy Designation					Guaranteed Minimum Properties in Designated Areas		
UNS	ASTM and SAE	Old SAE	Temper	Class[1]	Ultimate Tensile Strength, psi (MPa)	Yield Strength 0.2% Offset, psi (MPa)	Elongation in 2 in (50.8 mm), %
M11914	AZ91C	504	–T6	1	35 000 (241)	18 000 (124)	4
				2	29 000 (200)	16 000 (110)	3
				3	27 000 (186)	14 000 (97)	2
				X	17 000 (117)	12 000 (83)	0.75
M11920	AZ92A	500	–T6	1	40 000 (276)	25 000 (172)	3
				2	34 000 (234)	20 000 (138)	1
				3	30 000 (207)	18 000 (124)	0.75
				X	17 000 (117)	13 500 (93)	0.25
M13310	HK31A	507	–T6	1	33 000 (228)	16 000 (110)	6
				2	29 000 (200)	14 000 (97)	3
				3	25 000 (172)	12 000 (83)	1
				X	19 000 (131)	10 500 (72)	1
M18220	QE22A	—	–T6	1	40 000 (276)	28 000 (193)	4
				2	37 000 (255)	26 000 (179)	2
				3	33 000 (228)	23 000 (159)	2
				X	28 000 (193)	20 000 (138)	2
M16220	ZH62A	508	–T5	1	38 000 (262)	23 000 (159)	5
				2	34 000 (234)	21 000 (145)	3
				3	31 500 (217)	19 000 (131)	2
				X	28 500 (197)	17 500 (121)	1.25
M16510	ZK51A	509	–T5	1	36 000 (248)	21 000 (145)	6
				2	32 000 (221)	19 000 (131)	4
				3	29 000 (200)	17 000 (117)	3
				X	24 000 (165)	14 000 (97)	1.25
M16610	ZK61A	513	–T6	1	42 000 (290)	29 000 (200)	6
				2	37 000 (255)	26 000 (179)	4
				3	34 000 (234)	23 000 (159)	2
				X	30 000 (207)	21 000 (145)	1.25

1. Stress levels of various sections of the castings should be carefully considered before specifying the class of mechanical properties for any particular casting section. Since a uniform stress level is seldom required in casting design, it would be advantageous from the design and foundry aspect to have higher properties in local designated areas with the remainder of the casting having lower properties. Three classes (1–3) of mechanical properties are therefore incorporated in the specification for various stress levels. In addition, minimum properties are given for test specimens taken from castings in unspecified areas (X) of castings.

5. Investment Mold Castings—Any of the alloys listed in Table 3 may be used for investment castings. The complexity and quality requirements of investment castings has limited the application of most alloys except M11914, M10100, and to a lesser extent, M11920. However, alloys such as M18220, M12330, and M18010 are frequently used for investment castings.

Specifications applicable to sand and permanent mold castings (Table 3) are used commonly for investment castings, including composition and minimum properties limitations as called out in Tables 2 and 3.

Magnesium investment castings are used widely in applications requiring moderate to high degrees of configuration complexity, including coring and minimum weight, section thicknesses of 0.060 in (1.52 mm) being normal and 0.040 in (1.02 mm) possible in some cases over smaller areas. Tool costs are usually high relative to sand and permanent mold tools, and must be related to volume.

6. Die Casting

6.1 Introduction—The die casting process offers many advantages as a method of fabricating magnesium alloys, including low cost in quantity production, decrease in amount of machining, excellent surface finish, dimensional accuracy, and metal saving by virtue of being able to cast thin sections.

While most magnesium die castings are still produced on conventional cold-chamber die-casting machines, the use of hot-chamber machines for magnesium die castings is growing rapidly. With the exception of the metal melting equipment, both the machines and dies used in the cold-chamber process are practically interchangeable with those used for aluminum die casting.

The melting of magnesium is done in a non-oxidizing atmosphere, sometimes with a protective flux. Casting temperatures range from 1150–1250 °F (621–677 °C). When automatic metering of the magnesium is used, the metal is usually protected with a layer of molten flux. Some installations use protective gas atmospheres. When hand ladling, the metal is protected with either flux, sulfur dioxide, or an atmosphere of air-SF_6. Metal in hot-chamber die-casting machines is generally protected with an air-SF_6 atmosphere. Metal injection pressures lie between 2000 and 15 000 psi (14 and 103 MPa).

In amenability to intricate coring, magnesium die castings rank between zinc, which is the best, and aluminum. Required draft is greater than for zinc and less than for aluminum.

Magnesium castings do not have a tendency to solder or adhere to the die. Consequently, in contrast with aluminum, die coating solutions are not necessary and the need for die lubrication is decreased.

Molten magnesium does not react with iron or steel and can, therefore, be transferred in the molten state through steel pipes. This makes magnesium adaptable to automatic ladling and metal handling devices.

Due to the low heat content of magnesium, a part made with equivalent machines and dies may be cast at rates comparable to those obtained with zinc alloys, and at higher rates than for aluminum. The magnesium cools faster, permitting earlier removal from the die.

6.2 General Information—Alloys M11910 and M11912 - Magnesium alloy die castings have been used more extensively on automobiles than magnesium in any other form. Magnesium has been accepted as a competitive material in such applications as steering column parts such as shrouds, brackets, collars, and signal switches; instruments and transmission components; convertible top mechanism; generator end plates; clutch housings; fuel pump body and parts; oil pumps; and crankcases of air-cooled engines.