NONFERROUS ALLOYS

	Mg
9	Al
2	Zn

AZ 92 A

1. GENERAL

AZ 92 A is a heat treatable casting alloy which is a member of the aluminum and zinc containing family. Of this family it has the highest yield strength combined with moderate elongation and good pressure tightness. It is available in the form of sand, permanent mold, investment castings and welding rod. Castings of this alloy give stable properties up to 200 F and under low operating stresses give satisfactory service up to 350 F. It has good machinability and can be welded.

1.01 Commercial Designation. AZ 92 A.

1.02 Alternate Designation

1.03 Specifications, Table 1.03.

TABLE 1.03

AMS	Form	Military	ASTM
4434 F	Castings, sand (T6 Cond)	QQ-M-56(F, T7)	B 80-56T (F,T6)
4453	Castings, investment (T6 Cond)	-	-
4484 E	Castings, permanent mold (T6 Cond)	QQ-M-55 (F, T6)	B 199-56T
-	Ingot	-	B 93-56T

1.04 Composition, Table 1.04.

TABLE 1.04

Source	AMS (1) (2) (3)	
	Percent	
	Min	Max
Aluminum	8.3	9.7
Zinc	1.6	2.4
Manganese	0.10	-
Silicon	-	0.30
Copper	-	0.10
Nickel	-	0.01
Other impurities total	-	0.30
Magnesium	Balance	

1.05 Heat Treatment

1.051 Solution treat. As cast F Condition to T4 Condition.

1.0511 Load into preheated furnace (approximately 500 F), raise to 760 to 770 F in about 2 hr, hold at temperature for 18 hr, air cool. Use 0.5% SO_2 (min) in furnace atmosphere during heat and soak periods, (4, p. 3).

1.0512 Load into preheated furnace (approximately 500 F), raise to 760 to 770 F in about 2 hr, hold at temperature for 6 hr, furnace cool to 660 to 670 F, hold for 2 hr, raise to 760 to 770 F, hold for 10 hr, air cool. Use 0.5% SO_2 (min) in furnace atmosphere during heat and soak cycles. This treatment prevents germination, (4, p. 3).

1.052 Age

1.0521 As cast to T5 Condition, age at 490 to 510 F for 4 hr, air cool, (4, p. 2-3).

1.0522 T4 to T6 Condition, after solution heat treat, age at 490 to 510 F for 4 hr, air cool, (4, p. 4).

1.06 Hardenability

1.07 Forms and Conditions Available

1.071 Alloy is available in the full commercial range of sizes for sand, permanent mold and investment castings.

1.072 Castings are available in F, T4, T5 and T6 Conditions although use is almost exclusively in the T6 Condition.

1.08 Melting and Casting Practice

1.081 Standard magnesium alloy melting and casting practice.

1.09 Special Considerations

1.091 Heat treat temperature must not exceed 772 F to prevent burning, (6).

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting range. 830 to 1100 F minimum. Liquation (burning) temperature 770 F, (6).

2.012 Transformation temperature. None.

2.013 Thermal conductivity, Table 2.013.

TABLE 2.013 *

Source	(7, Tbl. V)			
Condition	F	T4	T5	T6
Temp - F	Btu ft per (hr sq ft F)			
68	30.2	25.6	33.6	33.6
100	-	-	35.1	35.1
200	-	-	38.7	38.7
300	-	-	-	41.8
400	-	-	-	44.8
500	-	-	-	47.6

* Calculated from electrical resistivity data

2.014 Thermal expansion at low and elevated temperatures, Fig. 2.014.

2.0141 Dimensional growth due to exposure at various temperatures, Fig. 2.0141.

2.015 Specific heat. 0.245 Btu per (lb F).

2.016 Emissivity. Variations in alloy composition do not significantly effect emissivity values.

2.0161 Effect of test temperature on emissivity of alloy, Fig. 2.0161.

2.017 Diffusivity. Thermal, 0.135 sq in per sec, (9, p.19).

2.02 Other Physical Properties

2.021 Density. 0.066 lb per cu in, 1.828 gr per cu cm.

2.022 Electrical resistivity, Table 2.022.

TABLE 2.022

Source	(7, Tbl. IV)			
Condition	F	T4	T5	T6
Temp - F	Microhm - in			
68	5.51	6.61	4.88	4.88
100	-	-	5.00	5.00
200	-	-	5.35	5.35
300	-	-	-	5.75
400	-	-	-	6.10
500	-	-	-	6.46

2.023 Magnetic properties. Nonmagnetic.

2.03 Chemical Properties

2.031 Corrosion resistance

2.0311 Alloy is resistant to most alkalis, some hydrocarbons, aldehydes, ethyl alcohol, phenols, amines, esters and most oils as well as pure chromic and hydrofluoric acids.

2.0312 Stress corrosion may occur after welding unless stress relieved.

2.0313 Susceptible to galvanic corrosion in presence of more noble metal unless protected.

2.032 Oxidation resistance. In moist air, alloy forms oxide film which retards but does not stop further oxidation. Needs full protection in marine atmospheres.

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties

3.011 AMS specified and producer's minimum mechanical properties, Table 3.011.

Mg	
9	Al
2	Zn

AZ 92 A

TABLE 3.011

Source	AMS (1) (3)	AMS (2)	Dow (9, p. 23)			
Alloy	Mg-9Al-2Zn					
Form	Sand and permanent mold castings	Investment castings	Sand and permanent mold castings			
Condition	T6	T6	F	T4	T5	T6
F_{tu}, min - ksi	34 (a), 25.5 (b), 17 (c)	37 (a), 27.5 (b), 19 (c)	20	34	20	34
F_{ty}, min - ksi	18 (a), 16 (b), 13.5 (c)	20 (a), 17.5 (b), 15 (c)	10 (f)	10 (f)	11 (f)	18 (f)
e, min - percent	1 (a) (d), 0.75 (i)	1 (a) (e), 0.7 (b) (g)	1 (d)	6 (d)		1 (d)
Hardness, BHN - min	70 (h)	63 (f)				
Hardness, BHN - max	95 (h)	93 (f)				

(a) For cast tensile specimens
(b) Average for tensile specimens cut from castings (not less than 4, preferably 10 specimens)
(c) For individual tensile specimen cut from castings
(d) In 2 in gage length
(e) In 1 in gage length
(f) Converted from Rockwell E 75-95
(g) In 4 D
(h) 500 kg - 10 mm ball
(i) AMS 4434 F specifies 2 in gage length
AMS 4484 E specifies 4 D gage length

3.02 Mechanical Properties at Room Temperature

3.021 Typical mechanical properties, Table 3.021.

TABLE 3.021

Source	(9, p. 23)			
Alloy	Mg-9Al-2Zn			
Form	Sand and permanent mold castings (separately cast test bars)			
Condition	F	T4	T5	T6
F_{tu}, typ - ksi	24	40	24	40
F_{ty}, typ - ksi	14	14	14	21
e (2 in) typ - percent	2	10	2	2
F_{cy}, typ - ksi	14	14	-	21
F_{su}, typ - ksi	19	19	20	22
F_{bru}, typ - ksi	50	68	50	80
F_{bry}, typ - ksi	46	46	46	65
Hardness, BHN - typ	65	63	-	84

3.022 Effect of exposure to elevated temperature on room temperature tensile properties of alloy in T6 Condition, Fig. 3.022.

3.023 The compressive yield strength of this alloy is essentially the same as the tensile yield strength, (8, p. 25).

3.024 Stress strain curves in tension at room temperature for alloy in F, T4 and T6 Condition, Fig. 3.024.

3.025 Stress strain curves in compression at room temperature for alloy in F, T4 and T6 Condition, Fig. 3.025.

3.026 Tangent modulus curves in tension at room temperature for alloy in F, T4 and T6 Condition, Fig. 3.026.

3.027 Tangent modulus curves in compression at room temperature for alloy in F, T4 and T6 Condition, Fig. 3.027.

3.028 Effect of stress concentration factor on room temperature notch tensile strength ratio of alloy in T4 and T6 Condition, Fig. 3.028.

3.03 Mechanical Properties at Various Temperatures

3.031 Short time tensile properties

3.0311 Stress strain curves at room and elevated temperature of alloy in T6 Condition, Fig. 3.0311.

3.0312 Effect of test temperature on tensile properties of alloy in T5 and T6 Condition, Fig. 3.0312.

3.0313 Effect of exposure and test temperature on tensile properties of alloy in T6 Condition, Fig. 3.0313.

3.0314 Effect of test temperature and strain rate on tensile properties of alloy in T6 Condition, Fig. 3.0314.

3.032 Short time properties other than tension

3.0321 Effect of test temperature on shear strength of alloy in T6 Condition, Fig. 3.0321.

3.0322 Effect of test temperature on bearing properties of alloy in T6 Condition, Fig. 3.0322.

3.04 Creep and Creep Rupture Properties

3.041 Creep curves of alloy in T6 Condition, Fig. 3.041.

3.042 Isochronous stress strain curves for alloy in T6 Condition at 300 and 400 F, Fig. 3.042.

3.05 Fatigue Properties

3.051 S-N curves for fatigue properties of alloy, Fig. 3.051.

3.052 Shot peening or surface rolling of castings induce residual compressive stresses favorable to increased fatigue life, (8, p. 36).

3.06 Elastic Properties

3.061 Modulus of elasticity at room and elevated temperatures, Fig. 3.061.

3.062 Modulus of rigidity, 2,400 ksi.

3.063 Poisson's ratio, 0.35.

4. FABRICATION

4.01 Forming and Casting

4.011 General. Standard flux melting procedure is used for magnesium alloys. Molten metal must be kept covered with flux. Crucibles having clay as a bond are attacked by molten magnesium while steel crucibles are not attacked. Welded low carbon or cast steel crucibles are almost always used. Impurities may be picked up from nickel steel crucibles. Moisture must be avoided.

4.012 Casting temperature. Sand, 1350 to 1550 F. Permanent mold, 1200 to 1500 F. Ingots, 1200 to 1300 F, (6).

4.02 Machining

This alloy possesses excellent machinability.

4.03 Welding

Alloy has fair weldability.

4.031 Alloy is welded by the inert shielded tungsten arc method, using an AZ 92 A welding rod, (6).

4.032 Gas welding is used mostly for emergency repairs. When gas welding, all flux must be completely removed by immersion and scrubbing in hot water. Part should be given chrome pickle treatment and then boiled for 2 hr in 5 percent sodium dichromate solution.

4.033 This alloy can be satisfactorily resistance welded, (6).

4.034 Stress relieve after welding, see 4.0423.

4.04 Heating and Heat Treating

4.041 Solution treatments require an atmosphere of at least 0.5 percent sulfur dioxide.

4.042 Heat treatment after welding with AZ 92 A welding rod.

4.0421 From T4 or T6 Condition before welding to T4 Condition after welding, heat 30 min at 760 to 770 F, (5).

4.0422 From T4 or T6 Condition before welding to T6 Condition after welding, heat 30 min at 760 to 770 F, age 4 hr at 500 F, (5).

4.0423 Stress relief after welding, 500 F, 30 min, (5).

4.05 Surface Treating

4.051 Dip coatings (chromic acid and sodium dichromate) and anodic coatings of various kinds are used. Both types serve as a base for special paints. Dip coatings are very thin and lack abrasive resistance. For service in marine atmospheres, anodic coatings plus paint must be used. Electroplating may be used for high wear resistance and protection at elevated temperatures, (8, p. 157, 158).

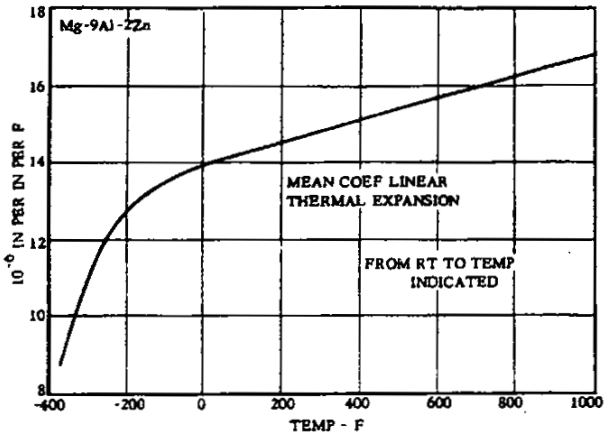


FIG. 2.014 THERMAL EXPANSION AT LOW AND ELEVATED TEMPERATURES (7, Tbl. I)

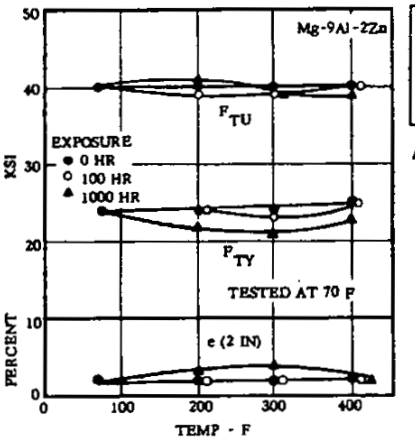


FIG. 3.022 EFFECT OF EXPOSURE TO ELEVATED TEMPERATURE ON ROOM TEMPERATURE TENSILE PROPERTIES OF ALLOY IN T6 CONDITION (8, p. 179)

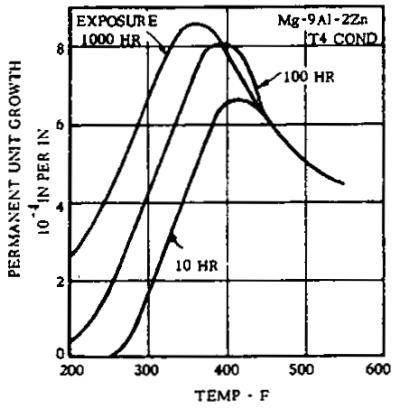


FIG. 2.0141 DIMENSIONAL GROWTH DUE TO EXPOSURE AT VARIOUS TEMPERATURES (8, p. 16-17)

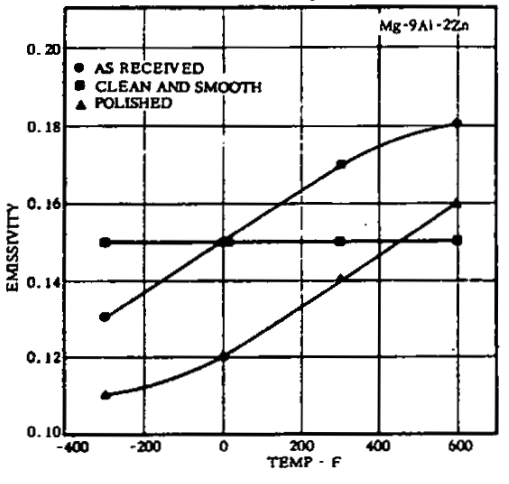


FIG. 2.0161 EFFECT OF TEST TEMPERATURE ON EMISSIVITY OF ALLOY (14)

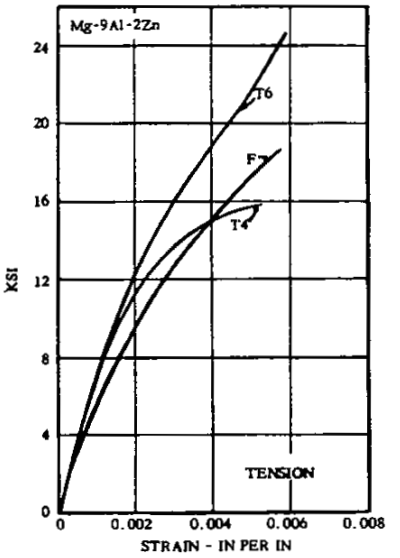


FIG. 3.024 STRESS STRAIN CURVES IN TENSION AT ROOM TEMPERATURE FOR ALLOY IN F, T4 AND T6 CONDITION (11, p. 4.62-4.69)

	Mg
9	Al
2	Zn

AZ 92 A

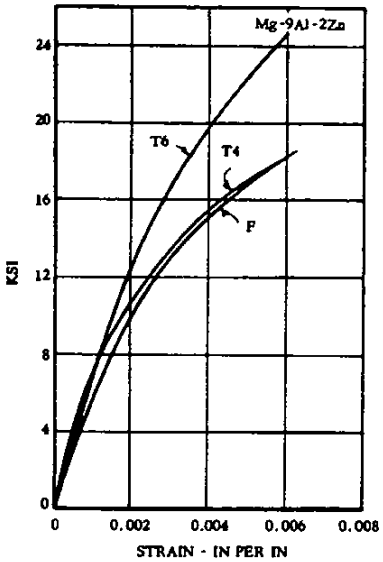


FIG. 3.025 STRESS STRAIN CURVES IN COMPRESSION AT ROOM TEMPERATURE FOR ALLOY IN F, T4 AND T6 CONDITION (11, p.4.62-4.69)

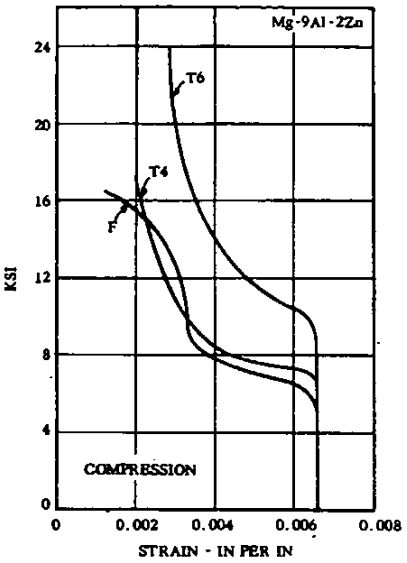


FIG. 3.027 TANGENT MODULUS CURVES IN COMPRESSION AT ROOM TEMPERATURE FOR ALLOY IN F, T4 AND T6 CONDITION (11, p.4.62-4.69)

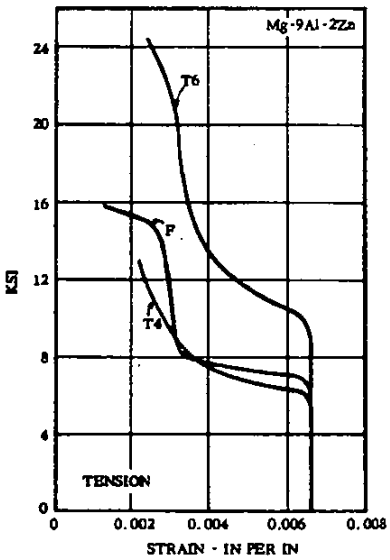


FIG. 3.026 TANGENT MODULUS CURVES IN TENSION AT ROOM TEMPERATURE FOR ALLOY IN F, T4 AND T6 CONDITION (11, p. 4.62-4.69)

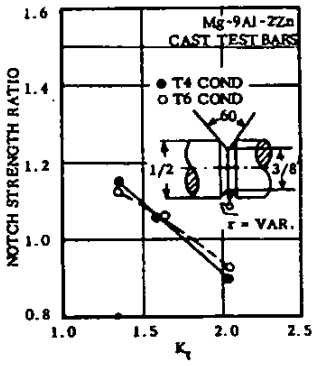


FIG. 3.028 EFFECT OF STRESS CONCENTRATION FACTOR ON ROOM TEMPERATURE NOTCH TENSILE STRENGTH RATIO OF ALLOY IN T4 AND T6 CONDITION (8, p.185)

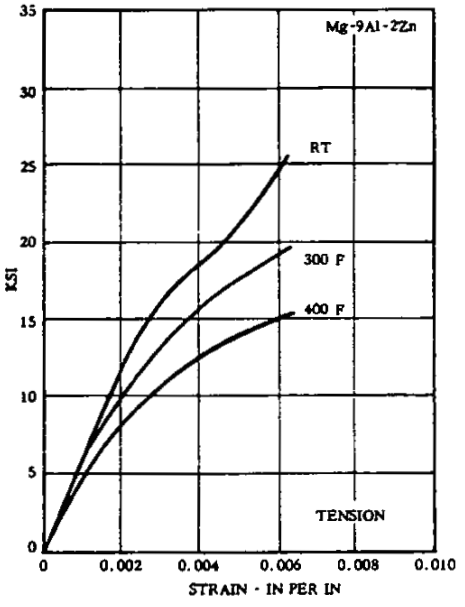
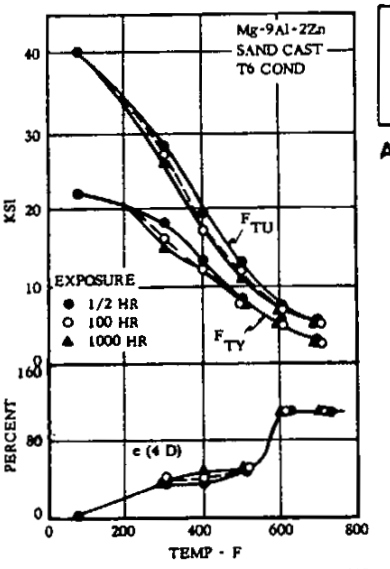


FIG. 3.0311 STRESS STRAIN CURVES AT ROOM AND ELEVATED TEMPERATURE OF ALLOY IN T6 CONDITION (11, p. 4.69-4.70)



	Mg
9	Al
2	Zn

AZ 92A

FIG. 3.0313 EFFECT OF EXPOSURE AND TEST TEMPERATURE ON TENSILE PROPERTIES OF ALLOY IN T6 CONDITION (10)

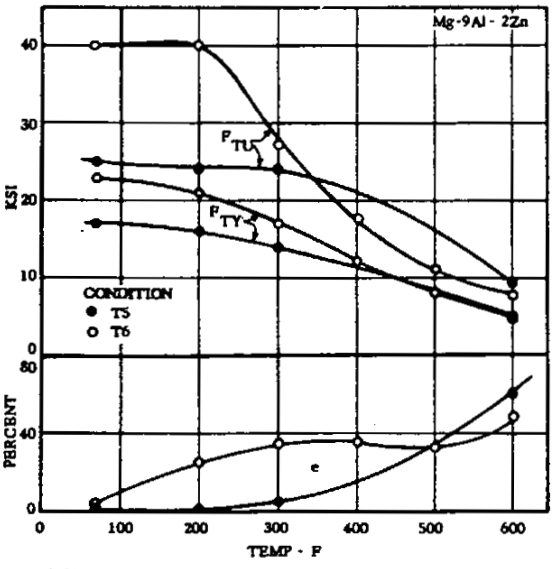


FIG. 3.0312 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF ALLOY IN T5 AND T6 CONDITION (8, p. 175)

Mg	
9	Al
2	Zn

AZ 92 A

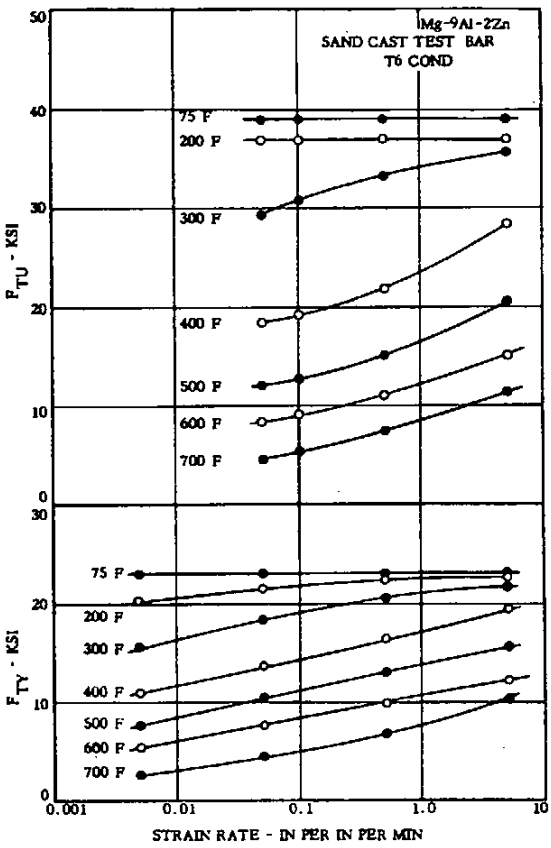


FIG. 3.0314 EFFECT OF TEST TEMPERATURE AND STRAIN RATE ON TENSILE PROPERTIES OF ALLOY IN T6 CONDITION (12, Tbl. IV)

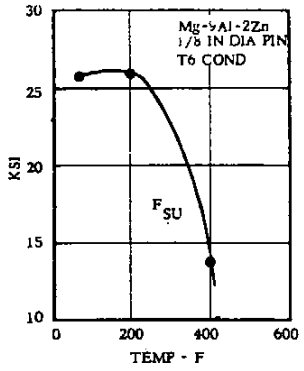


FIG. 3.0321 EFFECT OF TEST TEMPERATURE ON SHEAR STRENGTH OF ALLOY IN T6 CONDITION (13)

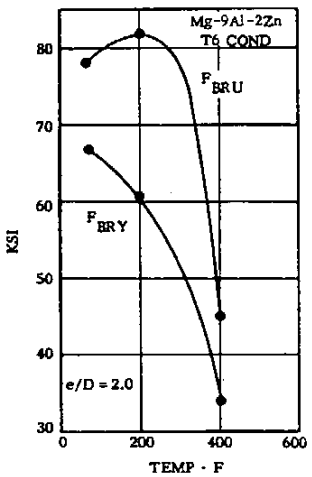


FIG. 3.0322 EFFECT OF TEST TEMPERATURE ON BEARING PROPERTIES OF ALLOY IN T6 CONDITION (13)

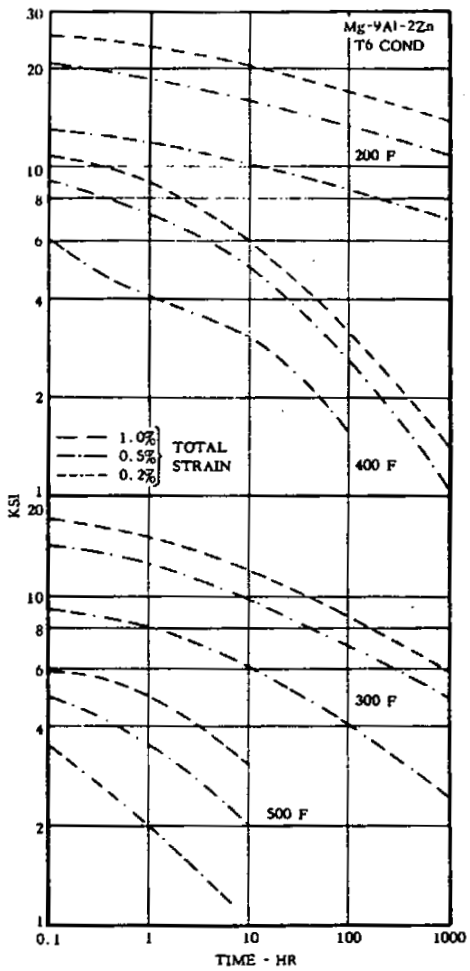


FIG. 3.041 CREEP CURVES OF ALLOY IN T6 CONDITION
(8, p.183)

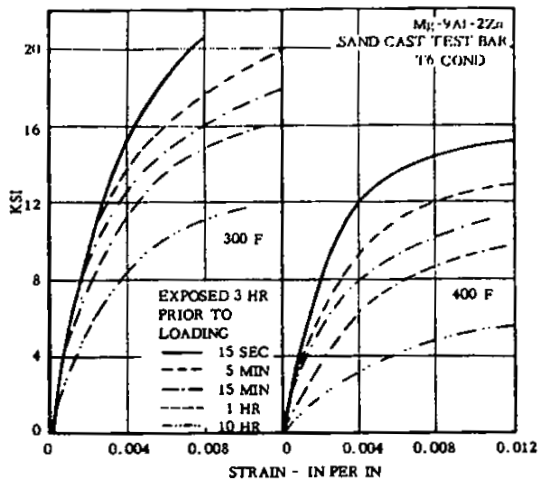


FIG. 3.042 ISOCHRONOUS STRESS STRAIN CURVES FOR ALLOY IN T6 CONDITION AT 300 AND 400 F
(15)

	Mg
9	Al
2	Zn

AZ 92 A

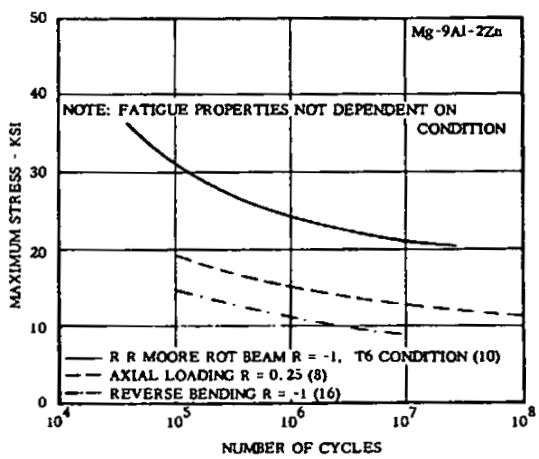


FIG. 3.051 S-N CURVES FOR FATIGUE PROPERTIES OF ALLOY
(8, p.38) (10) (16)

Mg	
9	Al
2	Zn

AZ 92 A

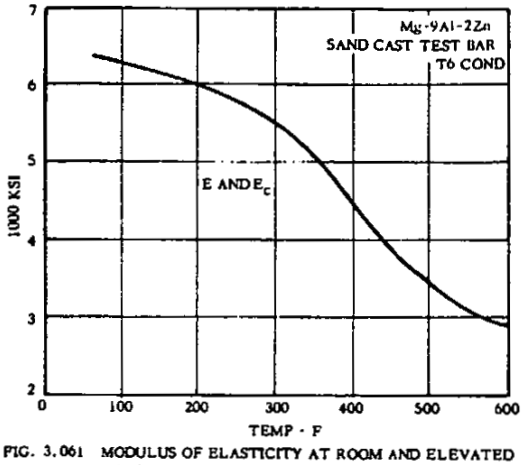


FIG. 3.061 MODULUS OF ELASTICITY AT ROOM AND ELEVATED TEMPERATURES

(11, p. 4.68)

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