REVISED: SEPTEMBER 1971
AUTHOR: J. R. KATTUS

NONFERROUS ALLOYS

	Mg
3	Th
1.5	Mn

HM31A

1. GENERAL

This heat treatable magnesium alloy is produced in the form of extrusions only. It is used primarily in the T5 condition (artificially aged), but is also sometimes used in the F condition (as extruded). At temperatures above 350F, it has the highest strength - both short-time and long-time - of all magnesium extrusion alloys; at lower temperatures AZ80A-T5 and ZK60A-T5 are stronger. HM31A has good formability and excellent weldability. Its primary uses are in aerospace and missile applications that require strength in the range 350 to 800F. Its corrosion resistance is similar to that of other magnesium alloys, surface coatings being needed for long-time protection.

1.01 Commercial Designation
HM31A

1.02 Alternate Designations
HM31XA (obsolete).

1.03 Specifications
AMS 4388B (F condition)
AMS 4389C (T5 condition)
MIL-M-8916A

1.04 Composition
Table 1.04.

1.05 Heat Treatment

1.051 T5 condition: Artificially age as extruded (F condition) at 415 to 435F 16 hours, air cool (3).

1.052 O condition, full anneal: 850F, 1 hour in furnace atmosphere containing 0.7 percent minimum SO_2 or 3 percent minimum CO_2, air cool (3).

1.053 Stress relief after forming and after welding: 800F, 1 hour in furnace atmosphere containing 0.7 percent minimum SO_2 or 3 percent minimum CO_2, air cool (3).

1.06 Hardness
T5 condition: 63 Brinell hardness No. (4).

1.07 Forms and Conditions Available
Produced only in the form of extrusions mostly in the T5 condition (artificially aged) and to a limited extent in the F condition (as extruded). Forms in regular production are rod, bar, solid shapes, structural shapes, and precision extrusions. Tubing and other hollow and semihollow shapes can also be produced for special requirements (5).

1.08 Melting and Casting Practice
(see AZ31B, Code 3601, section 1.08)

1.09 Special Considerations

1.091 Exposures to temperatures through 600F for periods of 1000 hours cause negligible change in short-time room and elevated temperature properties and cause very little drop in creep strength of HM31A-T5 (6).

1.092 Considerable data obtained on this alloy in the T5 condition show that both room and elevated temperature mechanical properties are sensitive to extrusion section size, strength decreasing with increasing size. This characteristic has not been thoroughly studied and documented in the F condition.

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting range, 1121-1202F (7).

2.012 Phase changes. In the as cast condition an unidentified compound forms a network at the grain boundaries. Mechanical working causes the network to break up, and high temperature treatment causes it to coalesce, but there is no metallographic evidence of solution and precipitation due to thermal treatments (8).

2.0121 Time-temperature-transformation diagrams.

2.013 Thermal conductivity, Figure 2.013.

2.014 Thermal expansion.

2.0141 Mean coefficient of thermal expansion from 68 to 392F, 14.9×10^{-6} per F (5).

2.015 Specific heat, Figure 2.015.

2.016 Thermal diffusivity, Figure 2.016.

2.02 Other Physical Properties

2.021 Density, 0.0652 lb per cu in (7).

2.022 Electrical properties, Table 2.022.

2.023 Magnetic properties. Non-magnetic.

2.024 Emittance.

2.025 Damping capacity. At a stress equal to 0.1 F_{ty} the specific damping capacity of HM31A-F is 5.0, which is a medium level compared with other magnesium alloys (9).

2.03 Chemical Properties

2.031 Corrosion resistance.

2.0311 The galvanic and general corrosion characteristics of HM31A are similar to those of AZ31B, Code 3601, sections 2.0311 and 2.0312.

2.0312 The resistance of HM31A to stress corrosion is somewhat superior to that of AZ31B, Code 3601, section 2.0313.

2.032 Safety precautions should be directed to the prevention of fires, burns, and explosions(see HZ32A, Code 3408, section 2.032).

2.04 Nuclear Properties

2.041 Thorium is a radioactive metal. For comments on precautions required by this characteristic see HZ32A, Code 3408, sections 2.041 and 2.042.

2.042 The high nuclear cross section caused by the manganese content of this alloy make it unsuitable for applications where shielding is not wanted.

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties
Table 3.01.

3.02 Mechanical Properties at Room Temperature

3.021 Tension.

3.0211 Stress-strain diagrams (see Figures 3.03111, 3.03112, 3.03113).

3.0212 Tensile properties for T5 and F conditions, Table 3.021

3.0213 Effect of exposures at elevated temperatures on tensile properties at room temperature, Figure 3.0213.

3.022 Compression.

3.0221 Stress-strain diagrams (see Figure 3.03211 and 3.03212)

3.0222 Compressive strength for T5 and F conditions, Table 3.0222.

3.0223 Effect of exposures at elevated temperatures on compressive yield strength at room temperature, Figure 3.0223.

3.023 Impact (see Figure 3.0331).

3.024 Bending.

3.025 Torsion and shear.

3.0251 Shear strength of different section sizes, Table 3.0251.

3.026 Bearing.

3.0261 Bearing properties of different section sizes, Table 3.0261.

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.

3.0311 Stress-strain diagrams.

3.03111 Stress-strain curves at room and elevated temperatures for extrusions in T5 condition, Figure 3.03111.

3.03112 Stress-strain curves at room and elevated temperatures for extrusions in F condition, Figure 3.03112.

3.03113 Complete stress-strain curves at low temperatures for extrusions in F condition, Figure 3.03113.

3.0312 Effects of temperature on tensile properties, Figure 3.0312.

REVISED: SEPTEMBER 1971
AUTHOR: J. R. KATTUS

NONFERROUS ALLOYS

	Mg
3	Th
1.5	Mn

HM31A

1. GENERAL

This heat treatable magnesium alloy is produced in the form of extrusions only. It is used primarily in the T5 condition (artificially aged), but is also sometimes used in the F condition (as extruded). At temperatures above 350F, it has the highest strength - both short-time and long-time - of all magnesium extrusion alloys; at lower temperatures AZ80A-T5 and ZK60A-T5 are stronger. HM31A has good formability and excellent weldability. Its primary uses are in aerospace and missile applications that require strength in the range 350 to 800F. Its corrosion resistance is similar to that of other magnesium alloys, surface coatings being needed for long-time protection.

1.01 Commercial Designation
HM31A

1.02 Alternate Designations
HM31XA (obsolete).

1.03 Specifications
AMS 4388B (F condition)
AMS 4389C (T5 condition)
MIL-M-8916A

1.04 Composition
Table 1.04.

1.05 Heat Treatment

1.051 T5 condition: Artificially age as extruded (F condition) at 415 to 435F 16 hours, air cool (3).

1.052 O condition, full anneal: 850F, 1 hour in furnace atmosphere containing 0.7 percent minimum SO_2 or 3 percent minimum CO_2, air cool (3).

1.053 Stress relief after forming and after welding: 800F, 1 hour in furnace atmosphere containing 0.7 percent minimum SO_2 or 3 percent minimum CO_2, air cool (3).

1.06 Hardness
T5 condition: 63 Brinell hardness No. (4).

1.07 Forms and Conditions Available
Produced only in the form of extrusions mostly in the T5 condition (artificially aged) and to a limited extent in the F condition (as extruded). Forms in regular production are rod, bar, solid shapes, structural shapes, and precision extrusions. Tubing and other hollow and semi-hollow shapes can also be produced for special requirements (5).

1.08 Melting and Casting Practice
(see AZ31B, Code 3601, section 1.08)

1.09 Special Considerations

1.091 Exposures to temperatures through 600F for periods of 1000 hours cause negligible change in short-time room and elevated temperature properties and cause very little drop in creep strength of HM31A-T5 (6).

1.092 Considerable data obtained on this alloy in the T5 condition show that both room and elevated temperature mechanical properties are sensitive to extrusion section size, strength decreasing with increasing size. This characteristic has not been thoroughly studied and documented in the F condition.

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting range, 1121-1202F (7).

2.012 Phase changes. In the as cast condition an unidentified compound forms a network at the grain boundaries. Mechanical working causes the network to break up, and high temperature treatment causes it to coalesce, but there is no metallographic evidence of solution and precipitation due to thermal treatments (8).

2.0121 Time-temperature-transformation diagrams.

2.013 Thermal conductivity, Figure 2.013.

2.014 Thermal expansion.

2.0141 Mean coefficient of thermal expansion from 68 to 392F, 14.9×10^{-6} per F (5).

2.015 Specific heat, Figure 2.015.

2.016 Thermal diffusivity, Figure 2.016.

2.02 Other Physical Properties

2.021 Density, 0.0652 lb per cu in (7).

2.022 Electrical properties, Table 2.022.

2.023 Magnetic properties. Non-magnetic.

2.024 Emittance.

2.025 Damping capacity. At a stress equal to 0.1 F_{ty} the specific damping capacity of HM31A-F is 5.0, which is a medium level compared with other magnesium alloys (9).

2.03 Chemical Properties

2.031 Corrosion resistance.

2.0311 The galvanic and general corrosion characteristics of HM31A are similar to those of AZ31B, Code 3601, sections 2.0311 and 2.0312.

2.0312 The resistance of HM31A to stress corrosion is somewhat superior to that of AZ31B, Code 3601, section 2.0313.

2.032 Safety precautions should be directed to the prevention of fires, burns, and explosions(see HZ32A, Code 3408, section 2.032).

2.04 Nuclear Properties

2.041 Thorium is a radioactive metal. For comments on precautions required by this characteristic see HZ32A, Code 3408, sections 2.041 and 2.042.

2.042 The high nuclear cross section caused by the manganese content of this alloy make it unsuitable for applications where shielding is not wanted.

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties
Table 3.01.

3.02 Mechanical Properties at Room Temperature

3.021 Tension.

3.0211 Stress-strain diagrams (see Figures 3.03111, 3.03112, 3.03113).

3.0212 Tensile properties for T5 and F conditions, Table 3.021

3.0213 Effect of exposures at elevated temperatures on tensile properties at room temperature, Figure 3.0213.

3.022 Compression.

3.0221 Stress-strain diagrams (see Figure 3.03211 and 3.03212)

3.0222 Compressive strength for T5 and F conditions, Table 3.0222.

3.0223 Effect of exposures at elevated temperatures on compressive yield strength at room temperature, Figure 3.0223.

3.023 Impact (see Figure 3.0331).

3.024 Bending.

3.025 Torsion and shear.

3.0251 Shear strength of different section sizes, Table 3.0251.

3.026 Bearing.

3.0261 Bearing properties of different section sizes, Table 3.0261.

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.

3.0311 Stress-strain diagrams.

3.03111 Stress-strain curves at room and elevated temperatures for extrusions in T5 condition, Figure 3.03111.

3.03112 Stress-strain curves at room and elevated temperatures for extrusions in F condition, Figure 3.03112.

3.03113 Complete stress-strain curves at low temperatures for extrusions in F condition, Figure 3.03113.

3.0312 Effects of temperature on tensile properties, Figure 3.0312.

	Mg
3	Th
1.5	Mn

HM31A

3.0313 Elevated temperature tensile properties at various strain rates, Figure 3.0313.

3.032 Compression.

3.0321 Stress-strain diagrams.

3.03211 Stress-strain curves in compression at room and elevated temperatures for extrusions in T5 condition, Figure 3.03211.

3.03212 Stress-strain curves in compression at room and elevated temperatures for extrusions in F condition, Figure 3.03212.

3.0322 Elevated temperature compressive yield strength of extrusions, Figure 3.0322.

3.033 Impact.

3.0331 Charpy V-notch impact properties at low temperatures, Figure 3.0331.

3.034 Bending.

3.035 Torsion and shear.

3.0351 Effect of temperature on single-shear strength, Figure 3.0351.

3.036 Bearing.

3.0361 Effect of test temperature on bearing properties, Figure 3.0361.

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 Short-time isochronous stress-strain curves for extrusions in T5 condition after rapid heating to test temperatures of 500, 600, 700, and 800F, Figure 3.041.

3.042 Isochronous stress-strain curves for extrusions in F condition after 3 hours exposure at test temperatures of 500, 600, 700, and 800F prior to loading, Figure 3.042.

3.043 Isochronous stress-strain curves for extrusions in F Condition after 3 hours exposure at test temperatures of 300 and 400F prior to loading, Figure 3.043.

3.044 Short-time isochronous stress-strain curves for extruded tubing in F condition after 5 seconds exposure at test temperatures of 500, 600, 700 and 800F prior to loading, Figure 3.044.

3.045 Effect of temperature on 100 hour creep strength for various extensions, Figure 3.045.

3.05 Fatigue Properties

3.051 Rotating beam fatigue properties, Figure 3.051.

3.06 Elastic Properties

3.061 Poisson's ratio, 0.35 (4)(5).

3.062 Modulus of elasticity.

3.0621 Effect of temperature on modulus of elasticity, Figure 3.0621.

3.0622 Compressive tangent modulus curves at room and elevated temperatures, Figure 3.0622.

3.0623 Compressive secant modulus curves at room and elevated temperatures, Figure 3.0623.

3.063 Modulus of rigidity, 2.4 x 10^3 ksi (4).

4. FABRICATION

4.01 Formability

4.011 HM31A can be formed by any of the processes commonly applied to extruded shapes. At room temperature the formability is limited, the minimum bend radius being about seven times the thickness. At the maximum recommended forming temperature of 800F (1 hour maximum time at temperature), the formability is good, the minimum bend radius being 2.5 times the thickness. Stress relief in accordance with section 1.053 is recommended after severe forming operations (5)(13)(14).

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. For further details, see HZ32A, Code 3408, sections 4.021 and 4.022.

4.022 The alloy can be chem-milled with sulfuric, nitric, or hydrochloric acid of 5 percent strength or greater (15).

4.03 Welding

4.031 HM31A has excellent weldability by arc and electric-resistance methods. For arc welding EZ33A magnesium alloy filler metal is generally used except when joining to an aluminum containing magnesium alloy, in which instances AZ92A or AZ61A are suitable filler alloys. Stress relief in accordance with section 1.053 is recommended after welding. For further details see AZ31B, Code 3601, section 4.031(5)(17).

4.032 Effect of temperature on tensile properties of extrusions, both unwelded and with transverse butt welds made by inert-gas-shielded tungsten-arc process, Figure 4.032.

4.04 Surface Treatment

4.041 The extrusions are normally oiled by the producer with a light corrosion inhibiting oil for protection during shipment and storage (1)(2).

4.042 For a discussion of the various surface treatments that can be applied for corrosion protection, see HZ32A, Code 3408, sections 4.042 and 4.043.

TABLE 1.04

Alloy	HM31A	
Source	(1)(2)	
	Percent	
Element	Minimum	Maximum
Thorium	2.5	3.5
Manganese	1.2	-
Impurities, each	-	0.1
Impurities, total	-	0.3
Magnesium	Balance	

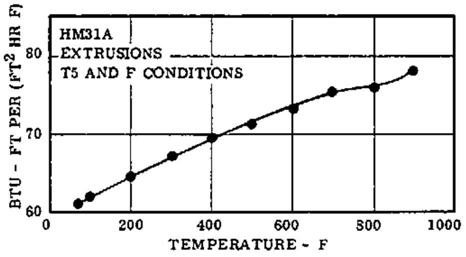

FIG. 2.013 THERMAL CONDUCTIVITY. (5)(7)

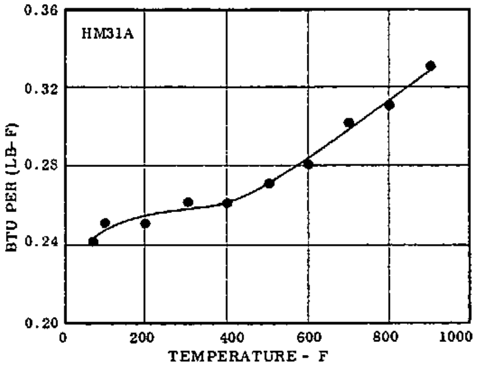

FIG. 2.015 SPECIFIC HEAT. (5)

	Mg
3	Th
1.5	Mn

HM31A

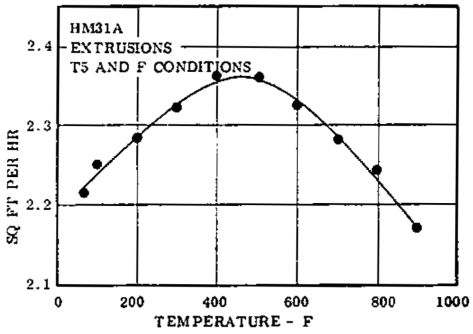

FIG. 2.016 THERMAL DIFFUSIVITY. (5)(7)

TABLE 2.022

Alloy	HM31A					
Source	(5)(7)					
	Electrical Conductivity				Electrical Resistivity	
	percent IACS		megmhos per in^3		microhm - in	
Condition	F	T5	F	T5	F	T5
Temp- F						
63	26.2	30.4	0.384	0.446	2.60	2.24
100	24.7	28.8	0.363	0.424	2.76	2.36
200	21.8	24.7	0.321	0.364	3.12	2.75
300	19.6	21.5	0.289	0.316	3.46	3.16
400	17.8	19.3	0.262	0.285	3.82	3.50
500	16.3	17.6	0.240	0.259	4.17	3.86

TABLE 3.01

Alloy	HM31A				
Form	Extrusions				
Size	4 square inches, maximum cross section				
Condition	Source	F_{tu} - ksi min	F_{ty} - ksi min	e(2 in) min	F_{cy}* - ksi min
T5	(2)	37.0	26.0	4	19.0
F	(1)	37.0	26.0	4	-

* Compression specimens oriented in longitudinal direction. Orientation of tensile specimens not specified.

TABLE 3.0212

Alloy	HM31A			
Form	Extrusions			
Size	4 square inches, maximum cross section			
Condition	Source	F_{tu} - ksi	F_{ty} - ksi	e(2 in)
T5	(5)	44	39	10
F	(10)	42	33	10

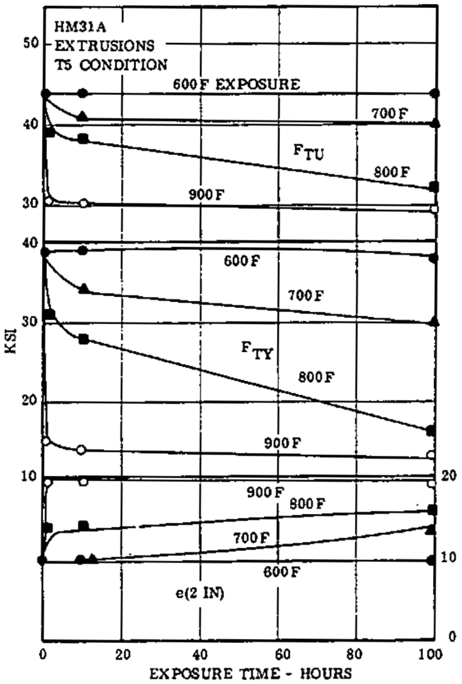

FIG. 3.0213 EFFECT OF EXPOSURES AT ELEVATED TEMPERATURES ON TENSILE PROPERTIES AT ROOM TEMPERATURE. (5)

TABLE 3.0222

Alloy	HM31A		
Form	Extrusions		
Condition	Cross section sq in	Source	F_{cy} ksi
T5	1.000 max	(5)	27
T5	1.000-3.999	(5)	23
F	4.000 max	(10)	27

	Mg
3	Th
1.5	Mn

HM31A

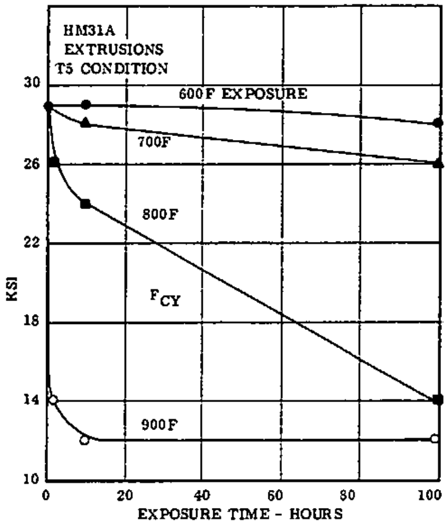

FIG. 3.0223 EFFECT OF EXPOSURES AT ELEVATED TEMPERATURES ON COMPRESSIVE YIELD STRENGTH AT ROOM TEMPERATURE. (5)

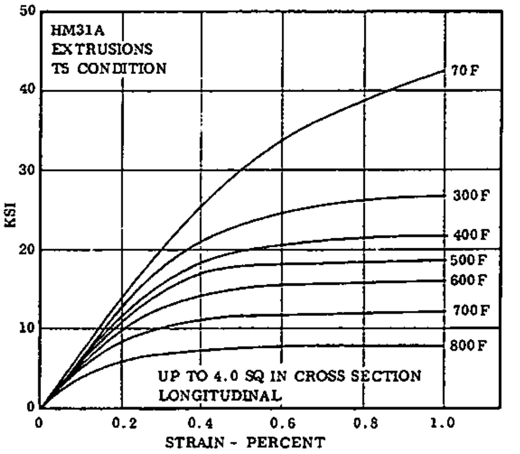

FIG. 3.03111 STRESS-STRAIN CURVES AT ROOM AND ELEVATED TEMPERATURES FOR EXTRUSIONS IN T5 CONDITION. (5)

TABLE 3.0251

Alloy	HM31A
Condition	T5
Form	Extrusions
Source	(5)
Cross section, sq in	F_{su} - ksi
1.000 maximum	27
1.000-3.999	22

TABLE 3.0261

Alloy	HM31A	
Condition	T5	
Form	Extrusions	
Source	(5)	
Cross section, sq in	F_{bru}* - ksi	F_{bry}* - ksi
1.000 maximum	68	48
1.00-3.999	58	42
* e/D = 2.5		

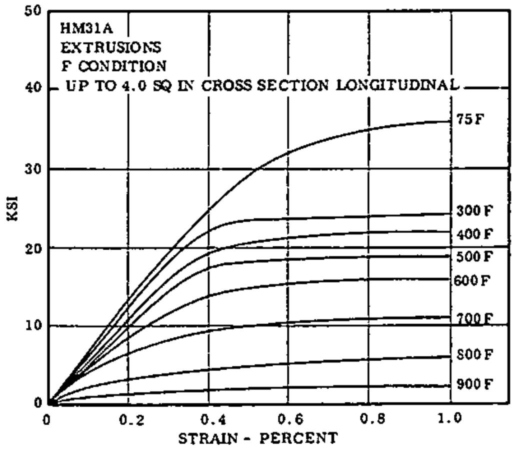

FIG. 3.03112 STRESS-STRAIN CURVES AT ROOM AND ELEVATED TEMPERATURES FOR EXTRUSIONS IN F CONDITION. (6)

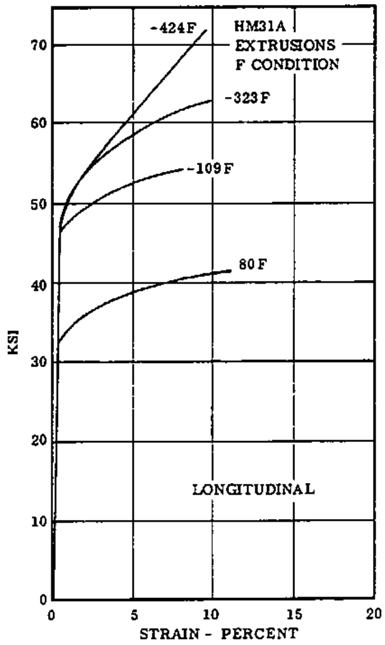

FIG. 3.03113 COMPLETE STRESS-STRAIN CURVES AT LOW TEMPERATURES FOR EXTRUSIONS IN F CONDITION. (11)

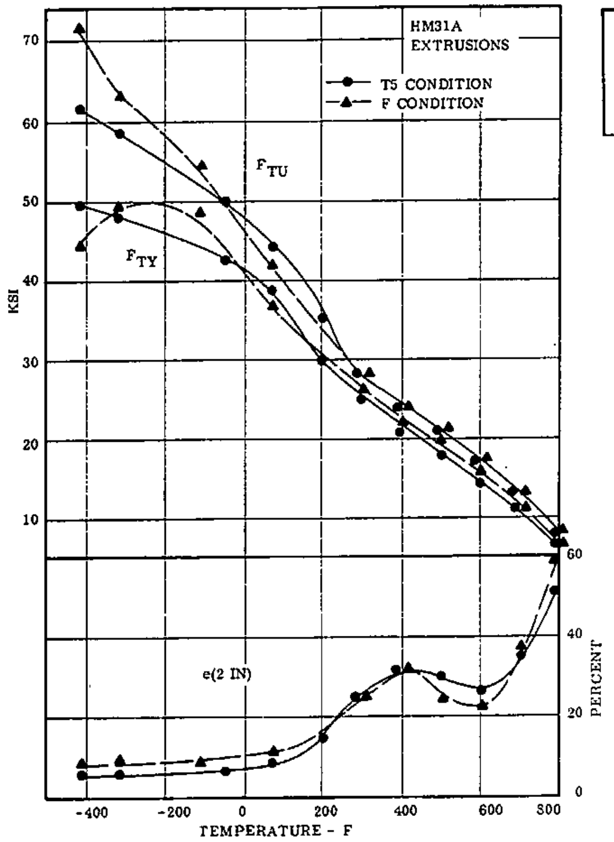

FIG. 3.0312 EFFECTS OF TEMPERATURE ON TENSILE PROPERTIES. (5)(11)(18)(19)

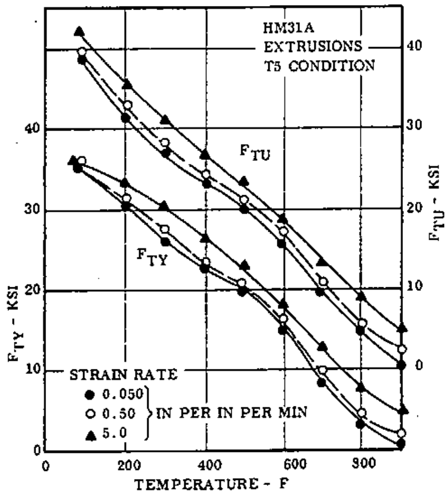

FIG. 3.0313 ELEVATED TEMPERATURE TENSILE PROPERTIES AT VARIOUS STRAIN RATES. (5)

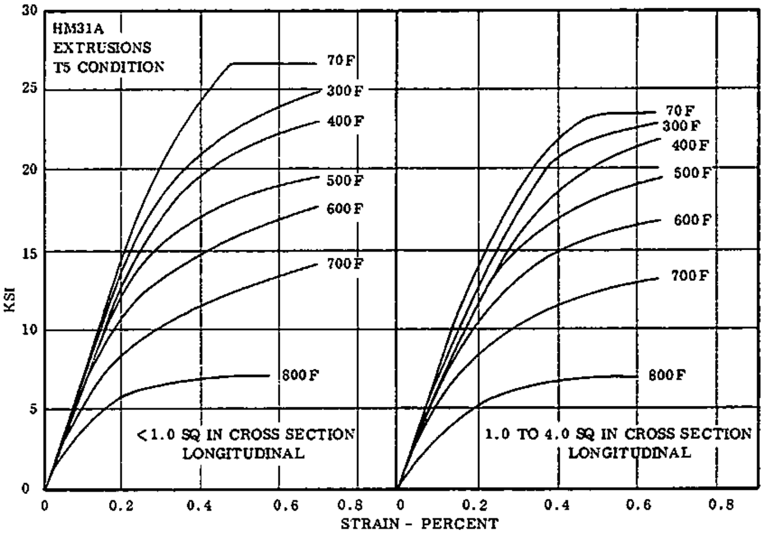

FIG. 3.03211 STRESS-STRAIN CURVES IN COMPRESSION AT ROOM AND ELEVATED TEMPERATURES FOR EXTRUSIONS IN T5 CONDITION. (5)

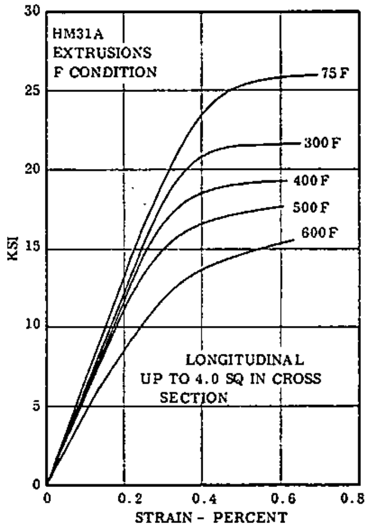

FIG. 3.03212 STRESS-STRAIN CURVES IN COMPRESSION AT ROOM AND ELEVATED TEMPERATURES FOR EXTRUSIONS IN F CONDITION. (6)

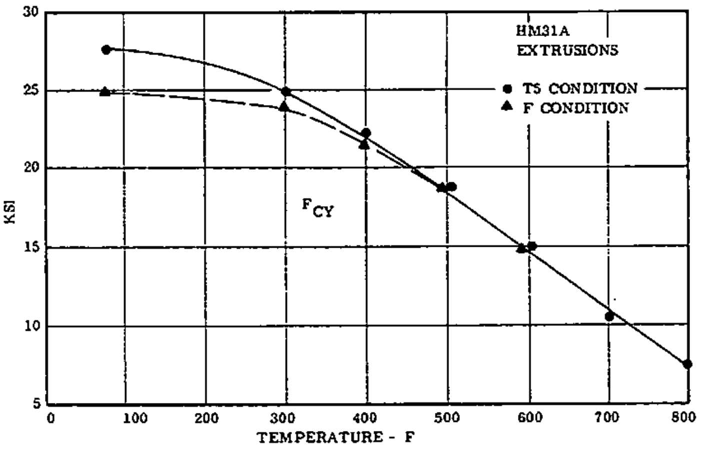

FIG. 3.0322 ELEVATED TEMPERATURE COMPRESSIVE YIELD STRENGTH OF EXTRUSIONS. (5)(6)

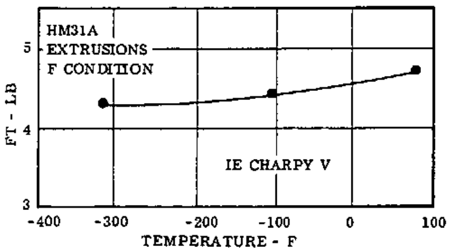

FIG. 3.0331 CHARPY V-NOTCH IMPACT PROPERTIES AT LOW TEMPERATURES. (11)

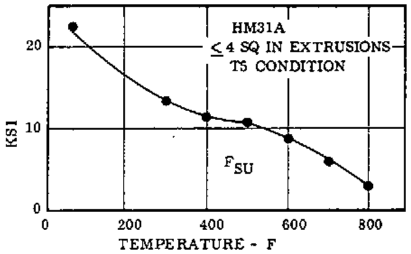

FIG. 3.0351 EFFECT OF TEMPERATURE ON SINGLE SHEAR STRENGTH. (6)

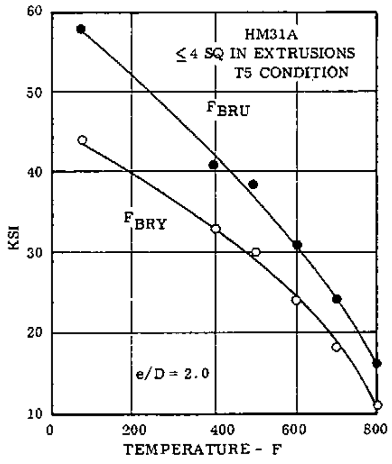

FIG. 3.0361 EFFECT OF TEMPERATURE ON BEARING PROPERTIES. (6)

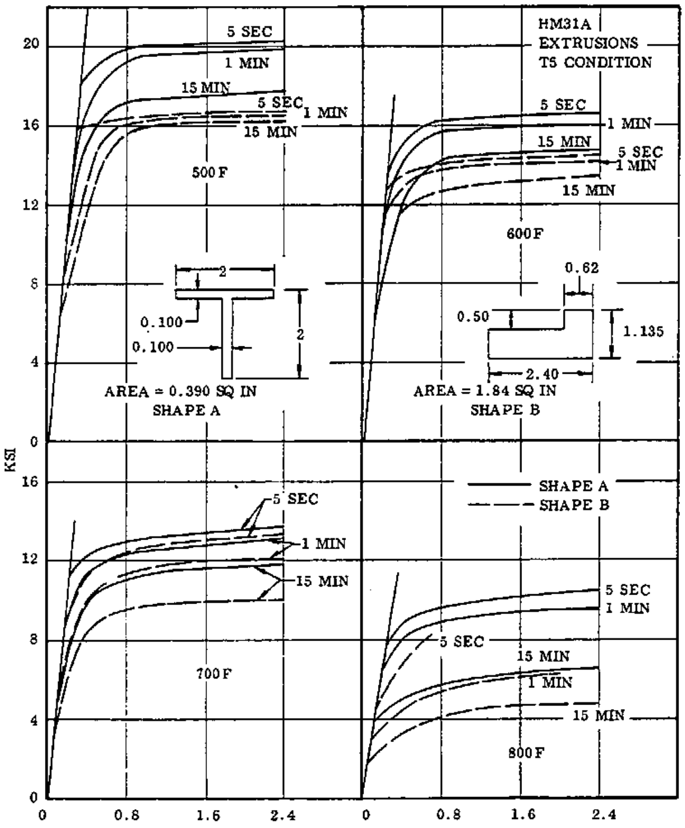

FIG. 3.041 SHORT-TIME ISOCHRONOUS STRESS-STRAIN CURVES FOR EXTRUSIONS IN T5 CONDITION AFTER RAPID HEATING TO TEST TEMPERATURES OF 500, 600, 700, AND 800 F. (5)

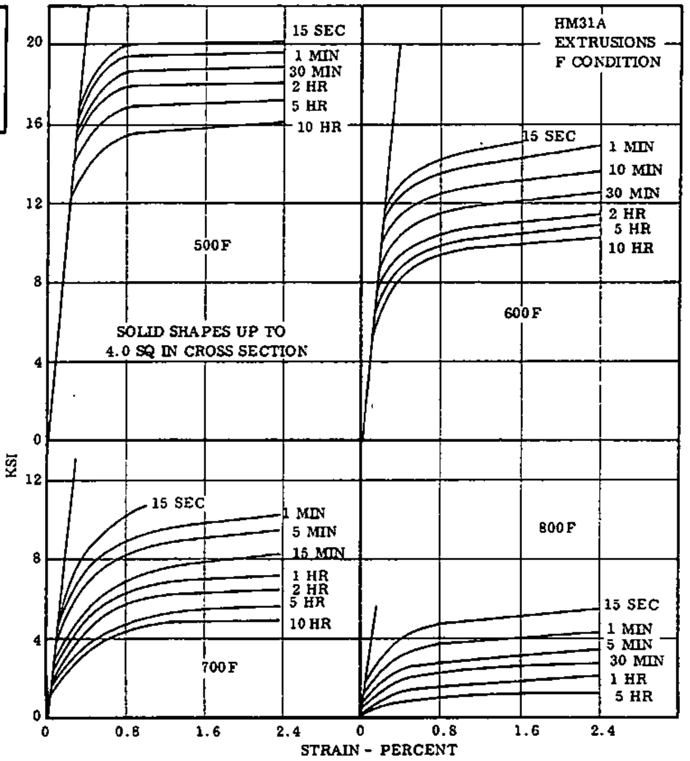

FIG. 3.042 ISOCHRONOUS STRESS-STRAIN CURVES FOR EXTRUSIONS IN F CONDITION AFTER 3 HOURS EXPOSURE AT TEST TEMPERATURES OF 500, 600, 700, AND 800F PRIOR TO LOADING. (6)

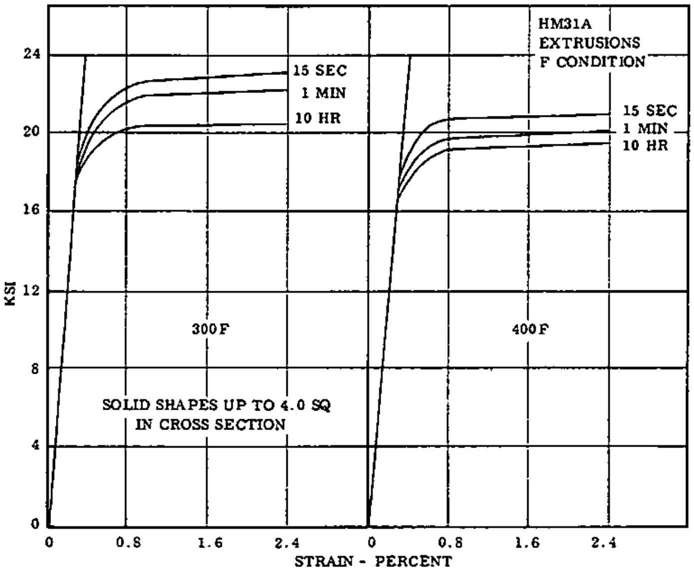

FIG. 3.043 ISOCHRONOUS STRESS-STRAIN CURVES FOR EXTRUSIONS IN F CONDITION AFTER 3 HOURS EXPOSURE AT TEST TEMPERATURES OF 300 AND 400F PRIOR TO LOADING. (6)

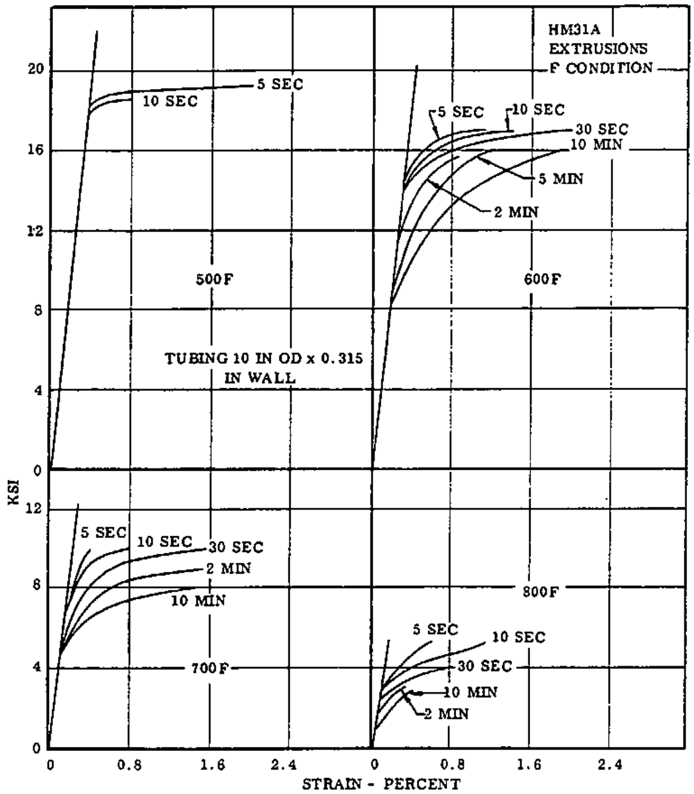

FIG. 3.044 SHORT-TIME ISOCHRONOUS STRESS-STRAIN CURVES FOR EXTRUDED TUBING IN F CONDITION AFTER 5 SECONDS EXPOSURE AT TEST TEMPERATURES OF 500, 600, 700, AND 800 F PRIOR TO LOADING. (6)

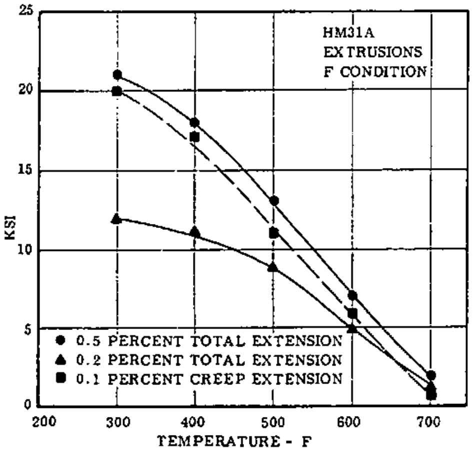

FIG. 3.045 EFFECT OF TEMPERATURE ON 100 HOUR CREEP STRENGTH FOR VARIOUS EXTENSIONS. (6)

	Mg
3	Th
1.5	Mn

HM31A

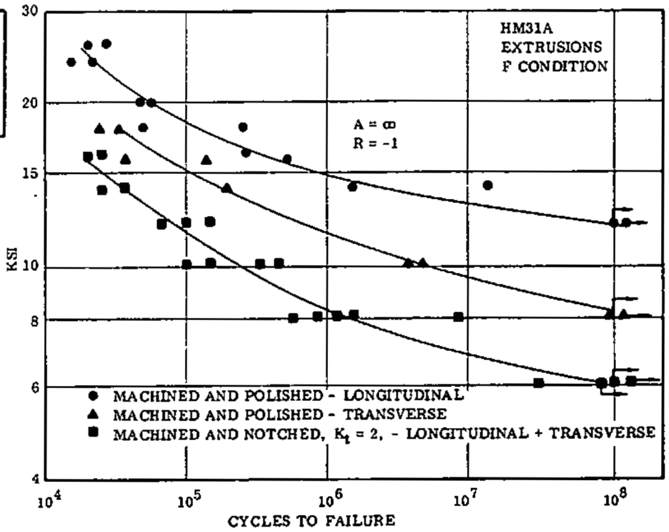

FIG. 3.051 ROTATING BEAM FATIGUE PROPERTIES. (6)

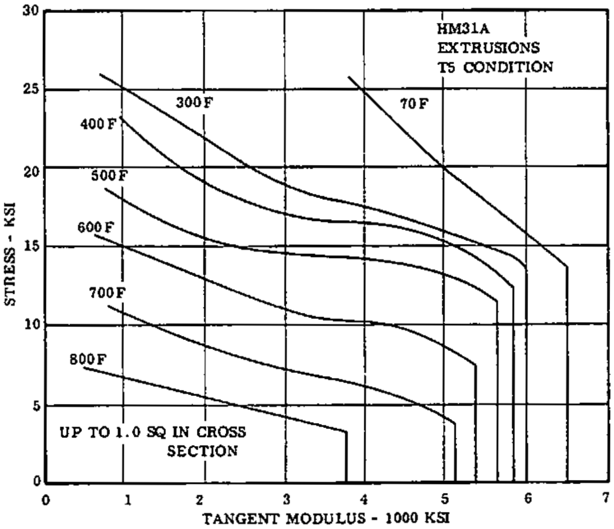

FIG. 3.0622 COMPRESSIVE TANGENT MODULUS CURVES AT ROOM AND ELEVATED TEMPERATURES. (5)

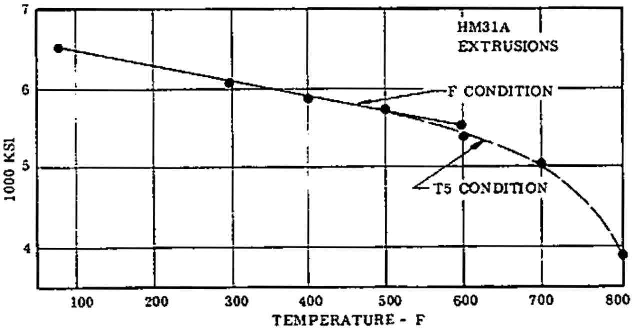

FIG. 3.0621 EFFECT OF TEMPERATURE ON MODULUS OF ELASTICITY. (5)(12)

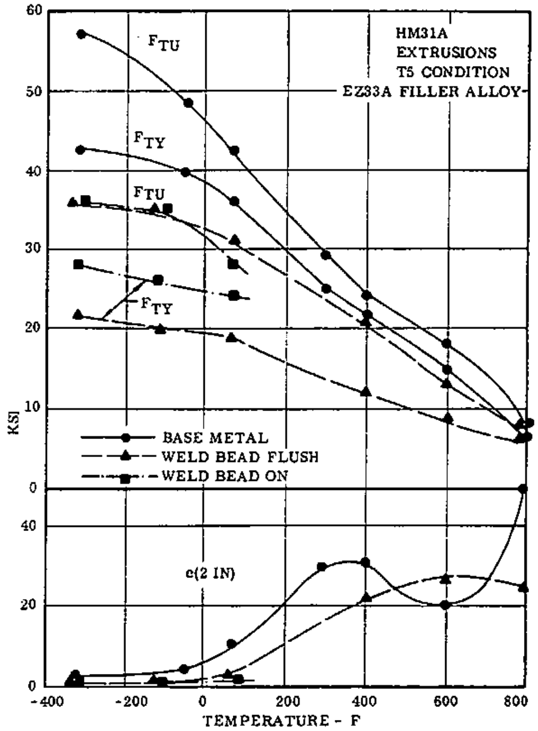

FIG. 4.032 EFFECT OF TEMPERATURE ON TENSILE PROPERTIES OF EXTRUSIONS, BOTH UNWELDED AND WITH TRANSVERSE BUTT WELDS MADE BY INERT-GAS-SHIELDED TUNGSTEN-ARC PROCESS. (5)(6)(16)

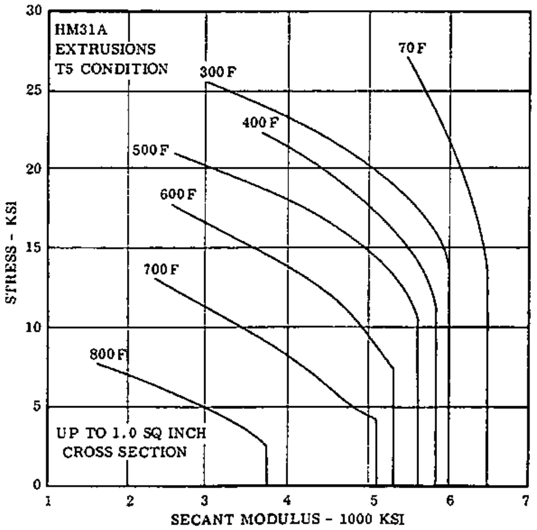

FIG. 3.0623 COMPRESSIVE SECANT-MODULUS CURVES AT ROOM AND ELEVATED TEMPERATURES. (5)

REFERENCES

1. AMS 4388B, HM31A-F (May 1, 1968).
2. AMS 4389C, HM31A-T5 (May 1, 1968).
3. "Heat Treatment of Magnesium Alloys," ASM Metals Handbook, Volume 2, 8th Edition (1964) pp. 292-297.
4. "Design it with Magnesium Mill Products," Form No. 141-233-70, Dow Chemical Company, Midland, Michigan (1970).
5. "Magnesium in Design," Form No. 141-213-67, Dow Chemical Company, Midland Michigan (1967).
6. "HM31XA Magnesium Alloy Extrusions," Bulletin No. 141-199, Dow Chemical Company, Midland, Michigan.
7. "Physical Properties of Magnesium and Magnesium Alloys," Code 2.51, Dow Chemical Company, Midland, Michigan (1967).
8. Leontis, T.E., "Properties of Magnesium-Thorium and Magnesium-Thorium-Cerium Alloys," Jr of Metals, Volume 4, (1952) pp. 287-294.
9. Jensen, J.W., "Damping Capacity - Cause and Effects," Light Metal Age, Volume 22 (December 1964) pp. 4-8.
10. "Shop Guide for Elevated Temperature Magnesium Alloys," Bulletin No. 141-204, Dow Chemical Company, Midland, Michigan (March 1959).
11. Reed, R.P., Mikesell, R.P. and Greeson, R.L., "Some Mechanical Properties of Magnesium Alloys at Low Temperature," ASTM STP 287, pp. 61-73 (1961).
12. Fenn, R.W. Jr., "Young's Modulus of Magnesium Alloys as a Function of Temperature and Metallurgical Variables," ASTM Proceeding, Volume 58, (1958) pp. 826-837.
13. "Forming Magnesium, Part 1," Form No. 141-305-65, Dow Chemical Company, Midland, Michigan (1965).
14. "Forming Magnesium, Part 3," Form No. 141-307-66, Dow Chemical Company, Midland, Michigan (1966).
15. "Design" Magnesium Electron Ltd., 1270 Avenue of the Americas, New York, New York 10020.
16. "Low Temperature Properties of Various Magnesium Alloys," Dow Chemical Company, Midland, Michigan (1958).
17. "Arc Welding Magnesium," Form 141-300-67, Dow Chemical Company, Midland, Michigan (1967).
18. Vorhees, H.R. and Freeman, J.W., "Elevated Temperature Properties of Aluminum and Magnesium Alloys," ASTM STP 291 (1960).
19. Hallowell, J.B. and Ogden, H.R., "An Introduction to Magnesium Alloys," DMIC Report 206, (August 26, 1964)

	Mg
3	Th
1.5	Mn

HM31A

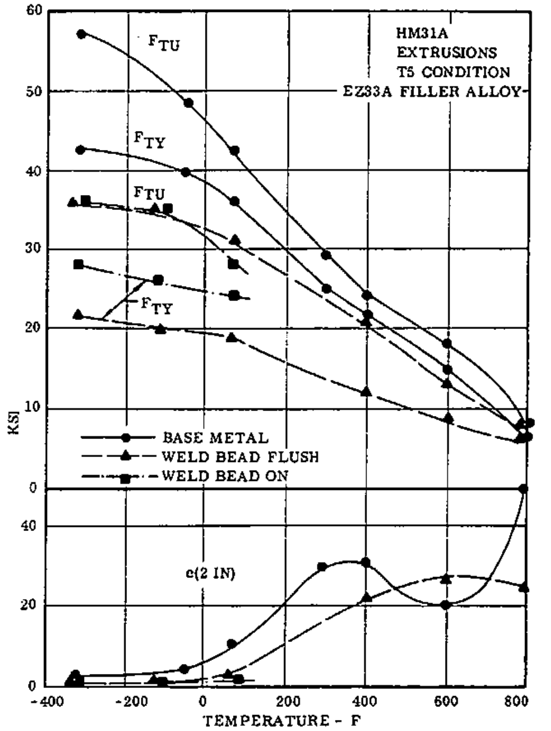

FIG. 4.032 EFFECT OF TEMPERATURE ON TENSILE PROPERTIES OF EXTRUSIONS, BOTH UNWELDED AND WITH TRANSVERSE BUTT WELDS MADE BY INERT-GAS-SHIELDED TUNGSTEN-ARC PROCESS. (5)(6)(16)

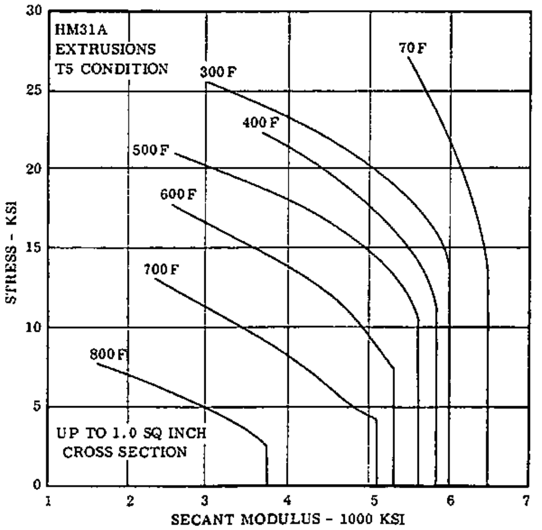

FIG. 3.0623 COMPRESSIVE SECANT-MODULUS CURVES AT ROOM AND ELEVATED TEMPERATURES. (5)

REFERENCES

1. AMS 4388B, HM31A-F (May 1, 1968).
2. AMS 4389C, HM31A-T5 (May 1, 1968).
3. "Heat Treatment of Magnesium Alloys," ASM Metals Handbook, Volume 2, 8th Edition (1964) pp. 292-297.
4. "Design it with Magnesium Mill Products," Form No. 141-233-70, Dow Chemical Company, Midland, Michigan (1970).
5. "Magnesium in Design," Form No. 141-213-67, Dow Chemical Company, Midland Michigan (1967).
6. "HM31XA Magnesium Alloy Extrusions," Bulletin No. 141-199, Dow Chemical Company, Midland, Michigan.
7. "Physical Properties of Magnesium and Magnesium Alloys," Code 2.51, Dow Chemical Company, Midland, Michigan (1967).
8. Leontis, T. E., "Properties of Magnesium-Thorium and Magnesium-Thorium-Cerium Alloys," Jr of Metals, Volume 4, (1952) pp. 287-294.
9. Jensen, J. W., "Damping Capacity - Cause and Effects," Light Metal Age, Volume 22 (December 1964) pp. 4-8.
10. "Shop Guide for Elevated Temperature Magnesium Alloys," Bulletin No. 141-204, Dow Chemical Company, Midland, Michigan (March 1959).
11. Reed, R. P., Mikesell, R. P. and Greeson, R. L., "Some Mechanical Properties of Magnesium Alloys at Low Temperature," ASTM STP 287, pp. 61-73 (1961).
12. Fenn, R. W. Jr., "Young's Modulus of Magnesium Alloys as a Function of Temperature and Metallurgical Variables," ASTM Proceeding, Volume 58, (1958) pp. 826-837.
13. "Forming Magnesium, Part 1," Form No. 141-305-65, Dow Chemical Company, Midland, Michigan (1965).
14. "Forming Magnesium, Part 3," Form No. 141-307-66, Dow Chemical Company, Midland, Michigan (1966).
15. "Design" Magnesium Electron Ltd., 1270 Avenue of the Americas, New York, New York 10020.
16. "Low Temperature Properties of Various Magnesium Alloys," Dow Chemical Company, Midland, Michigan (1958).
17. "Arc Welding Magnesium," Form 141-300-67, Dow Chemical Company, Midland, Michigan (1967).
18. Vorhees, H.R. and Freeman, J. W., "Elevated Temperature Properties of Aluminum and Magnesium Alloys," ASTM STP 291 (1960).
19. Hallowell, J. B. and Ogden, H. R., "An Introduction to Magnesium Alloys," DMIC Report 206, (August 26, 1964)