

1. **GENERAL**
 Nimonic 105 is a wrought nickel-cobalt-chromium base superalloy strengthened by additions of molybdenum, aluminum, and titanium. It combines solid-solution strengthening with precipitation hardening. Its creep resistance and oxidation resistance make it suitable for service at temperatures up to about 1750 F. The alloy can be readily hot worked, but its cold workability, machinability, and weldability are only marginal. In aerospace structures it is used for turbine blades, discs, forgings, ring sections, bolts, and fasteners.

1.01 **Commercial Designation**
 Nimonic 105

1.02 **Alternate Designations**
 None

1.03 **Specifications**
 Table 1.03

1.04 **Composition**
 Table 1.04

1.05 **Heat Treatment**

1.051 For optimum long-term creep strength and ductility at temperatures up to 1750 F, the following three-stage heat treatment is recommended: 2100 F 4 hrs, AC + 1920-1950 F 16 hrs, AC + 1560 F 16 hrs, AC.

1.052 This treatment provides maximum precipitation hardening at the sacrifice of some solid solution hardening.(2)

1.053 When long-term properties are not of paramount importance, tensile and impact properties may be enhanced for service temperatures up to 1300 F with the following two-stage heat treatment.

2050 F 4 hrs, AC + 1560 F 16 hrs, AC. This treatment sacrifices some of the precipitation hardening for enhanced solid-solution strengthening.(2)

1.054 Annealing should be carried out 4 hours at 2100 F followed by air cooling or fluidized-bed quenching. Water quenching is not recommended since surface cracking may result from thermal shock. This treatment will recrystallize cold-worked material, but it will not soften the alloy much, if any, below the hardness levels provided by the three-stage and two-stage heat treatments given above, since it results in maximum solution hardening but no precipitation hardening.(2, 5)

1.055 The exact heat treat conditions given above are sometimes varied somewhat for certain product forms, for example, shorter times at temperature for light sections.

1.06 **Hardness**

1.061 The hardness of Nimonic 105 is in the range 350-400 Vickers (Rockwell C35-41) in all of the heat-treated conditions, including annealed, given in Section 1.05.(6)

1.07
 1.071

Forms and Conditions Available
 Nimonic 105 is generally available in bars and billets for forging, rod and bar, and extruded sections, rectangular or profile. These forms are normally available from the mills in the as-hot-worked or cold-finished condition.(2, 6)

1.08
 1.081

Melting and Casting Practice
 The alloy is normally produced by induction melting in air and casting into ingots for subsequent working into the various product forms. For critical applications requiring optimum properties, it is vacuum remelted. An electroflux refined version is also available.

1.09
 1.091

Special Considerations
 Long exposures in the temperature ranges 1560 F to 1650 F and 1100 F to 1200 F tend to cause significant reductions in impact properties, both at room temperature and at the exposure temperatures, whereas exposures at intermediate or lower temperature do not have great effects. (See Figures 3.0231, 3.0232, 3.0233, 3.0331, 3.0332, and 3.0333)

2. **PHYSICAL PROPERTIES AND ENVIRONMENTAL EFFECTS**

2.01
 2.011
 2.012
 2.0121
 2.0122

Thermal Properties
 Melting range: 2354 F to 2453 F(2)
 Phase changes.
 Time-temperature-transformation diagrams. In the annealed or solution-treated condition, the alloy has a homogenous face-centered cubic structure. Age hardening results in the precipitation of an intermetallic compound, called gamma prime, with the formula Ni₃TiAl(5)

2.013
 2.0131
 2.014
 2.0141

Thermal conductivity.
 Effect of temperature on thermal conductivity, Figure 2.0131.
 Thermal expansion.
 Effect of temperature on thermal expansion, Figure 2.0141.

2.015
 2.0151
 2.016

Specific heat.
 Effect of temperature on specific heat, Figure 2.0151.
 Thermal diffusivity.

2.02
 2.021
 2.022
 2.023
 2.024
 2.025

Other Physical Properties
 Density: 0.289 lb/in³, 8.01 g/cm³.(2)
 Electrical Properties, Table 2.022.
 Magnetic properties, Table 2.023.
 Emittance.
 Damping capacity.

2.03
 2.031

Chemical Environments
 Descaled weight loss due to 100-hours exposures to various elevated temperatures in air, Figure 2.031.

2.032

Gain in weight as a result of oxidation during exposures to air at 1740 F, Figure 2.032.

2.033

Effects of cyclic heating (15 minutes in furnace, 5 minutes outside furnace) to various maximum temperatures on spalling, Table 2.033.

2.034

Resistance to atmospheres containing sulfur dioxide at elevated temperatures, Table 2.034.

	Ni
20	Co
14.8	Cr
5	Mo
4.7	Al
1.2	Ti
+	B

Nimonic 105

	Ni
20	Co
14.8	Cr
5	Mo
4.7	Al
1.2	Ti
+	B

Nimonic 105

2.04	<u>Nuclear Environments</u>	3.04	<u>Creep and Creep-Rupture Properties</u>
3.	MECHANICAL PROPERTIES	3.041	Effects of temperature on stress to cause rupture of extruded bar in times ranging from 100 to 1000 hours, Figure 3.041.
3.01	<u>Specified Mechanical Properties</u>	3.042	Effects of temperature on stress to cause rupture of forgings in times ranging from 100 to 3000 hours, Figure 3.042.
3.02	<u>Mechanical Properties at Room Temperature</u>	3.043	Creep and rupture curves for extruded bar, Figure 3.043.
3.021	Tension-stress-strain diagrams - tensile properties, see Figures 3.0311, 3.0312, and 3.0313.	3.05	<u>Fatigue Properties</u>
3.022	Compression-stress-strain diagrams - compression properties.	3.051	Modified Goodman diagram showing fatigue properties of smooth specimens at room temperature, Figure 3.051.
3.023	Impact.	3.052	Modified Goodman diagram showing fatigue properties of smooth specimens at 750 F, Figure 3.052.
3.0231	Effects of long exposures to elevated temperatures on impact properties of extruded and cold-rolled sections at room temperature, Figure 3.0231.	3.053	Modified Goodman diagram showing fatigue properties of smooth specimens at 1200 F, Figure 3.053.
3.0232	Effects of long exposures to elevated temperatures on impact properties of forgings at room temperature, Figure 3.0232.	3.054	Modified Goodman diagram showing fatigue properties of smooth specimens at 1380 F, Figure 3.054.
3.0233	Effects of long exposures in the range 900 to 1200 F on room-temperature impact properties of bar, Figure 3.0233.	3.055	Modified Goodman diagram showing fatigue properties of smooth specimens at 1600 F, Figure 3.055.
3.024	Bending.	3.056	Modified Goodman diagram showing fatigue properties of smooth specimens at 1795 F, Figure 3.056.
3.025	Torsion and shear, see Figure 3.0351.	3.06	<u>Elastic Properties</u>
3.026	Bearing.	3.061	Poisson's ratio.
3.027	Stress concentration.	3.062	Modulus of elasticity.
3.0271	Notch properties.	3.0621	Effect of temperature on modulus of elasticity, Figure 3.0621.
3.0272	Fracture toughness.	3.063	Modulus of rigidity.
3.028	Combined properties.	3.0631	Effect of temperature on modulus of rigidity, Figure 3.0631.
3.03	<u>Mechanical Properties at Various Temperatures.</u>	3.064	Tangent modulus.
3.031	Tension-stress-strain diagrams - tensile properties.	3.065	Secant modulus.
3.0311	Effects of temperature on tensile properties of bar with two different heat treatments, Figure 3.0311.	4.	FABRICATION
3.0312	Effects of temperature on tensile properties of forgings and extrusions, Figure 3.0312.	4.01	<u>Forming</u>
3.0313	Effects of temperature on tensile properties of wire, Figure 3.0313.	4.011	Nimonic 105 can be hot worked, preferably in the temperature range 1920 F to 2190 F.(2)
3.032	Compression-stress-strain diagrams-compression properties.	4.012	The alloy can be cold worked only to a few percent since it work hardens rapidly and is not easily deformed at room temperature. It should be in the annealed condition for cold working.(5)
3.033	Impact.	4.02	<u>Machining and Grinding</u>
3.0331	Effects of various exposure times to test temperature on the elevated-temperature impact properties of extruded and cold-rolled sections, Figure 3.0331.	4.021	Nimonic 105 can best be machined in the fully heat-treated condition. The use of tungsten carbide cutting tools is advisable, although high-speed shock-proof cutting tools can be used if the cut is of an intermittent nature.(2)
3.0332	Effects of various exposure times to test temperature on the elevated-temperature impact properties of forgings, Figure 3.0332.	4.03	<u>Joining</u>
3.0333	Effects of various exposure times to test temperature on the impact properties of bar in the range 900 F to 1200 F, Figure 3.0333.	4.031	Fusion welding of Nimonic 105 with conventional processes such as gas-tungsten-arc and gas-metal-arc is not recommended as micro-fissuring can occur both in the welds and heat-affected zones. Electron-beam welding has been used successfully, but the danger of
3.034	Bending.		
3.035	Torsion and shear.		
3.0351	Effects of temperature on shear strength of bar, Figure 3.0351.		
3.036	Bearings.		
3.037	Stress concentration.		
3.0371	Notch properties.		
3.0372	Fracture toughness.		
3.038	Combined properties.		

- microfissuring still exists, and welding trials should be carried out before the process is specified. Similar difficulties can be expected with resistance spot, stitch, or seam welding. Flash-butt welding, however, is quite satisfactory, having been used successfully in the production of turbine rings.⁽²⁾
- 4.032 Brazing in vacuum, hydrogen, or inert atmosphere is satisfactory for joining Nimonic 105. The brazing cycle should not involve temperatures above the solution-treatment temperature (2100 F), as this could adversely affect the mechanical properties.⁽²⁾
- 4.04 Surface Treating
- 4.041 Removal of hot-work and heat-treat scale is best done by immersion in one of the commercially available caustic-base salt baths followed by pickling in hot sulfuric and hot nitric-hydrofluoric acid.

	Ni
20	Co
14.8	Cr
5	Mo
4.7	Al
1.2	Ti
+	B

Nimonic 105

REFERENCES

- Hancock, P., "Summary of the Mechanisms of Hot Corrosion in Marine Gas Turbines and the Role of Scale Failure", Proceedings of the 1974 Gas Turbine Materials in the Marine Environment Conference, MCIC Report 75-27, Battelle's Columbus Laboratories, p 225-236 (July 1974).
- "Nimonic Alloy 105", Publication 3491A, Henry Wiggin & Co., Ltd., Hereford, England, (May 1974).
- "The Nimonic Series of High-Temperature Alloys", Publication 1303A, Henry Wiggin Co., Ltd., Hereford, England (Aug 1961).
- Thomlinson, J., "Properties of Some Spring Wires and Springs in the Temperature Range Room Temperature - 700 C", Normalair-Garrett Ltd., Yeovil, England, S & T Memo 7/67 (June 1968).
- Private communication from D. R. Darrell, Henry Wiggin & Co. Ltd., Hereford, England (Sept. 1978).
- "Nimonic Alloys", Publication 3609, Henry Wiggin Co., Ltd., Hereford, England (March 1973).

	Ni
20	Co
14.8	Cr
5	Mo
4.7	Al
1.2	Ti
+	B

Nimonic 105

Form	Specification
Billets, bars, forgings	BS, HR3 (British)
Billets, bars, forgings	AECMA Ni-P61-HT (French)
Forged bar	MH. 14 (Royal Swedish Bir Board)
Forged bar	Werkstoff 2.4634LN (German)
Forged bar	DIN NiCo20Cr15MoAlTi (German)

Table 1.03 Specifications for Nimonic 105 (2)

Element	Percent	
	Min	Max
Chromium	14.0	15.7
Cobalt	18.0	22.0
Aluminum	4.5	4.9
Molybdenum	4.5	5.5
Titanium	0.9	1.5
Boron	0.003	0.010
Carbon	-	0.12
Silicon	-	1.0
Copper	-	0.2
Iron	-	1.0
Manganese	-	1.0
Lead	-	0.0015
Sulfur	-	0.015
Zirconium	-	0.15
Nickel	Balance	

Table 1.04 Composition for Nimonic 105 (2)

Form	Wire		
	Condition		
	2100 F 15 min. AC + 1920 F 1 hr. AC + 1560 F 16 hrs. AC		
Temperature, F	Electrical Conductivity		Electrical Resistivity, Microhm-in.
	percent IACS	megohms per in. ³	
68	1.31	0.0193	51.6
212	1.29	0.0189	52.9
392	1.26	0.0185	54.0
572	1.23	0.0181	55.3
752	1.22	0.0179	56.0
932	1.19	0.0175	57.1
1112	1.14	0.0168	59.5
1292	1.13	0.0166	60.3
1472	1.19	0.0175	57.1
1652	1.22	0.0179	56.0
1832	1.25	0.0184	54.4

Table 2.022 Electrical Properties of Nimonic 105 (2)

Form	Forging
Condition	2100 F 4 hrs. AC + 1920 F 16 hrs. AC + 1560 F 16 hrs. AC
Mass susceptibility at 1000 oersted	$7.09 \times 10^{-6} \text{ cm}^3 \text{ per } 9$
Volume susceptibility at 1000 oersted	56.9×10^{-6}
Magnetic permeability from 200-2000 oersted	1.000715

Table 2.023 Magnetic properties of Nimonic 105 (2)

Max Cycle Temp. F	Time at Max Cycle Temp to Start of Spalling, hrs	Rate of Spalling at Max Cycle temp. mg/cm ² /hr
1635	>1000	-
1670	>1000	-
1815	600	0.150
1850	300	0.408
1995	150	0.946
2030	75	1.170

Table 2.033 Effects of cyclic heating Nimonic 105 (15 min in furnace, 5 min outside furnace) to various maximum temperature on spalling (2)

Atmosphere	Descated Weight Loss after 1000 hours at Temp. mg/cm ²			
	1110 F	1920 F	1470 F	1830 F
3 percent SO ₂ - Argon	1.6	8.7	15.0	-
3 percent SO ₂ - Air	2.3	1.1	0.6	1.6
3 percent SO ₂ + 5 percent O ₂ - Argon	2.1	0.5	0.6	2.1

Table 2.034 Resistance of Nimonic 105 to atmospheres containing sulfur dioxide at elevated temperatures (2)

	Ni
20	Co
14.8	Cr
5	Mo
4.7	Al
1.2	Ti
+	B

Nimonic 105

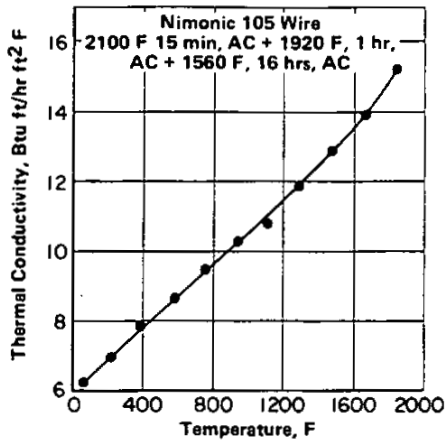


FIGURE 2.0131. EFFECT OF TEMPERATURE ON THERMAL CONDUCTIVITY (2)

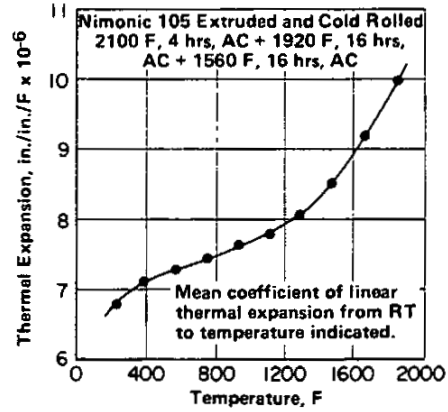


FIGURE 2.0141. EFFECT OF TEMPERATURE ON THERMAL EXPANSION (2)

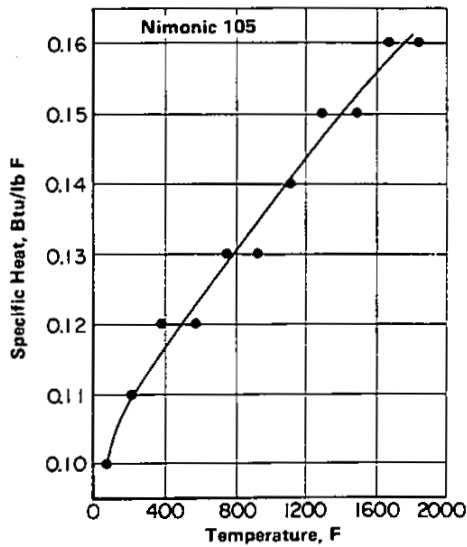


FIGURE 2.0151. EFFECT OF TEMPERATURE ON SPECIFIC HEAT (2)

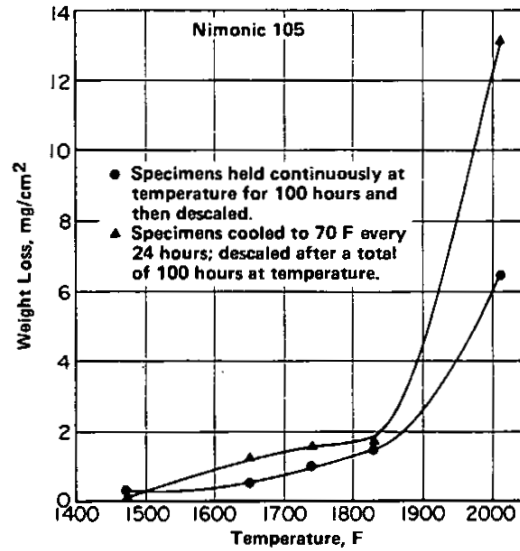


FIGURE 2.031. DESCALED WEIGHT LOSS DUE TO 100-HOURS EXPOSURES TO VARIOUS ELEVATED TEMPERATURES IN AIR (2)

	Ni
20	Co
14.8	Cr
5	Mo
4.7	Al
1.2	Ti
+	B

Nimonic 105

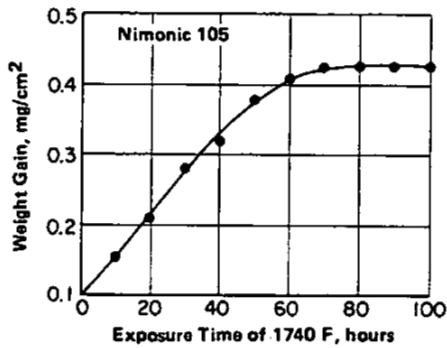


FIGURE 2.032. GAIN IN WEIGHT AS A RESULT OF OXIDATION DURING EXPOSURE TO AIR AT 1740 F (1)

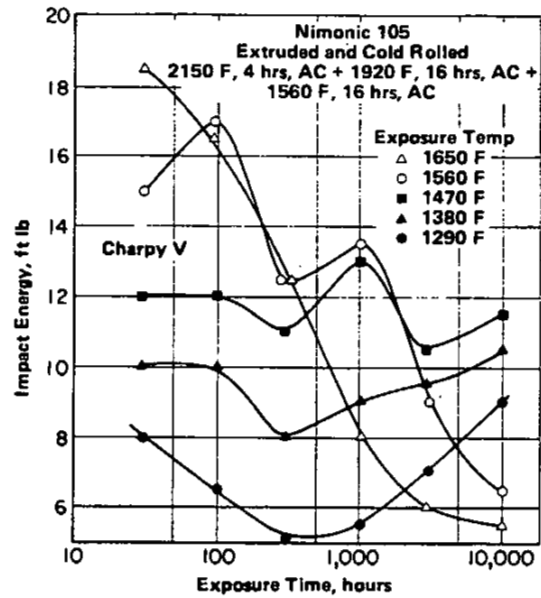


FIGURE 3.0231. EFFECTS OF LONG EXPOSURES TO ELEVATED TEMPERATURES ON IMPACT PROPERTIES OF EXTRUDED AND COLD-ROLLED SECTIONS AT ROOM TEMPERATURE (2)

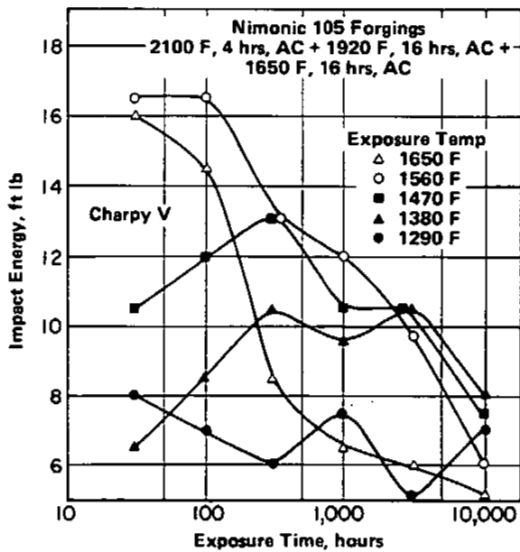


FIGURE 3.0232. EFFECTS OF LONG EXPOSURES TO ELEVATED TEMPERATURES ON IMPACT PROPERTIES OF FORGINGS AT ROOM TEMPERATURE (2)

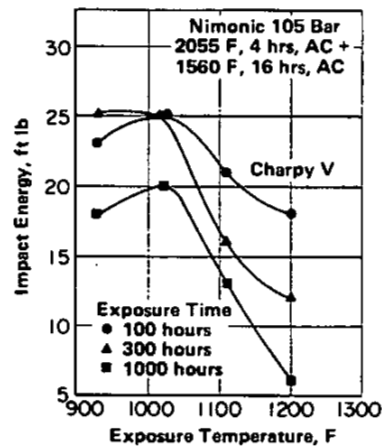


FIGURE 3.0233. EFFECTS OF LONG EXPOSURES IN THE RANGE 900 TO 1200 F ON ROOM-TEMPERATURE IMPACT PROPERTIES OF BAR (2)

	Ni
20	Co
14.8	Cr
5	Mo
4.7	Al
1.2	Ti
+	B

Nimonic 105

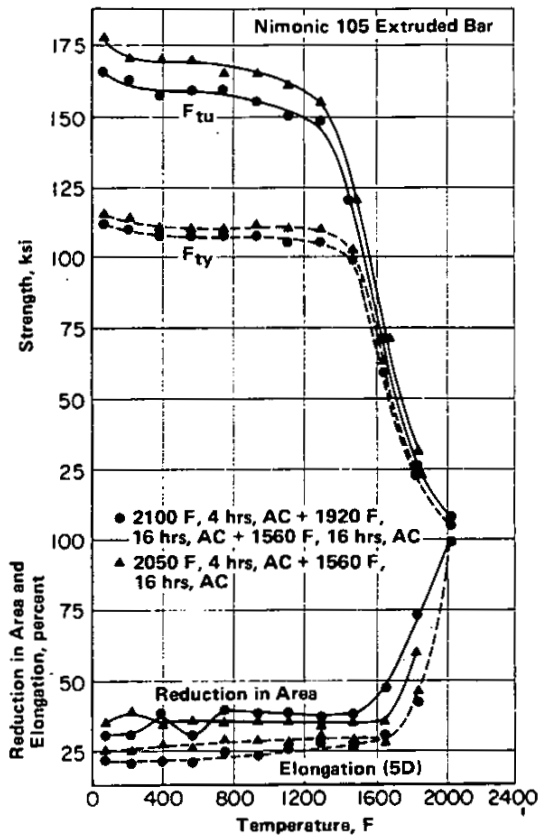


FIGURE 3.0311. EFFECTS OF TEMPERATURE ON TENSILE PROPERTIES OF BAR WITH TWO DIFFERENT HEAT TREATMENTS (2)

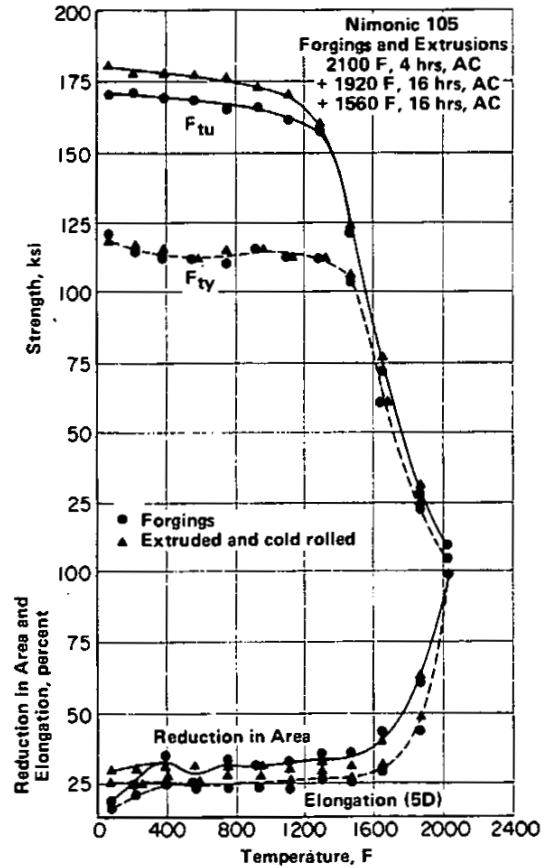


FIGURE 3.0312. EFFECTS OF TEMPERATURE ON TENSILE PROPERTIES OF FORGINGS AND EXTRUSIONS (2)

	Ni
20	Co
14.8	Cr
5	Mo
4.7	Al
1.2	Ti
+	B

Nimonic 105

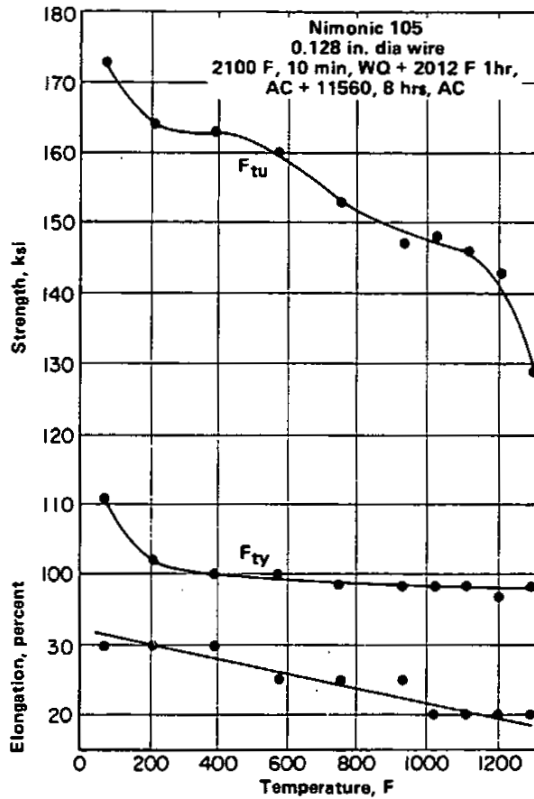


FIGURE 3.0313. EFFECTS OF TEMPERATURE ON TENSILE PROPERTIES OF WIRE (4)

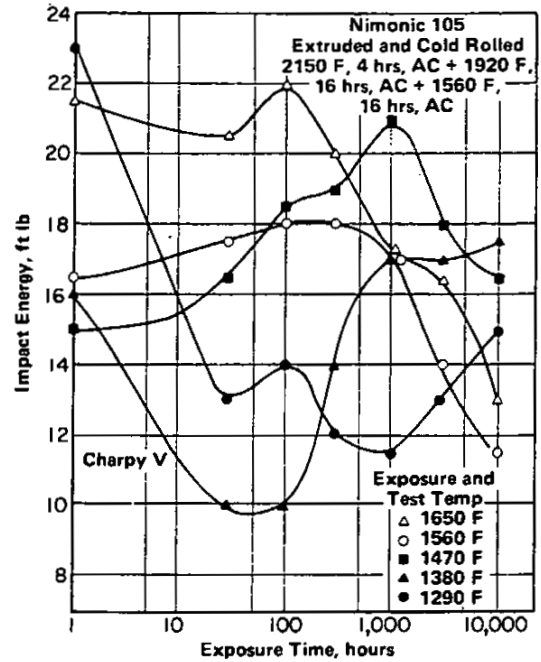


FIGURE 3.0331. EFFECTS OF VARIOUS EXPOSURE TIMES TO TEST TEMPERATURE ON THE ELEVATED-TEMPERATURE IMPACT PROPERTIES OF EXTRUDED AND COLD-ROLLED SECTIONS (2)

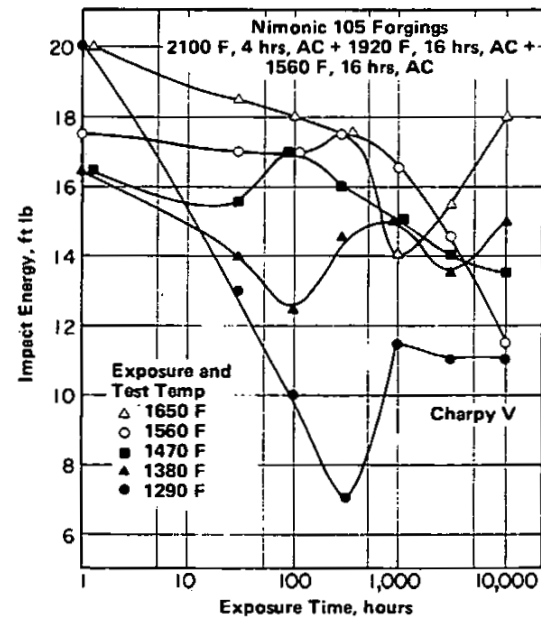


FIGURE 3.0332. EFFECTS OF VARIOUS EXPOSURE TIMES TO TEST TEMPERATURE ON THE ELEVATED-TEMPERATURE IMPACT PROPERTIES OF FORGINGS (2)

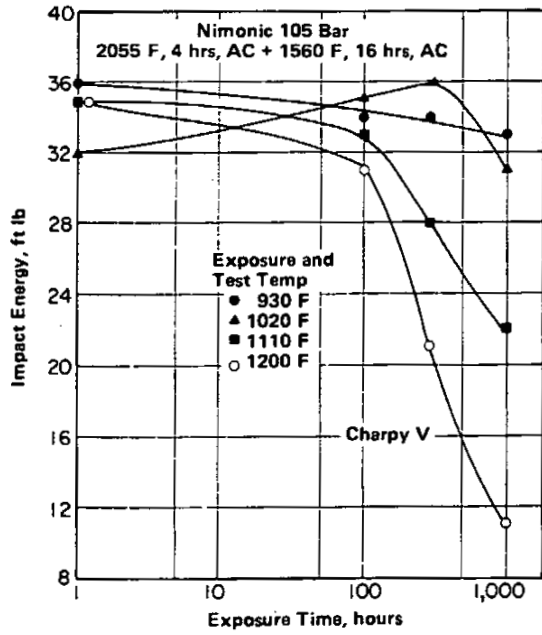


FIGURE 3.0333. EFFECTS OF VARIOUS EXPOSURE TIMES TO TEST TEMPERATURE ON THE IMPACT PROPERTIES OF BAR IN THE RANGE 900 TO 1200 F (2)

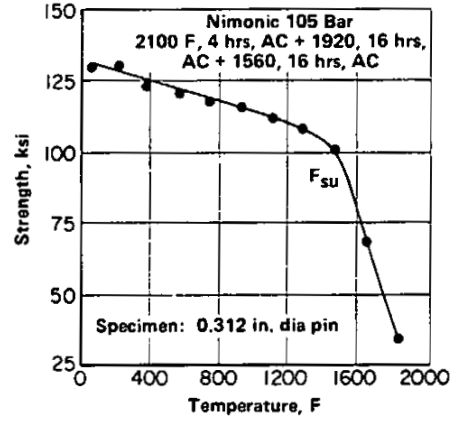


FIGURE 3.0351. EFFECTS OF TEMPERATURE ON SHEAR STRENGTH OF BAR (3)

	Ni
20	Co
14.8	Cr
5	Mo
4.7	Al
1.2	Ti
+	B

Nimonic 105

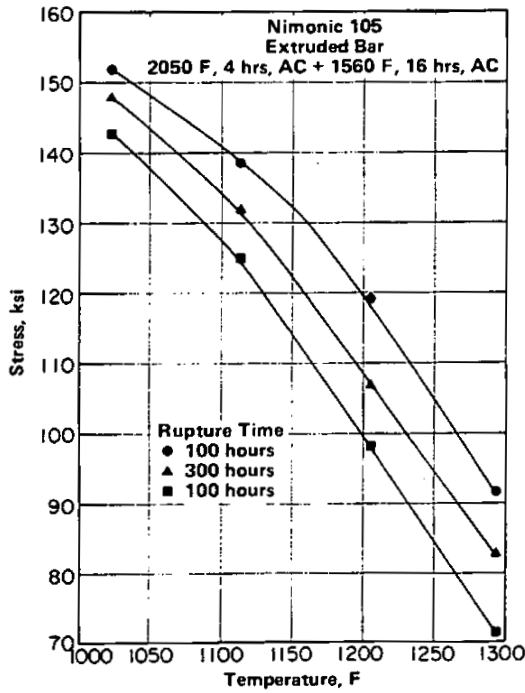


FIGURE 3.041. EFFECTS OF TEMPERATURE ON STRESS TO CAUSE RUPTURE OF EXTRUDED BAR IN TIMES RANGING FROM 100 TO 1000 HOURS (2)

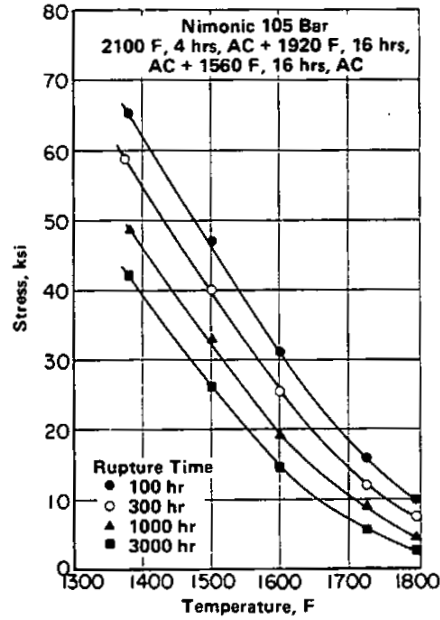


FIGURE 3.042. EFFECTS OF TEMPERATURE ON STRESS TO CAUSE RUPTURE OF FORGINGS IN TIMES RANGING FROM 100 TO 3000 HOURS (2)

	Ni
20	Co
14.8	Cr
5	Mo
4.7	Al
1.2	Ti
+	B

Nimonic 105

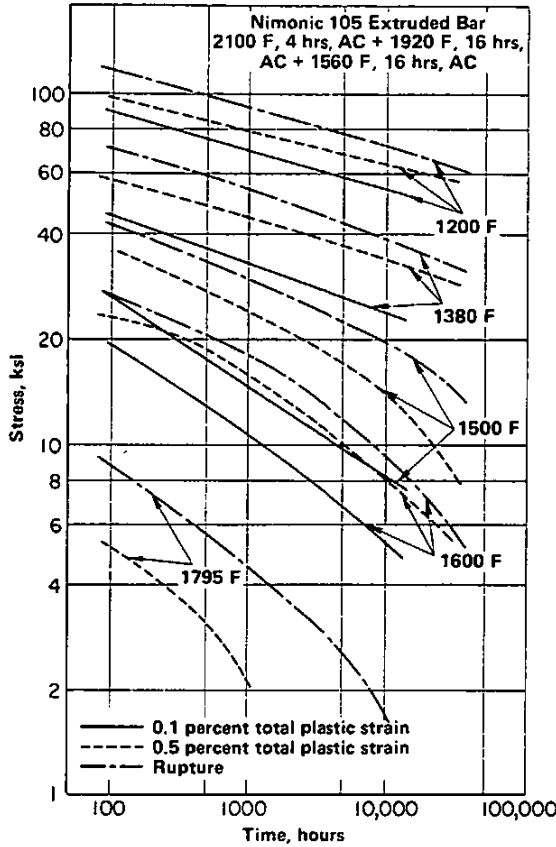


FIGURE 3.043. CREEP AND RUPTURE CURVES FOR EXTRUDED BAR (2)

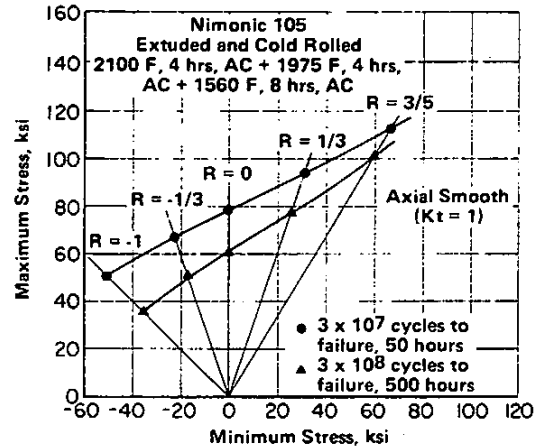


FIGURE 3.051. MODIFIED GOODMAN DIAGRAM SHOWING FATIGUE PROPERTIES OF SMOOTH SPECIMENS AT ROOM TEMPERATURE (2)

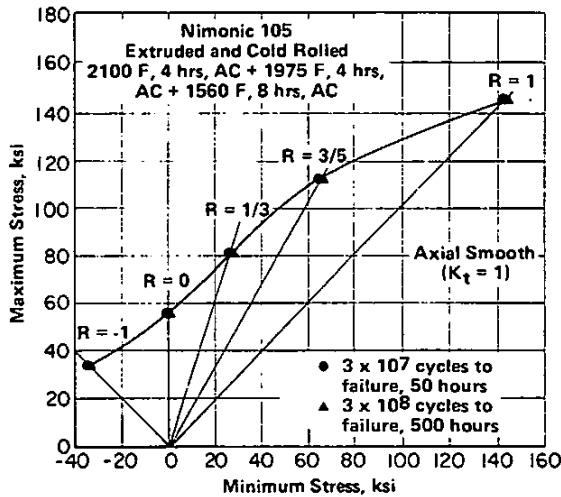


FIGURE 3.052. MODIFIED GOODMAN DIAGRAM SHOWING FATIGUE PROPERTIES OF SMOOTH SPECIMENS AT 750 F (2)

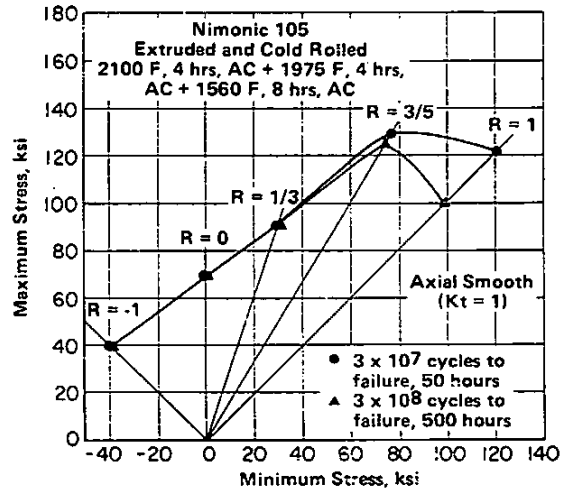


FIGURE 3.053. MODIFIED GOODMAN DIAGRAM SHOWING FATIGUE PROPERTIES OF SMOOTH SPECIMENS AT 1200 F (2)

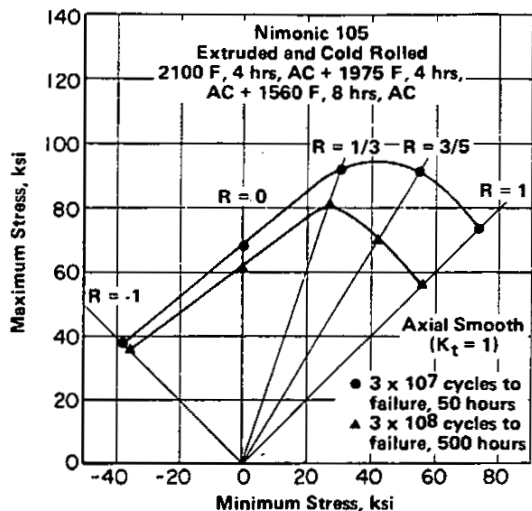


FIGURE 3.054. MODIFIED GOODMAN DIAGRAM SHOWING FATIGUE PROPERTIES OF SMOOTH SPECIMENS AT 1380 F (2)

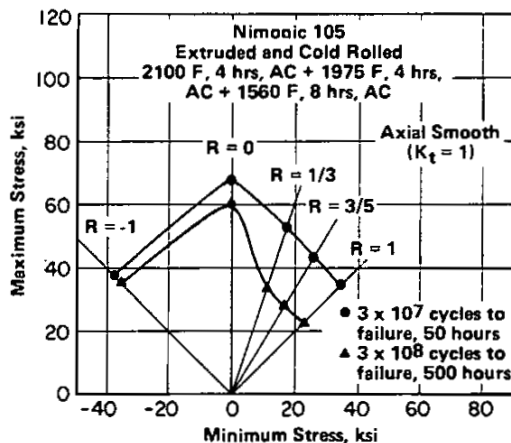


FIGURE 3.055. MODIFIED GOODMAN DIAGRAM SHOWING FATIGUE PROPERTIES OF SMOOTH SPECIMENS AT 1600 F (2)

Ni
20 Co
14.8 Cr
5 Mo
4.7 Al
1.2 Ti
+ B

Nimonic 105

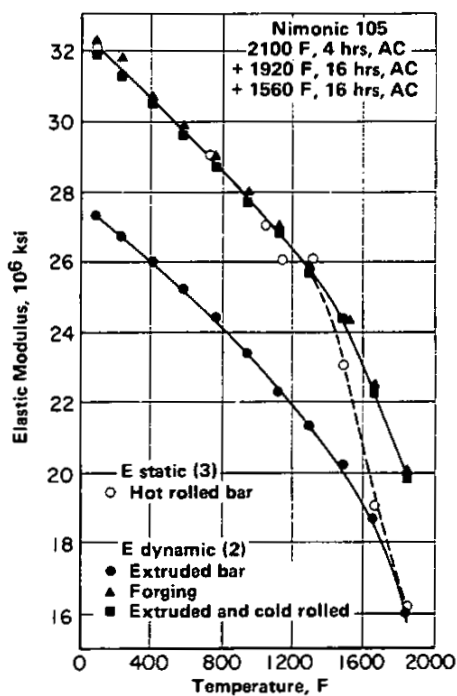


FIGURE 3.0621. EFFECT OF TEMPERATURE ON MODULUS OF ELASTICITY (2, 3)

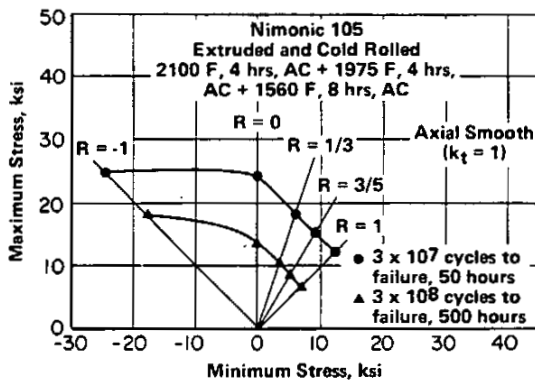


FIGURE 3.056 MODIFIED GOODMAN DIAGRAM SHOWING FATIGUE PROPERTIES OF SMOOTH SPECIMENS AT 1795 F (2)

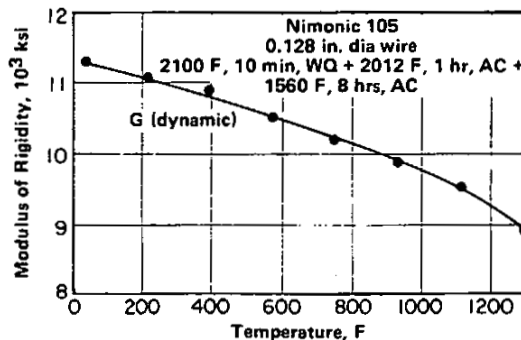


FIGURE 3.0631. EFFECT OF TEMPERATURE ON MODULUS OF RIGIDITY (4)

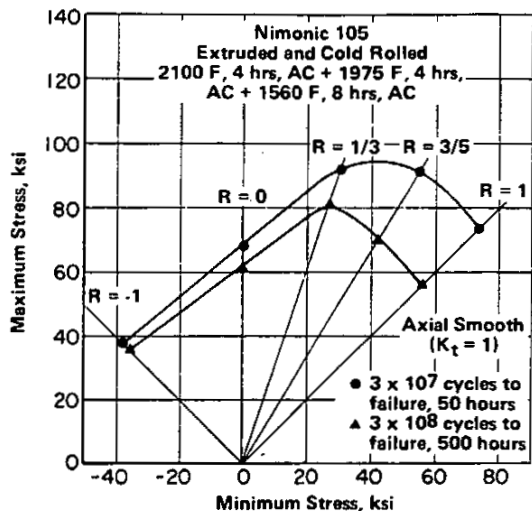


FIGURE 3.054. MODIFIED GOODMAN DIAGRAM SHOWING FATIGUE PROPERTIES OF SMOOTH SPECIMENS AT 1380 F (2)

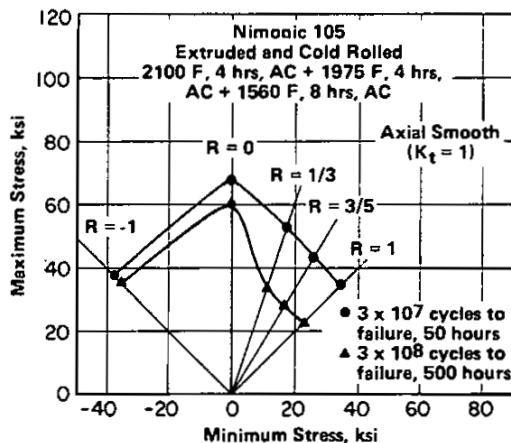


FIGURE 3.055. MODIFIED GOODMAN DIAGRAM SHOWING FATIGUE PROPERTIES OF SMOOTH SPECIMENS AT 1600 F (2)

Ni
20 Co
14.8 Cr
5 Mo
4.7 Al
1.2 Ti
+ B

Nimonic 105

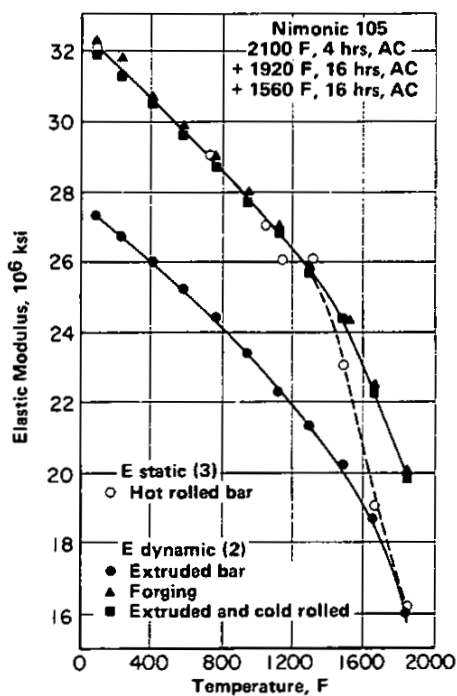


FIGURE 3.0621. EFFECT OF TEMPERATURE ON MODULUS OF ELASTICITY (2, 3)

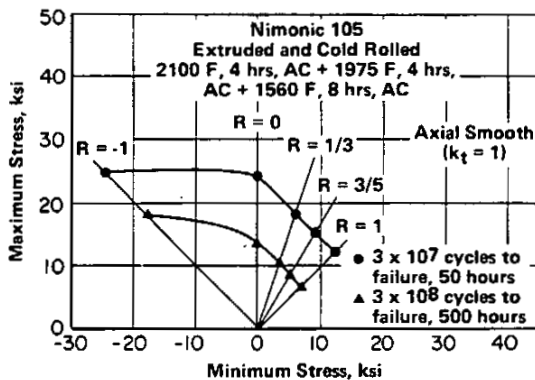


FIGURE 3.056 MODIFIED GOODMAN DIAGRAM SHOWING FATIGUE PROPERTIES OF SMOOTH SPECIMENS AT 1795 F (2)

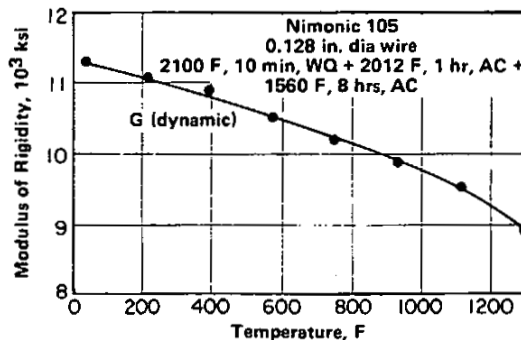


FIGURE 3.0631. EFFECT OF TEMPERATURE ON MODULUS OF RIGIDITY (4)