

REVISED: DECEMBER 1969
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NONFERROUS ALLOYS

1. GENERAL
HZ32A, which is a magnesium-base casting alloy used in the artificially aged (T5) condition, has reasonably good foundry characteristics and medium room temperature mechanical properties similar to those of HK31A. The relatively high thorium content (3.2 percent) in these two alloys gives them outstanding elevated temperature strength among the magnesium casting alloys. The addition of 2.1 percent zinc to HZ31A to produce HZ32A results in optimum creep resistance at temperatures of 500F and above, whereas HZ31A is somewhat superior at lower temperatures. HZ32A exhibits excellent long time stability at elevated temperatures, exposures of at least 1000 hours at 600F having no detrimental effect on room temperature mechanical properties. It has excellent machinability and reasonably good weldability. For long time use or even short time use under severe corrosive conditions, chemical treatment followed by painting is recommended. HZ32A-T5 should be considered for use in aerospace or any other applications where the prime requirement is a high strength-to-weight ratio primarily in the temperature range of 500 to 650F.

- 1.01 Commercial Designation
HZ32A

- 1.02 Alternate Designations
HZ32XA, ZT1 (British)

- 1.03 Specifications
AMS 4447B
ASTM B80-68
U. S. Federal QQ-M-56b (1)
U. S. Federal QQ-M-55b

- 1.04 Composition
Table 1.04.

Alloy	HZ32A			
	Composition			
	AMS 4447B (20)		ASTM B80-68	
	Percent		Percent	
Source	Minimum	Maximum	Minimum	Maximum
Zinc	1.7	2.5	1.7	2.5
Thorium	2.5	4.0	2.5	4.0
Zirconium				
total	0.50	1.0	0.50	1.0
soluble*	0.50	-	-	-
Copper	-	0.10	-	0.10
Rare Earths	-	0.10	-	0.10
Nickel	-	0.01	-	0.01
Others	-	0.20	-	0.30
Magnesium	Balance		Balance	

* Soluble zirconium is that portion of the zirconium that is soluble in 1:4 hydrochloric acid held below its boiling point.

- 1.05 Heat Treatment
Cast plus artificially aged (T5) at 600F for 16 hours (1)(2).
- 1.06 Hardness
1.061 BHN 50-75 with 1000 kg load and 10 mm ball (AMS 4447B)
1.062 BHN 45-70 with 500 kg load and 10mm ball or 1000 kg load and 9/16 inch ball (AMS 4447B).
- 1.07 Forms and Conditions Available
Produced as castings and used in the T5 (artificially aged) condition.
- 1.08 Melting and Casting Practice
Melting practice for magnesium alloys containing zirconium is somewhat different from practices used for the alloys containing aluminum. A cast or fabricated and welded steel crucible is normally used for both melting and pouring, since transfer from a melting to a pouring crucible results in zirconium losses. Melting is carried out in gas- or oil-fired furnaces. The magnesium

is brought to a temperature of 1450 to 1500F for alloying under a crucible-flux cover, which normally consists of magnesium chloride with other chlorides and fluorides. This type of flux first melts to form a liquid cover; but after some time at 1400F or above, it gradually becomes more viscous and finally forms a dry scaly crust. Alloying additions are made by immersing them below the melt surface on a steel ladle and gently agitating. Metallic zinc, which is subject to little or no melting loss, is added first. Thorium is then introduced, as pellets made from compacted and sintered thorium powder or as a magnesium-thorium hardener alloy. As thorium oxidizes readily, care must be taken to avoid raising it to a high temperature in air. (Considerable loss of thorium occurs, which must be determined by experience for different foundry conditions.) Finally, zirconium is added in the form of a magnesium-zirconium hardener alloy containing 30 to 50 percent zirconium or in the form of zirconium fluoride or chloride in a fused-salt mixture. Because of the low solubility of zirconium, it is necessary to add about 3 to 5 times the required percentage. After the alloying additions have been made, the melt should be thoroughly stirred and skimmed, covered with additional crucible flux, and held for 20 minutes before pouring to allow separation of the flux from the metal and to allow undissolved zirconium to settle. The flux is skimmed from the surface just before pouring, and burning is prevented during pouring by dusting the melt surface with a mixture of sulfur and boric acid or a proprietary preparation. The metal is poured between 1350 and 1550F, depending upon the section size of the casting. A heel 2 to 3 inches deep should be left in the crucible to minimize the possibility of pouring into the mold a residue consisting of zirconium containing sludge and flux (2).

- 1.09 Special Considerations
1.091 HZ32A-T5 tends to shrink slightly with increasing exposure times at elevated temperatures.
1.092 Shrinkage due to exposures at elevated temperatures, Figure 1.092
1.093 Contaminations with more than 0.005 percent aluminum should be avoided because aluminum forms undesirable intermetallic compounds with zirconium (5).
1.094 The presence of 0.1 percent or more rare-earth metals causes loss in creep resistance (5).

2. PHYSICAL AND CHEMICAL PROPERTIES

- 2.01 Thermal Properties
2.011 Melting range, 1026-1198F (2).
2.012 Phase changes. Magnesium-thorium-zinc compounds in acicular shape, which enhance creep resistance, form at the grain boundaries during artificial aging (4).
2.0121 Time-temperature-transformation diagrams.
2.013 Thermal conductivity, 63.2 Btu ft per (hr sq ft) at 68F (2)(5).
2.014 Thermal expansion, 14.8×10^{-6} per °F from 68 to 392F (5)(6).
2.015 Specific heat, 0.23 Btu per (lb F) from 68 to 392F (5)(6).
2.016 Thermal diffusivity.
- 2.02 Other Physical Properties
2.021 Density, 1.83 g/cc (2)(5). 0.0657 lb/cu in (6).
2.022 Electrical properties.
2.0221 Electrical conductivity, 0.35 megmhos/inch³ at 68F (6).
2.0222 26.5 percent IACS at 68F (5).
2.0223 Electrical resistivity, 2.56 microhm - inch at 68F (5).
2.023 Magnetic properties.
2.024 Emission.
2.025 Damping capacity. At a stress equal to 0.1 F_{Ty} the specific damping capacity is 5, which is an intermediate level compared with other magnesium alloys (7).
- 2.03 Chemical Properties
2.031 HZ32A is subject to general and pitting-type corrosion when exposed to most natural environments. When properly surface treated and painted, it will perform satisfactorily in all of these environments except immersed in

Mg
3.2 Th
2.1 Zn
0.7 Zr

HZ32A

CODE 3408

PAGE 1

Mg
3.2 Th
2.1 Zn
0.7 Zr

HZ32A

2.032 water (19). For a discussion of galvanic corrosion, see AZ31B, Code 3601, Section 2.0312. Safety precautions should be directed to the prevention of fires, burns, and explosions. The hazards of the molten metal coming into contact with moisture or water are similar to those of other magnesium alloys and greater than with other metals, since molten magnesium reacts violently with water. The ignition point of HZ32A in air, as for other magnesium alloys, is 800F or above. The ease of combustion depends upon the size and shape of the material. Finely divided material, such as dust and powders, ignite readily and may explode when mixed with air. Machining and sawing operations generate particles that are generally too large to form an explosive mixture. The fire hazard is less than with powder, but shavings burn readily once they are heated above the ignition point. Large sections burn only after prolonged heating. Graphite powder, sodium-chloride base salts, and cast iron chips are the recommended materials for extinguishing fires. Wet dust collector systems conforming to NFPA Bulletin No. 48 (21) are recommended for grinding and welding operations. During heat treatment, a minimum of one percent sulfur dioxide or three percent carbon dioxide should be maintained in the furnace atmosphere to minimize the possibility of fire (1)(2)(3).

2.04 Nuclear Properties
 2.041 Thorium is a radioactive metal, but at the concentration in this alloy it constitutes little or no hazard in normal storage, handling, and use. Since the fumes given off during melting and welding are slightly radioactive, adequate ventilation should be provided. Thorium-magnesium hardener alloys and thorium pellets used in the manufacture of HZ32A, as well as sludge left from melting operations, are radioactive and should be handled in accordance with the regulations of the Atomic Energy Commission or local codes, whichever are stricter (2).
 2.042 No interference in the sending or receiving of radio or radar signals is caused by the slight radioactivity of the alloy (8).

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties
 Table 3.01.

TABLE 3.01

Alloy		HZ32A					
Form		Sand-Cast					
Condition		T5					
Specification		AMS 4447B (20)			ASTM B30-68		
Specimen	Temp F	F _{tu} min ksi	F _{ty} min ksi	e(2 in) min	F _{tu} min ksi	F _{ty} min ksi	e(2 in) min
Cut from casting							
single	75.0	-	10.5	-	19.0	10.5	-
average of 4 or more	75.0	23.0	11.7	2.0	23.0	11.7	1.0
single	500.0	-	-	-	10.0	6.0	-
Separately cast	75.0	27.0	13.0	4.0	27.0	13.0	4.0

3.02 Mechanical Properties at Room Temperature
 3.021 Tension, typical: F_{tu} = 30.0 ksi, F_{ty} = 14.0 ksi, and e(2 inches) = 7 percent (2)(3)(5).
 3.0211 Stress-strain diagrams (see Figure 3.0311)
 3.0212 Effect of end chill on tensile properties of cast plates of two thicknesses, Figure 3.0212.
 3.0213 Effect of elevated-temperature exposure on tensile strength, Table 3.0213.

TABLE 3.0213

Source	(10)
Alloy	HZ32A
Form	Sand Castings
Condition	T5
Exposure	F _{tu} , ksi
None	29.0
1000 hours at 400F	32.0
1000 hours at 500F	34.0

3.022 Compression, typical F_{cy} = 14.0 ksi (10).
 3.0221 Stress-strain diagrams.
 3.023 Impact.
 3.024 Bending.
 3.025 Torsion and shear.
 3.0251 Typical shear, F_{su} = 20.0 ksi (10).
 3.026 Bearing, typical for separately sand-cast specimens with e/D=2.5: F_{bru} = 60.0 ksi, F_{bry} = 37.0 ksi (3)(10).
 3.027 Stress concentration.
 3.0271 Notch properties.
 3.0273 Fracture toughness.
 3.028 Combined properties.

3.03 Mechanical Properties at Various Temperatures
 3.031 Tension.
 3.0311 Stress-strain diagrams.
 3.03111 Tensile stress-strain curves, Figure 3.0311.
 3.0312 Effect of elevated temperatures on tensile properties, Figure 3.0312.
 3.0313 Effect of variations in strain rate on tensile properties at different temperatures, Figure 3.0313.
 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
 3.041 Effect of temperature and stress on the time to 0.1 percent creep extension, Figure 3.041.
 3.042 Effect of temperature and stress on the time to 0.2 percent creep extension, Figure 3.042.
 3.043 Effect of temperature and stress on the time to 0.5 percent creep extension, Figure 3.043.

3.05 Fatigue Properties
 3.051 Room temperature fatigue strength, Table 3.051.

TABLE 3.051

Alloy		HZ32A		
Form		Sand-Cast Specimens		
Condition		T5		
Type Test	Surface Condition	Source	Cycles to Failure	ksi
Reverse Bend	Smooth Machined	(14)	5 X 10 ⁷	10.08
Reverse Bend	Notched*	(14)	5 X 10 ⁷	10.08
R. R. Moore	Smooth Machined	(2)	10 ⁸	10.0
Rotating Beam	Smooth Machined	(15)	10 ⁶	13.0
Rotating Beam	Notched*	(15)	10 ⁶	10.0
Reverse Bend	As Cast	(15)	10 ⁶	7.0
Reverse Bend	Smooth Machined	(15)	10 ⁶	15.0

* Stress-concentration factor of 2.

3.052 Effect of temperature on fatigue strength of smooth, machined specimens at 10⁷ and 10⁸ cycles to failure, Figure 3.052.

3.06 Elastic Properties
 3.061 Poisson's ratio, 0.3 (5).
 3.062 Modulus of elasticity.
 3.0621 Effect of temperature on tension modulus, Figure 3.0621.
 3.063 Modulus of rigidity, 2.5 X 10³ ksi (5).

4. FABRICATION

4.01 Formability
 4.02 Machining and Grinding
 4.021 This alloy, like other magnesium alloys, has exceptionally good machinability, which enables it to be machined at high speeds and feeds. It can usually be machined dry;

but occasionally a cutting fluid is desirable for cooling the work, minimizing the possibility of distortion and reducing the chances of ignition of fine chips. Cutting fluids should always be mineral oils, since animal or vegetable oils are not suitable for use on magnesium alloys. Similarly, water-soluble oils, oil-water emulsions, or water solutions of any kind must not be used because they would severely intensify a fire in the chips if one should start. Chips wet with these coolants present a serious hazard in storage and have little scrap value (17).

4.022 The alloy can be chemically milled with sulfuric, nitric, or hydrochloric acid of 5 percent strength or greater (6).

Welding

4.03 The alloy can be arc welded with helium or argon shielding and HZ32A or EZ33A welding rods. After welding, the artificial aging treatment (16 hours at 600F) should be applied (1)(3)(5).

4.032 HZ32A should not be gas welded because of probable loss of zirconium (6)

Surface Treatment

4.041 The producing foundries normally chrome pickle the castings prior to shipment to protect them from corrosion and tarnish during shipment and storage (20)(ASTM B80-68). A suitable alternative is to oil with a light corrosion-inhibiting oil (20).

4.042 The following surface treatments, which have been developed for magnesium alloys, can be applied successfully to HZ32A to provide a good paint base as well as some degree of corrosion resistance (12) (18):

- Chrome pickle, MIL-M-3171A-Type 1
- Galvanic anodize, MIL-M-3171A-Type 4
- Sealed chrome pickle, MIL-M-3171A-Type 2
- Anodize, MIL-M-45202
- Dilute chromic acid, MIL-M-3171B
- Stannate immersion
- HAE anodize, MIL-M-45202 (ORD)

4.043 For elevated temperature applications, the anodize treatment (MIL-M-45202) is preferred because it is stable to the melting point of the alloy. The best paints for service at 500 to 600F are the straight silicone resins followed by the silicone-modified epoxies or epoxy phenolic systems. In the 400 to 500F range, other promising resins are epoxy esters and various combinations of phenolics and epoxies (15).

Mg
3.2 Th
2.1 Zn
0.7 Zr

HZ32A

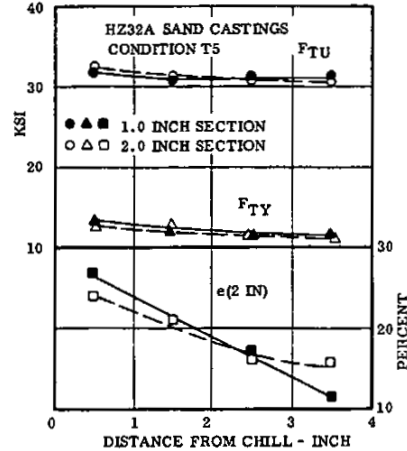


FIG. 3.0212 EFFECT OF END CHILL ON TENSILE PROPERTIES OF CAST PLATES OF TWO THICKNESSES. (9)

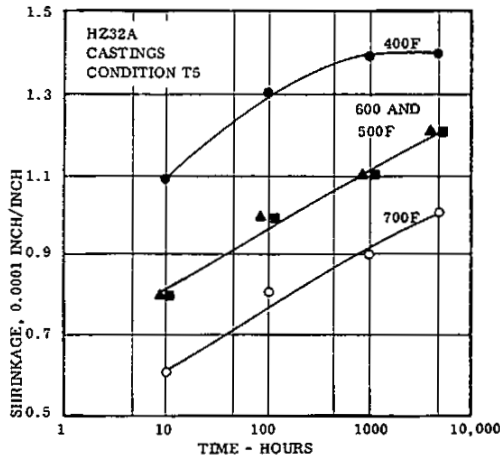


FIG. 1.092 SHRINKAGE DUE TO EXPOSURES AT ELEVATED TEMPERATURES. (1)

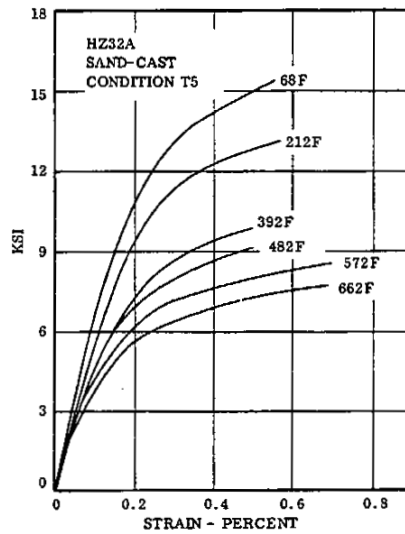


FIG. 3.03111 TENSILE STRESS-STRAIN CURVES. (6)

Mg
3.2 Th
2.1 Zn
0.7 Zr

HZ32A

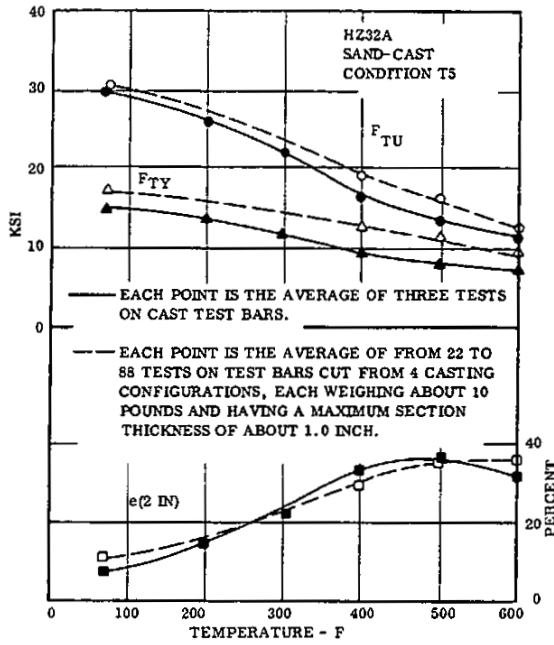


FIG. 3.0312 EFFECT OF ELEVATED TEMPERATURES ON TENSILE PROPERTIES. (10)(11)(12)

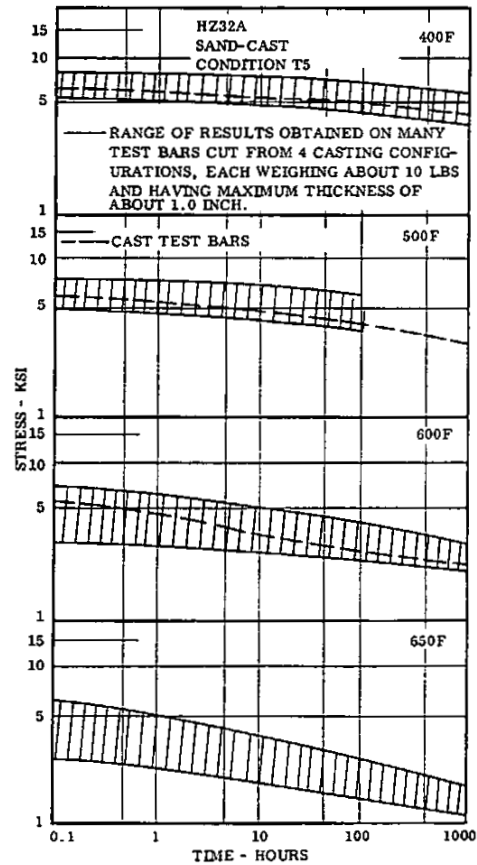


FIG. 3.041 EFFECT OF TEMPERATURE AND STRESS ON THE TIME TO 0.1 PERCENT CREEP EXTENSION. (12)

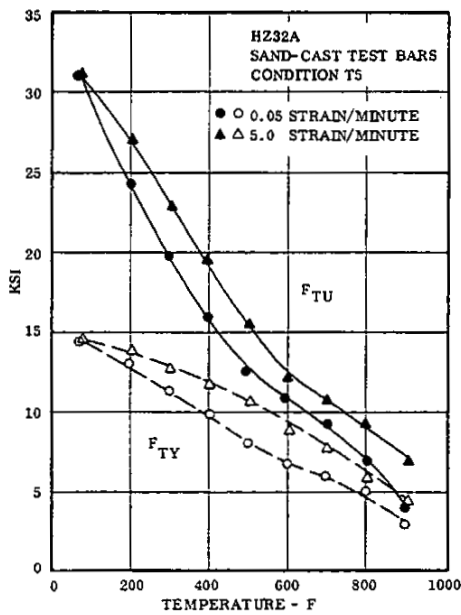


FIG. 3.0313 EFFECT OF VARIATIONS IN STRAIN RATE ON TENSILE PROPERTIES AT DIFFERENT TEMPERATURES. (13)

	Mg
3.2	Th
2.1	Zn
0.7	Zr

HZ32A

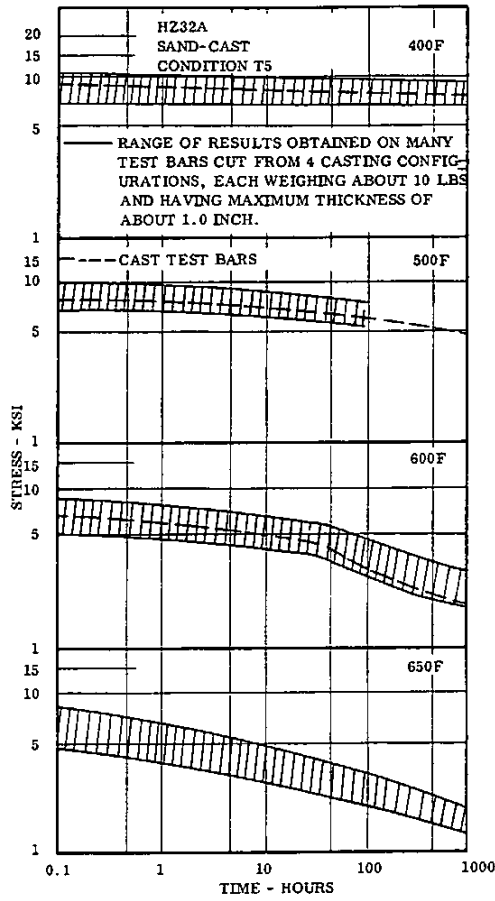


FIG. 3.042 EFFECT OF TEMPERATURE AND STRESS ON THE TIME TO 0.2 PERCENT CREEP EXTENSION. (12)

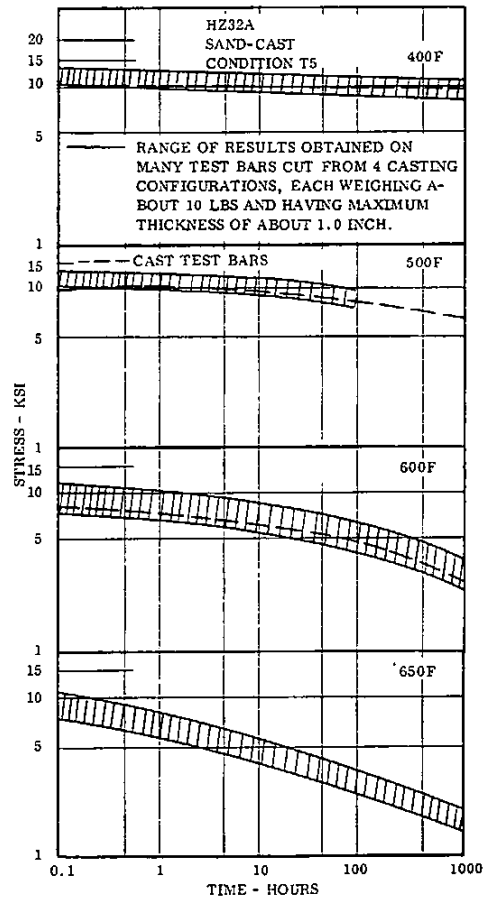


FIG. 3.043 EFFECT OF TEMPERATURE AND STRESS ON THE TIME TO 0.5 PERCENT CREEP EXTENSION. (12)

Mg
3.2 Th
2.1 Zn
0.7 Zr

HZ32A

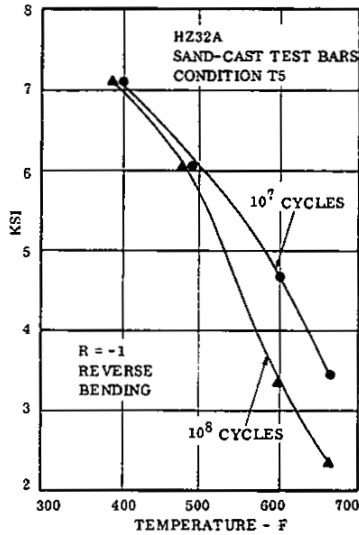


FIG. 3.052 EFFECT OF TEMPERATURE ON FATIGUE STRENGTH OF SMOOTH MACHINED SPECIMENS AT 10^7 AND 10^8 CYCLES TO FAILURE. (14)

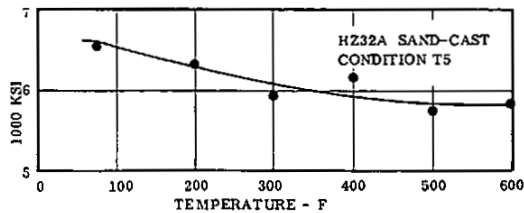


FIG. 3.0621 EFFECT OF TEMPERATURE ON TENSION MODULUS. (16)

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