HASTELLOY® N alloy

HASTELLOY® N alloy (UNS N10003) has good resistance to aging and embrittlement and good fabricability. It has excellent resistance to hot fluoride salts in the temperature range of 1300°F to 1600°F (705°C-870°C).

Principal Features

HASTELLOY® N alloy (UNS N10003) 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 Haynes International locations. 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 waterquenching.

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 here.

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

Nominal Composition

	Weight %

Nickel:	71 Balance
Chromium:	7
Molybdenum:	16
Iron:	4 max.
Silicon:	1 max.
Manganese:	0.8 max.
Vanadium:	0.5 max.
Carbon:	0.06
Cobalt:	0.2 max.
Copper:	0.35 max.
Tungsten:	0.5 max.
Aluminum + Titanium	0.5 max

Oxidation Resistance

Temperature		**Weight Gain*, mg./cm^2**		**Shape of Rate Curve**
°F	**°C**	**100 h**	**1000 h**	**-**
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^2=0.001 inch of oxidation

** Extrapolated from data obtained after 170 hours at temperature

Average Room Temperature Hardness

Form	**Condition**	**Aging**		**HRBW**
		°F	**h**	-
Sheet	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

HRB = Hardness Rockwell “B", Tungsten Indentor.

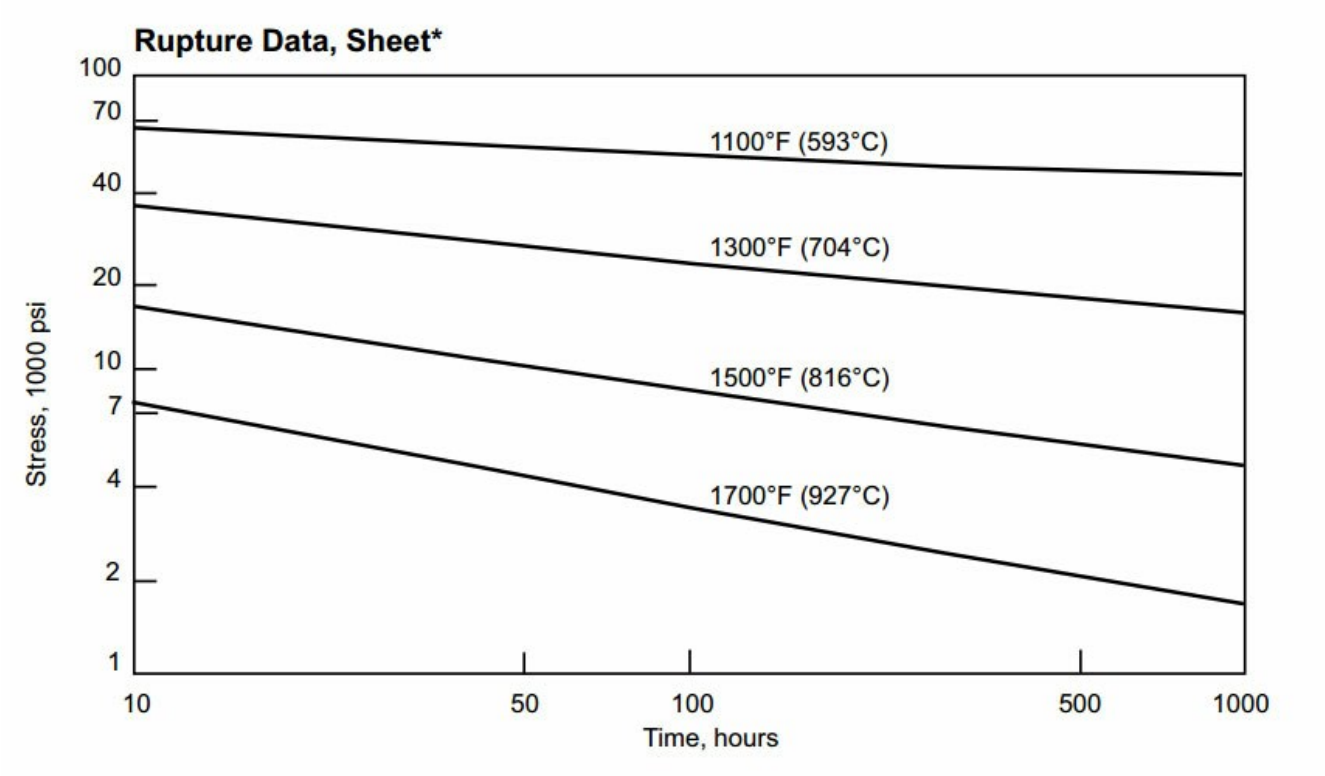
Average Stress-Rupture Data

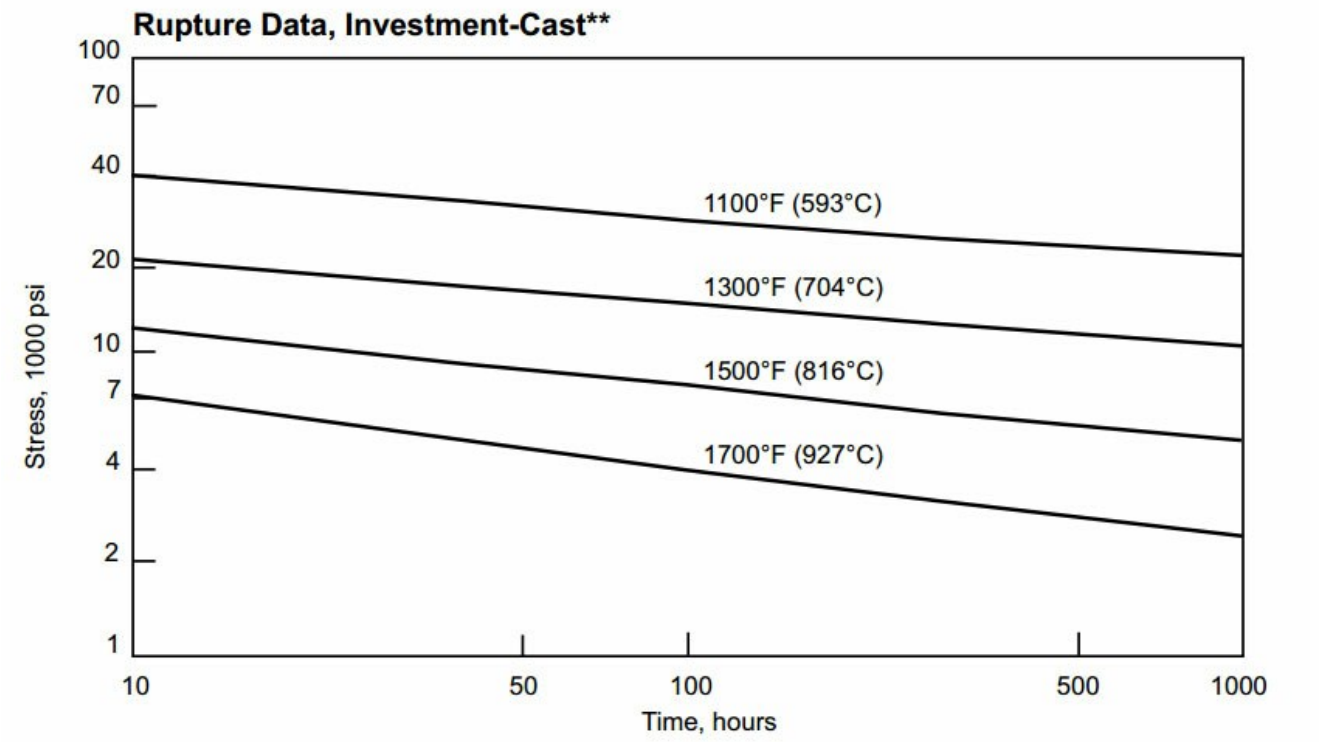
Form	Test Temperature		Stress	Life	Elongation	Reduction of Area
	°F	°C	psi	h	%	%
Sheet	1100	593	80,000	0.4	44.0	31.6
			60,000	38.9	21.0	19.4
			55,000	87.7	17.4	16.9
	1300	704	35,000	18.6	11.8	11.0
			25,000	129.6	26.5	10.3
			20,000	338.6	12.6	9.0
	1500	816	15,000	19.0	15.4	9.6
			10,000	78.6	13.8	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

Average Rupture Data, Weld Metal

Test Temperature		Stress	Average Rupture time, h			Average Elongation %	
°F	°C	psi	As Welded	Stress Relieved[1]		Stress Relieved[1]	
		-	-	Hydrogen	Argon	Hydrogen	Argon
1100	593	74,000	1.3	1.7	-	14.1	-
		54,000	197.8	188.3	-	2.5	-
		49,000	308.4	570.5	-	2.2	-
1300	704	45,000	3.7	6.4	5.5	3.9	5.4
		24,000	158.4	337.8	185.4	3.7	7.4
		20,000	472.3	936.7	4522.0	4.6	3.7
1500	816	22,000	12.7	12.1	-	16.9	-
		13,000	172.1	117.5	-	14.4	-
		10,000	446.9	314.5	-	8.3	-

[1]Stress-relieved at 1600°F for 2 hrs. in atmosphere specified





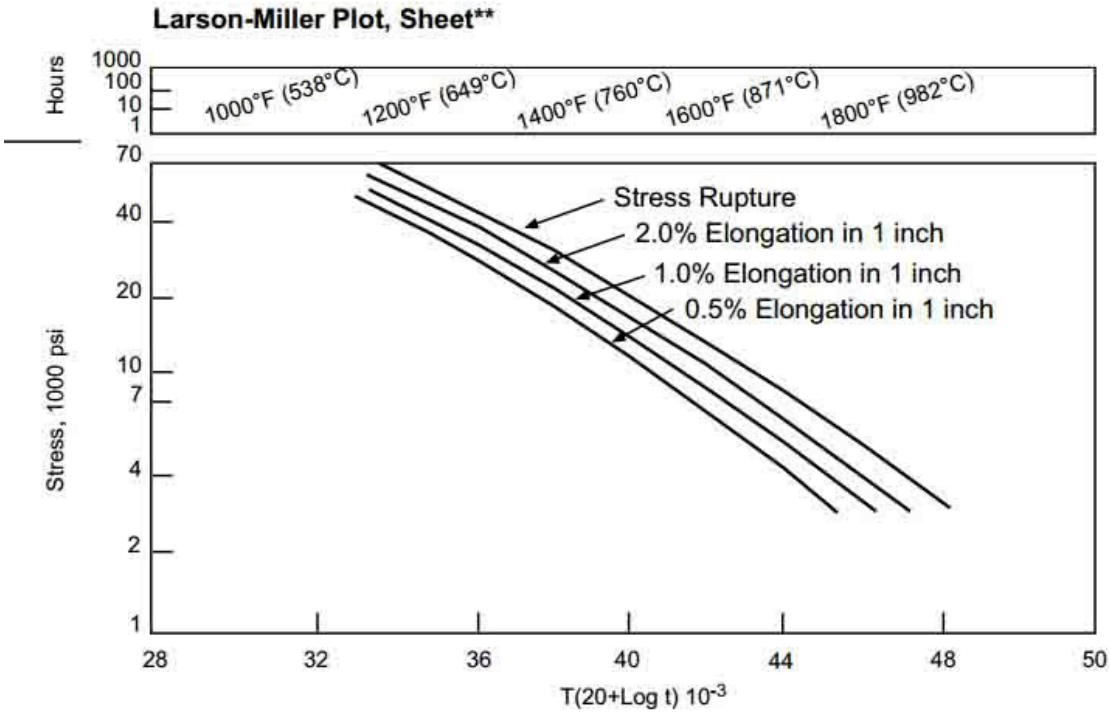
* Plotted by best line method from limited data

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

Total Elongation

0.063 - in. SHEET

Test Temperature		Stress	Life	Time, Hours, for Elongation of											
°F	°C	psi	h	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



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

Comparative Aqueous Corrosion Data (mm/y)

Chemical	Concentration	Temperature		Corrosion Rates (mpy)			
-	wt. %	°F	°C	N	B-2	C-22®	W
Hydrochloric Acid	2	RT	RT	**1**	< 1	< 1	-
	2	150	66	**18**	11	< 1	10
	2	Boiling	Boiling	**73**	3	61	-
	5	RT	RT	**1**	< 1	< 1	-
	5	150	66	**20**	9	17	14
	15	RT	RT	**3**	2	< 1	-
	25	RT	RT	**2**	1	2	-
	37	RT	RT	**< 1**	< 1	2	-
Sulfuric Acid	5	RT	RT	**1**	< 1	< 1	-
	5	150	66	**11**	6	< 1	3
	5	Boiling	Boiling	**11**	3	9	1
	25	RT	RT	**1**	< 1	< 1	-
	25	150	66	**10**	5	< 1	3
	50	RT	RT	**< 1**	< 1	< 1	-
	80	RT	RT	**< 1**	< 1	< 1	-
	96	RT	RT	**< 1**	< 1	< 1	-
Ferric Chloride	2	RT	RT	**1**	138	< 1	158
Phosphoric Acid	10	RT	RT	**< 1**	< 1	< 1	-
	10	150	66	**1**	3	< 1	-
	10	Boiling	Boiling	**6**	1	< 1	14
	30	RT	RT	**1**	< 1	< 1	-
	30	150	66	**1**	2	< 1	-
	50	RT	RT	**< 1**	< 1	< 1	-
	85	RT	RT	**< 1**	< 1	< 1	-
Hydrofluoric Acid	5	RT	RT	**2**	< 1	< 1	1
	5	175	79	**20**	11	15	-
	25	RT	RT	**3**	5	5	3
	45	RT	RT	**5**	3	6	3
	48	175	79	**31**	25	27	-
Acetic Acid	10	RT	RT	**1**	< 1	< 1	-
	10	150	66	**3**	< 1	< 1	2
	10	Boiling	Boiling	**1**	< 1	< 1	-
	50	RT	RT	**1**	< 1	< 1	-
	50	150	66	**3**	< 1	< 1	2
	50	Boiling	Boiling	**2**	< 1	< 1	-
	99	RT	RT	**< 1**	< 1	< 1	-
	99	150	66	**< 1**	< 1	< 1	< 1
	99	Boiling	Boiling	**< 1**	< 1	< 1	-

RT= Room Temperature

Average Fatigue Data

Rotating

Form	Condition	Test Temperature	Stress for Failure in 10^6 Cycles:
Sheet	Heat-treated at 2150°F (1177°C), RAC	1100 °F	47,500 psi
		1300 °F	38,000 psi
		1500 °F	23,000 psi

Boiler Code Design Data

Metal Temperature Not Exceeding		Maximum Allowable Stress Values, psi All Material Other Than Boiling	Boiling
°F	°C	-	-
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

Physical Properties

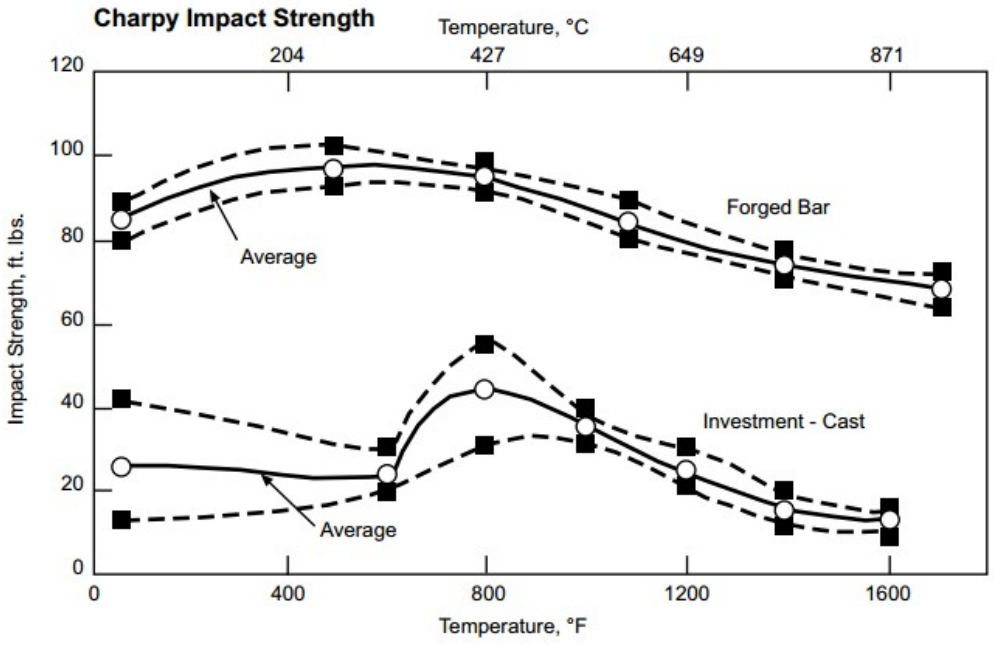
Physical Property	British Units		Metric Units	
Density	RT	0.320 lb./in.^{3}	RT	8.86 g/cm^3
Melting Range	2375-2550°F	-	1300-1400°C	-
Thermal Conductivity	400°F	89 Btu-in./ft.^{2}-hr.-°F	200°C	13.1 W/m-ºC
	600°F	101 Btu-in./ft.^{2}-hr.-°F	300°C	14.4 W/m-ºC
	800°F	114 Btu-in./ft.^{2}-hr.-°F	400°C	16.5 W/m-ºC
	1000°F	130 Btu-in./ft.^{2}-hr.-°F	500°C	18.0 W/m-ºC
	1200°F	151 Btu-in./ft.^{2}-hr.-°F	600°C	20.3 W/m-ºC
	1400°F	176 Btu-in./ft.^{2}-hr.-°F	700°C	23.6 W/m-ºC
Mean Coefficient of Thermal Expansion	70-400°F	6.9 µin/in.-°F	20-200°C	12.3 µm/m-°C
	70-600°F	7.3 µin/in.-°F	20-400°C	13.0 µm/m-°C
	70-800°F	7.4 µin/in.-°F	20-600°C	13.4 µm/m-°C
	70-1000°F	7.5 µin/in.-°F	20-700°C	13.8 µm/m-°C
	70-1200°F	7.9 µin/in.-°F	20-800°C	14.5 µm/m-°C
	70-1400°F	8.2 µin/in.-°F	20-900°C	14.9 µm/m-°C
Electrical Resistivity	70°F	47.5 µohm-in.	20°C	120.5 µohm-cm
	1300°F	49.6 µohm-in.	705°C	126.0 µohm-cm
	1500°F	48.8 µohm-in.	815°C	124.1 µohm-cm
Dynamic Modulus of Elasticity	70°F	31.7 x 10^6psi	20°C	219 GPa
	400°F	29.4 x 10^6psi	200°C	204 GPa
	800°F	27.7 x 10^6psi	400°C	192 GPa
	1000°F	26.7 x 10^6psi	600°C	181 GPa
	1200°F	25.8 x 10^6psi	700°C	171 GPa
	1400°F	24.1 x 10^6psi	800°C	163 GPa
	1600°F	22.4 x 10^6psi	900°C	151 GPa
	1800°F	20.1 x 10^6psi	1000°C	136 GPa

RT= Room Temperature

Impact Strength

Form	Condition	Test Temperature		Charpy V-Notch Impact Strength	
		°F	°C	Range ft.-lb.	Mean Value, ft.-lb.
Bar, forged, 1/2-inch diameter	Heat-treated for 30 minutes at 2150°F (1177°C), RAC	RT	RT	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

RT= Room Temperature



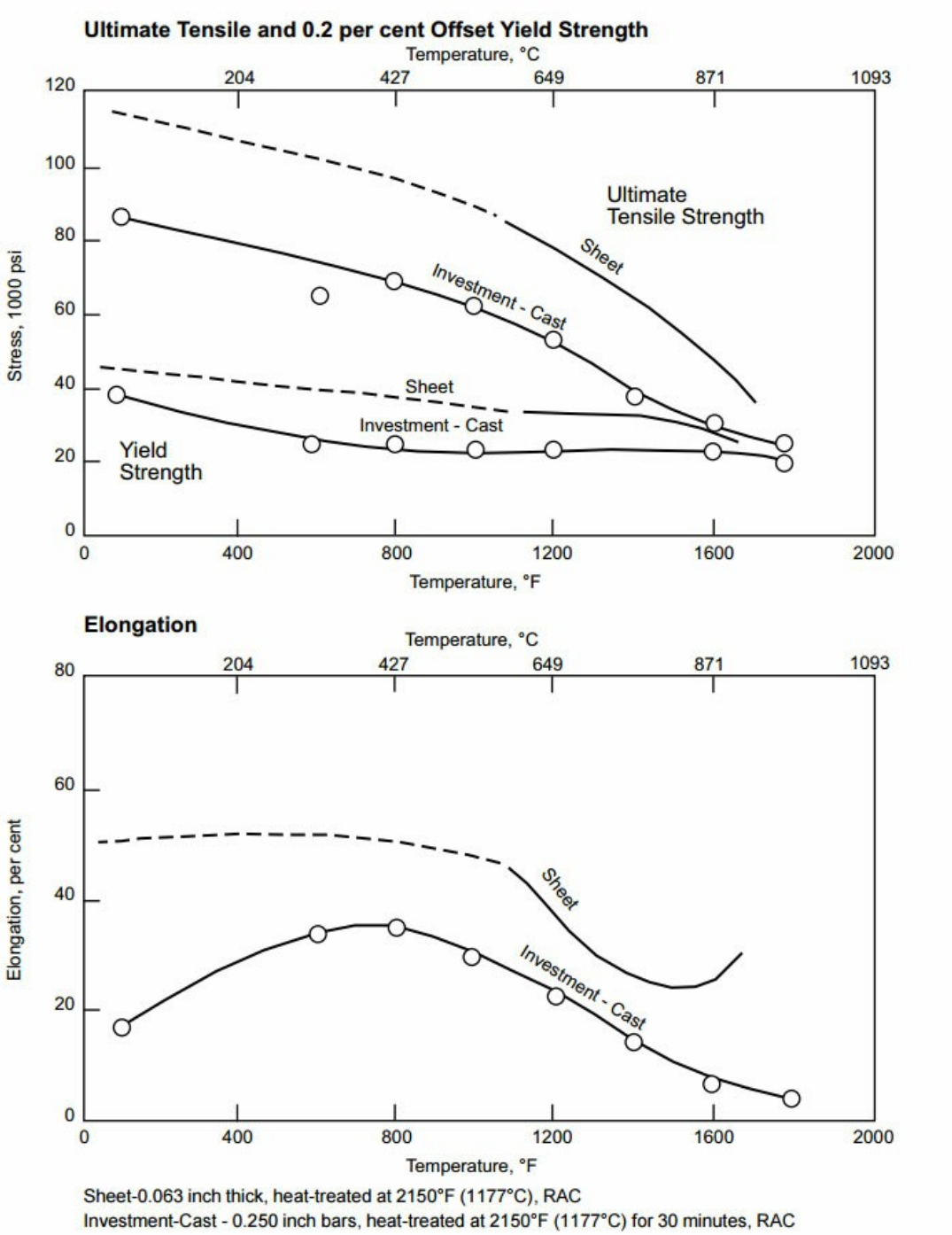
Tensile Data

Short-Time Tensile Data

Form	Condition	Aging			Test Temperature		0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
		°F	°C	Time, h	°F	°C	ksi	MPa	ksi	MPa	%
Sheet 0.063 in. thick	Heat-treated for at 2150°F (1177°C), RAC	-	-	-	RT	RT	45.5	314	115.1	794	50.7
		-	-	-	1100	593	32.9	227	86.9	599	45.3
		-	-	-	1300	706	31.6	218	69.6	480	30.0
		-	-	-	1500	816	29.5	203	55.9	385	24.3
		-	-	-	1700	927	25.9	179	34.0	234	30.0
	Aged	1500	816	128	RT	RT	49.3	340	115.4	796	46.8
	Heat-treated at 2150°F (1177°C), then welded andtested as-welded	-	-	-	RT	RT	-	-	116.1	800	37.5
		-	-	-	1200	649	-	-	71.5	493	17.0
		-	-	-	1300	704	-	-	63.5	438	10.5
		-	-	-	1500	816	-	-	52.0	359	8.5
Sheet 0.045 in. thick	Heat-treated at 2150°F (1177°C), then welded andtested as-welded, RAC	-	-	-	RT	RT	44.7	308	114.4	789	50.0
		-	-	-	1000	538	28.3	195	93.0	641	46.0
		-	-	-	1100	593	28.9	199	93.0	641	50.0
		-	-	-	1200	648	27.5	190	82.4	568	37.0
		-	-	-	1300	704	28.0	193	69.9	482	24.0
		-	-	-	1400	760	26.2	181	61.8	426	21.0
	Aged	1000	538	10,000	RT	RT	45.1	311	117.7	812	50.0
		1100	593	10,000	RT	RT	47.5	328	120.0	827	49.0
		1200	648	10,000	RT	RT	46.8	323	116.0	800	46.0
		1300	704	10,000	RT	RT	45.8	316	115.5	796	46.0
		1400	760	10,000	RT	RT	43.6	301	115.0	793	40.0
		1000	538	10,000	1000	538	-	-	97.7	674	46.0
		1100	593	10,000	1100	593	-	-	90.5	624	40.0
		1200	648	10,000	1200	649	-	-	81.9	565	32.0
		1300	704	10,000	1300	704	-	-	76.1	525	24.0
		1400	760	10,000	1400	760	-	-	65.1	449	20.0
Weld Metal	As Welded	-		-	RT	RT	-	-	116.1	800	39.3*
		-		-	1200	649	-	-	73.6	507	18.1*
	Aged	1200	648	500	RT	RT	-	-	116.8	805	38.6*
		1200	648	500	1200	649	-	-	82.7	570	26.5*

*Elongation in one inch

RT= Room Temperature



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

Formability

Form	Condition	Erichsen Cup Depth, mm.
Sheet, 0.063 inch thick	Heat-treated for 8 minutes at 2150°F (1177°C), RAC	13.4

Specifications & Codes

Specifications

Codes

HASTELLOY® N alloy (N10003)	
Sheet, Plate & Strip	AMS 5607 SB 434/B 434 P= 44
Billet, Rod & Bar	AMS 5771 SB 573/B 573 P= 44
Coated Electrodes	-
Bare Welding Rods & Wire	SFA 5.14/ A 5.14 (ERNiMo-2) F= 44
Seamless Pipe & Tube	-
Welded Pipe & Tube	-
Fittings	SB 366/B 366 P= 44
Forgings	AMS 5771
DIN	-
TÜV	-
Others	Mil-N24390B

HASTELLOY® N alloy (N10003)			
ASME	**Section I**	-	
	Section III	**Class 1**	-
		Class 2	-
		Class 3	-
	Section VIII	**Div. 1**	1300°F (704°C)[1]
		Div. 2	800°F (427°C)[1]
	Section XII	650°F (343°C)[1]	
	B16.5	1300°F (704°C)[2]	
	B16.34	1300°F (704°C)[2]	
	B31.1	-	
	B31.3	-	
VdTÜV (doc #)		-	

[1]Plate, Sheet, Bar
[2]Plate, Bar

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