

## Technical Information

# HASTELLOY® N alloy

HASTELLOY® N alloy is a nickel-base alloy that was invented at Oak Ridge National Laboratories as a container material for molten fluoride salts. It has good oxidation resistance to hot fluoride salts in the temperature range of 1300 to 1600°F (704 to 871°C).

In tests of over two years duration, corrosion attack on HASTELLOY N alloy in molten fluoride salts at temperatures up to 1300°F (704°C), was less than one mil per year. It is expected that alloy N will be most useful in environments involving fluorides at high temperatures; however, the alloy compares favorably with other HASTELLOY alloys in various corrosive media, as shown in the table of penetration rates. Corrosion test samples of the alloy are available from any of the locations listed on the back cover of this technical information. It is especially suggested that the alloy be tested in molten halides of zirconium, beryllium, lithium, sodium, potassium, thorium or uranium.

HASTELLOY N alloy has good oxidation resistance in air. It shows promise for continuous operations at temperatures up to 1800°F (982°C). Intermittent use at temperatures up to 1900°F (1038°C) may also be possible. No discernible oxidation could be measured for the alloy at temperatures up to 1200°F (649°C).

Metallographic examinations have shown that the elements in alloy N remain in solid solution in the 1100 to 1600°F (593 to 871°C) range. Tensile tests have indicated no tendency toward embrittlement for prolonged periods at 1500°F (816°C). Alloy N has good weldability and can be readily forged. The hot working range is between 1600 and 2150°F (871 to 1177°C). It has been successfully extruded and further processed into high-quality seamless or manufactured as welded and drawn tubing.

Solution heat-treatment is recommended after hot or cold working of HASTELLOY N alloy parts. For sheet and plate, this is accomplished by soaking at 2150°F (1177°C) [sections up to 1/4 inch thick] and then cooling rapidly in air, or at 2165°F (1185°C) [sections 1/4 inch and thicker] followed by water-quenching.

HASTELLOY N alloy can be supplied, to order, in the forms of sheet, plate, and bar.

HASTELLOY N alloy sheet, plate, bar, rod, and welded and seamless wrought pipe and tubing have been approved for use in the construction of unfired pressure vessels in accordance with the requirements of the ASME Boiler and Pressure Vessel Code Section VIII under Case 1315 (Special Ruling). Alloy N is approved for use at temperatures up to 1300°F (704°C). Design data can be found on page 11.

The properties data listed are typical or average values and should not be interpreted as guaranteed values except where so stated.

## NOMINAL CHEMICAL COMPOSITION, WEIGHT PERCENT

Nickel <sup>a</sup>	Chromium	Molybdenum	Iron	Silicon	Manganese	Carbon	Others
71	7	16	5*	1*	0.80*	0.08*	Co=0.20* Cu=0.35* W=0.50* Al+Ti=0.35*

\* Maximum    <sup>a</sup> As balance

## AVERAGE PHYSICAL PROPERTIES

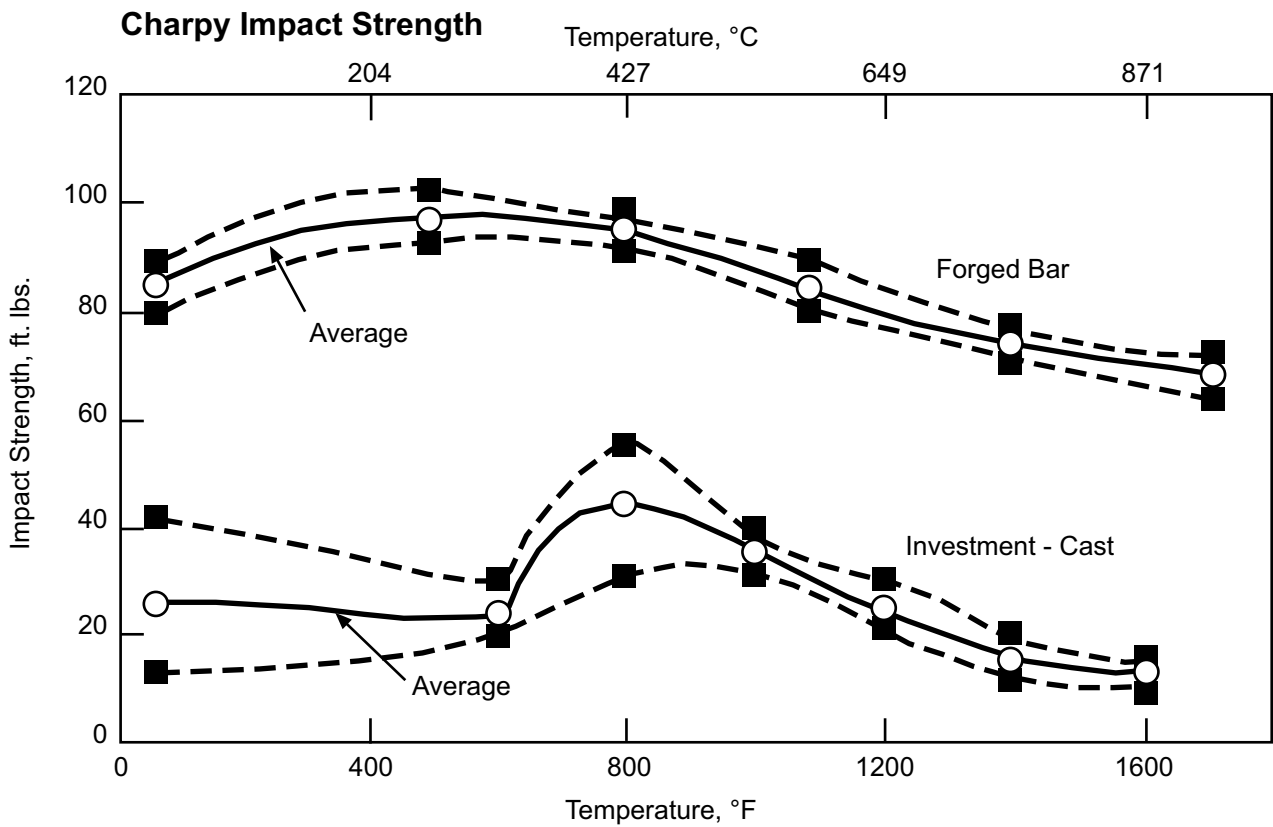
Physical Property	Temp., °F	British Units	Temp., °C	Metric Units
Density	72	0.320 lb./in. <sup>3</sup>	22	8.86 g/cm <sup>3</sup>
Melting Range	2375-2550		1300-1400	
Electrical Resistivity	Room 1300 1500	47.5 microhm-in. 49.6 microhm-in. 48.8 microhm-in.	Room 705 815	1.20 microhm-m 1.26 microhm-m 1.24 microhm-m
Mean Coefficient of Thermal Expansion	70-400 70-600 70-800 70-1000 70-1200 70-1400 70-1600 70-1800	6.4 microinches/in.-°F 6.7 microinches/in.-°F 7.0 microinches/in.-°F 7.4 microinches/in.-°F 7.8 microinches/in.-°F 8.1 microinches/in.-°F 8.5 microinches/in.-°F 8.8 microinches/in.-°F	21-204 21-316 21-427 21-538 21-649 21-760 21-871 21-982	11.6 x 10 <sup>-6</sup> m/m-K 12.3 x 10 <sup>-6</sup> m/m-K 12.7 x 10 <sup>-6</sup> m/m-K 13.4 x 10 <sup>-6</sup> m/m-K 14.0 x 10 <sup>-6</sup> m/m-K 14.7 x 10 <sup>-6</sup> m/m-K 15.3 x 10 <sup>-6</sup> m/m-K 15.8 x 10 <sup>-6</sup> m/m-K
Thermal Conductivity	212 392 572 752 932 1112 1292	79 Btu-in./ft. <sup>2</sup> -hr.-°F 88 Btu-in./ft. <sup>2</sup> -hr.-°F 99 Btu-in./ft. <sup>2</sup> -hr.-°F 109 Btu-in./ft. <sup>2</sup> -hr.-°F 124 Btu-in./ft. <sup>2</sup> -hr.-°F 140 Btu-in./ft. <sup>2</sup> -hr.-°F 162 Btu-in./ft. <sup>2</sup> -hr.-°F	100 200 300 400 500 600 700	11.5 W/m-K 13.1 W/m-K 14.4 W/m-K 16.5 W/m-K 18.0 W/m-K 20.3 W/m-K 23.6 W/m-K
Specific Heat	212 392 572 752 896 1004 1058 1094 1148 1220 1256 1292	0.100 Btu/lb.-°F 0.105 Btu/lb.-°F 0.109 Btu/lb.-°F 0.112 Btu/lb.-°F 0.114 Btu/lb.-°F 0.116 Btu/lb.-°F 0.125 Btu/lb.-°F 0.135 Btu/lb.-°F 0.140 Btu/lb.-°F 0.139 Btu/lb.-°F 0.138 Btu/lb.-°F 0.138 Btu/lb.-°F	100 200 300 400 480 540 570 590 620 660 680 700	419 J/Kg-K 440 J/Kg-K 456 J/Kg-K 469 J/Kg-K 477 J/Kg-K 485 J/Kg-K 523 J/Kg-K 565 J/Kg-K 586 J/Kg-K 582 J/Kg-K 578 J/Kg-K 578 J/Kg-K

<b>FORMABILITY</b>				
<b>Form</b>	<b>Condition</b>	<b>Erichsen Cup Depth, mm.</b>		
Sheet, 0.063 inch thick	Heat-treated for 8 minutes at 2150°F (1177°C), RAC	13.4		
<b>OXIDATION RESISTANCE</b>				
<b>Temperature, °F (°C)</b>	<b>Weight gain*, mg./cm<sup>2</sup></b>		<b>Shape of Rate Curve</b>	
	<b>100 hours</b>	<b>1000 hours</b>		
1200 (649)	0.00	0.00	Cubic or Logarithmic	
1600 (871)	0.25	0.67**	Cubic	
1800 (982)	0.48	1.5**	Parabolic	
1900 (1038)	0.52	2.0**	Parabolic	
2000 (1093)	2.70	28.2**	Linear	
* 3.7mg./cm <sup>2</sup> =0.001 inch of oxidation ** Extrapolated from data obtained after 170 hours at temperature				
<b>AVERAGE DYNAMIC MODULUS OF ELASTICITY</b>				
<b>Form</b>	<b>Condition</b>	<b>Test Temperature, °F</b>	<b>Dynamic Modulus of Elasticity, psi x 10<sup>6</sup></b>	
Sheet	Heat-treated at 2150°F (1177°C), RAC	57	31.7	
		430	29.3	
		770	27.8	
		930	27.1	
		1070	26.3	
		1170	26.2	
		1290	24.8	
		1470	23.7	
		1570	22.7	
		1660	21.9	
		1750	20.7	
		1830	19.7	
1920	17.7			
<b>AVERAGE ROOM TEMPERATURE HARDNESS</b>				
<b>Form</b>	<b>Condition</b>	<b>Aging</b>		<b>Hardness, Rockwell-B</b>
		<b>Temp., °F</b>	<b>Time, hrs.</b>	
Sheet, 0.063 inch thick	Heat-treated at 2150°F (1177°C), RAC	-	-	96
		1500	4	92
		1500	8	97
		1500	16	96
		1500	32	97
		1500	64	99
		1500	128	96

RAC - Rapid Air Cooled

# AVERAGE IMPACT STRENGTH

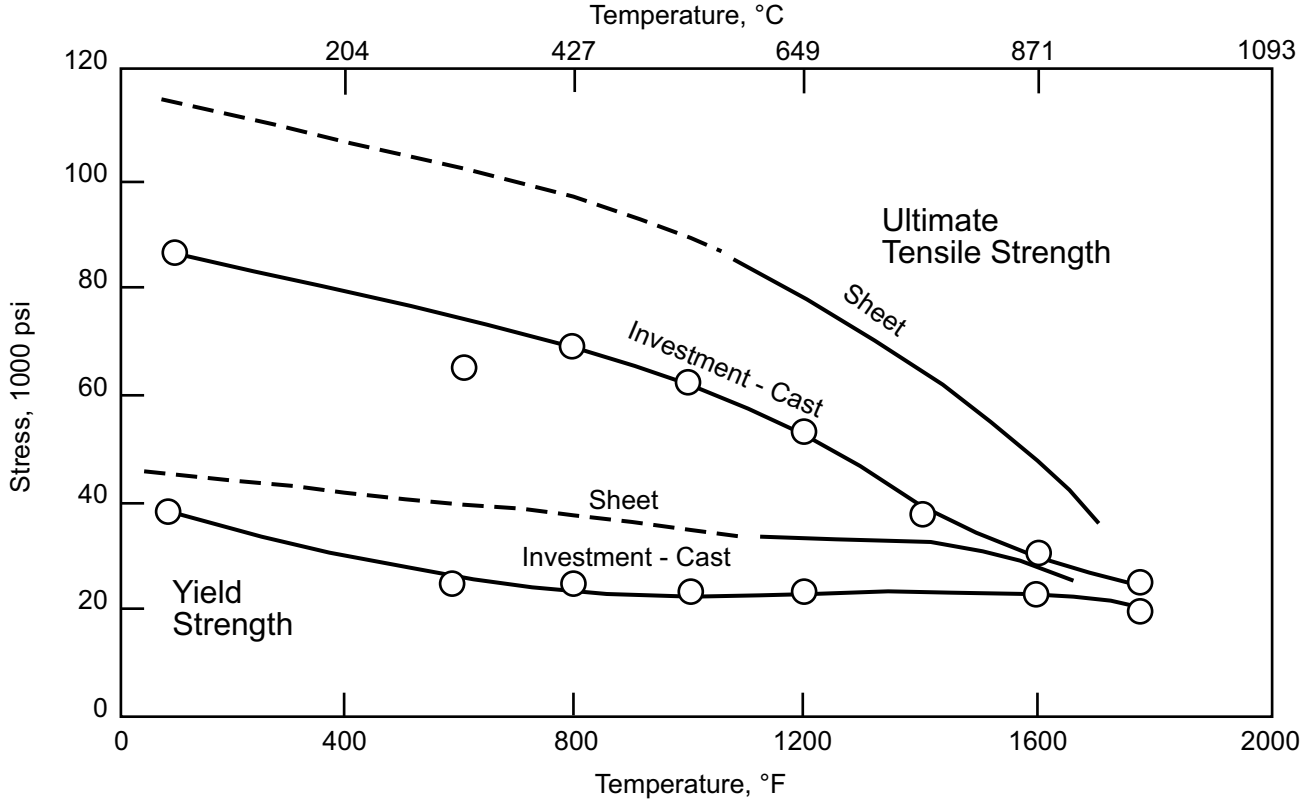
Form	Condition	Test Temp., °F (°C)	Charpy V-Notch Impact Strength	
			Range, ft.-lb.	Mean Value, ft.-lb
Bar, forged, 1/2-inch diameter	Heat-treated for 30 minutes at 2150°F (1177°C), RAC	Room	80-88	85.0
		500 (260)	94-102	97.4
		800 (427)	94-96	94.8
		1100 (593)	80-90	83.4
		1400 (760)	73-76	74.8
		1700 (927)	63-72	68.6



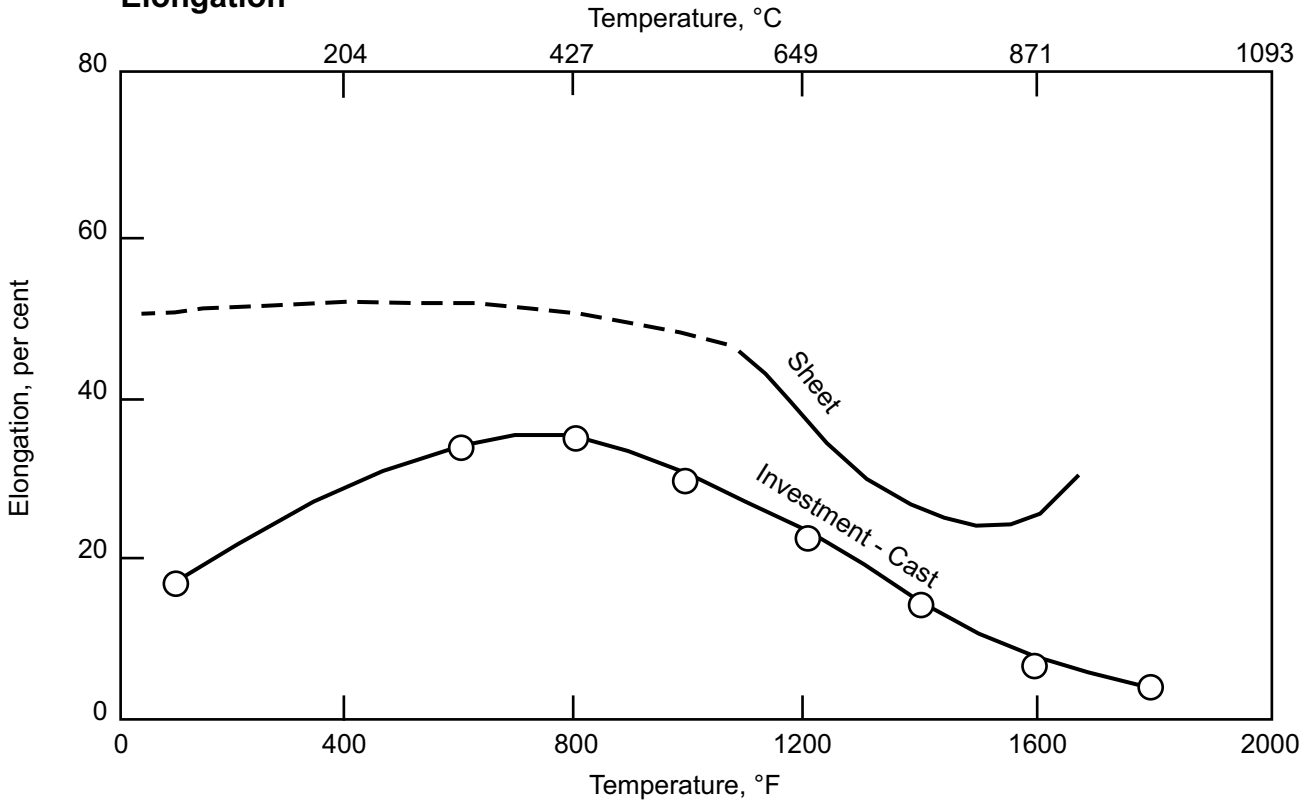
SHORT-TIME TENSILE DATA							
Form	Condition	Aging		Test Temp., °F (°C)	Ultimate Tensile Strength, psi	Yield Strength at 0.2% offset, psi	Elongation in 2 in., %
		Temp., °F (°C)	Time hrs.				
Sheet, 0.063-inch thick	Heat-treated at 2150°F (1177°C), RAC	-	-	Room	115,100	45,500	50.7
		-	-	1100 (593)	86,900	32,900	45.3
		-	-	1300 (764)	69,600	31,600	30.0
		-	-	1500 (816)	55,900	29,500	24.3
		-	-	1700 (927)	34,000	25,900	30.0
		1500	128	Room	115,400	49,300	46.8
	Heat-treated at 2150°F (1177°C), then welded and tested as-welded <sup>2</sup>	-	-	Room	116,100	-	37.5
		-	-	1200 (649)	71,500	-	17.0
		-	-	1300 (704)	63,500	-	10.5
-		-	1500 (816)	52,000	-	8.5	
Sheet, 0.045-inch thick	Heat-treated at 2100°F (1177°C), RAC	-	-	Room	114,400	44,700	50
		-	-	1000 (538)	93,000	28,300	46
		-	-	1100 (593)	93,000	28,900	50
		-	-	1200 (648)	82,400	27,500	37
		-	-	1300 (704)	69,900	28,000	24
		-	-	1400 (760)	61,800	26,200	21
		1000 1100 1200 1300 1400	10,000	Room	117,700	45,100	50
				Room	120,000	47,500	49
				Room	116,000	46,800	46
				Room	115,500	45,800	46
				Room	115,000	43,600	40
		1000 1100 1200 1300 1400	10,000	1000 (538)	97,700	-	46
				1100 (593)	90,500	-	40
				1200 (649)	81,900	-	32
			1300 (704)	76,100	-	24	
			1400 (760)	65,100	-	20	
Weld Metal	As-Welded	-	-	Room	116,100	-	39.3*
		-	-	1200 (649)	73,600	-	18.1*
		1200	500	Room	116,800	-	38.6*
			1200 (649)	82,700	-	26.5*	

\* Elongation in one inch

### Ultimate Tensile and 0.2 per cent Offset Yield Strength



### Elongation



Sheet-0.063 inch thick, heat-treated at 2150°F (1177°C), RAC

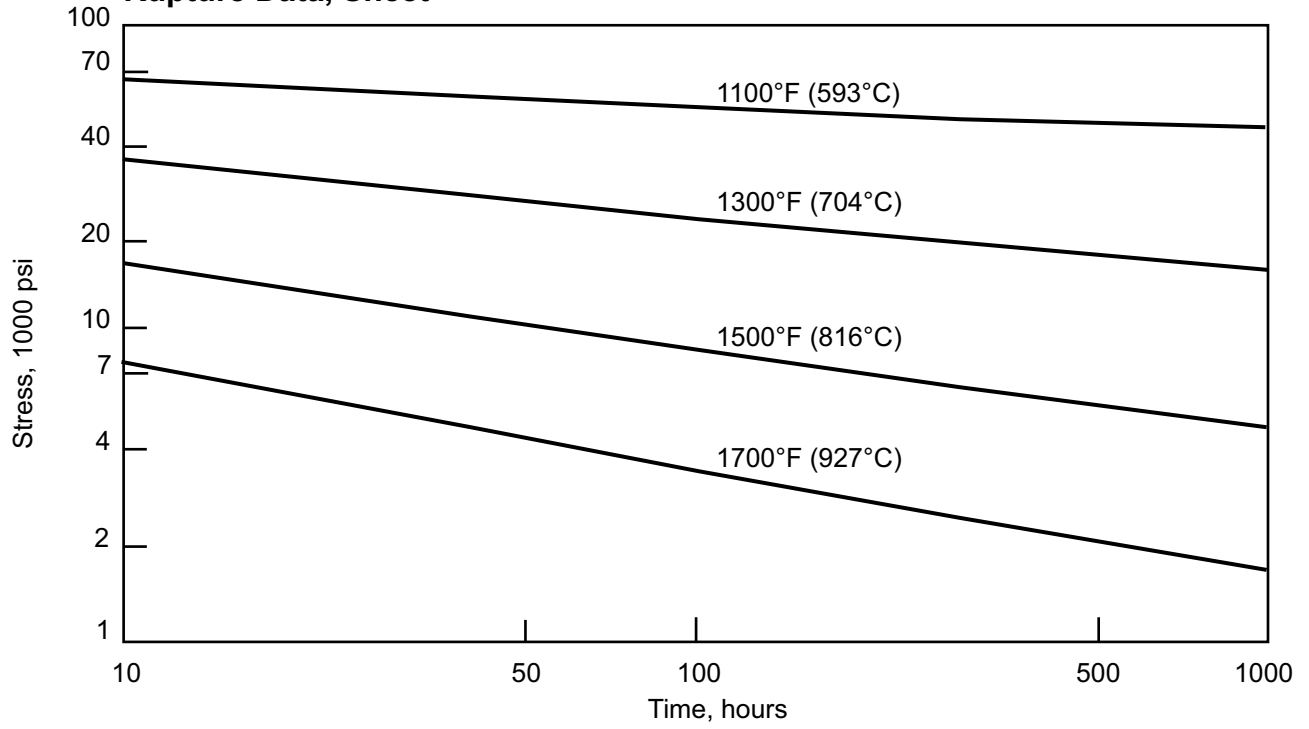
Investment-Cast - 0.250 inch bars, heat-treated at 2150°F (1177°C) for 30 minutes, RAC

<b>AVERAGE RUPTURE DATA</b>					
<b>Form</b>	<b>Test Temp., °F (°C)</b>	<b>Stress, psi</b>	<b>Life, hrs.</b>	<b>Elongation, per cent</b>	<b>Reduction of Area, per cent</b>
Sheet*	1100 (593)	80,000	0.4	44.0	31.6
		60,000	38.9	21.0	19.4
		55,000	87.7	17.4	16.9
	1300 (704)	35,000	18.6	11.8	11.0
		25,000	129.6	26.5	10.3
		20,000	338.6	12.6	9.0
	1500 (816)	15,000	19.0	15.4	9.6
		10,000	78.6	13.8	9.5
		8,000	172.2	18.4	10.1
	1700 (927)	6,000	24.3	21.0	21.4
		4,000	75.5	19.3	11.5
		3,000	219.6	28.0	11.5

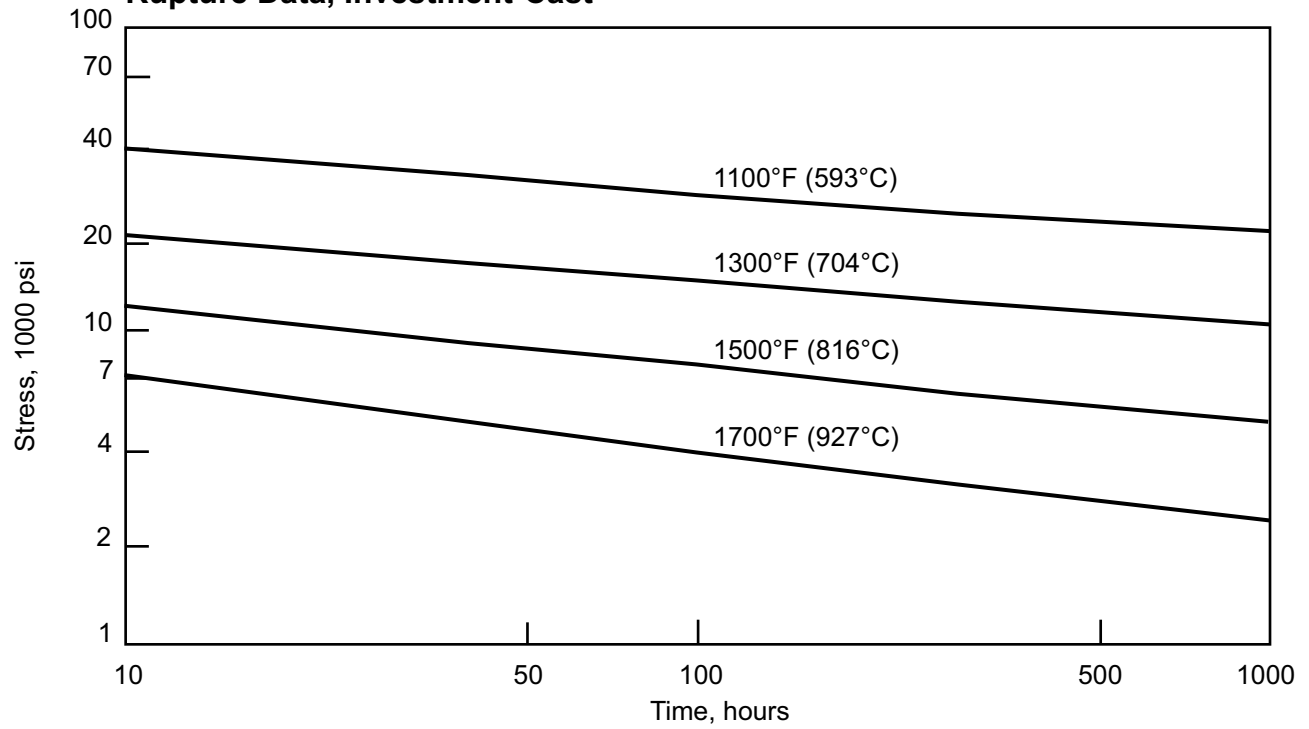
<b>AVERAGE RUPTURE DATA, WELD METAL</b>							
<b>Test Temp., °F (°C)</b>	<b>Stress, psi</b>	<b>Average Rupture Time, Hrs.</b>			<b>Average Elongation, per cent</b>		
		<b>As- Welded</b>	<b>Stress-relieved<sup>1</sup></b>		<b>As- Welded</b>	<b>Stress-relieved<sup>1</sup></b>	
			<b>Hydrogen</b>	<b>Argon</b>		<b>Hydrogen</b>	<b>Argon</b>
1100 (593)	74,000	1.3	1.7	-	14.1	13.0	-
	54,000	197.8	188.3	-	2.5	8.2	-
	49,000	308.4	570.5	-	2.2	5.3	-
1300 (704)	45,000	3.7	6.4	5.5	3.9	8.2	5.4
	24,000	158.4	337.8	185.4	3.7	8.8	7.4
	20,000	472.3	936.7	4522.0	4.6	10.8	3.7
1500 (816)	22,000	12.7	12.1	-	16.9	20.9	-
	13,000	172.1	117.5	-	14.4	9.8	-
	10,000	446.9	314.5	-	8.3	8.1	-

<sup>1</sup>Stress-relieved at 1600°F for 2 hrs. in atmosphere specified

### Rupture Data, Sheet\*



### Rupture Data, Investment-Cast\*\*



\* Plotted by best line method from limited data

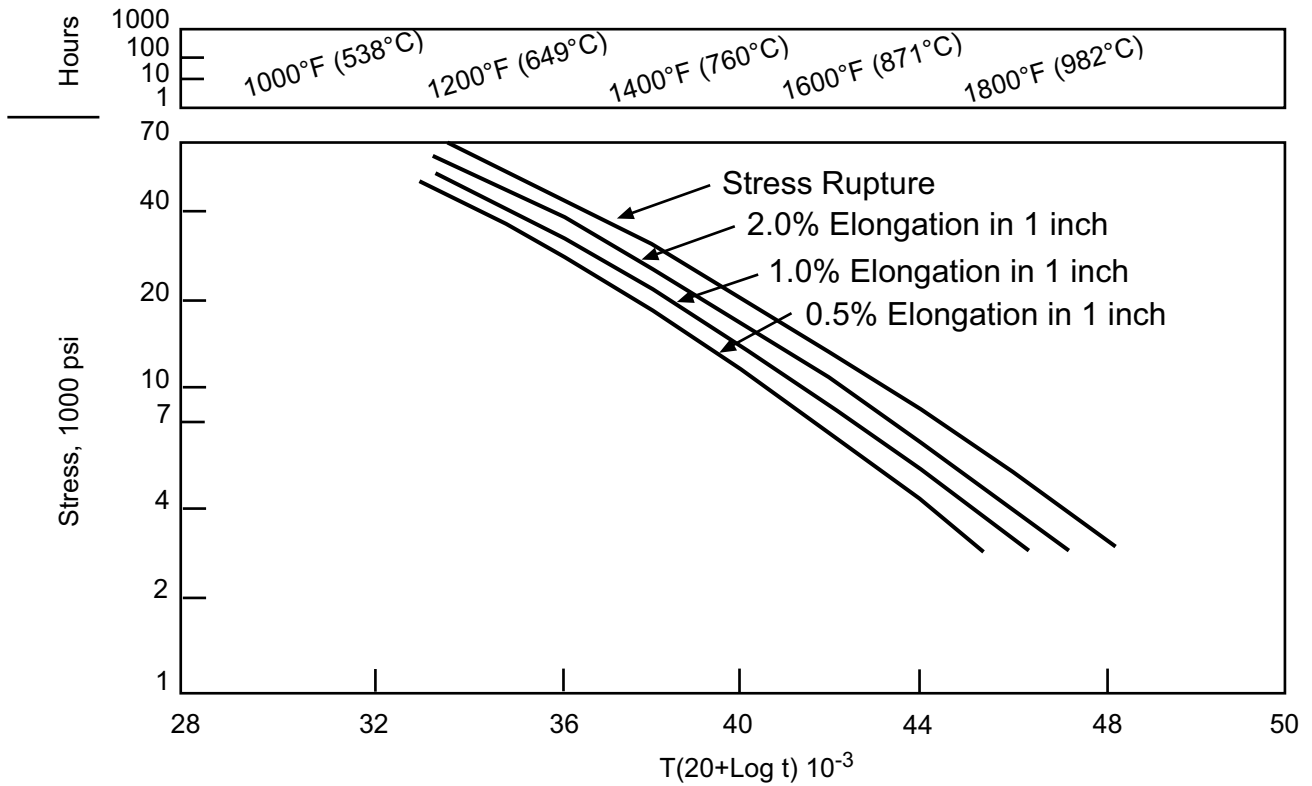
\*\* Plotted from Larson-Miller plot of the limited data on the preceding page



TOTAL ELONGATION, 0.063 - in. SHEET															
Test Temp., °F (°C)	Stress, psi	Life, hrs.	Time, hours, for elongation of:												
			0.1 %	0.2 %	0.3 %	0.4 %	0.5 %	0.75 %	1.0 %	1.5 %	2.0 %	3.0 %	4.0 %	5.0 %	
1300 (704)	20,000	285.5	0.29	15.0	26.9	33.7	40.5	57.0	70.5	96.8	121.7	168.7	209.5	245.5	
	20,000	277.4	20.2	52.4	58.9	65.4	72.0	87.8	103.4	133.0	160.0	207.1	219.4	-	
	20,000	462.9	0.86	16.2	29.4	46.6	50.2	62.0	73.7	96.7	141.7	225.5	326.9	369.9	
	20,000	328.6	1.1	7.3	15.3	23.1	30.7	50.0	64.8	94.0	123.0	178.2	223.9	265.5	
	25,000	109.6	-	0.14	1.14	2.43	5.14	7.74	10.3	15.4	20.6	41.2	60.6	78.6	
	25,000	165.9	-	3.9	12.8	20.2	26.5	37.4	47.9	64.7	80.3	109.8	133.8	-	
	25,000	116.9	-	1.9	5.63	9.5	13.2	22.8	28.5	37.4	46.4	63.1	78.6	91.9	
	25,000	125.8	-	6.6	10.9	15.2	19.6	30.3	36.0	47.0	57.2	82.4	116.3	-	
	35,000	19.0	-	-	-	-	-	-	-	0.62	4.78	-	-	-	
	35,000	16.9	-	-	-	-	-	-	0.38	3.7	-	-	-	-	
	35,000	23.3	-	-	-	-	-	-	-	3.0	5.9	-	-	-	
	35,000	15.1	-	-	-	-	-	-	-	-	1.4	4.4	-	-	
	1500 (816)	8,000	157.7	2.34	7.31	11.6	16.0	20.4	29.7	37.7	53.4	69.4	95.4	116.8	132.4
		8,000	136.8	0.9	4.4	7.8	11.5	15.2	24.4	30.7	43.0	55.8	78.9	97.3	110.7
		8,000	210.0	0.75	3.7	7.0	10.6	14.2	23.5	31.1	46.1	59.2	89.5	114.4	136.2
		8,000	184.6	0.75	4.0	8.1	12.9	17.8	28.5	37.5	55.3	73.3	103.2	128.6	145.1
10,000		80.2	0.67	3.8	7.0	8.4	9.4	13.3	16.8	23.8	28.3	38.4	47.3	56.8	
10,000		64.3	1.3	3.3	5.0	6.47	7.8	11.2	-	-	-	-	-	-	
10,000		86.5	1.58	4.17	6.5	9.3	10.4	15.3	20.2	28.8	36.6	51.6	62.5	73.5	
10,000		83.4	1.17	3.7	6.0	8.0	9.7	14.1	18.5	25.9	32.0	44.1	56.2	68.2	
15,000		19.8	0.15	0.73	1.02	1.55	1.94	2.9	3.85	5.76	-	-	-	-	
15,000		19.7	0.27	1.1	1.84	2.21	2.45	3.15	3.82	-	-	-	-	-	
15,000		20.9	-	-	0.2	0.48	0.76	1.53	2.32	3.9	5.5	-	-	-	
15,000		15.5	-	0.54	1.06	1.32	1.57	2.27	2.95	4.3	5.7	-	-	-	
1700 (927)		3,000	297.7	1.67	7.5	13.1	18.7	24.3	38.7	53.0	78.4	97.8	130.1	155.2	176.0
		3,000	155.6	2.3	5.3	7.9	10.3	13.1	19.8	26.5	39.7	53.0	76.6	93.2	106.8
		3,000	237.5	2.14	5.54	8.8	11.7	14.6	22.0	29.4	44.0	58.7	83.4	102.9	119.0
		3,000	187.5	1.72	4.41	6.97	9.9	12.9	20.4	28.0	42.9	58.0	85.4	103.9	118.3
	4,000	69.0	0.18	0.55	0.9	1.25	1.6	3.67	6.53	12.1	17.8	28.6	-	-	
	4,000	62.7	0.25	0.88	1.47	2.11	3.66	7.21	10.2	15.9	21.7	-	-	-	
	4,000	87.0	1.54	3.85	6.0	7.8	9.1	14.4	18.9	28.0	34.8	48.2	58.6	66.8	
	4,000	83.1	0.6	2.47	5.1	7.51	8.95	12.6	16.6	23.6	-	-	-	-	
	6,000	23.4	0.26	0.7	1.1	1.5	1.9	2.8	3.67	5.23	6.25	8.3	10.3	12.3	
	6,000	22.5	0.12	0.5	0.81	1.13	1.45	2.24	4.53	5.9	-	-	-	-	
	6,000	17.5	0.13	0.57	0.9	1.2	1.47	2.2	2.9	4.25	5.5	-	-	-	
	6,000	33.9	0.28	0.8	1.41	2.0	2.64	4.2	5.7	8.4	11.2	16.6	22.1	26.1	

\* Heat-Treated at 2150°F, RAC

### Larson-Miller Plot, Sheet\*\*



\*\* 0.063 inch thick, heat-treated at 2150°F, RAC

### AVERAGE FATIGUE DATA (Rotating)

Form	Condition	Test Temp., °F	Stress (psi) for Failure in $10^8$ Cycles
Sheet	Heat-treated at 2150°F (1177°C), RAC	1100	47,500
		1300	38,000
		1500	23,000

COMPARATIVE AQUEOUS CORROSION DATA						
Media	Concentration % by weight	Temp., °F (°C)	Corrosion Rates (mpy) HASTELLOY Alloy			
			N	B-2	C-22®	W
Hydrochloric Acid	2	Room	1	< 1	< 1	10
	2	150 (66)	18	11	< 1	
	2	Boiling	73	3	61	
	5	Room	1	< 1	< 1	14
	5	150 (66)	20	9	17	
	15	Room	3	2	< 1	
	25	Room	2	1	2	
	37	Room	< 1	< 1	2	
Sulfuric Acid	5	Room	1	<1	< 1	3
	5	150 (66)	11	6	< 1	
	5	Boiling	11	3	9	
	25	Room	1	< 1	< 1	3
	25	150 (66)	10	5	< 1	
	50	Room	< 1	< 1	< 1	
	80	Room	< 1	< 1	< 1	
	96	Room	< 1	< 1	< 1	
Ferric Chloride	2	Room	1	138	< 1	158
Phosphoric Acid	10	Room	< 1	< 1	< 1	14
	10	150 (66)	1	3	< 1	
	10	Boiling	6	1	< 1	
	30	Room	1	< 1	< 1	
	30	150 (66)	1	2	< 1	
	50	Room	< 1	< 1	< 1	
	85	Room	< 1	< 1	< 1	
Hydrofluoric Acid	5	Room	2	< 1	< 1	1
	5	175 (79)	20	11	15	3
	25	Room	3	5	5	
	45	Room	5	3	6	
	48	175 (79)	31	25	27	
Acetic Acid	10	Room	1	< 1	< 1	2
	10	150 (66)	3	< 1	< 1	
	10	Boiling	1	< 1	< 1	
	50	Room	1	< 1	< 1	2
	50	150 (66)	3	< 1	< 1	
	50	Boiling	2	< 1	< 1	
	99	Room	< 1	< 1	< 1	
	99	150 (66)	< 1	< 1	< 1	
	99	Boiling	< 1	< 1	< 1	< 1

BOILER CODE DESIGN DATA		
Metal Temperature Not Exceeding °F (°C)	Maximum Allowable Stress Values, psi All Material Other Than Boiling	Boiling
100 (38)	25,000	10,000
200 (93)	24,000	9,300
300 (149)	23,000	8,600
400 (204)	21,000	8,000
500 (260)	20,000	7,700
600 (316)	20,000	7,500
700 (371)	19,000	7,200
800 (427)	18,000	7,000
900 (482)	18,000	6,800
1000 (538)	17,000	6,600
1100 (593)	13,000	6,000
1200 (649)	6,000	3,500
1300 (704)	3,500	1,600

# STANDARD PRODUCTS

By Brand or Alloy Designation:

# HAYNES

International

## HASTELLOY® Family of Corrosion-Resistant Alloys

B-2, B-3®, C-4, C-22®, C-276, C-2000®, D-205™, G-3, G-30®, G-50®, and N

## HASTELLOY Family of Heat-Resistant Alloys

S, W, and X

## HAYNES® Family of Heat-Resistant Alloys

25, R-41, 75, HR-120®, HR-160®, 188, 214™, 230®, 230-W™, 242™, 263, 556™, 617, 625, 65SQ®, 718, X-750, MULTIMET®, and Waspaloy

## Corrosion-Wear Resistant Alloy

ULTIMET®

## Wear-Resistant Alloy

6B

## HAYNES Titanium Alloy Tubular

Ti-3Al-2.5V

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### Standard Forms:

Bar, Billet, Plate, Sheet, Strip, Coils, Seamless or Welded Pipe & Tubing, Pipe Fittings, Flanges, Fittings, Welding Wire, and Coated Electrodes

### Properties Data:

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