

# NONFERROUS ALLOYS

	Ni
23	Cr
1.5	Al
14	Fe

IN-601

1. GENERAL  
Inconel 601 is a general-purpose alloy for applications requiring resistance to both heat and corrosion at temperatures up to about 2100F. Although it is not strengthened by heat treatment, broad ranges of strength and hardness can be achieved by the combination of cold work and annealing treatments. Its outstanding characteristic is its resistance to high-temperature oxidation; in addition, it has good resistance to carburizing and sulfur-containing environments and to aqueous corrosion. The alloy can be readily formed, machined, and welded by standard procedures. Aerospace applications that have been reported for Inconel 601 are combustion-can liners, diffuser assemblies, containment rings, exhaust liners, and igniters for gas turbines. It is also used in various types of heat-processing, chemical-processing, steam-power-generation, and pollution-control equipment. (3) (4) (9) (10)
- 1.01 Commercial Designation  
Inconel 601
- 1.02 Alternate Designations  
Altemp 601 (Allegheny Ludlum)
- 1.03 Specifications  
AMS 5715 (5-15-72) Alloy Bars, Forgings, and Rings (1)  
AMS 5870 (5-15-72) Alloy Sheet, Strip and Plate (2)
- 1.04 Composition  
Table 1.04
- 1.05 Heat Treatment
- 1.051 Inconel 601 is used most frequently in the annealed condition, the annealing temperature varying from 1800F to 2200F. Over that range of annealing temperatures, the grain size of the alloy increases markedly (see Fig. 1.052) resulting in decreased tensile strength at ordinary temperatures, but increased rupture strength at high temperatures. Consequently, annealing temperatures of 1800 to 1850F are recommended for tensile-limited applications (temperatures below about 1000F), but annealing temperatures of 2000 to 2200F are recommended for rupture-limited applications (temperature above 1000F). For the high-temperature (2000-2200F) annealing range, the term "solution-treatment" is often used to distinguish it from the lower-temperature annealing. Although the rate of cooling from the annealing temperature has little effect on mechanical properties, air cooling or faster should be used to avoid sensitization, which can occur if the alloy is cooled very slowly through the range 1400-1000F. In addition to variations in annealing temperature, variations in hot-working temperature or in the amount of cold work can also be used to change the properties of Inconel 601. (3)
- 1.052 Effect of annealing temperature on the grain size in hot-finished rod, Figure 1.052.
- 1.06 Hardness
- 1.061 Hardness range for various product forms and conditions, Figure 1.061.
- 1.062 Effect of cold work on hardness, Figure 1.062.
- 1.063 Effect of hot-working temperature on hardness of bar at room temperature, Figure 1.063.
- 1.07 Forms and Conditions Available  
Table 1.07
- 1.08 Melting and Casting Practice  
Inconel 601 is normally induction melted in air atmosphere and cast into ingots. For aerospace applications requiring optimum properties, vacuum melting techniques, such as consumable-electrode or vacuum-induction, are recommended.
- 1.09 Special Considerations
- 1.091 Inconel 601 is similar to austenitic stainless steels in that it can be sensitized—made susceptible to intergranular attack in some aggressive media—by prolonged heating in the 1000-1400F range. Such exposures, however, are not detrimental to toughness. (3)
- 1.092 Heating for annealing or hot working should be carried out in low-sulfur slightly reducing atmospheres to prevent surface contamination. (3)
- 1.093 Like other high-nickel alloys, Inconel 601 should be clean—free of grease, oil, paint, and shop soil—before heating operations are performed. (3)
2. PHYSICAL AND ENVIRONMENTAL EFFECTS
- 2.01 Thermal Properties
- 2.011 Melting range: 2374-2494F (3) (4)
- 2.012 Phase changes
- 2.0121 Time-temperature-transformation diagrams
- 2.0122 The alloy has a microstructure consisting of scattered particles of chromium carbide and titanium nitride in a face-centered-cubic solid solution, which is highly stable throughout its useful temperature range. (3)
- 2.013 Thermal conductivity, Figure 2.013
- 2.014 Thermal expansion, Figure 2.014
- 2.015 Specific heat
- 2.0151 Specific heat at room and elevated temperatures, Figure 2.0151
- 2.016 Thermal diffusivity
- 2.02 Other Physical Properties
- 2.021 Density: 0.291 lb. per in.<sup>3</sup>; 8.05 gr. per cm<sup>3</sup>
- 2.022 Electrical Properties
- 2.0221 Electrical resistivity at room and elevated temperatures, Fig. 2.0221
- 2.023 Magnetic properties
- 2.0231 The magnetic permeability at 200 oersted is 1.003 at room temperature, 1.004 at -109F, and 1.016 at -320F (3)
- 2.0232 The Curie temperature is below -320F. (3)
- 2.024 Emission
- 2.025 Damping capacity
- 2.03 Chemical Environment
- 2.031 Inconel 601 has excellent resistance to oxidation and spalling at temperatures as high as 2300F. In addition it has relatively good elevated-temperature resistance to carburization and sulfidation. (3) (4)
- 2.0311 Loss of weight as a result of oxidation during exposures to air at various elevated temperatures; at each temperature exposures were interrupted at 50-hour intervals for cooling to room-temperature and reheating, Figure 2.0311.
- 2.0312 Gain in weight as a result of exposures to carburizing and carbo-nitriding atmospheres, Table 2.0312.
- 2.0313 Loss of weight as a result of sulfidation for 100 hours at various temperatures in an atmosphere of 1.5 percent hydrogen sulfide and 98.5 percent hydrogen, Figure 2.0313.
- 2.0314 Inconel 601 has excellent resistance to oxidation and other corrosive attack in gasoline-engine exhaust systems at temperatures up to at least 1800F and in gasoline-engine thermal reactors (after burners) at temperatures up to at least 1900F. (6) (7) (8)
- 2.0315 In an evaluation of metals for the space-shuttle thermal-protection system, annealed Inconel 601 sheet was subjected to 100 thirty-minute exposures to 2200F in air at a pressure of 10 torr; each exposure was followed by cooling to room temperature in the same atmosphere. Although these exposures resulted in negligible change in weight, oxidation of the metal surfaces resulted in a reduction of metal thickness of 0.0038 in. (5)
- 2.032 The alloy has good resistance to nitric acid, but it is not resistant to sulfuric, hydrochloric, or hydrofluoric acid. (3)
- 2.0321 Rate of corrosion in boiling nitric acid of various concentrations, Figure 2.0321.

	Ni
23	Cr
1.5	Al
14	Fe

## IN-601

- 2.033 It has good resistance to phosphoric acid at concentrations up to 10 percent, but the resistance decreases markedly as the concentration increases above that level. (3)
- 2.034 Inconel 601 resists general corrosion by both concentrated and dilute sodium hydroxide solutions at temperatures up to the boiling point, but it is attacked at a rate of 3 mpy in molten sodium hydroxide. (3)
- 2.035 It has good resistance to corrosion in sea water and in fresh water. (3)
- 2.036 The alloy's high nickel content provides resistance to reducing environments while its substantial chromium content provides resistance to oxidation. (3)
- 2.037 Inconel 601 has excellent resistance to the following environments: neutral and alkaline salt solutions, magnesium-chloride solutions, organic acids as they occur in food and beverage products, dilute ammonium chloride, hydroxide, and sulfate solutions, dry chlorine, dry hydrogen chloride, and all mixtures of air, steam, and carbon dioxide. (3)
- 2.038 It has good resistance to stress-corrosion cracking in the presence of chloride ions, mercury, and solutions of sodium-hydroxide. (3)
- 2.04 Nuclear Environment
3. MECHANICAL PROPERTIES
- 3.01 Specified Mechanical Properties  
Table 3.01
- 3.02 Mechanical Properties at Room Temperature
- 3.021 Tension-Stress-Strain Diagrams-Tension Properties
- 3.0211 Effects of annealing temperature on tensile properties of hot-finished rod at room temperature, Figure 3.0211.
- 3.0212 Effects of annealing temperature on room-temperature tensile properties of cold-drawn wire, Figure 3.0212.
- 3.0213 Effects of hot-working temperature on tensile properties of bar at room temperature, Figure 3.0213.
- 3.0214 Room-temperature tensile properties of annealed products, Table 3.0214.
- 3.0215 Room-temperature tensile properties of solution-treated products, Table 3.0215.
- 3.0216 Room-temperature longitudinal tensile properties of hot-finished rod and bar, Table 3.0216.
- 3.0217 Effects of cold drawing on tensile properties of wire, Figure 3.0217.
- 3.022 Compression-Stress-Strain Diagrams-Compression Properties
- 3.023 Impact
- 3.0231 Effects of exposures to elevated temperatures on room-temperature impact strength, Figure 3.0231.
- 3.0232 Room-temperature impact strength of hot-finished rod in the solution-treated and annealed conditions, Table 3.0232.
- 3.024 Bending
- 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-Stress-Strain Diagrams-Tension Properties
- 3.0311 Effects of elevated temperatures on tensile properties of hot-finished rod in various conditions, Figure 3.0311.
- 3.032 Compression-Stress-Strain Diagrams-Compression Properties
- 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 Creep-rupture time at various stresses and temperatures, Figure 3.041.
- 3.042 Minimum creep rate at various temperatures and stresses, Figure 3.042.
- 3.05 Fatigue Properties
- 3.051 Fatigue properties of solution-treated and annealed rod, Figure 3.051.
- 3.052 Fatigue properties of annealed sheet, Figure 3.052.
- 3.06 Elastic Properties
- 3.061 Poisson's Ratio
- 3.0611 Poisson's ratio at room and elevated temperatures, Figure 3.0611.
- 3.062 Modulus of Elasticity
- 3.0621 Effect of temperature on modulus of elasticity, Figure 3.0621.
- 3.063 Modulus of Rigidity
- 3.0631 Effect of temperature on modulus of rigidity, Figure 3.0631.
- 3.064 Tangent Modulus
- 3.065 Secant Modulus
4. FABRICATION
- 4.01 Forming
- 4.011 Inconel 601 can be readily hot formed in the range 1500 to 2250F, but hot-working operations requiring large deformations should be performed in the range 1900 to 2200F. The alloy has relatively low ductility at temperatures from 1200 to 1600F; consequently, it should not be worked in that range. Light working at temperatures below 1200F can be done to develop high tensile properties. The rate of cooling following hot working is not critical with respect to thermal cracking; to avoid sensitization, the alloy should be cooled rapidly through the 1400 to 1000F range. (3) (4)
- 4.012 Inconel 601 can be cold formed with conventional equipment and procedures. (3)
- 4.02 Machining and Grinding
- 4.021 All standard machining operations can be readily performed on Inconel 601. The solution-treated condition provides the best machinability. (3) (4)
- 4.03 Joining
- 4.031 The alloy has good weldability with all of the common commercial welding processes. Inconel 601 and other nickel-base-alloy filler metals are available, which provide high joint efficiencies and resistance to corrosion and oxidation comparable to that of the base metal. The optimum filler metal depends on the service conditions to which the joint will be exposed. (3) (4)
- 4.0311 Effects of elevated temperatures on tensile properties of transverse butt-welded joints made by shielded-metal-arc process, Figure 4.0311.
- 4.0312 Effects of elevated temperatures on tensile properties of transverse butt-welded joints made by gas-metal-arc process, Figure 4.0312.
- 4.0313 Effects of elevated temperatures on tensile properties of transverse butt-welded joints made by gas-tungsten-arc process, Figure 4.0313.
- 4.04 Surface Treatment
- 4.0411 Removal of hot-work and heat-treat scales 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.

NONFERROUS ALLOYS

Alloy			
INCONEL 601			
Source			
(1) (2) (3)			
Composition percent	min		max
	Carbon	--	--
Manganese	--	--	1.00
Silicon	--	--	0.50
Sulfur	--	--	0.015
Chromium	21.00	--	25.00
Nickel	58.00	--	63.00
Aluminum	1.00	--	1.70
Boron	--	--	0.006
Copper	--	--	1.00
Iron	remainder		

TABLE 1.04 COMPOSITION

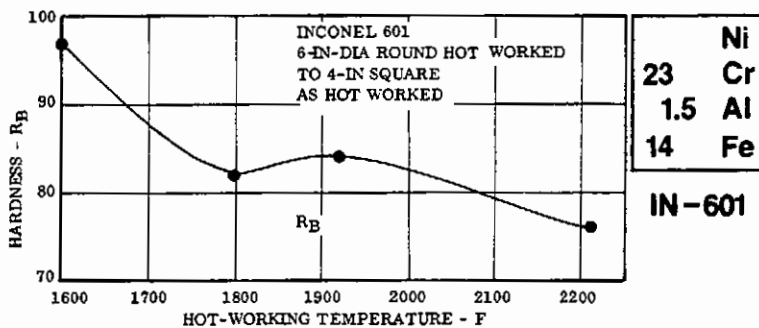


FIG. 1.063 EFFECT OF HOT-WORKING TEMPERATURE ON HARDNESS OF BAR AT ROOM TEMPERATURE (3)

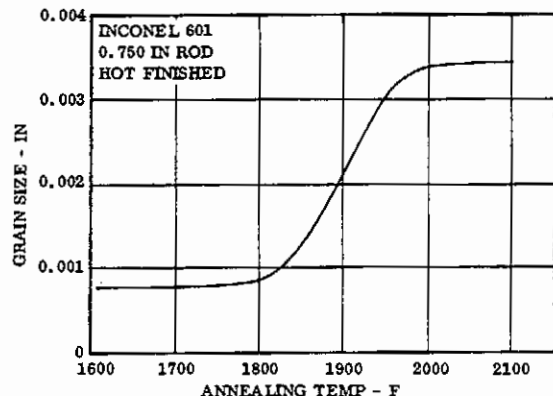


FIG. 1.052 EFFECT OF ANNEALING TEMPERATURE ON THE GRAIN SIZE IN HOT-FINISHED ROD (3)

Alloy	
INCONEL 601	
Source	
(3) (10)	
Form	Conditions
Rod and bar	Hot-finished, Annealed
Plate	Annealed
Sheet and strip	Cold-rolled, Annealed
Tube and pipe	Cold-drawn, Annealed
Wire	Cold-drawn, Annealed
Forgings	Annealed
Welding rods and wire	Annealed

TABLE 1.07 FORMS AND CONDITIONS AVAILABLE

Alloy		
INCONEL 601		
Source		
(3)		
Form	Condition	Hardness, RB <sup>(a)</sup>
Rod and bar	Hot-finished	65-95
Rod and bar	Annealed	80-80
Plate	Annealed	60-75
Sheet	Annealed	65-80
Strip	Annealed	65-80
Tube and pipe	Annealed	70-95
All forms	Solution-treated	55-95

TABLE 1.061 HARDNESS RANGES FOR VARIOUS PRODUCT FORMS AND CONDITIONS

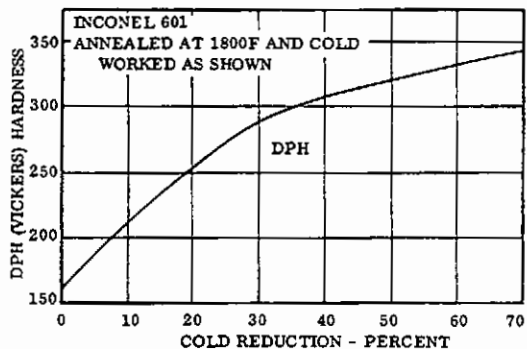


FIG. 1.062 EFFECT OF COLD WORK ON HARDNESS (3)

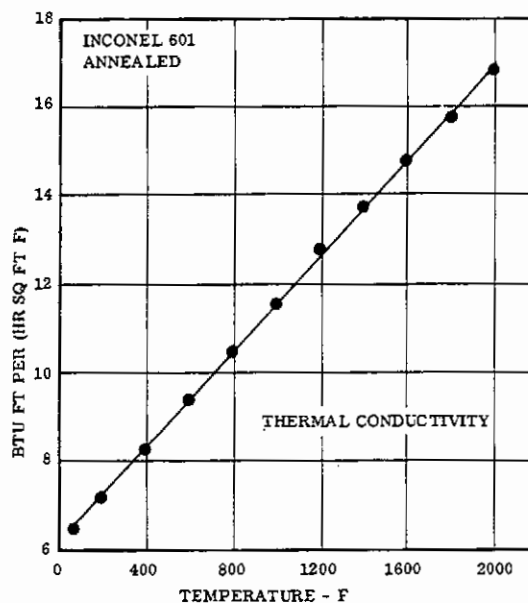


FIG. 2.013 THERMAL CONDUCTIVITY (3)(4)

Ni  
23 Cr  
1.5 Al  
14 Fe  
IN-601

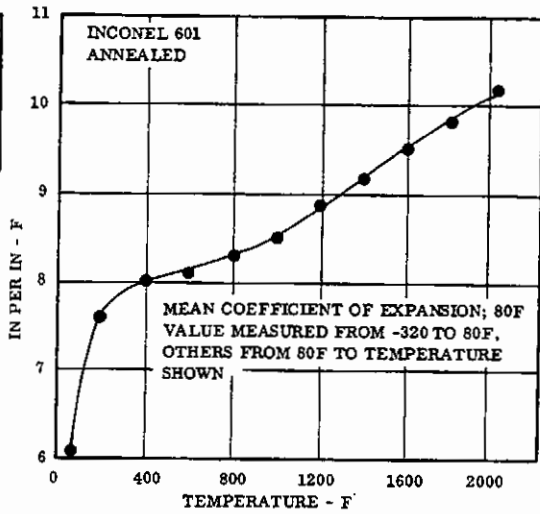


FIG. 2.014 THERMAL EXPANSION (3) (4)

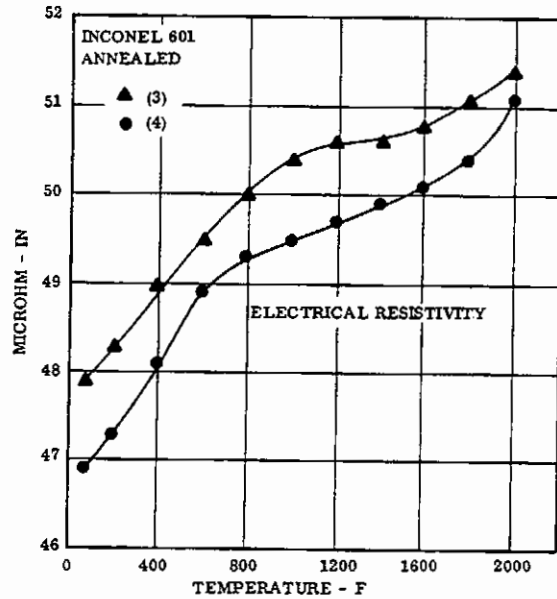


FIG. 2.0221 ELECTRICAL RESISTIVITY AT ROOM AND ELEVATED TEMPERATURES (3)(4)

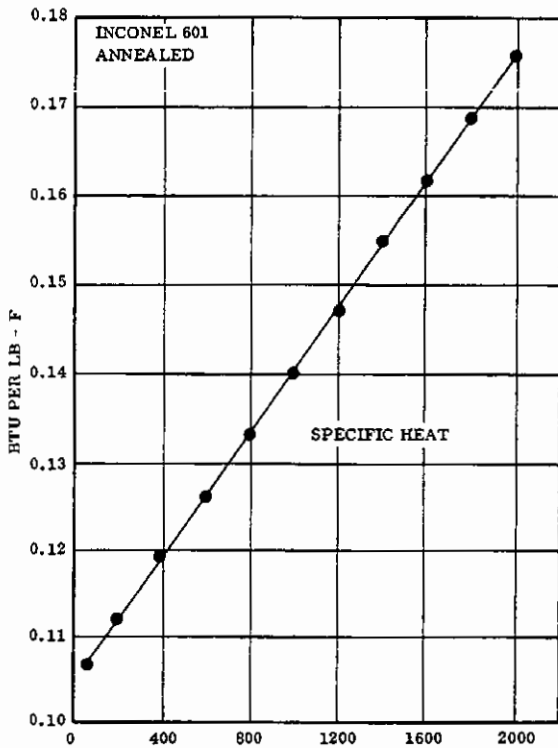


FIG. 2.0151 SPECIFIC HEAT AT ROOM AND ELEVATED TEMPERATURES (3)(4)

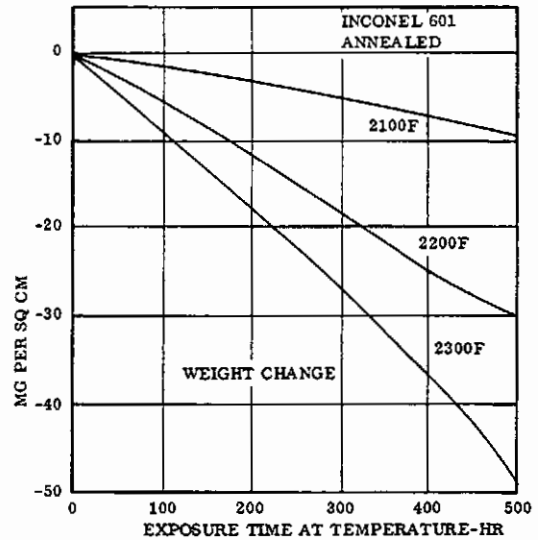


FIG. 2.0311 LOSS OF WEIGHT AS A RESULT OF OXIDATION DURING EXPOSURES TO AIR AT VARIOUS ELEVATED TEMPERATURES: AT EACH TEMPERATURE EXPOSURES WERE INTERRUPTED AT 50 - HOUR INTERVALS FOR COOLING TO ROOM TEMPERATURE AND REHEATING (3)

TEMPERATURE - F

NONFERROUS ALLOYS

INCONEL 601					
Condition: Annealed					
Source: (3)					
Atmosphere Type	Atmosphere Content			Temp F	Weight Gain in 100 hr mg per cm <sup>2</sup>
	CH <sub>4</sub>	H <sub>2</sub>	NH <sub>3</sub>		
Carburizing	2	98	-	1700	2.72
Carburizing	2	98	-	1800	4.32
Carburizing	2	98	-	2000	14.68
Carbo-nitriding	2	93	5	2000	16.66

TABLE 2.0312 GAIN IN WEIGHT AS A RESULT OF EXPOSURES TO CARBURIZING AND CARBO-NITRIDING ATMOSPHERES

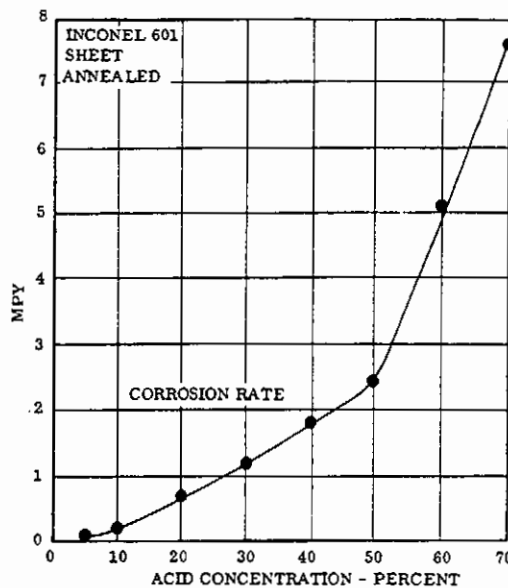


FIG. 2.0321 RATE OF CORROSION IN BOILING NITRIC ACID OF VARIOUS CONCENTRATIONS (3)

Ni	23
Cr	14
Al	1.5
Fe	14
<b>IN-601</b>	

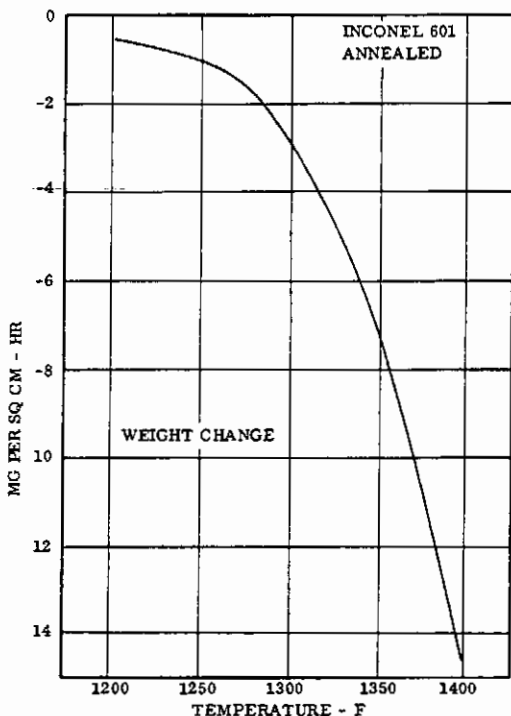


FIG. 2.0313 LOSS OF WEIGHT AS A RESULT OF SULFIDATION FOR 100 HOURS AT VARIOUS TEMPERATURES IN AN ATMOSPHERE OF 1.5 PERCENT HYDROGEN SULFIDE AND 98.5 PERCENT HYDROGEN (3)

INCONEL 601		
Alloy	AMS5870 (2)	AMS 5715 (1)
Source	AMS5870 (2)	AMS 5715 (1)
Form	Sheet, Strip, Plate	Bars, Forgings
Condition	Annealed	Annealed
F <sub>ty</sub> , (ksi) min.	30	30
F <sub>tu</sub> , (ksi) min.	80	80
E(4D), (percent) min.	35	35
Bend Factor <sup>(a)</sup>		
up to 0.050 (in.)	1	-
0.051 to 0.250 (in.)	2	-
(a) Flat products must not crack when bent through an angle of 180 degrees around a diameter equal to the bend factor times the nominal thickness, with axis of bend parallel to the rolling direction.		

TABLE 3.01 SPECIFIED MECHANICAL PROPERTIES

	Ni
23	Cr
1.5	Al
14	Fe

IN-601

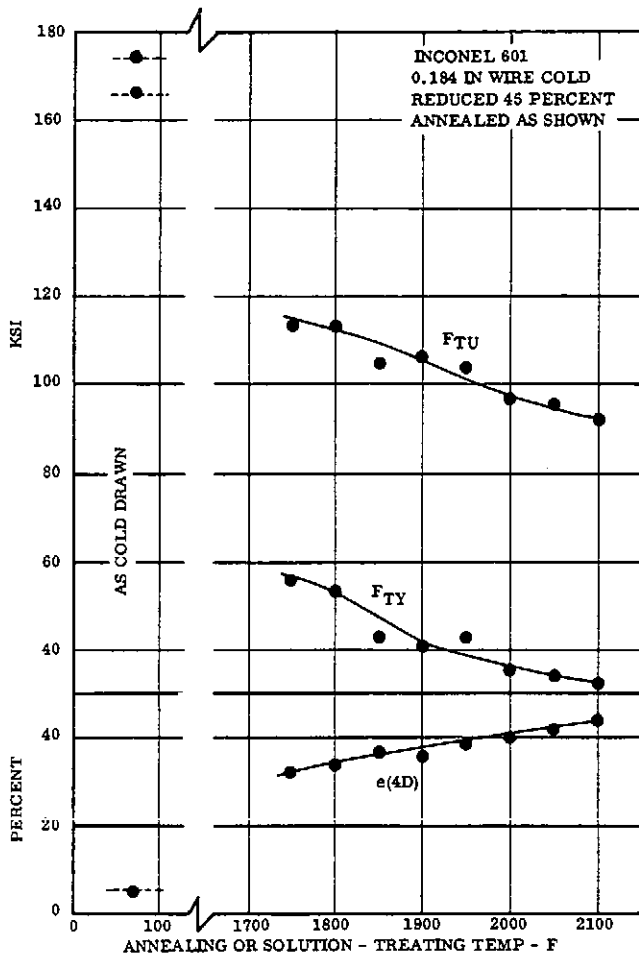


FIG. 3.0212 EFFECTS OF ANNEALING TEMPERATURE ON ROOM-TEMPERATURE TENSILE PROPERTIES OF COLD-DRAWN WIRE

(3)

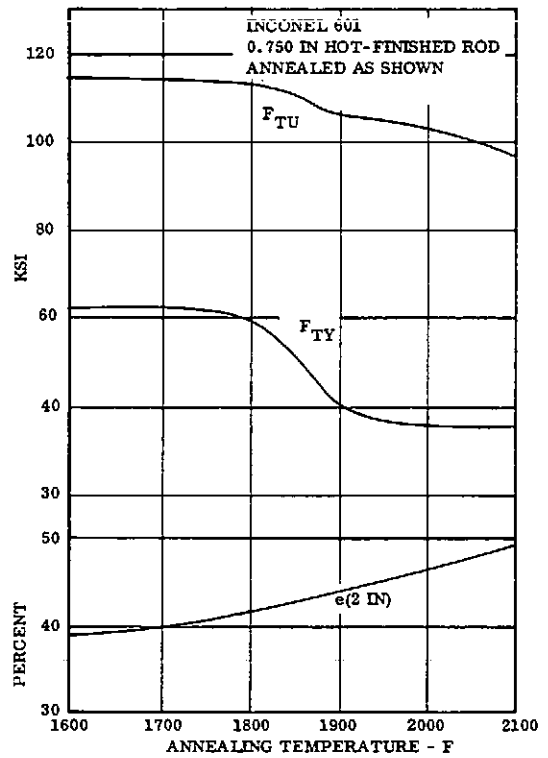


FIG. 3.0211 EFFECTS OF ANNEALING TEMPERATURE ON TENSILE PROPERTIES OF HOT-FINISHED ROD AT ROOM TEMPERATURE

(3)

NONFERROUS ALLOYS

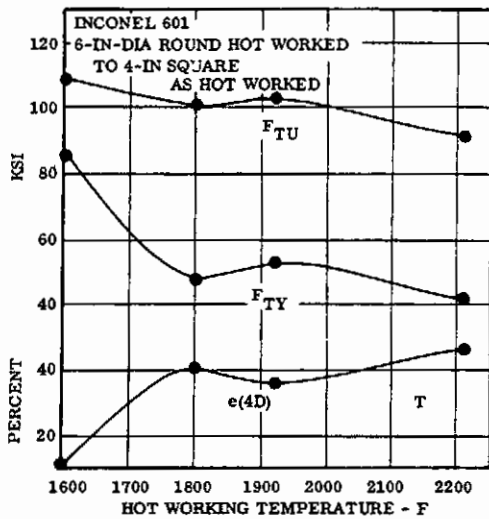


FIG. 3.0213 EFFECTS OF HOT-WORKING TEMPERATURE ON TENSILE PROPERTIES OF BAR AT ROOM TEMPERATURE (3)

Alloy	INCONEL 601		
Form	Rod and Bar		
Condition	Hot-Finished		
Source	(3)		
Size, in.	F <sub>ty</sub> (ksi)	F <sub>tu</sub> (ksi)	e(2in.)
2.5 x 2.5	60.0	93.0	40
2.0 x 2.0	44.0	97.5	49
3.0 dia.	50.5	98.0	45
4.0 dia.	41.5	94.0	-

Ni
23 Cr
1.5 Al
14 Fe
IN-601

TABLE 3.0216 ROOM-TEMPERATURE LONGITUDINAL TENSILE PROPERTIES OF HOT-FINISHED ROD AND BAR

Alloy	INCONEL 601				
Condition	Annealed				
Source	(3)				
Form	Size (in.)	Annealing Temp F	F <sub>ty</sub> (ksi)	F <sub>tu</sub> (ksi)	e(2in.) (percent)
Hot-Finished Rod	0.625 dia.	2000	42.1	107.5	47
Hot-Finished Rod	0.625 dia.	1800	66.0	112.0	41
Hot-Finished Bar	0.5 x 1.0	2000	37.6	102.8	46
Hot-Finished Bar	2.5 x 2.5	2000	31.0	91.0	57
Hot-Finished Bar	0.125 x 2.0	1800	47.1	101.6	42
Hot-Finished Plate	0.312	2000	40.7	99.7	46
Cold-Rolled Sheet	0.125	2000	42.3	97.9	46
Cold-Rolled Sheet	0.062	1900	61.0	115.5	36
Hot-Finished Rod	0.750	1800	65.5	115.0	41

TABLE 3.0214 ROOM-TEMPERATURE TENSILE PROPERTIES OF ANNEALED PRODUCTS

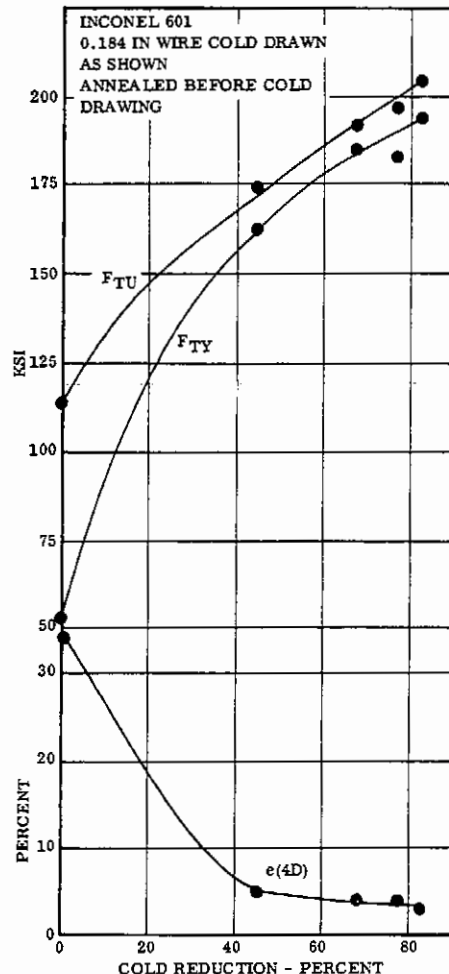


FIG. 3.0217 EFFECTS OF COLD DRAWING ON TENSILE PROPERTIES OF WIRE (3)

Alloy	INCONEL 601			
Condition	Solution Treated At 2150F			
Source	(3)			
Form	Size, in.	F <sub>ty</sub> (ksi)	F <sub>tu</sub> (ksi)	e(2in.) (percent)
Cold-Drawn Tube	2.562 <sup>(a)</sup> x 0.250 <sup>(b)</sup>	37.4	84.9	63
Hot-Finished Flat	0.250 x 2.0	27.6	85.2	70
Cold-Rolled Sheet	0.062	43.7	99.5	47
Hot-Finished Plate	0.250	39.4	85.7	52
Hot-Finished Rod	1.50 dia.	30.0	87.5	59
Hot-Finished Rod	0.750 dia.	35.9	102.0	49
Hot-Finished Rod	0.625 dia.	34.6	102.0	50

TABLE 3.0215 ROOM-TEMPERATURE TENSILE PROPERTIES OF SOLUTION-TREATED PRODUCTS (a) OD (b) Wall thickness

	Ni
23	Cr
1.5	Al
14	Fe

IN-601

Alloy			INCONEL 601
Form			0.625-in.-Dia, Hot-Finished Rod
Condition			Solution Treated at 2100F
Source			(3)
Temperature -F	Time at Temp. Hr.	Charpy V IE, ft. lb.	
80	-	130	
1000	100	86	
	400	89	
	1000	89	
1100	100	88	
	300	92	
	1000	93	
1200	1100	93	
	300	90	
	1000	94	
1300	100	95	
1400	146	105	
1500	159	117	
1600	103	117	

TABLE 3.0231 EFFECTS OF EXPOSURES TO ELEVATED TEMPERATURES ON ROOM-TEMPERATURE IMPACT STRENGTH

Alloy			INCONEL 601
Form			Hot Finished Rod
Source			(3)
Rod Dia, in.	Condition	Charpy V IE, ft. lb.	
0.750	Solution-treated 2100F	136	
0.625	Solution-treated 2100F	130	
0.750	Annealed 1800F	99	
0.625	Annealed 1800F	103	

TABLE 3.0232 ROOM-TEMPERATURE IMPACT STRENGTH OF HOT-FINISHED ROD IN THE SOLUTION-TREATED AND ANNEALED CONDITIONS

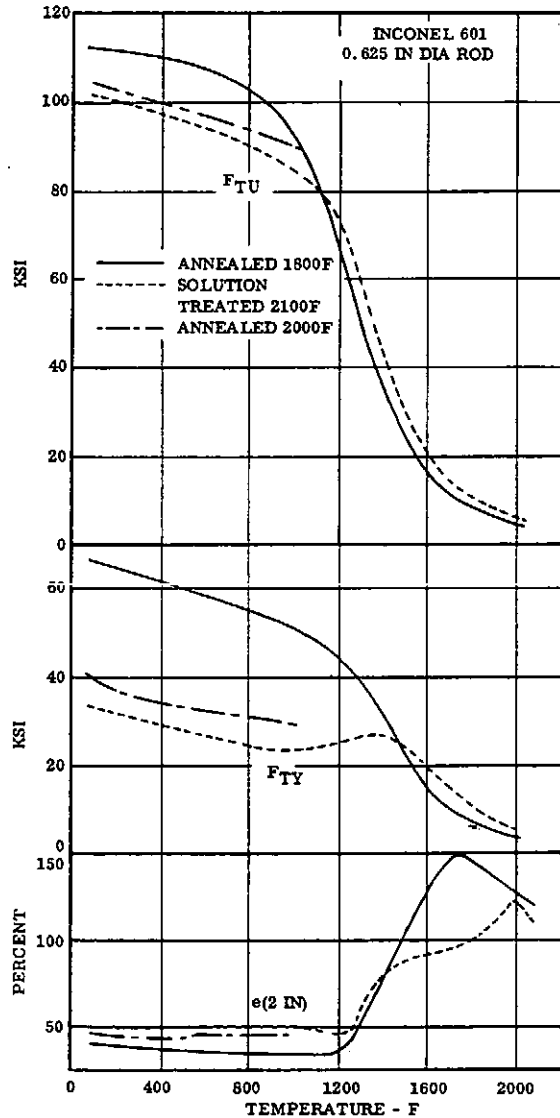


FIG. 3.0311 EFFECTS OF ELEVATED TEMPERATURES ON TENSILE PROPERTIES OF HOT-FINISHED ROD IN VARIOUS CONDITIONS (3)

NONFERROUS ALLOYS

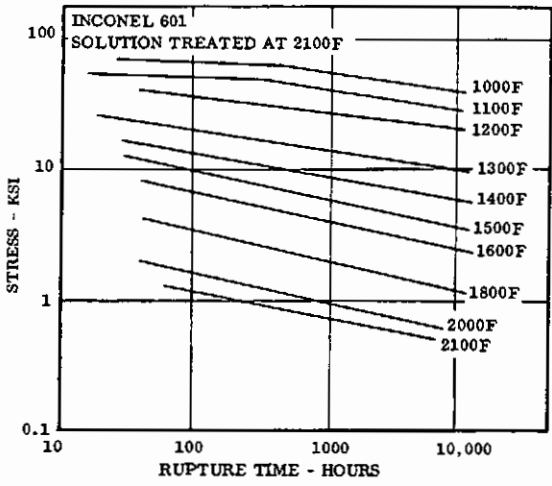
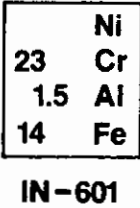


FIG. 3.041 CREEP-RUPTURE TIME AT VARIOUS STRESSES AND TEMPERATURES (3)

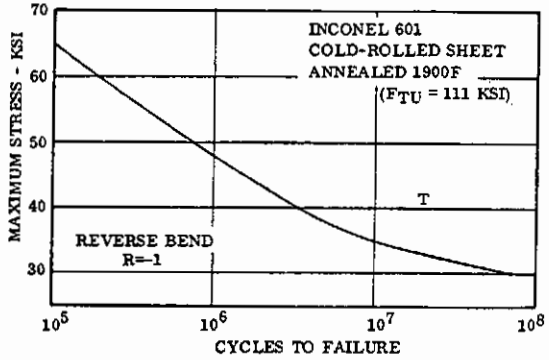


FIG. 3.052 FATIGUE PROPERTIES OF ANNEALED SHEET (3)

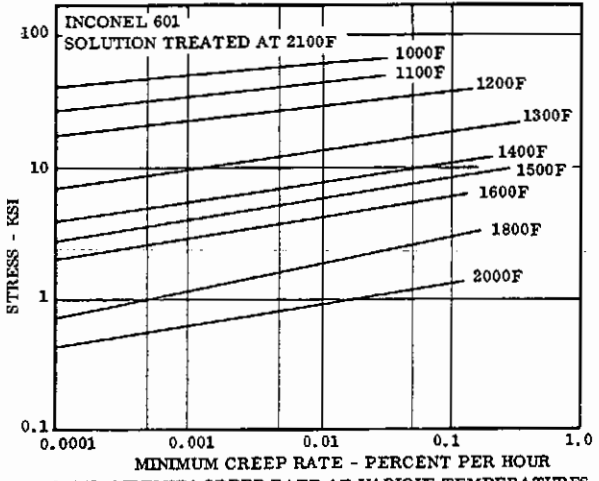


FIG. 3.042 MINIMUM CREEP RATE AT VARIOUS TEMPERATURES AND STRESSES (3)

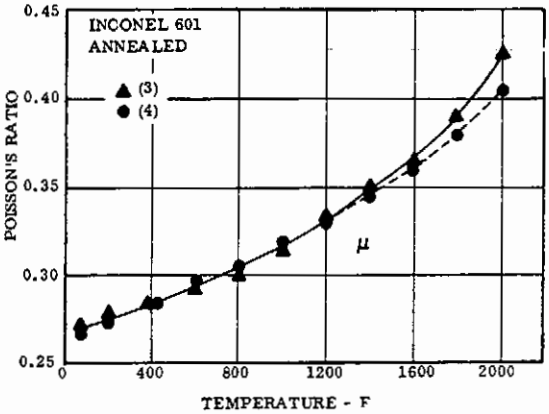


FIG. 3.0611 POISSON'S RATIO AT ROOM AND ELEVATED TEMPERATURES (3) (4)

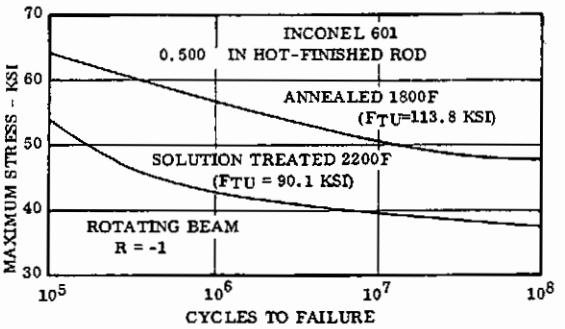


FIG. 3.051 FATIGUE PROPERTIES OF SOLUTION-TREATED AND ANNEALED ROD (3)

	Ni
23	Cr
1.5	Al
14	Fe
<b>IN-601</b>	

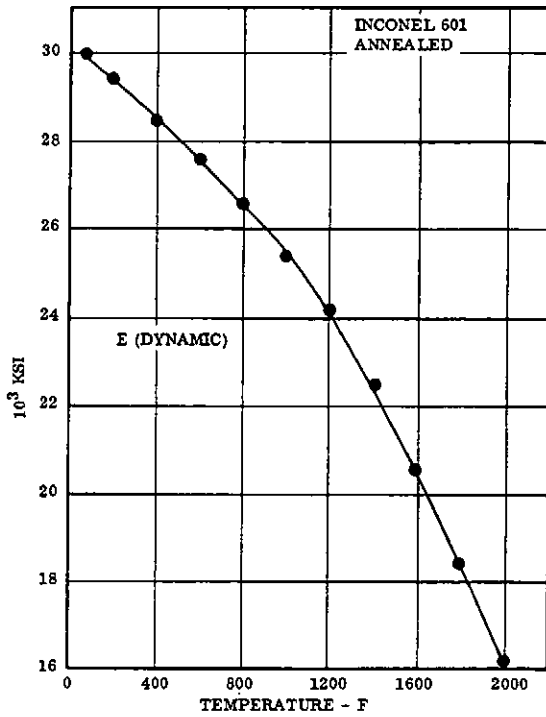


FIG. 3.0621 EFFECT OF TEMPERATURE ON MODULUS OF ELASTICITY (3)(4)

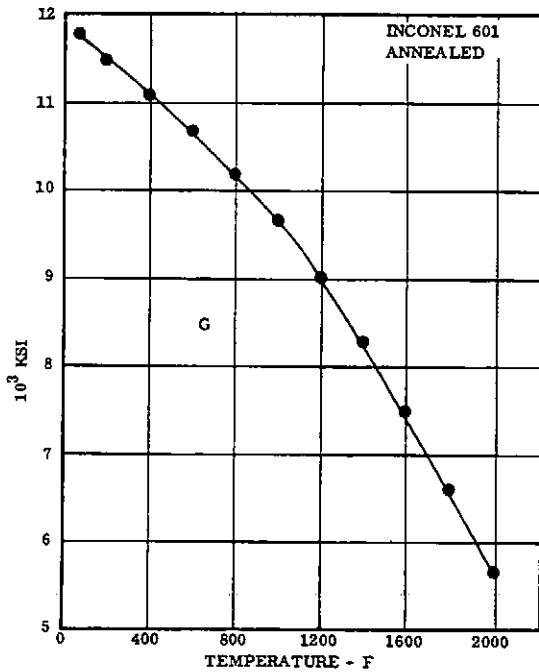


FIG. 3.0631 EFFECT OF TEMPERATURE ON MODULUS OF RIGIDITY (3)(4)

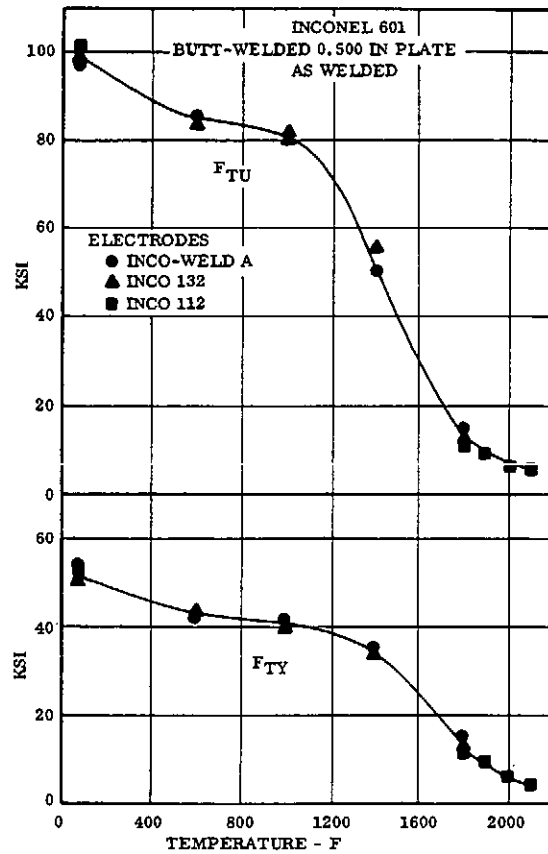


FIG. 4.0311 EFFECTS OF ELEVATED TEMPERATURES ON TENSILE PROPERTIES OF TRANSVERSE BUTT-WELDED JOINTS MADE BY SHIELDED-METAL-ARC PROCESS (3)

NONFERROUS ALLOYS

	Ni
23	Cr
1.5	Al
14	Fe

IN-601

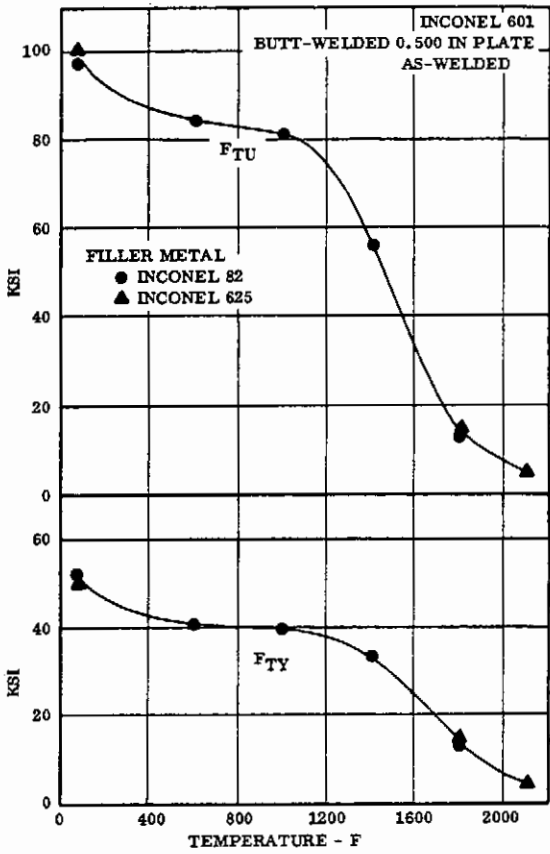


FIG. 4.0312 EFFECTS OF ELEVATED TEMPERATURES ON TENSILE PROPERTIES OF TRANSVERSE BUTT-WELDED JOINTS MADE BY GAS-METAL-ARC PROCESS (3)

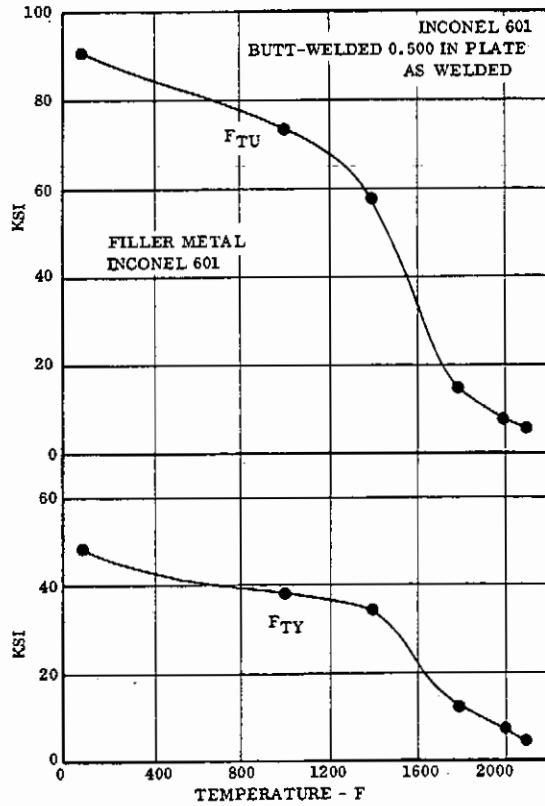


FIG. 4.0313 EFFECTS OF ELEVATED TEMPERATURES ON TENSILE PROPERTIES OF TRANSVERSE BUTT-WELDED JOINTS MADE BY GAS-TUNGSTEN-ARC PROCESS (3)

	Ni
23	Cr
1.5	Al
14	Fe

IN-601

## REFERENCES

1. AMS 5715 (May 15, 1972)
2. AMS 5870 (May 15, 1972)
3. "Inconel Alloy 601", The International Nickel Co., Inc. (1973)
4. "Nickel Base Alloy Altemp 601", Allegheny Ludlum Steel Corp. Blue Sheet
5. Sanders, W.A. and Barrett, C.A., "Oxidation Screening at 1204C (2200F) of Candidate Alloys For the Space Shuttle Thermal Protection System", NASA TM X-67864, Lewis Research Center (July 1971)
6. Oldrieve, R.E. "Exploratory Screening Tests of Several Alloys and Coatings For Automobile Thermal Reactors", NASA TM X-67984, Lewis Research Center (Dec. 1971)
7. Blankenship, C.P. and Oldrieve, R.E. "Evaluation of Alloys and Coatings For Use In Automobile Thermal Reactors", NASA TN D-7699, Lewis Research Center (July 1974)
8. Michels, H.T., "Corrosion Performance of Heat-Resisting Alloys in Automobile Exhausts", Metals Engineering Quarterly (August 1974)
9. "Nickel and High-Nickel Alloys", The International Nickel Co. Inc.
10. "Huntington Alloys Handbook", The International Nickel Co. Inc. (1970)