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NONFERROUS ALLOYS

1. GENERAL
- The lower lithium content of LA91A, as compared with its sister alloy LA141A, results in a two-phase structure of hexagonal-close-packed alpha in a matrix of body-centered cubic beta. When the alpha phase is thoroughly broken up and distributed throughout the beta matrix, primarily by hot work, the strength of LA91A equals or exceeds that of LA141A. In addition, LA91A exhibits somewhat better ductility, and has considerably better stability when exposed to an elevated temperature of 200F. The LA91A alloy, however, is slightly more dense than LA141A (1). Although it has been reported that LA91A can be significantly strengthened by heat treatment (2), available data do not support this claim. The as-hot-rolled material retains relatively stable properties during aging for 48 hours at 200F (1) (see Table 3.0212). Cold rolling up to 50 percent reduction produces increases in strength of about 10 percent, but further cold working appears to be detrimental.
- LA91A is readily formable by most commercial processes both at room temperature and at elevated temperatures, and may be readily joined by the various fusion welding techniques. The atmospheric corrosion resistance of the alloy is comparable to that of most commercial magnesium alloys. Suitable coatings are recommended for humid, salt-spray, and marine environments.
- LA91A should be considered for applications similar to those associated with LA141A (aerospace structures, meteorite shields, instrument housing, and armor plate) particularly where temperatures above room temperature might be involved.
- 1.01 Commercial Designation
LA91A.
- 1.02 Alternate Designations
LA91, LA91XA.
- 1.03 Specifications
None.
- 1.04 Composition
Table 1.04

TABLE 1.04

Composition*	Percent	
	Minimum	Maximum
Aluminum	1.00	1.50
Copper	-	0.04
Iron	-	0.005
Lithium	8.0	10.0
Manganese	-	0.15
Nickel	-	0.005
Silicon	-	0.10
Sodium	-	0.005
Total, other impurities	-	0.30
Magnesium	Balance	

* Composition limits of elements other than Lithium taken from AMS 4386 for LA 141A

- 1.041 Since no specification has been published, the composition limits for LA141A in AMS 4386 (3) are used as a guide in defining the composition limits for LA91A in Table 1.04.
- 1.05 Heat Treatment
None.
- 1.051 Available data indicate that there is little or no improvement in properties gained through solution treatment as compared with as-hot-worked properties (1)(4). Aging of the solution treated material at

- 200F results in a marked decrease in strength and increase in ductility of the solution treated material but has little effect on the as-hot-worked material (1) (see Table 3.0214).
- 1.052 No data are available on the effects of stabilizing treatment at 350F as is specified for LA141A in AMS 4386 (3).
- 1.06 Hardness
55 to 75 RE
- 1.07 Forms and Conditions Available
Commercially, none.
- 1.071 The alloy has been made experimentally in the form of sheet, plate, forging, extrusion, and casting (1).
- 1.08 Melting and Casting Practice
- 1.081 Because the alloy reacts readily with oxygen and nitrogen in the temperature range 1200 to 1400F required for melting, it must be protected from oxygen by one of several methods during melting. A technique applicable to small heats is the use of a molten-flux cover. One such flux consists of 3:1 LiCl-LiF in an amount equivalent to about one third of the metal weight. A late addition of LiBr may be made to improve the separation of the flux from the metal (2).
- Another flux that has been used is 12.5 percent LiF-37.5 percent LiCl-50 percent KCl, its weight being about one-tenth the weight of the metal (5).
- 1.0812 A better technique is the use of an inert atmosphere, normally argon, to protect the molten metal (2).
- 1.0813 Finally, vacuum melting and casting is an effective technique to prevent oxidation of LA91A during melting (2). An effective variation of this technique is to melt under a small partial pressure of argon (1).
- 1.082 Because of excessive reactivity, LA91A should not be melted in conventional ceramic or graphite crucibles. Steel crucibles are recommended (1).
- 1.083 Steel or graphite molds are normally used to produce ingots or other cast shapes (1)(6).

- 1.09 Special Considerations
- 1.091 The attainment of optimum strength in LA91A is highly dependent upon sufficient hot work to break up the coarse as-cast structure of alpha and beta phases into a fine dispersion of alpha in a beta matrix. In hot rolling, a reduction ratio of 40:1 is ample for this purpose. Although similar figures have not been established for extrusion and forging, it is known that a 24:1 extrusion ratio is insufficient and 75 percent upset reduction by forging is insufficient (1).

2. PHYSICAL AND CHEMICAL PROPERTIES

- 2.01 Thermal Properties
- 2.011 Melting range. Approximately 1060 - 1070F.
- 2.012 Phase changes. There is some indication that a third phase, theta (identified as Mg Li₂ Al), and perhaps additional phases precipitate during aging, but these reactions have not been clearly established (2)(7).
- 2.0121 Time-temperature-transformation diagrams.
- 2.013 Thermal conductivity. 32.3 Btu ft per (hr sq ft F) (50 to 300F) (1)(8).
- 2.014 Thermal expansion. 18×10^{-6} inch per inch degree F (68 to 200F) (1.)
- 2.015 Specific heat, Figure 2.015.
- 2.016 Thermal diffusivity.
- 2.02 Other Physical Properties
- 2.021 Density. 0.0523 lb per cu in (8).
1.52 gr per cu cm (1)
- 2.022 Electrical properties.
- 2.023 Magnetic properties.
- 2.024 Emissance, Figure 2.024.
- 2.025 Damping capacity.
- 2.03 Chemical Properties

	Mg
9	Li
1	Al

LA91A

CODE 3508

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	Mg
9	Li
1	Al

LA91A

2.031 Corrosion. In humid atmospheres the corrosion resistance of LA91A is equivalent to most other magnesium alloys, but in salt water or salt spray it corrodes at somewhat faster rates than most of the other alloys (9). In a vacuum of 1 to 2×10^{-6} mm of Hg it loses no weight at temperatures up to 600F; at 800F it loses weight at a rate of 1.1×10^{-2} $\mu\text{g}/\text{cm}^2/\text{sec}$ (1). In general, the corrosion products on LA91A are less adherent than those on most commercial alloys. Over long exposure periods the corrosion rates for the commercial alloys decrease with time; those for magnesium-lithium alloys are more likely to remain constant or to decrease much more slowly (9). LA91A is sufficiently resistant to normal atmospheric corrosion for only limited structural service. Protective coatings are necessary for most applications, especially when prolonged periods of time are involved.

2.04 Nuclear Properties

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties

3.02 Mechanical Properties at Room Temperature

- 3.021 Tension.
- 3.0211 Stress-strain diagrams.
- 3.0212 Typical tensile properties as-hot-rolled and after 48 hours exposure to 200F, Table 3.0212.

TABLE 3.0212

Source		(1)					
Alloy		LA91A					
Form		0.063 Inch Sheet					
Data		Room Temperature Tensile					
Condition	As-Hot-Rolled			After 48 Hours Anneal at 200F			
	Ru Ksi	F _{ty} Ksi	e(2 In)	F _{tu} Ksi	F _{ty} Ksi	e(2 In)	
Mg-9Li-1.0Al	27.8	21.8	34	26.2	20.3	38	
Mg-9Li-1.5Al	25.0	21.4	38	26.4	20.6	36	

3.0213 Effect of fabrication procedure, Table 3.0213.

3.0214 Effect of heat treatment, Table 3.0214.

TABLE 3.0214

Source		(1)					
Alloy		LA91A					
Form		0.063 Inch Sheet					
	Solution Treat		Age Treat		F _{tu} , ksi	F _{ty} , ksi	e (2 in)
	Time, hr	Temp, F	Time, hr	Temp, F			
As-extruded and hot-rolled	-	-	-	-	28.1	24.0	15
	1/2	650	-	-	27.9	22.1	25
As-forged and hot-rolled	-	-	-	-	29.5	20.2	34
	1/2	650	24	200	27.8	23.2	28
As-forged and hot-rolled	-	-	-	-	21.7	16.7	45
	1/2	650	24	200	21.7	16.7	45

3.0215 Effect of cold rolling at 75F and -100F on tensile properties of sheet previously hot rolled at 450F, Figure 3.0215.

- 3.022 Compression.
- 3.0221 Stress-strain diagrams.
- 3.023 Impact.
- 3.024 Bending.
- 3.0241 Bend radius for sheet, 1T to 3T (1).
- 3.025 Torsion and shear.
- 3.026 Bearing.
- 3.027 Stress concentration.
- 3.0271 Notch properties.
- 3.0272 Fracture toughness.
- 3.028 Combined properties.

3.03 Mechanical Properties at Various Temperatures

- 3.031 Tension. Effect of temperature on tensile properties. Figure 3.031.
- 3.0311 Stress-strain diagrams.
- 3.032 Compression.
- 3.0321 Stress-strain diagrams.
- 3.033 Impact.
- 3.034 Bending.
- 3.035 Torsion and shear.
- 3.036 Bearing.
- 3.037 Stress concentration.
- 3.0371 Notch properties.
- 3.0372 Fracture toughness.
- 3.038 Combined properties.

3.04 Creep and Creep Rupture Properties

3.05 Fatigue Properties

3.06 Elastic Properties

- 3.061 Poisson's ratio.
- 3.062 Modulus of elasticity : 6.6×10^3 ksi (S).
- 3.063 Modulus of rigidity.

TABLE 3.0213

Source		(1)				
Alloy		LA91A				
Condition		As-Hot-Worked				
Method of Fabrication	Fabrication Procedure	Reduction Ratio	F _{tu} , ksi	F _{ty} , ksi	e(2 In)	
As-extruded	0.187 x 2 x 2 inch, T-section extruded from 4 7/16 - inch diameter billet at 500° F	24:1	21.0	18.1	30	
As-extruded and rolled	0.187 x 2 - inch flange of T-section rolled at 450° F to 0.063 - inch thick sheet	40:1	28.1	24.0	18	
		4:1	23.6	20.8	39	
As-forged	Bar stock hammer forged at 550° F from cast ingot					
As-forged and rolled	Forged bar rolled at 450° F to 0.063 inch thick sheet	40:1	29.5	20.2	34	
		40:1	30.8	24.9	15	
As-rolled	As-cast ingot rolled at 450° F to 0.063 inch thick steel					

4. FABRICATION

4.01 Formability

4.011 General. LA91A, like LA141A and in contrast to most commercial magnesium alloys, is easily fabricated and formed, even at room temperature. Primarily, the excellent forming characteristics of LA91A are a result of its body centered cubic matrix structure, whereas most magnesium alloys have hexagonal close packed structures, which are much more difficult to form.

4.012 Parts can be produced by all methods of fabrication. For severe forming, such as deep drawing, impact extruding, spinning, hammer forging, and large rolling reductions, elevated temperatures (normally in the range 350 to 500F) should be used. The needed temperature depends upon the severity of forming (2)(9).

4.02 Machining and Grinding

4.021 General. LA91A is easily machined, cut, sawed, or chemically milled. In machinability it is comparable to other magnesium alloys and aluminum. The same precautions used in magnesium machining must be observed. Where a machining coolant or lubricant is desired, a mineral oil (non water soluble) is recommended. For cutting or sawing, mineral oil or paraffin may be used (2)(9).

4.022 Chemical milling. The alloy can be chemically milled in phosphoric or sulfuric acid solutions. Acid strength and temperature vary depending upon the physical size of parts and the amount of material to be removed, so that convenient etching rates can be selected. Masking techniques similar to those used for aluminum can be used (9).

4.03 Welding

4.031 General. LA91A can be readily fusion welded. Joint efficiencies are high and weld cracking difficulties are rare. Both GTA and GMA processes, with manual or automatic techniques, are applicable. The use of helium gas maintains a cleaner appearance of the liquid pool; however, weldments with 100 percent joint efficiency have been obtained with the use of argon. Backside shielding is required to reduce underside oxidation. Prior to welding, the material must be cleaned by abrasion with aluminum oxide or with stainless steel or aluminum wire brushes. No preheating is necessary, but a postweld stress relief at 250 to 350F is recommended. The alloy can also be resistance spot welded on equipment conventionally used for other magnesium alloys (2).

4.032 Filler metals. Welding wires of LA141A, EZ33A AZ92A, and AZ61A have been used successfully. As with the base metal, it is necessary to use freshly cleaned welding wire, which can be cleaned by passing through stainless steel wool (2).

4.033 Tensile properties of LA91A sheet TIG welded with EZ33A filler wire, Table 4.033.

TABLE 4.033

Source		(2)			
Alloy		LA91A			
Form		0.090 Inch Sheet			
Condition		GTA Welded with EZ 33 A Filler Wire			
Temp, F	F _{tu} Ksi	F _{ty} Ksi	e (2 In)	Fracture Location	
75	23.7	21.2	6	Base Metal	
75	23.7	21.8	6	Base Metal	
75	23.4	21.4	6	Base Metal	
-320	30.4	25.7	7	Base Metal	
-320	30.2	-	12	Base Metal	
-423	43.3	-	6	Fusion Zone	
-423	35.1	-	1	Fusion Zone	
-423	39.4	-	3	Fusion Zone	

4.04 Surface Treatment

4.041 General. Several treatments developed originally for commercial magnesium alloys have been applied with fair success to LA91A. These are Dow 17, HAE, fluoride anodize, and stannate treatments. All of them require subsequent paint coatings, preferably baking or room temperature curing resins, for protection in outdoor, salt-air, or humid environments (2)(5)(9).

4.042 Metallic coatings. There are three accepted methods for applying metallic coatings to commercial magnesium alloys; immersion zinc plating, electroless (immersion) nickel plating, and direct electro-plating of nickel. On LA91A the first two are much more effective than the third. In each case, other metals that can be electroplated can be deposited by standard methods over the initial layer of zinc or nickel (2) (9).



LA91A

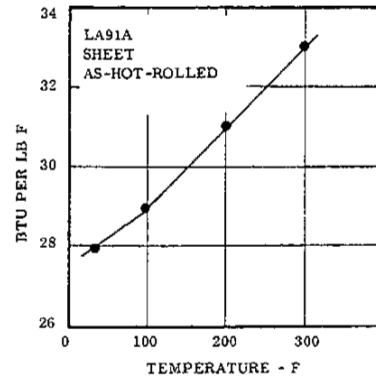


FIG. 2.015 SPECIFIC HEAT. (1)

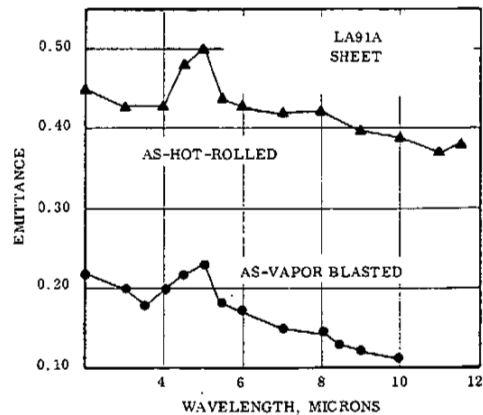


FIG. 2.024 NORMAL SPECTRAL EMITTANCE AT 360° K. (1)

	Mg
9	Li
1	Al

LA91A

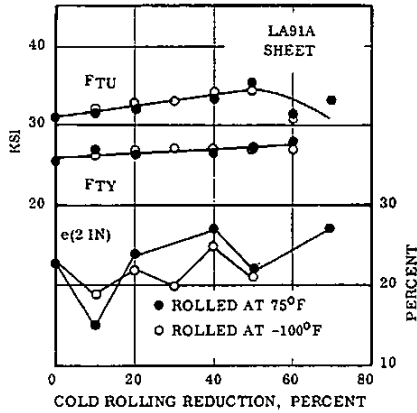


FIG. 3.0215 EFFECT OF COLD ROLLING AT 75F AND -100F ON TENSILE PROPERTIES OF SHEET PREVIOUSLY HOT-ROLLED AT 450°F. (1)

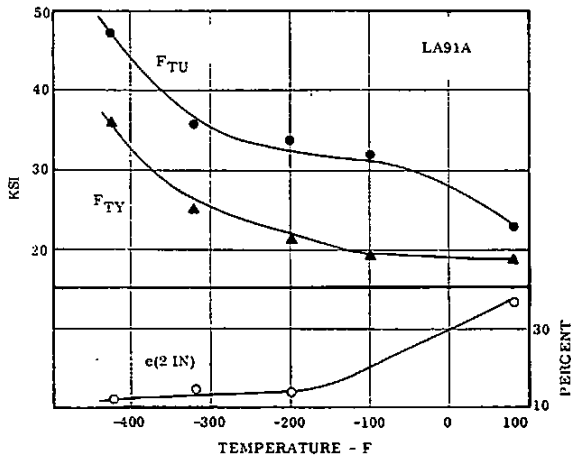


FIG. 3.031 TENSION EFFECT OF TEMPERATURE ON TENSILE PROPERTIES. (2)

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