HAYNES International HIGH-TEMPERATURE ALLOYS

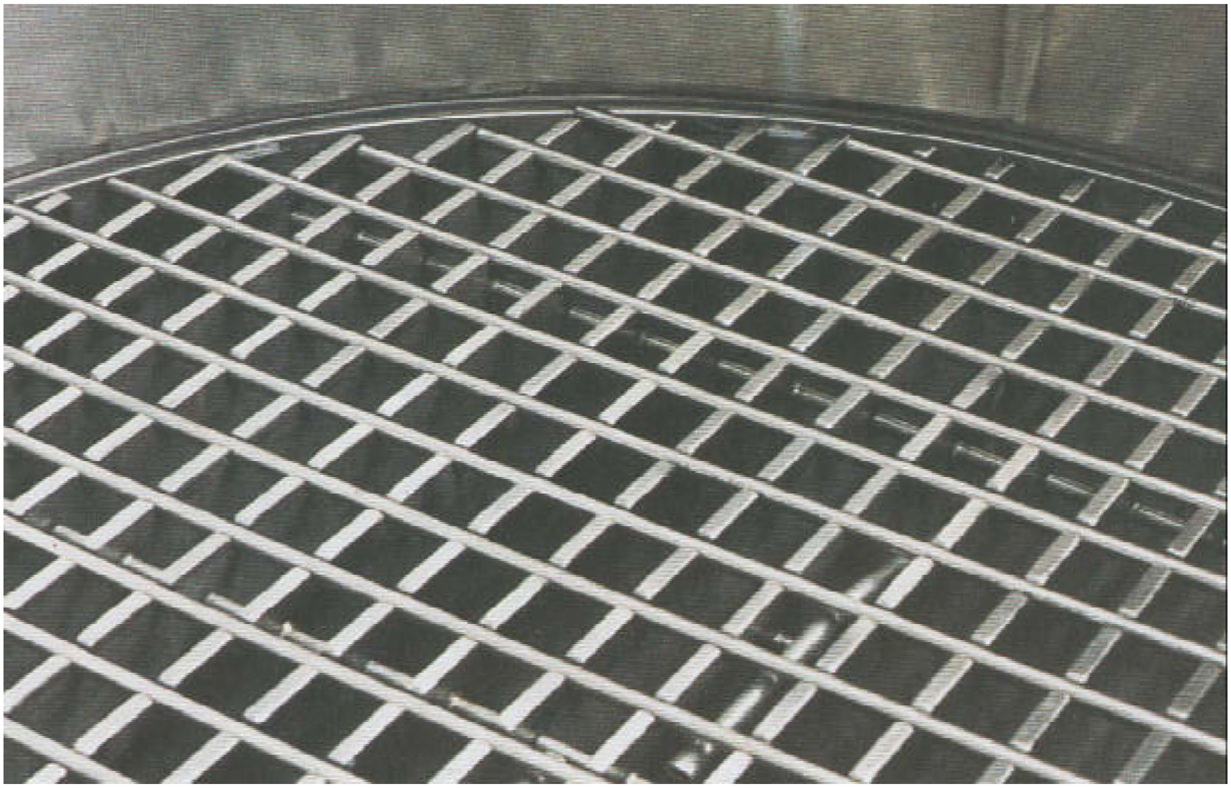
HAYNES® 230® ALLOY

A Ni-Cr-W-Mo alloy that combines excellent high-temperature strength and oxidation resistance with superior long term stability and good fabricability.

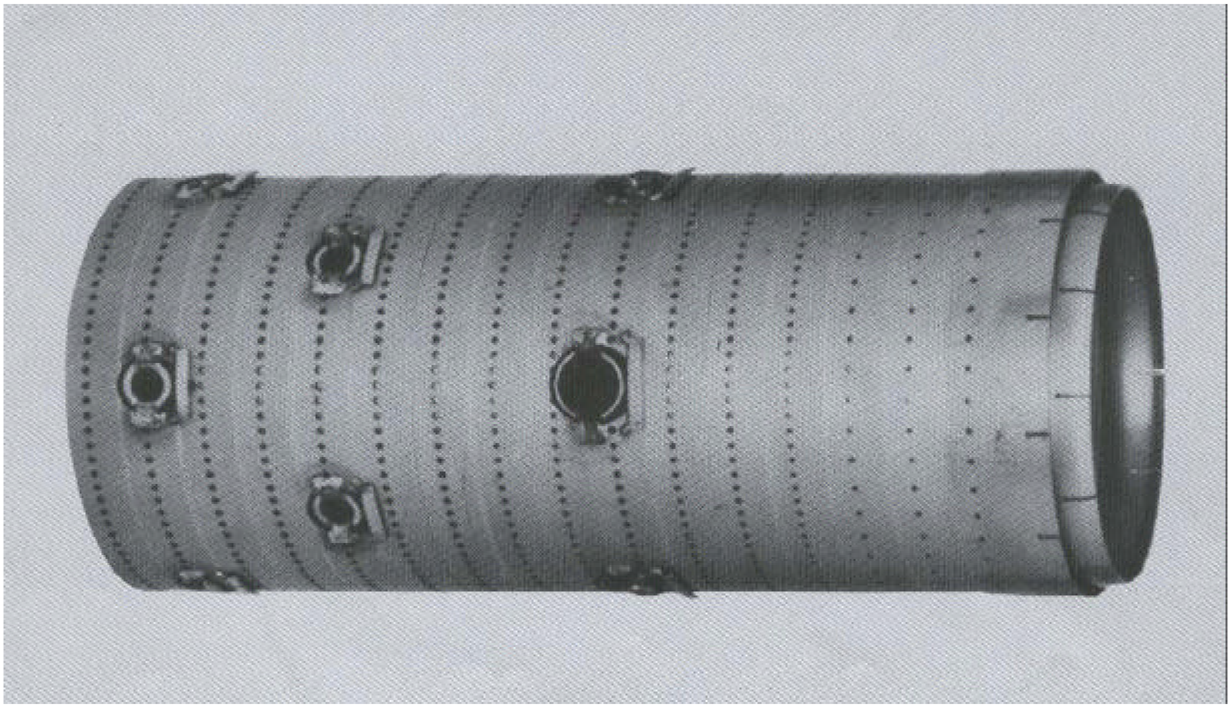
Contents

H-3000H

TYPICAL APPLICATIONS



Nitric acid catalyst grids support made from HAYNES® 230® alloy plate and bar. Excellent creep strength at 1700°F (927°C) makes the alloy highly suitable for this application.



Textron Lycoming gas turbine engine combustor made of HAYNES 230 alloy.

PRINCIPAL FEATURES

Excellent High-Temperature Strength, Thermal Stability, and Environment Resistance

HAYNES® 230® alloy is a nickel-chromium-tungsten-molybdenum alloy that combines excellent high-temperature strength, outstanding resistance to oxidizing environments up to 2100°F (1149°C) for prolonged exposures, premier resistance to nitriding environments, and excellent long-term thermal stability. It is readily fabricated and formed, and is castable. Other attractive features include lower thermal expansion characteristics than most high-temperature alloys, and a pronounced resistance to grain coarsening with prolonged exposure to high-temperatures.

Easily Fabricated

HAYNES 230 alloy has excellent forming and welding characteristics. It may be forged or otherwise hot-worked, providing it is held at 2150°F (1177°C) for a time sufficient to bring the entire piece to temperature. As a consequence of its good ductility, 230 alloy is also readily formed by cold-working. All hot- or cold-worked parts should be annealed and rapidly cooled in order to restore the best balance of properties.
The alloy can be welded by a variety of techniques, including gas tungsten arc (GTAW), gas metal arc (GMAW), and resistance welding.

Heat-Treatment

Wrought 230 alloy is furnished in the solution heat-treated condition, unless otherwise specified. The alloy is solution heat-treated in the range of 2150 to 2275°F (1177 to 1246°C) and rapidly cooled or water-quenched for optimum properties.

Annealing at temperatures lower than the solution heat-treating temperatures will produce some carbide precipitation in 230 alloy, which may marginally affect the alloy's strength and ductility.

Castings

HAYNES 230 alloy may be cast using traditional air-melt sand mold or vacuum-melt investment casting foundry practices. Silicon levels at the high end of the specification range are recommended for enhanced fluidity. Castings may be used in either the as-cast or solution-heat-treated condition depending upon property requirements.

Available in Convenient Forms

HAYNES 230 alloy is produced in the form of plate, sheet, strip, foil, billet, bar, wire welding products, pipe, tubing, and remelt bar.

Applications

HAYNES 230 alloy combines properties which make it ideally suited for a wide variety of component applications in the aerospace and power industries. It is used for combustion cans, transition ducts, flameholders, thermocouple sheaths, and other important gas turbine components. In the chemical process industry, 230 alloy is used for catalyst grid supports in ammonia burners, high-strength thermocouple protection tubes, high-temperature heat exchangers, ducts, high-temperature bellows, and various other key process internals.

In the industrial heating industry, applications for 230 alloy include furnace retorts, chains and fixtures, burner flame shrouds, recuperator internals, dampers, nitriding furnace internals, heat-treating baskets, grates, trays, sparger tubes, thermocouple protection tubes, cyclone internals, and many more.

Applicable Specifications

HAYNES 230 alloy is covered by ASME Section VII, Division I. Plate, sheet, strip, bar, forging, tubing, pipe, and fittings are covered by ASME specifications SB 435, SB 572, SB 564, SB 619, SB 622, SB 626, and SB 366 and ASTM specifications B 435, B 572, B 564, B 619, B 622, B 626, and B 366. DIN specifications are 17744 No. 2.4733 (all forms) and NiCr22W14Mo (all forms). The UNS number for the alloy is N06230. Sheet, strip and plate are also covered by AMS specification 5878, while bar and forging are covered by AMS specification 5891.

ASME Vessel Code

HAYNES 230 alloy is covered by ASME Vessel Code case No. 2063 for Section I and Section VIII Division 1 construction to 1650°F (899°C).

Nominal Chemical Composition, Weight Percent

Ni	Cr	W	Mo	Fe	Co	Mn	Si	Al	C	La	B
57[a]	22	14	2	3*	5*	0.5	0.4	0.3	0.10	0.02	0.015*

*Maximum [a]As balance

CREEP AND STRESS-RUPTURE STRENGTH

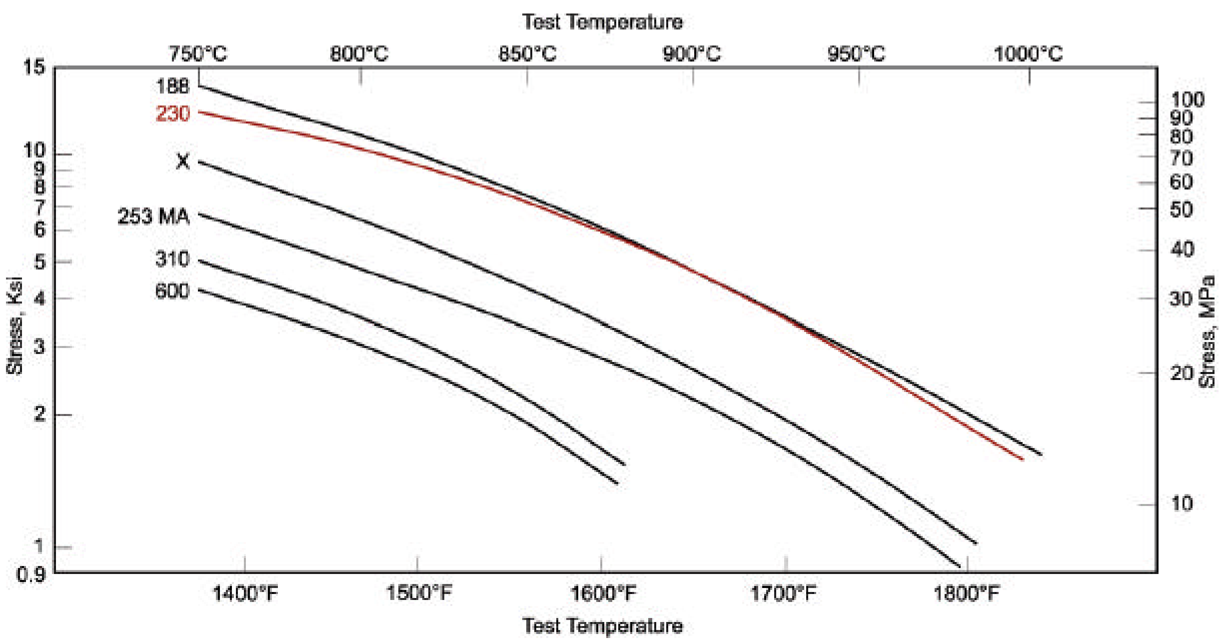
HAYNES® 230® alloy is a solid-solution-strengthened material which combines excellent high-temperature strength with good fabricability at room temperature. It is particularly effective for very long-term applications at temperatures of 1200°F (649°C) or more, and is capable of outlasting stainless steels and nickel alloys by as much as 100 to 1 depending upon the temperature. Alternatively, the higher strength of 230 alloy allows for the use of design section thicknesses as much as 75 percent thinner than lesser alloys with no loss in load-bearing capability.

Stress-Rupture Lives for Various Alloys at Fixed Test Conditions (Bar and Plate)*

Alloy	Hours to Rupture 1400°F/15.0 Ksi (760°C/103 MPa)	Hours to Rupture 1600°F/4.5 Ksi (871°C/31 MPa)	Hours to Rupture 1800°F/2.0 Ksi (982°C/14 MPa)
230® alloy	**8,200**	**65,000**	**5,000**
625 alloy	19,000	14,000	2,400
X alloy	900	5,000	2,100
Alloy 800H	130	1,200	920
INCONEL® alloy 601	50	1,200	1,000
253 MA® alloy	140	900	720
Alloy 600	15	280	580
Type 316 Stainless Steel	100	240	130
RA330® alloy	30	230	130
Type 304 Stainless Steel	10	100	72

*Based upon Larson-Miller extrapolation

Comparison of Stress to Produce 1% Creep in 1000 Hours (Sheet)



Sheet - 2250°F (1232°C) Solution Anneal

Test Temperature °F (°C)	Creep, Percent	Approximate Initial Stress, Ksi (MPa) to Produce Specified Creep in:			
		10 Hours	100 Hours	1,000 Hours	10,000 Hours*
1200 (649)	0.5	48.0 (330)	32.0 (220)	22.0 (150)	----
	1.0	51.0 (350)	36.0 (250)	25.0 (170)	----
	Rupture	67.0 (460)	48.0 (330)	36.0 (250)	27.0 (185)
1300 (704)	0.5	31.0 (215)	21.3 (145)	14.5 (100)	----
	1.0	34.0 (235)	24.0 (165)	16.5 (115)	----
	Rupture	47.0 (325)	34.0 (235)	25.0 (170)	18.5 (130)
1400 (760)	0.5	17.2 (120)	13.7 (95)	10.8 (75)	----
	1.0	20.0 (140)	14.8 (100)	11.7 (81)	----
	Rupture	32.0 (220)	24.5 (170)	18.2 (125)	13.2 (91)
1500 (816)	0.5	13.1 (90)	10.3 (71)	7.8 (54)	----
	1.0	14.1 (97)	11.2 (77)	8.6 (59)	----
	Rupture	23.3 (160)	17.5 (120)	12.5 (86)	8.4 (58)
1600 (871)	0.5	I0.0 (69)	7.6 (52)	5.5 (38)	----
	1.0	11.0 (76)	8.4 (58)	5.8 (40)	----
	Rupture	17.0 (115)	12.1 (83)	8.2 (57)	5.6 (39)
1700 (927)	0.5	7.5 (52)	5.4 (37)	3.4 (23)	----
	1.0	8.3 (57)	5.7 (39)	3.6 (25)	----
	Rupture	12.0 (83)	8.0 (55)	4.9 (34)	3.2 (22)
1800 (982)	0.5	5.4 (37)	3.4 (23)	1.7 (12)	----
	1.0	5.7 (39)	3.6 (25)	1.9 (13)	----
	Rupture	8.0 (55)	4.9 (34)	2.6 (18)	1.1 (7.6)
1900 (1038)	0.5	----	----	----	----
	1.0	----	----	----	----
	Rupture	7.5 (52)	3.5 (24)	1.6 (11)	----

*Significant Extrapolation of Data

Plate and Bar - 2250°F (1232°C) Solution Anneal

Test Temperature °F (°C)	Creep, Percent	Approximate Initial Stress, Ksi (MPa) to Produce Specified Creep in:			
		10 Hours	100 Hours	1,000 Hours	10,000 Hours*
1200 (649)	0.5	59.0 (405)	34.0 (235)	23.0 (160)	----
	1.0	60.0 (415)	39.0 (270)	26.4 (180)	17.5 (120)
	Rupture	----	56.0 (385)	42.5 (295)	29.0 (200)
1300 (704)	0.5	30.0 (205)	20.5 (140)	15.0 (105)	----
	1.0	35.0 (240)	23.5 (160)	18.0 (125)	12.3 (85)
	Rupture	52.0 (360)	39.0 (270)	29.0 (200)	21.0 (145)
1400 (760)	0.5	19.0 (130)	14.0 (97)	11.0 (76)	----
	1.0	21.5 (150)	15.9 (110)	11.5 (79)	8.0 (55)
	Rupture	37.0 (255)	27.0 (185)	20.0 (140)	14.2 (98)

Plate and Bar - 2250°F (1232°C) Solution Anneal (con't)

Test Temperature °F (°C)	Creep, Percent	Approximate Initial Stress, Ksi (MPa) to Produce Specified Creep in: 10 Hours	100 Hours	1,000 Hours	10,000 Hours
1500 (816)	0.5	13.4 (92)	10.6 (73)	8.2 (57)	----
	1.0	15.0 (105)	12.0 (83)	9.2 (63)	6.5 (45)
	Rupture	26.0 (180)	19.0 (130)	14.0 (97)	9.8 (68)
1600 (871)	0.5	10.3 (71)	8.0 (55)	5.6 (39)	----
	1.0	11.7 (81)	9.0 (62)	6 0 (41)	4.4 (30)
	Rupture	18.8 (130)	13.7 (95)	9.5 (66)	6.2 (43)
1700 (927)	0.5	7.8 (54)	5.5 (38)	3.4 (23)	----
	1.0	8.8 (61)	6.3 (43)	4.0 (28)	2.6 (18)
	Rupture	13.4 (92)	9.4 (65)	6.0 (41)	3.5 (24)
1800 (982)	0.5	5.5 (38)	3.4 (23)	1.6 (11)	----
	1.0	6.3 (43)	3.8 (26)	2.0 (14)	1.1 (7.6)
	Rupture	9.4 (65)	6.0 (41)	3.0 (21)	1.6 (11)
1900(1038)*	0.5	----	----	----	----
	1.0	4.4 (30)	2.0 (14)	0.9 (6.2)	----
	Rupture	7.0 (48)	3.5 (24)	1.8 (12)	----
2000(1093)*	0.5	----	----	----	----
	1.0	2.3 (16)	0.8 (5.5)	----	----
	Rupture	4.2 (29)	2.1 (14)	1.0 (6.9)	----
2100(1149)*	0.5	----	----	----	----
	1.0	1.1 (7.6)	0.4 (2.8)	----	----
	Rupture	2.3 (16)	1.2 (8.3)	0.6 (4.1)	----

*Based upon limited data

Vacuum Investment Casting (As Cast)

Test Temperature °F (°C)	Approximate Initial Stress, Ksi (MPa) to Produce Rupture in: 10 Hours	100 Hours	1,000 Hours	10,000 Hours*
1400 (760)	32.0 (220)	23.8 (165)	18.3 (125)	13.9 (96)
1500 (816)	23.0 (160)	17.4 (120)	13.0 (90)	9.8 (68)
1600 (871)	17.0 (115)	12.5 (86)	9.3 (64)	6.7 (46)
1700 (927)	12.5 (86)	9.0 (62)	6.4 (44)	4.5 (31)
1800 (982)	9.0 (62)	6.4 (44)	4.4 (30)	2.9 (20)
1900 (1038)	6.5 (45)	4.5 (31)	2.9 (20)	1.7 (12)
2000 (1093)	4.7 (32)	3.0 (21)	1.8 (12)	----
2100 (1149)	3.2 (22)	1.9 (13)	0.9 (6.2)	----

*Significant Extrapolation of Data

ASME VESSEL CODE ALLOWABLE STRESSES

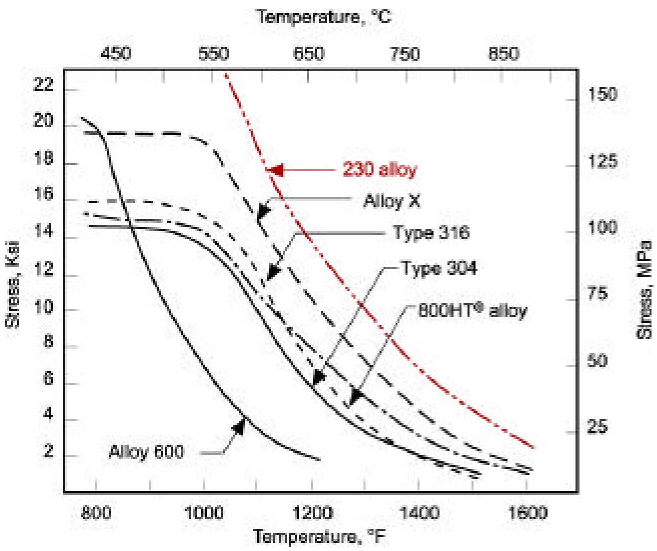
HAYNES® 230® alloy is approved for ASME Vessel Code Section I and Section VIII Division 1 construction to 1650°F (899°C) in Section II, Part D for plate, sheet, strip, bar, and forgings. (See also Code Case No. 2063 for Section I, Applications). Allowable stresses are reprinted here by permission of the ASME.

NOTE (1)
Due to the relatively low yield strength of this material, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. These higher stress values exceed 67%, but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.

ASME Vessel Section II, Part D, Table 1B

Metal Temperatures Not Exceeding		Maximum Allowable Stress Values			
		Standard		Note (1)	
°F	°C	Ksi	MPa	Ksi	MPa
100	37	30.0	207	30.0	207
200	93	28.2	194	30.0	207
300	149	26.4	182	30.0	207
400	204	24.7	170	30.0	207
500	260	23.1	159	30.0	207
600	315	22.0	152	29.4	203
650	343	21.5	146	29.1	200
700	371	21.2	145	28.7	198
750	398	21.0	145	28.4	196
800	426	20.9	144	28.2	194
850	454	20.9	144	28.2	194
900	482	20.9	144	28.2	194
950	510	20.9	144	28.2	194
1000	537	20.9	144	28.2	194
1050	565	20.9	144	28.2	194
1100	593	20.9	144	23.2	160
1150	621	19.0	131	19.0	131
1200	648	15.6	107	15.6	107
1250	676	12.9	89	12.9	89
1300	704	10.6	73	10.6	73
1350	732	8.5	59	8.5	59
1400	760	6.7	46	6.7	46
1450	787	5.3	37	5.3	37
1500	815	4.1	28	4.1	28
1550	843	2.7	19	2.7	19
1600	871	1.8	12	1.8	12
1650	898	1.2	8	1.2	8

Comparative Design Strength Values*

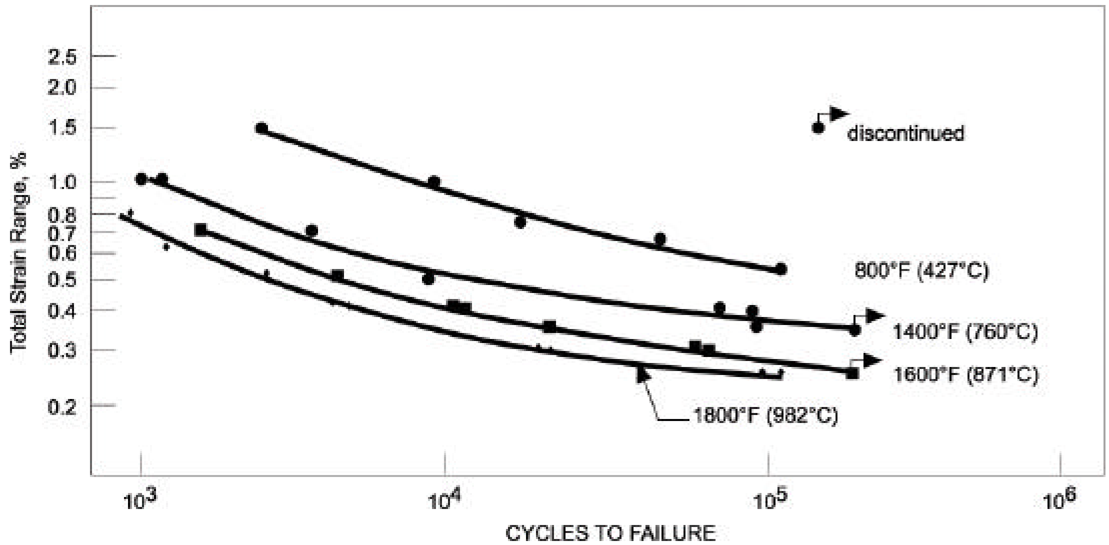


*All values taken from ASME Vessel Code Section VIII Division 1 or appropriate Code Cases.

HAYNES 230 alloy exhibits significant design strength advantages over other ASME vessel code covered materials for Section VIII Division 1 construction at temperatures up to 1650°F (899°C).

LOW CYCLE FATIGUE PROPERTIES

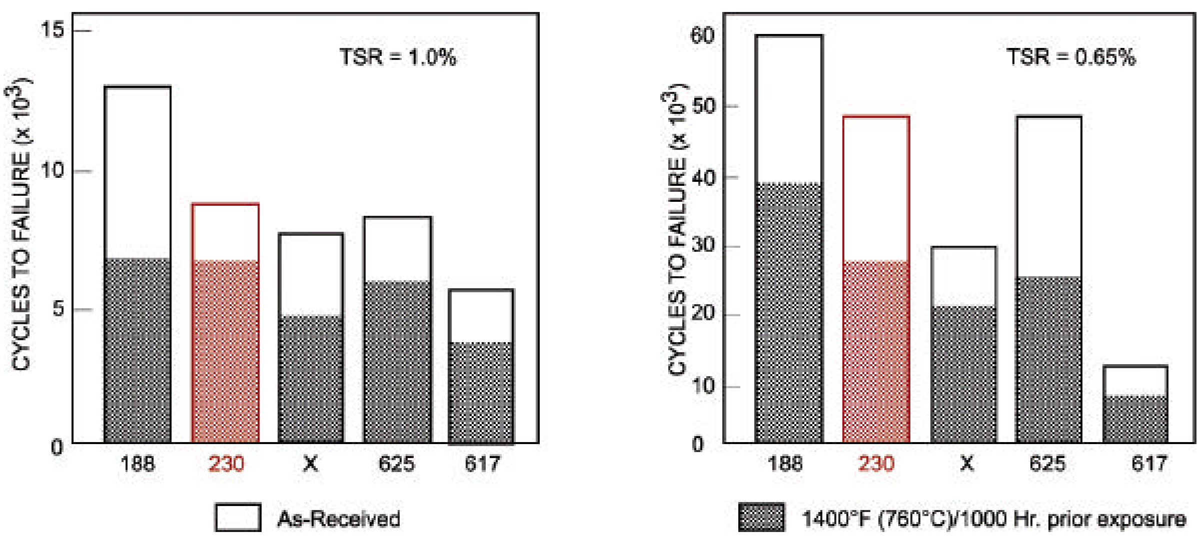
HAYNES® 230® alloy exhibits excellent low cycle fatigue properties at elevated temperature. Results shown below are for strain-controlled tests run in the temperature range from 800 to 1800°F (427 to 982°C). Samples were machined from plate. Tests were run with fully reversed strain (R=-1) at a frequency of 20 cpm (0.33 Hz).



Comparative Low Cycle Fatigue Properties

The graph below compares the low cycle fatigue lives of a number of alloys tested at 800°F (427°C) in both the as-received and 1400°F(760°C)/1000 hour pre-exposed condition. Samples were machined from plate or bar, after exposure for exposed samples. Tests were again run with fully reversed strain (R=-1) at a frequency of 20 cpm (0.33 Hz). TSR=Total Strain Range.

800°F (427°C) LCF Life for Various Alloys



TYPICAL TENSILE PROPERTIES

Cold-Rolled and 2250°F (1232°C) Solution Annealed (Sheet)

Test Temperature		Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Elongation in 2 in. (50.8 mm)
°F	°C	Ksi	MPa	Ksi	MPa	%
Room	Room	121.6	838	61.3	422	47.2
1000	538	101.5	699	44.0	303	53.7
1200	649	97.2	668	43.6	300	56.7
1400	760	78.3	539	46.9	323	61.2
1600	871	44.7	308	33.9	234	75.0
1800	982	25.0	172	18.2	125	50.2
2000	1093	13.1	90	10.0	69	37.0

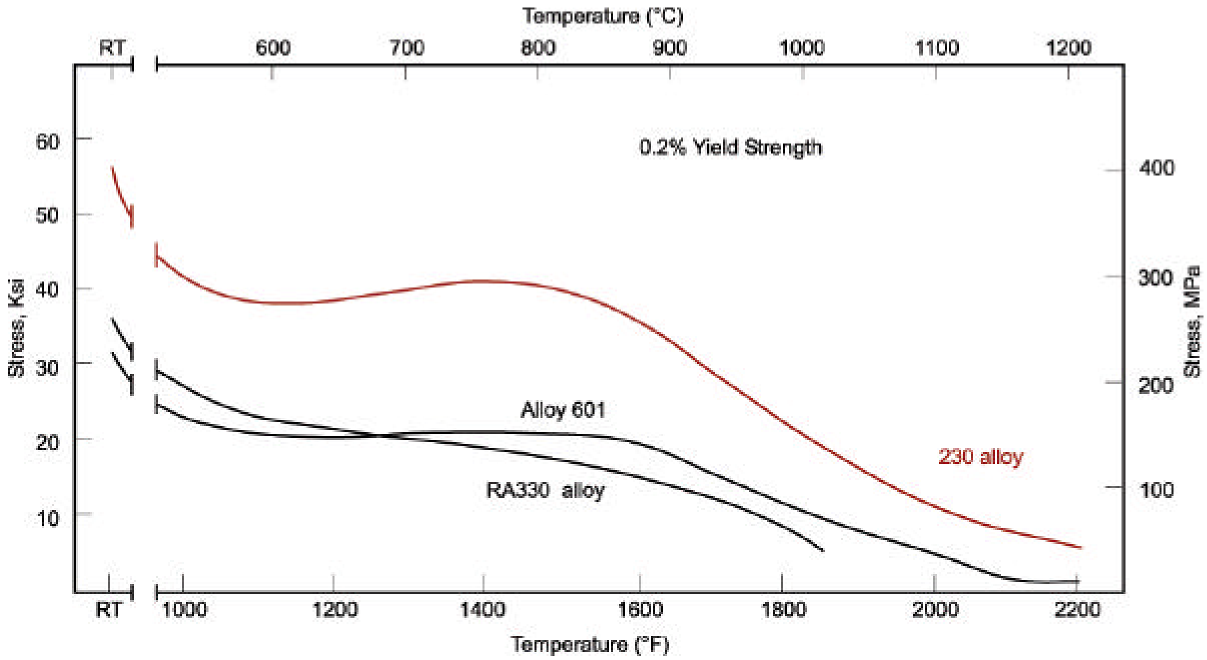
Hot-Rolled and 2250°F (1232°C) Solution Annealed (Plate)

Test Temperature		Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Elongation in 2 in. (50.8 mm)
°F	°C	Ksi	MPa	Ksi	MPa	%
Room	Room	121.8	840	54.4	375	47.7
1000	538	100.1	690	36.4	251	54.6
1200	649	96.0	662	37.0	255	54.5
1400	760	76.9	530	36.7	253	69.5
1600	871	45.6	315	35.1	242	99.5
1800	982	24.7	171	17.0	118	96.3
2000	1093	13.2	91	9.1	63	92.1

Vacuum Investment Castings (As Cast)

Test Temperature		Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Elongation in 5D	Reduction in Area
°F	°C	Ksi	MPa	Ksi	MPa	%	%
Room	Room	89.0	615	46.8	325	37.8	37.7
1000	538	65.6	450	33.1	230	38.2	35.9
1200	649	69.8	480	32.4	225	44.2	34.9
1400	760	55.8	385	32.9	225	32.3	36.0
1600	871	41.0	285	26.6	185	19.0	29.8
1800	982	29.4	205	24.8	170	25.5	39.9
2000	1093	12.9	89	12.6	87	41.0	46.6

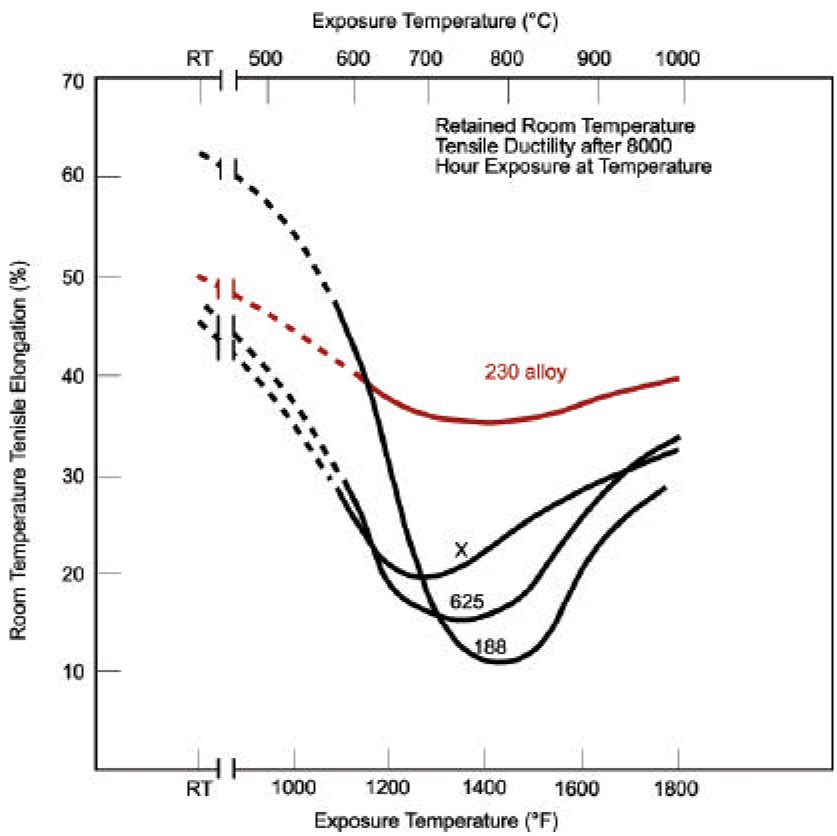
Comparison of Yield Strengths (Plate)



THERMAL STABILITY

HAYNES® 230® alloy exhibits excellent retained ductility after long-term thermal exposure at intermediate temperatures. It does not exhibit sigma phase, mu phase, or other deleterious phase formation even after 16,000 hours of exposure at temperatures from 1200 to 1600°F (649 to 871°C). Principal phases precipitated from solid solution are all carbides.

This contrasts markedly with many other solid-solution-strengthened superalloys such as HAYNES 188 alloy, HAYNES 625 alloy, and HASTELLOY® X alloy. These alloys all precipitate deleterious phases, which impair both tensile ductility and impact strength.



Room-Temperature Properties After Thermal Exposure (Plate)

Exposure Temperature °F (°C)	Hours	Ultimate Tensile Strength Ksi	MPa	Yield Strength at 0.2% Offset Ksi	MPa	Elongation in 2 in. (50.8mm) %	Impact Strength ft.-lb.	Joules
1200	0	123	850	59	405	51	54	73
(649°C)	1000	130	895	64	440	43	34	46
	4000	130	895	59	405	41	29	39
	8000	130	895	61	420	38	30	41
	16000	133	915	65	450	37	28	38
1400	0	123	850	59	405	51	54	73
(760°C)	1000	128	885	59	405	33	18	24
	4000	129	890	55	380	38	22	30
	8000	131	905	57	395	35	21	28
	16000	132	910	61	420	33	19	26
1600	0	123	850	59	405	51	54	73
(871°C)	1000	126	870	54	370	37	18	24
	4000	127	875	51	350	43	26	35
	8000	127	875	51	350	36	21	28
	16000	129	890	57	395	34	19	26

Comparative Room-Temperature Impact Strength

Alloy	Solution-Annealed Charpy V-Notch Impact ft.-lb. (Joules)		Charpy V-Notch Impact after 8000 Hours at Temperatures, ft.-lb. (Joules) 1200° F (649°C)		1400°F (760°C)		1600°F (871°C)	
230®	**54**	**(73)**	**30**	**(41)**	**21**	**(28)**	**21**	**(28)**
625	81	(110)	5	(7)	5	(7)	15	(20)
X	54	(73)	15	(20)	8	(11)	15	(20)
188	143	(194)	23	(31)	3	(4)	9	(12)

RESISTANCE TO GRAIN GROWTH

HAYNES® 230® alloy exhibits excellent resistance to grain growth at high temperatures. As a consequence of its very stable primary carbides, 230 alloy can be exposed at temperatures as high as 2200°F (1204°C) for up to 24 hours without exhibiting significant grain growth. Materials such as HAYNES 188 alloy or HASTELLOY® X alloy exhibit greater grain growth under such conditions, as would most iron-, nickel-, or cobalt-bae alloys and stainless steels.

Grain Size for Alloys Exposed at Temperature for Various Times*
(ASTM Grain Size No.)

Exposure Time (Hours)	230 alloy 2150°F (1177°C)	230 alloy 2200°F (1204°C)	HAYNES 188 alloy 2150°F (1177°C)	HAYNES 188 alloy 2200°F 1204°C)	HASTELLOY X alloy 2150°F (1177°C)	HASTELLOY X alloy 2200°F (1204°C)
0	4-4 1/2	4-4 1/2	4-5	4-5	3 1/2	3 1/2
1	4-5	4-4 1/2	2-5	2-4	3 1/2	0-1
4	4-4 1/2	4-4 1/2	3 1/2	3	3 1/2	0-1
24	4	4-4 1/2	0-2	1-3	00-4	0-1 1/2

*Plate Product

TYPICAL PHYSICAL PROPERTIES

	Temperature, °F	British Units	Temperature, °C	Metric Units
Density	Room	0.324 lb/in^3	Room	8.97 g/cm^3
Melting Range	2375-2500		1301-1371	
Electrical Resistivity	Room	49.2 microhm-in.	Room	125.0 microhm-cm
	200	49.5 microhm-in.	100	125.8 microhm-cm
	400	49.8 microhm-in.	200	126.5 microhm-cm
	600	50.2 microhm-in.	300	127.3 microhm-cm
	800	50.7 microhm-in.	400	128.4 microhm-cm
	1000	51.5 microhm-in.	500	130.2 microhm-cm
	1200	51.6 microhm-in.	600	131.2 microhm-cm
	1400	51.1 microhm-in.	700	130.7 microhm-cm
	1600	50.3 microhm-in.	800	129.1 microhm-cm
	1800	49.3 microhm-in.	900	127.1 microhm-cm
			1000	125.0 microhm-cm
Thermal Diffusivity	Room	3.8 x 10^{-3} in.^{2}/sec.	Room	24.2 x 10^{-3} cm^2/sec.
	200	4.1 x 10^{-3} in.^{2}/sec.	100	26.8 x 10^{-3} cm^2/sec.
	400	4.7 x 10^{-3} in.^{2}/sec.	200	29.9 x 10^{-3} cm^2/sec.
	600	5.2 x 10^{-3} in.^{2}/sec.	300	32.9 x 10^{-3} cm^2/sec.
	800	5.6 x 10^{-3} in.^{2}/sec.	400	35.7 x 10^{-3} cm^2/sec.
	1000	6.1 x 10^{-3} in.^{2}/sec.	500	38.5 x 10^{-3} cm^2/sec.
	1200	6.5 x 10^{-3} in.^{2}/sec.	600	41.9 x 10^{-3} cm^2/sec.
	1400	6.7 x 10^{-3} in.^{2}/sec.	700	43.0 x 10^{-3} cm^2/sec.
	1600	6.7 x 10^{-3} in.^{2}/sec.	800	43.2 x 10^{-3} cm^2/sec.
	1800	7.3 x 10^{-3} in.^{2}/sec.	900	44.4 x 10^{-3} cm^2/sec.
			1000	48.2 x 10^{-3} cm^2/sec.
Thermal Conductivity	Room	62 Btu-in./ft.^{2} hr.-°F	Room	8.9 W/m-K
	200	71 Btu-in./ft.^{2} hr.-°F	100	10.4 W/m-K
	400	87 Btu-in./ft.^{2} hr.-°F	200	12.4 W/m-K
	600	102 Btu-in./ft.^{2} hr.-°F	300	14.4 W/m-K
	800	118 Btu-in./ft.^{2} hr.-°F	400	16.4 W/m-K
	1000	133 Btu-in./ft.^{2} hr.-°F	500	18.4 W/m-K
	1200	148 Btu-in./ft.^{2} hr.-°F	600	20.4 W/m-K
	1400	164 Btu-in./ft.^{2} hr.-°F	700	22.4 W/m-K
	1600	179 Btu-in./ft.^{2} hr.-°F	800	24.4 W/m-K
	1800	195 Btu-in./ft.^{2} hr.-°F	900	26.4 W/m-K
			1000	28.4 W/m-K

Typical Physical Properties (continued)

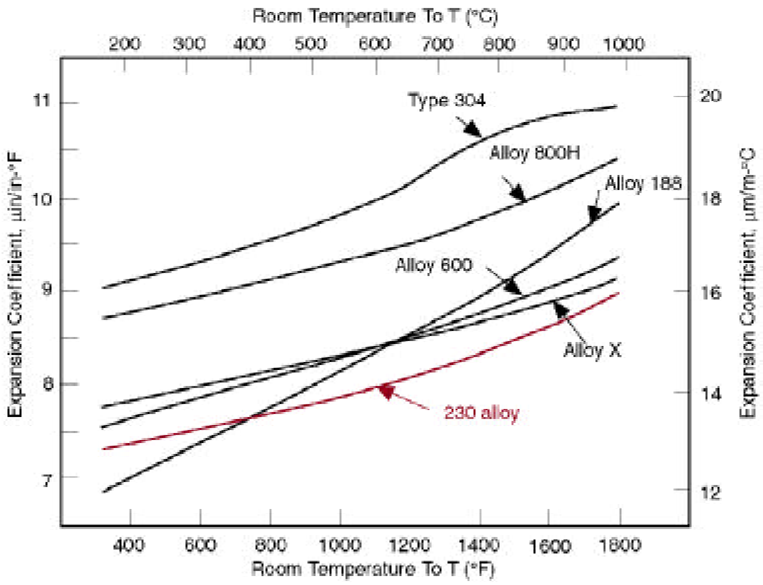
	Temperature, °F	British Units	Temperature, °C	Metric Units
Specific Heat	Room	0.095 Btu/lb.-°F	Room	397 J/Kg-K
	200	0.099 Btu/lb.-°F	100	419 J/Kg-K
	400	0.104 Btu/lb.-°F	200	435 J/Kg-K
	600	0.108 Btu/lb.-°F	300	448 J/Kg-K
	800	0.112 Btu/lb.-°F	400	465 J/Kg-K
	1000	0.112 Btu/lb.-°F	500	473 J/Kg-K
	1200	0.134 Btu/lb.-°F	600	486 J/Kg-K
	1400	0.140 Btu/lb.-°F	700	574 J/Kg-K
	1600	0.145 Btu/lb.-°F	800	595 J/Kg-K
	1800	0.147 Btu/lb.-°F	900	609 J/Kg-K
			1000	617 J/Kg-K
Mean Coefficient of Thermal Expansion	70-200	6.5 microinches/in.-°F	25-100	11.8 10^{-6} m/m-°C
	70-400	6.9 microinches/in.-°F	25-200	12.4 10^{-6} m/m-°C
	70-600	7.2 microinches/in.-°F	25-300	12.8 10^{-6} m/m-°C
	70-800	7.4 microinches/in.-°F	25-400	13.2 10^{-6} m/m-°C
	70-1000	7.6 microinches/in.-°F	25-500	13.6 10^{-6} m/m-°C
	70-1200	8.0 microinches/in.-°F	25-600	14.1 10^{-6} m/m-°C
	70-1400	8.3 microinches/in.-°F	25-700	14.7 10^{-6} m/m-°C
	70-1600	8.6 microinches/in.-°F	25-800	15.2 10^{-6} m/m-°C
	70-1800	8.9 microinches/in.-°F	25-900	15.7 10^{-6} m/m-°C
			25-1000	16.1 10^{-6} m/m-°C

Dynamic Modulus of Elasticity

Temperature, °F	Dynamic Modulus of Elasticity, 10^6 psi	Temperature, °C	Dynamic Modulus of Elasticity, GPa
Room	30.6	Room	211
200	30.1	100	207
400	29.3	200	202
600	28.3	300	196
800	27.3	400	190
1000	26.4	500	184
1200	25.3	600	177
1400	24.1	700	171
1600	23.1	800	164
1800	21.9	900	157
		1000	150

Thermal Expansion Characteristics

HAYNES® 230® alloy has relatively low thermal expansion characteristics compared to most high-strength superalloys, iron-nickel-chromium alloys, and austenitic stainless steels. This means lower thermal stresses in service for complex component fabrications, as well as tighter control over critical part dimensions and clearances.



OXIDATION RESISTANCE

HAYNES 230 alloy exhibits excellent resistance to both air and combustion gas oxidizing environments, and can be used for long-term continuous exposure at temperatures up to 2100°F (1149°C). For exposures of short duration, 230 alloy can be used at higher temperatures.

Schematic Representation of Metallographic Technique used for Evaluating Oxidation

1. Metal Loss = (A-B)/2
2. Average Internal Penetration = C
3. Maximum Internal Penetration = D
4. Average Metal Affected = ((A-B)/2) + C
5. Maximum Metal Affected = ((A-B)/2) + D

Comparative Burner Rig Oxidation Resistance 1000 Hour Exposure at 1800°F (982°C)

	Metal Loss		Average Metal Affected		Maximum Metal Affected	
Alloy	**Mils**	**µm**	**Mils**	**µm**	**Mils**	**µm**
230® alloy	**0.8**	**20**	**2.8**	**71**	**3.5**	**89**
HAYNES® 188 alloy	1.1	28	3.5	89	4.2	107
HASTELLOY® X alloy	2.7	69	5.6	142	6.4	163
625 Alloy	4.9	124	7.1	180	7.6	193
RA330 alloy	7.8	198	10.6	269	11.8	300
Type 310 Stainless Steel	13.7	348	16.2	406	16.5	419
Alloy 600	12.3	312	14.4	366	17.8	452
INCONEL alloy 601	3.0	76	18.8	478	20.0	508

Oxidation Test Parameters

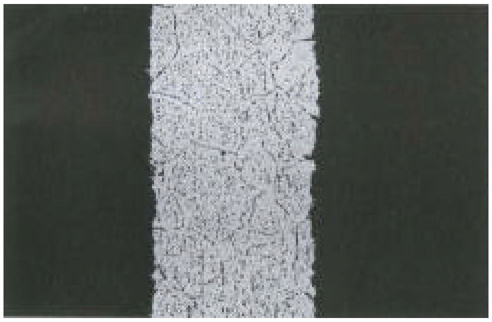
Burner rig oxidation tests were conducted by exposing samples 3/8 inch x 2.5 inches x thickness (9 mm x 64 mm x thickness), in a rotating holder, to the products of combustion of No. 2 fuel oil burned at a ratio of air to fuel of about 50:1. (Gas velocity was about 0.3 mach.) Samples were automatically removed from the gas stream every 30 minutes and fan-cooled to near ambient temperature and then reinserted into the flame tunnel.

Comparative Burner Rig Oxidation Resistance at 2000°F (1093°C) for 500 Hours

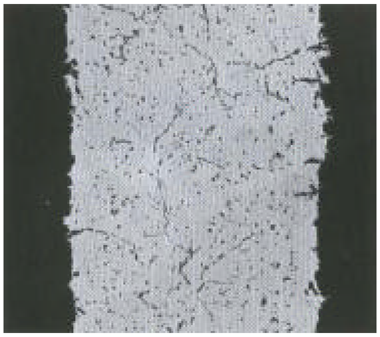
(Width of Micros Indicates Original Sample Thickness)

230 alloy
Average Metal Affected
= 5.2 Mils (132 µm)/Side

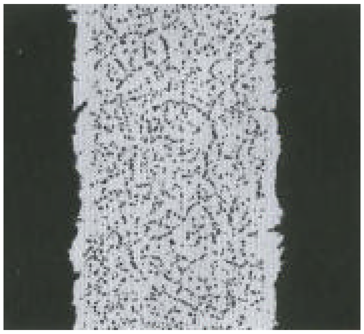
Alloy 600
Average Metal Affected
= 19.5 Mils (495 µm)/Side



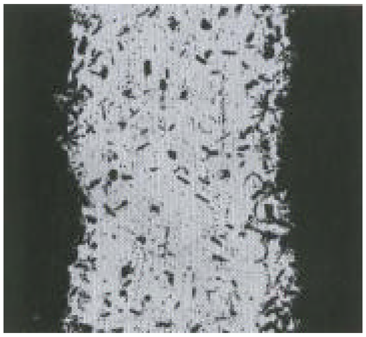
Type 310 Stainless Steel
Average Metal Affected
= 23.7 Mils (602 µm)/Side



HASTELLOY X alloy
Average Metal Affected
= 12.9 Mils (328 µm)/Side



RA330 Alloy
Average Metal Affected
= 12.9 Mils (328 µm)/Side



INCONEL alloy 601
Average Metal Affected
= > 24.0 Mils (610 µm)/Side

Comparative Oxidation Resistance in Flowing Air*

	Average Metal Affected in 1008 Hours**							
	1800°F (982°C)		2000°F (1093°C)		2100°F (1149°C)		2200°F (1204°C)	
Alloy	**Mils**	**µm**	**Mils**	**µm**	**Mils**	**µm**	**Mils**	**µm**
HAYNES® 230® alloy	**0.7**	**18**	**1.3**	**33**	**3.4**	**86**	**7.9**	**201**
HAYNES 188 alloy	0.6	15	1.3	33	8.0	203	>21.7	>551
INCONEL alloy 601	1.3	33	2.6	66	5.3	135	7.5***	191***
HASTELLOY® X alloy	0.9	23	2.7	69	5.8	147	>35.4	>889
Alloy 625	0.7	18	4.8	122	18.2	462	>47.6	>1209
Alloy 800H	1.8	46	7.4	188	8.9	226	13.6	289
Type 446 Stainless Steel	2.3	58	14.5	368	>21.7	>551	>23.3	>592
Type 316 Stainless Steel	14.3	363	>68.4	>1737	>105.0	>2667	>140.4	>3566

*Flowing air at a velocity of 7.0 feet/minute (213.4 cm/minute) past the samples. Samples cycled to room temperature once-a-week.

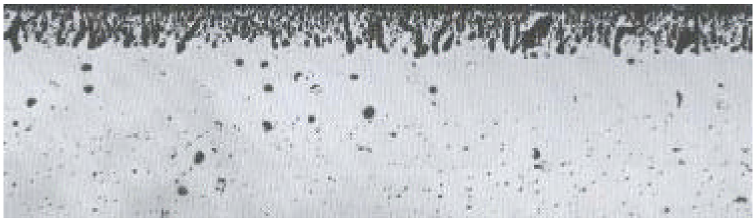
**Metal Loss + Average Internal Penetration

***601 Sample exhibited very large internal voids.

Comparative Oxidation in Flowing Air 2100°F (1149°C) For 1008 Hours

Microstructures shown are for coupons exposed for 1008 hours at 2100°F (1149°C) in air flowing 7.0 feet/minute (2.1 m/minute) past the samples. Samples were descaled by cathodically charging the coupons while they were immersed in a molten salt solution. The black area shown at the top of each picture represents actual metal loss due to oxidation. The data clearly show HAYNES 230 alloy to be superior to both INCONEL alloy 601 and alloy 800H, as well as the other heat-resistant materials listed in the table above.

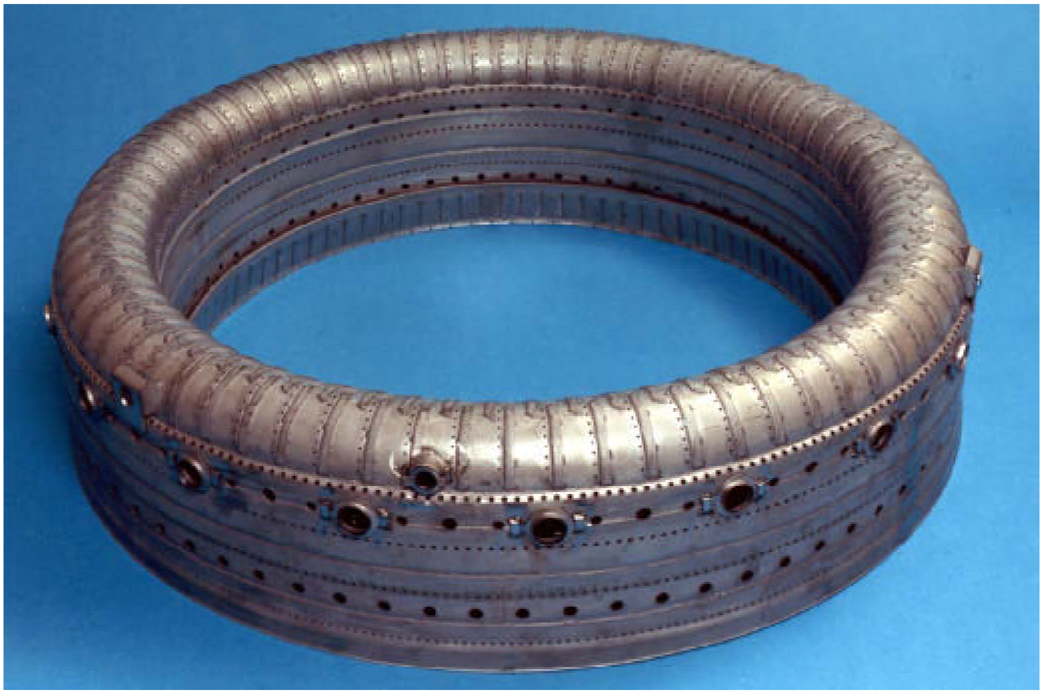
230 alloy
Average Metal Affected
= 3.4 mils (86 µm)



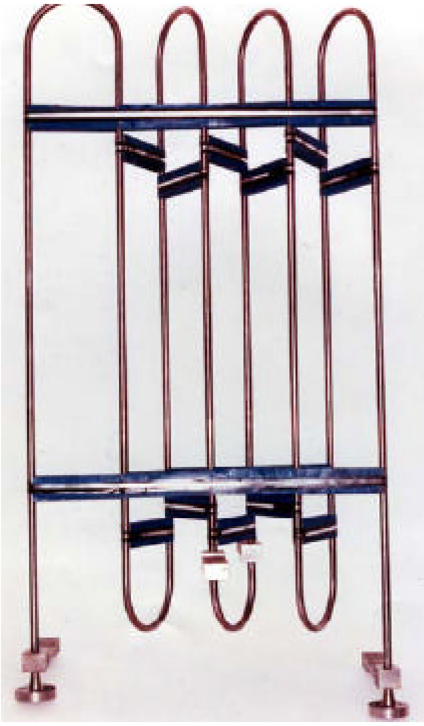
INCONEL alloy 601
Average Metal Affected
= 5.3 mils (135 µm)

Alloy 800H
Average Metal Affected
= 8.9 mils (226 µm)

TYPICAL APPLICATIONS



Prototype 230® combustor for Dresser-Rand DR-990 land-based turbine.



Resistance-heated 230 superheater tubes at the Penn State Applied Research Laboratory. Used to produce about 1625°F (885°C) high-pressure steam.

Prototype 230 high-temperature expansion bellows made of 0.020-inch (0.5mm) thick sheet in a catalytic cracker configuration.

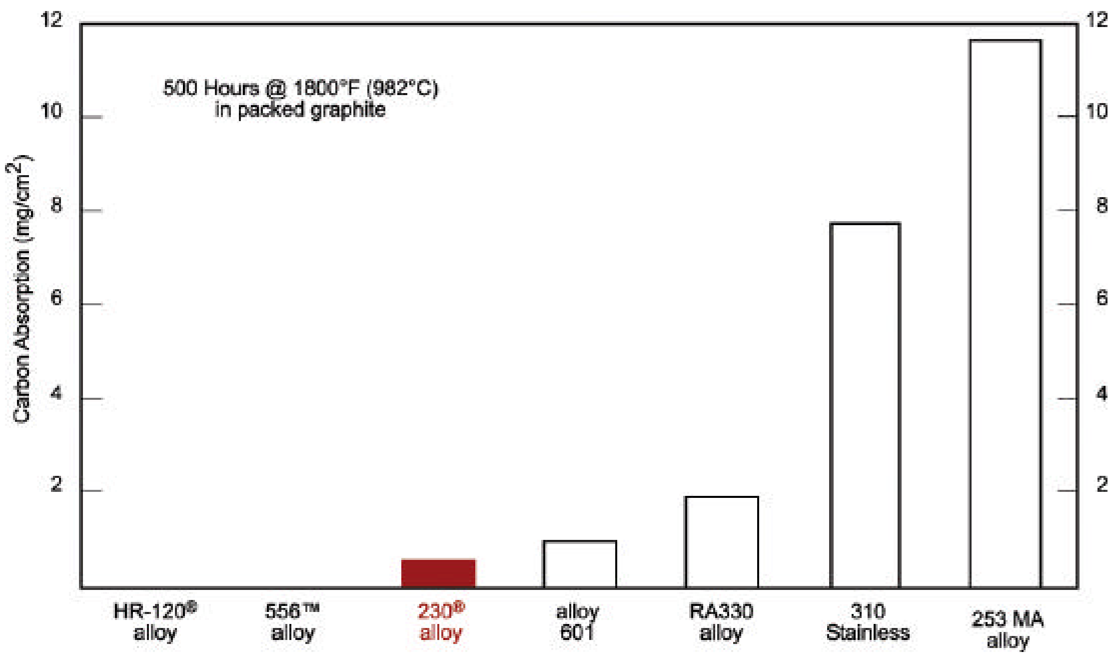
NITRIDING RESISTANCE

HAYNES® 230® alloy is one of the most nitriding resistant materials commercially available. Tests were performed in flowing ammonia at 1200°F (649°C) and 1800°F (982°C) for 168 hours. Nitrogen absorption was determined by chemical analysis of samples before and after exposure and knowledge of the exposed specimen area.

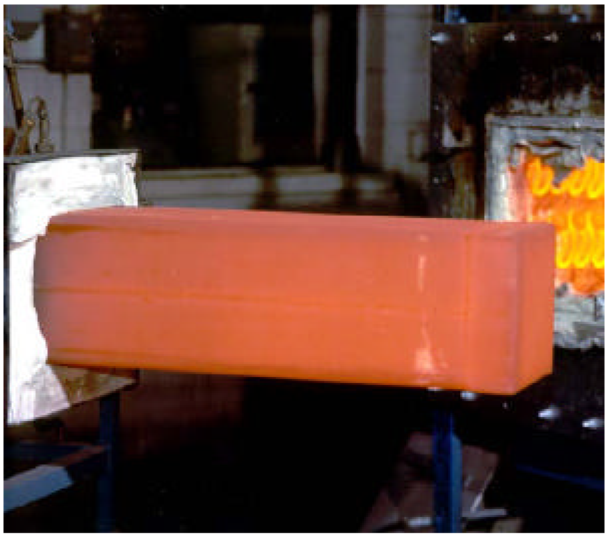
Alloy	Nitrogen Absorption (mg/cm^2) 1200°F (649°C)	Nitrogen Absorption (mg/cm^2) 1800°F (982°C)
HAYNES® 230® alloy	**0.7**	**1.4**
Alloy 600	0.8	0.9
Alloy 625	0.8	2.5
HASTELLOY® X alloy	1.7	3.2
RA330 Alloy	3.9	-
Alloy 800H	4.3	4.0
Type 316 Stainless Steel	6.9	6.0
Type 310 Stainless Steel	7.4	7.7
Type 304 Stainless Steel	9.7	7.3

CARBURIZATION RESISTANCE

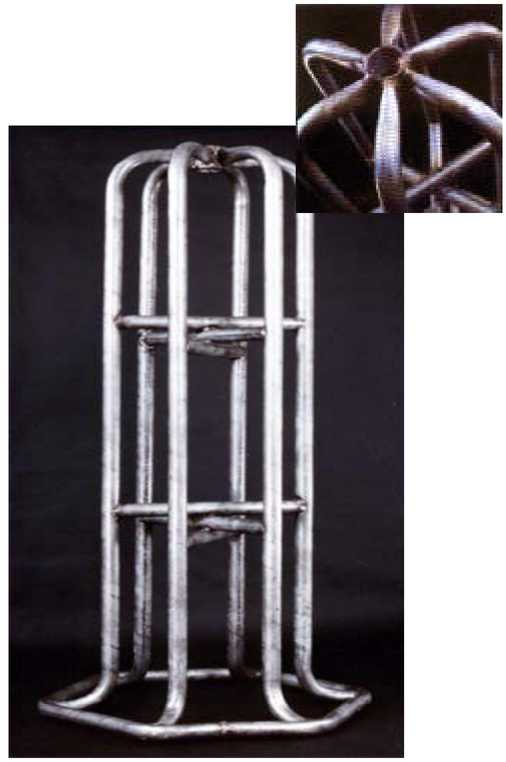
HAYNES 230 alloy exhibits good resistance to carburization when compared with many other industrial alloys. Test results were generated for 500 hours exposure in packed graphite at 1800°F (982°C). Carbon absorption was determined by chemical analysis of samples before and after exposure and knowledge of the exposed specimen area.



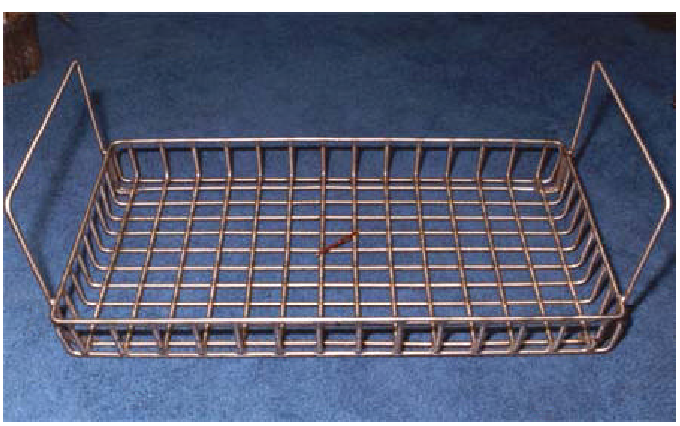
TYPICAL APPLICATIONS



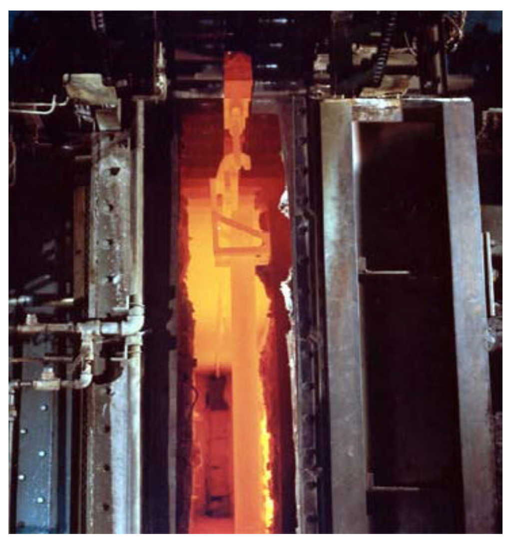
This horizontal electrically fired 230® retort replaced an alloy 600 retort which lasted only an average of eight months in 1400 to 2200°F (760 to 1204°C) service in hydrogen atmosphere. The 230 retort was still in excellent condition after 24 months service, as shown.



Wire annealing fixture of 230 alloy reduces thermal mass and cycle times after replacing massive carbon-steel “stub” used previously.



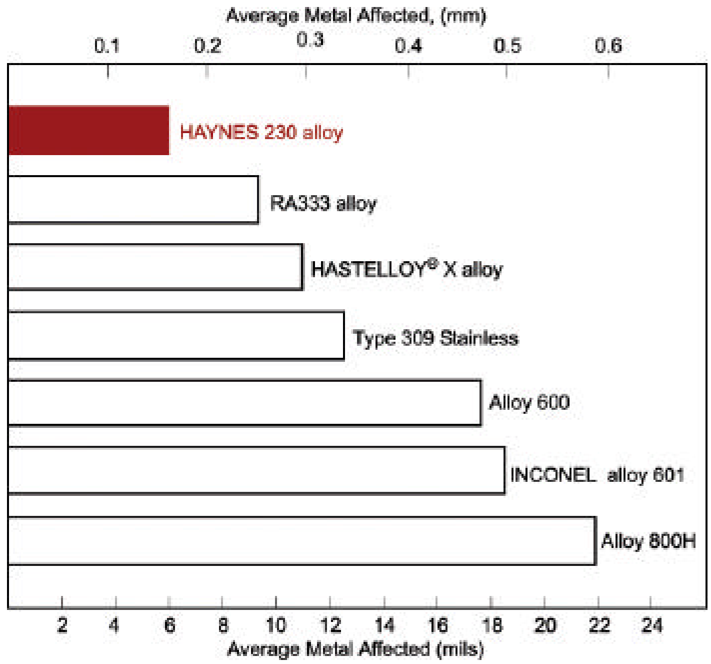
Fabricated heat-treating basket for vacuum furnace application to 2300°F (1260°C). Made from 1/2-inch (12.7 mm) diameter 230 bar.



This striking shot of a HAYNES 230 heat-treat fixture was taken at a leading off-road automotive equipment plant. This conveyor fixture operates at 1550°F (843°C) with a subsequent water quench followed by a four hour cycle at 1050°F (566°C).

FIELD EXPERIENCE - WASTE INCINERATION

Coupon exposures performed in the flue of an industrial waste incinerator burning wood, cardboard, and other plant waste revealed that HAYNES® 230® alloy was very resistant to the mildly sulfidizing flue gases produced. Coupons were exposed in the average 1700°F (927°C) gases for more than 400 hours over 31 days. Seven start-up/shut-down cycles were experienced.



HYDROGEN EMBRITTLEMENT RESISTANCE

Notched tensile tests performed in hydrogen and air reveal that 230 alloy is resistant to hydrogen embrittlement. Tests were performed in MIL-P-27201B grade hydrogen, with a cross-head speed of 0.005 in/min (0.13 mm/min). Specimens were notched with a K_T value of 8.0.

Temperature		Hydrogen Pressure		Ratio of Notched Tensile Strength
°F	°C	Psig	MPa	Hydrogen/Air
70	21	3000	21	0.92
70	21	5000	34	1.07
1200	649	3000	21	1.00
1600	871	3000	21	1.00

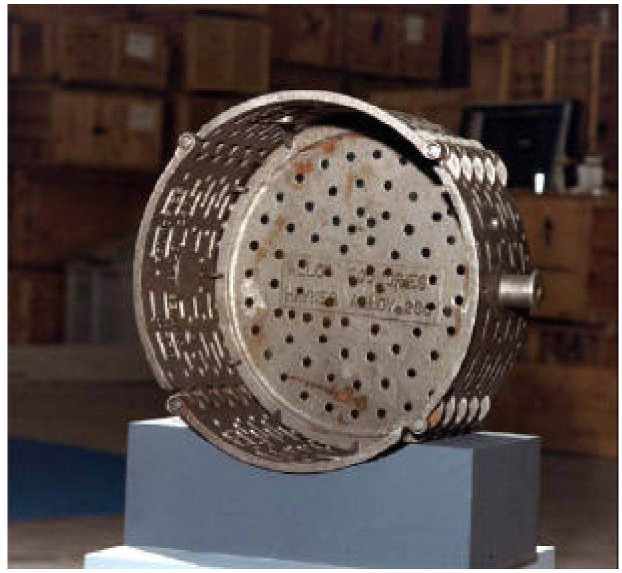
AQUEOUS CORROSION RESISTANCE

Coupons were exposed for four 24-hour periods in various acids at the stated temperatures, and general corrosion rates were calculated from weight change measurements.

	Corrosion Rate (mils per year)		
	10% HNO_3 Boiling	10% H_2SO_4 150°F (66°C)	10%HCl 150°F (66°C)
230 alloy	**0.3**	**0.6**	**112**
Alloy 625	0.7	0.4	65
Alloy 600	0.8	41.8	366
Type 316 Stainless Steel	1.0	17.8	3408
HASTELLOY X alloy	-	<0.1	99

TYPICAL APPLICATIONS

HAYNES® 230® damper atop this glass melting furnace withstands 2300°F (1260°C) for short times and 2000°F (1093°C) for sustained periods.



Cast heat-treat basket of 230 alloy in use at Alloy Foundries, Division of the Eastern Company, Naugatuck, Connecticut.

Substrate holder and box of 230 alloy resist temperatures of 1650°F (899°C) during the production of semiconductors.

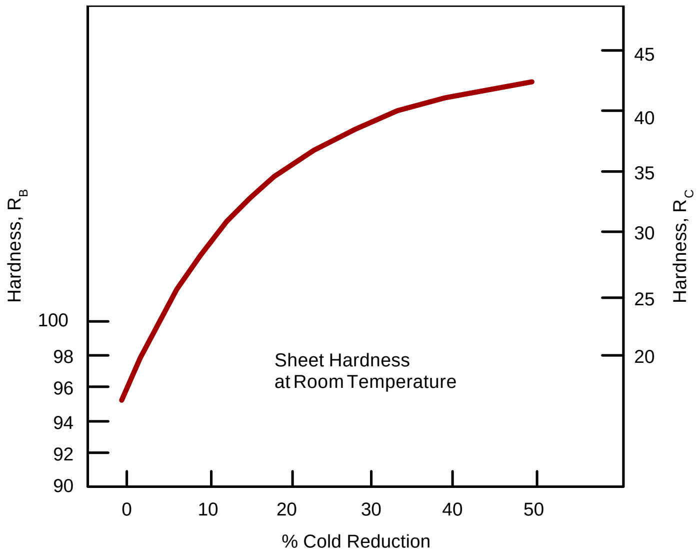
230 retorts operate at 2100°F (1149°C) with a hydrogen atmosphere (inside) and combustion products outside.

FABRICATION CHARACTERISTICS

Heat Treatment

HAYNES® 230® alloy is normally final solution heat-treated at 2250°F (1232°C) for a time commensurate with section thickness. Solution heat-treating can be performed at temperatures as low as about 2125°F (1163°C), but resulting material properties will be altered accordingly. Annealing during fabrication can be performed at even lower temperatures, but a final, subsequent solution heat treatment is needed to produce optimum properties and structure. Please refer to following sections and publication H-3159 for additional information.

Typical Hardness Properties



Solution Annealed Room Temperature Hardness

Form	R_B	Pieces Tested
Sheet	92.5	37
Plate	95.2	26
Bar	92.7	24

Effect of Cold Reduction Upon Room-Temperature Tensile Properties*

Percent Cold Reduction	Subsequent Anneal Temperature	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	Yield Strength at 0.2% Offset Ksi	Yield Strength at 0.2% Offset MPa	Elongation in 2 in. (50.8 mm) %
0	None	128.2	885	61.8	425	46.6
10		144.5	995	104.0	715	31.8
20		163.9	1130	133.4	920	16.8
30		187.5	1295	160.1	1105	9.7
40		201.5	1390	172.4	1190	7.5
50		214.6	1480	184.6	1275	6.0

Effect of Cold Reduction Upon Room-Temperature Tensile Properties*- (cont.)

Percent Cold Reduction	Subsequent Anneal Temperature	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	Yield Strength at 0.2% Offset Ksi	Yield Strength at 0.2% Offset MPa	Elongation in 2 in. (50.8 mm) %
10	1950°F (1066°C) for 5 min.	143.5	990	91.9	635	32.9
20		141.9	980	80.8	555	35.6
30		142.1	980	75.9	525	35.7
40		145.5	1005	81.2	560	32.3
50		147.7	1020	86.1	595	34.6
10	2050°F (1121°C) for 5 min.	139.0	960	80.8	555	36.5
20		135.7	935	65.4	450	39.2
30		140.0	965	72.0	495	37.6
40		142.3	980	76.1	525	35.5
50		143.9	990	80.8	555	36.3
10	2150°F (1177°C) for 5 min.	129.5	895	55.5	385	43.7
20		134.3	925	64.4	445	40.1
30		138.1	950	70.2	485	38.5
40		139.2	960	73.4	505	38.1
50		137.7	950	71.9	495	39.1

*Based upon rolling reductions taken upon 0.120-inch (3.0 mm) thick sheet. Duplicate tests.

TYPICAL MICROSTRUCTURE

(ASTM 5 grain size) Annealed at 2250°F (1232°C)

Etchant 95ml
HCl plus 5 gm
oxalic acid, 4 volts

WELDING

HAYNES® 230® alloy is readily welded by Gas Tungsten Arc Welding (GTAW), Gas Metal Arc Welding (GMAW) Shielded Metal Arc Welding (SMAW), and resistance welding techniques. Its welding characteristics are similar to those for HASTELLOY® X alloy. Sub-merged-Arc welding is not recommended as this process is characterized by high heat input to the base metal and slow cooling of the weld. These factors can increase weld restraint and promote cracking.

Base Metal Preparation

The welding surface and adjacent regions should be thoroughly cleaned with an appropriate solvent prior to any welding operation. All greases, oils, cutting oils, crayon marks, machining solutions, corrosion products, paint, scale, dye penetrant solutions, and other foreigh matter should be completely removed. It is preferable, but not necessary, that the alloy be in the solution-annealed condition when welded.

Filler Metal Selection

HAYNES 230-W™ filler wire (AWS A5.14, ERNiCrWMo-1) is recommended for joining 230 alloy by Gas Tungsten Arc or Gas Metal Arc welding. Coated electrodes of 230-W alloy are also available for Shielded Metal Arc welding in non-ASME code construction . For dissimilar metal joining of 230 alloy to nickel-, cobalt-, or iron-base materials, 230-W filler wire, HAYNES 556™ alloy, HASTELLOY S alloy (AMS 5838) or HASTELLOY W alloy (AMS 5786, 5787) welding products may all be considered, depending upon the particular case. Please see HAYNES publication H-3159 for more information.

Preheating, Interpass Temperatures, and Post-Weld Heat Treatment

Preheat is not required. Preheat is generally specified as room temperature (typical shop conditions). Interpass temperature should be maintained below 200°F (93°C). Auxiliary cooling methods may be used between weld passes, as needed, providing that such methods do not introduce contaminants. Post-weld heat treatment is not generally required for 230 alloy. For further information please consult HAYNES publication H-3159.

Nominal Welding Parameters

Nominal welding parameters are provided as a guide for performing typical operations. These are based upon welding conditions used in our laboratories. Details are given for GTAW, GMAW and SMAW welding.

Automatic Gas Tungsten-Arc Welding

Square Butt Joint - No Filler Metal Added

	Material Thickness		
	0.040" (1.0 mm)	**0.063" (1.6 mm)**	**0.125" (3.2 mm)**
Current (DCEN), amperes	50	80	120
Voltage, volts	8	8.5	9.5
Travel Speed, in/min. (mm/min)	10 (254)	12 (305)	12 (305)
Electrode Size - EWTH-2, in (mm)	0.063 (1.6)	0.094 (2.4)	0.125 (3.6)
Electrode Shape	45° inc	45° inc	45° inc
Cup Size	#8	#8	#8
Shield Gas Flow, CFH (liters per min.)	30 (14.2)	30 (14.2)	30 (14.2)
Gas	argon	argon	argon
Backing Gas Flow, CFH (liters per min.)	10 (4.7)	10 (4.7)	10 (4.7)
Gas	argon	argon	argon

Manual Gas Tungsten Arc Welding

V-or U-Groove - All Thicknesses 0.125" (3.6 mm) or greater

Technique	-	Stringer Bead
Current (DCEN), amperes	-	120 root, 140-150 Fill
Voltage, volts	-	11 to 14
Filler Metal	-	230-W™ filler wire, 0.125" (3.6 mm) diameter
Travel Speed, in/min (mm/min)	-	4 to 6 (102 to 152)
Electrode Size - EWTH-2, in (mm)	-	0.125 (3.6)
Electrode Shape	-	30° included
Cup Size	-	#8 or larger
Shield Gas Flow, CFH (liters per min.) Gas	- -	30 to 35 (14.2 to 16.5) Argon
Backup Gas Flow, CFH (liters per min.) Gas	- -	10 (4.7) Argon
Preheat	-	None if T > 32°F (0°C)
Interpass Temperature Maximum	-	212°F (100°C)

Gas Metal Arc Welding

Short Circuiting Transfer Mode - All Thicknesses 0.090" (2.3 mm) or greater

Technique	-	Stringer Bead or Slight Weave
Current (DCEP), amperes	-	100 to 130
Voltage, volts	-	18 to 21
Feed Rate, in/min (m/min)	-	170 to 190 (4.3 to 4.8)
Stickout, in (min)	-	0.5 to 0.75 (12.7 to 19.1)
Filler Metal	-	230-W filler wire, 0.045" (1.1 mm) diameter
Travel Speed, in/min (mm/min)	-	8 to 14 (203 to 356)
Torch Gas Flow, CFPH (LPH) Gas	- -	50 (1416) Ar-25% He

Typical Shielded Metal Arc Welding Parameters (Flat Position)*

Electrode Diameter in.	(mm)	Approximate Welding Voltage Volts	Welding Current Aim Amps	Welding Current Range Amps
3/32	(2.4)	22-24	65-70	55-75
1/8	(3.2)	22-24	90-100	80-100
5/32	(4.0)	22-25	130-140	125-150
3/16	(4.8)	24-26	160-170	150-180

*DCEP

Typical Tensile Properties For GMAW Deposit Weld Metal

Test Temperature		Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Elongation in 2 in. (50.8 mm)
°F	°C	Ksi	MPa	Ksi	MPa	%
Room	Room	113.9	785	71.0	490	48.2
1000	538	88.7	610	62.8	435	34.8
1600	871	44.7	310	39.6	275	45.4

Typical face and root bends for welded 230® alloy 0.5-inch (13 mm) plate and matching filler metal. Bend radius was 1.0-inch (25 mm).

HEALTH AND SAFETY INFORMATION

Those involved with the welding industry are obligated to provide safe working conditions and be aware of the potential hazards associated with welding fumes, gases, radiation, electrical shock, heat, eye injuries, burns, etc. Various local, municipal, state, and federal regulations (OSHA, for example) relative to the welding and cutting processes must be considered.

Nickel-, cobalt-, and iron-based alloy products may contain, in varying concentrations, the following elemental constituents: aluminum, cobalt, chromium, copper, iron, manganese, molybdenum, nickel, and tungsten. For specific concentrations of these and other elements present, refer to the Material Safety Data Sheets (MSDS) H2071 and H1072 for the product.

The operation and maintenance of welding and cutting equipment should conform to the provisions of American National Standard ANSI Z49.1, Safety in Welding and Cutting. Attention is especially called to Section 4 (Protection of Personnel), Section 5 (Ventilation), and Section 7 (Confined Spaces) of that document. Adequate ventilation is required during all welding and cutting operations. Specific requirements are included in Section 5 for natural ventilation versus mechanical ventilation methods. When welding in confined spaces, ventilation shall also be sufficient to assure adequate oxygen for life support.

The following precautionary warning, which is supplied with all welding products, should be provided to, and fully understood by, all employees involved with welding.

Caution

Welding may produce fumes and gases hazardous to health. Avoid breathing these fumes and gases. Use adequate ventilation. See ANSI/AWS Z49.1, Safety in Welding and Cutting published by the American Welding Society.

EXPOSURES: Maintain all exposures below the limits shown in the Material Safety Data Sheet, and the product label. Use industrial hygiene air monitoring to ensure compliance with the recommended exposure limits. ALWAYS USE EXHAUST VENTILATION .

RESPIRATORY PROTECTION: Be sure to use a fume respirator or air supplied respirator when welding in confined spaces or where local exhaust or ventilation does not keep exposure below the PEL and TLV limits.

WARNING: Protect yourself and others. Be sure the label is read and understood by the welder. FUMES and GASES can be dangerous to your health. Overexposure to fumes and gases can result in LUNG DAMAGE. ARC RAYS can injure eyes and burn skin. ELECTRIC SHOCK can kill.

MACHINING

HAYNES® 230® alloy is similar in machining characteristics to other solid-solution-strengthened nickel-base alloys. These alloys as a group are classified as moderate to difficult to machine; however, it should be emphasized that they can be machined using conventional methods at satisfactory rates. As these alloys will work-harden rapidly, the keys to successful machining are to use slower speeds and feeds, and to take heavier cuts than would be used for machining stainless steels. See Haynes International publication H-3159 for more detailed information.

Normal Roughing (Turning/Facing)

Use carbide C-2/C-3 grade tool

Speed: 90 surface feet/minute
Feed: 0.010 in./revolution
Depth of Cut: 0.150 in.

Negative rake square insert, 45° SCEA[1] 1/32 in. nose radius. Tool holder: 5° negative back and side rakes.

Lubricant: Dry[2], Oil[3] or water-base[4,5]

Finishing (Turning/Facing)

Use carbide C-2/C-3 grade tool

Speed: 95-110 surface feet/minute
Feed: 0.005-0.007 in./revolution
Depth of Cut: 0.040 in.

Positive rake square insert, if possible, 45° SCEA, 1/32 in. nose radius. Tool holder: 5° positive back and side rakes.

Lubricant: Dry or water-base

Drilling

Use high speed steel M-33/M-40 series[6]/ or T-15 grades*

Speed: 10-15 surface feet/minute (200 RPM maximum for 1/4 in. diameter or smaller)

Lubricant: Oil or water-base. Use coolant feed drills if possible

Short, heavy-web drills with 135° crank shaft point. Thinning of web at point may reduce thrust.

Feed (per revolution):
0.001 in. rev. 1/8 in. dia. 0.002 in. rev. 1/4 in. dia.
0.003 in. rev. 1/2 in. dia. 0.005 in. rev. 3/4 in. dia.
0.007 in. rev. 1 in. dia.

* Carbide drills not recommended, but may be used in some set-ups. See Haynes International publication H-3159 for details.

Notes:

1 SCEA-Side cutting edge angle, or lead angle of the tool.

2 At any point where dry cutting is recommended, an air jet directed on the tool may provide substantial tool life increases. A water-base coolant mist may also be effective.

3 Oil coolant should be a premium quality, sulfochlorinated oil with extreme pressure additives. A viscosity at 100°F from 50 to 125 SSU is standard.

4 Water-base coolant should be a 15:1 mix of water with either a premium quality, sulfochlorinated water soluble oil or a chemical emulsion with extreme pressure additives.

5 Water-base coolants may cause chipping or rapid failure of carbide tools in interrupted cuts.

6 M-40 series High Speed Steels include M-41 through M-46 at time of writing, others may be added, and should be equally suitable.

Acknowledgements:
253 MA is a registered trademark of Avesta Jernwerks Aktiebolag.
RA330 is a registered trademark of Rolled Alloys, Inc.
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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-35™, 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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