HAYNES® 282® alloy

Principal Features

Excellent High Temperature Strength

HAYNES® 282® alloy (UNS N07208) is a, wrought, gamma-prime strengthened superalloy developed for high temperature structural applications, especially those in aero and industrial gas turbine engines. It possesses a unique combination of creep strength, thermal stability, weldability, and fabricability not found in currently available commercial alloys. The excellent creep strength in the temperature range of 1200 to 1700°F (649 to 927°C) surpasses that of Waspaloy alloy, and approaches R-41 alloy without sacrificing weldability.

Easily Fabricated

This high level of creep strength in HAYNES® 282® alloy has been attained at a relatively low volume fraction of the strengthening gamma-prime phase, resulting in outstanding resistance to strain-age cracking (normally a problem with superalloys in this creep strength range). Additionally, slow gamma-prime precipitation kinetics allow for the alloy to have excellent ductility in the as-annealed condition. Consequently, HAYNES® 282® alloy exhibits superior weldability and fabricability. Machinability is similar to that of Waspaloy.

Heat Treatment

HAYNES® 282® alloy is provided in the solution-annealed condition, in which it is readily formable. The typical solution-annealing temperature is in the range of 2050 to 2100°F (1121 to 1149°C). After component fabrication, an age hardening treatment is required to put the alloy into the high-strength condition. The standard two-step treatment includes 1850°F (1010°C) / 2 hours / AC (air cool) + 1450°F (788°C) / 8 hours / AC, but alternative heat treatments are available to optimize properties for specific performance requirements or for manufacturability.

NOTE: The heat treatment for Advanced Ultra-Supercritical (A-USC), Supercritical CO_2, and Other ASME Boiler Code Applications is different from the standard heat treatment. For information regarding the heat treatment for ASME code related applications, please click here.

Product Forms

HAYNES® 282® alloy is available in a full range of product forms and sizes, including plate, sheet and coil products from foil thickness up to cross-sections greater than 2” (>50mm) thick; Bar and wire from up to 9” in diameter, Reforge billet and ingot products from 4” up to 20” (100-500mm) diameters; and seamless and welded Pipe and tube in some standard sizes. Vacuum castings have also been produced for various applications, and powder products are available to support many Additive Manufacturing methods.

Applications

The features of HAYNES® 282® alloy make it suitable for critical gas turbine applications found in the combustors, turbine and exhaust sections, and nozzle components. Fabrication methods commonly employed include sheet and plate fabrications, seamless and flash butt-welded rings, closed die forgings and components directly machined from bar and heavy plate blanks. In industrial gas turbines, HAYNES® 282® alloy is defining performance standards for combustors and transition sections, and other hot-gas-path components requiring exceptional creep life and low cycle fatigue (LCF) resistance. Automotive turbocharger applications, such as seals and high temperature springs, benefit from the superior high-temperature properties.

HAYNES® 282® alloy is also a strong candidate for use in Advanced Ultra-Supercritical (A-USC) boiler and steam turbines, Supercritical CO_2 power cycle, and concentrating solar power plant, where creep life is required to surpass 100,000 hours at 14.5 ksi (100 MPa) at 1400°F (760°C). ASME Code Case 3024 covers a new single-step age-hardening treatment for HAYNES® 282® alloy for use in Advanced Ultra-Supercritical (A-USC) and Supercritical CO_2 and other ASME Boiler Code applications. For additional information regarding the single-step age-hardened material, please click here.

Nominal Composition

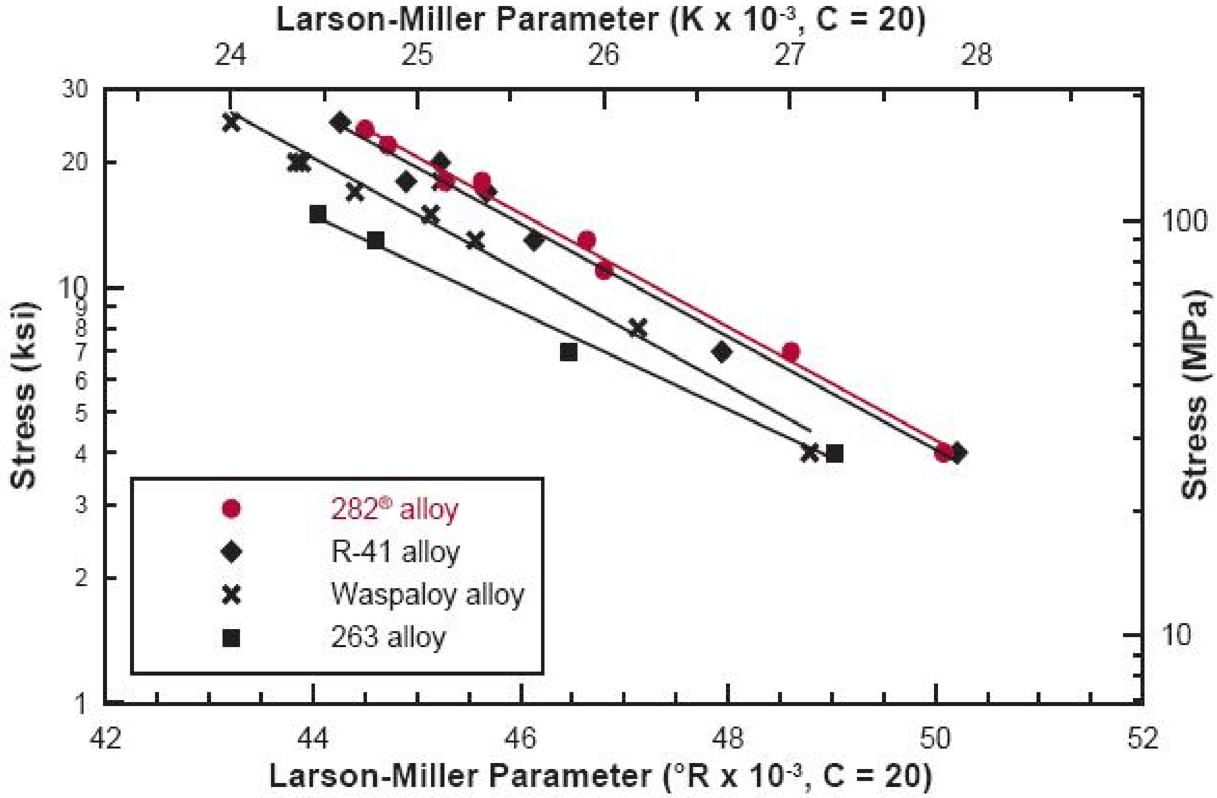
Weight %

Nickel:	57 Balance
Chromium:	20
Cobalt:	10
Molybdenum:	8.5
Titanium:	2.1
Aluminum:	1.5
Iron:	1.5 max.
Manganese:	0.3 max.
Silicon:	0.15 max.
Carbon:	0.06
Boron:	0.005

Creep and Stress-Rupture Strength

HAYNES® 282® alloy possesses exceptional creep strength in the temperature range 1200-1700°F (649-927°C). For example, it has superior strength to 263 alloy at all temperatures in this range in terms of both 1% creep and rupture. Despite the exceptional fabricability of 282® alloy, it compares well to less fabricable alloys developed for high creep strength. For example, its rupture strength is equivalent to the well-known, but less fabricable, Waspaloy alloy at the lower temperatures in this range and actually has a distinct advantage at the higher end of the temperature range. In terms of 1% creep strength, 282® alloy is superior to Waspaloy alloy across the entire temperature range. At temperatures of 1500-1700°F (816-927°C), 282® alloy has creep strength equivalent to even that of R-41 alloy, an alloy developed for excellent creep strength, but notorious for poor fabricability.

Creep Strength of Various Superalloys in the Temperature Range 1500-1700°F (816-927°C) (Sheet Products)



Creep and Stress-Rupture Strength Continued

Comparative Creep-Rupture Properties of Gamma-Prime Strengthened Alloys* (Sheet)

Property	Test Temperature		263		R-41		Waspaloy		282®	
	°F	°C	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
Stress-to-Produce 1% Creep in 100 h ksi (MPa)	1200	649	75	517	105	724	81	558	-	-
	1300	704	54	372	75	517	63	434	**72**	**496**
	1400	760	37	255	53	365	41	283	**48**	**331**
	1500	816	22	152	32	221	25	172	**32**	**221**
	1600	871	11	76	17	117	15	103	**18**	**124**
	1700	927	6	41	8	55	6	41	**9**	**62**
Stress-to-Produce 1% Creep in 1000 h ksi (MPa)	1200	649	58	400	84	579	67	462	**79**	**545**
	1300	704	41	283	59	407	46	317	**53**	**365**
	1400	760	25	172	34	234	28	193	**35**	**241**
	1500	816	12	83	18	124	16	110	**21**	**145**
	1600	871	6	41	9	62	7	48	**10**	**69**
	1700	927	3	21	5	34	3	21	**5**	**34**
Stress-to-Produce Rupture in 100 h ksi (MPa)	1200	649	77	531	110	758	92	634	-	-
	1300	704	60	414	85	586	75	517	**75**	**517**
	1400	760	42	290	63	434	53	365	**56**	**386**
	1500	816	25	172	39	269	32	221	**37**	**255**
	1600	871	14	97	23	159	19	131	**22**	**152**
	1700	927	7	48	13	90	10	69	**12**	**83**
Stress-to-Produce Rupture in 1000 h ksi (MPa)	1200	649	64	441	90	621	80	552	**80**	**552**
	1300	704	45	310	68	469	58	400	**56**	**386**
	1400	760	28	193	43	296	36	248	**38**	**262**
	1500	816	15	103	24	165	20	138	**23**	**159**
	1600	871	7	48	13	90	7	48	**12**	**83**
	1700	927	4	28	7	48	3	21	**6**	**41**

*Age-hardened (263 alloy: 1472°F (800°C)/8h/AC, Waspaloy alloy : 1825°F (996°C)/2h/AC + 1550°F (843°C)/4h/AC + 1400°F (760°C)/16h/AC, R-41 alloy: 1650°F (899°C)/4h/AC, 282® alloy: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC)

Creep and Stress-Rupture Strength Continued

Solution Annealed* + Age Hardened 282® Sheet**

Test Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in:			
			100 h		1,000 h	
°F	°C	%	ksi	MPa	ksi	MPa
1200	649	0.5	-	-	78	538
		1	-	-	79	545
		Rupture	-	-	80	552
1300	704	0.5	70	483	51	352
		1	72	496	53	365
		Rupture	75	517	56	386
1400	760	0.5	46	317	33	228
		1	48	331	35	241
		Rupture	56	386	38	262
1500	816	0.5	30	207	18	124
		1	32	221	21	145
		Rupture	37	225	23	159
1600	871	0.5	17	117	9	62
		1	18	124	10	69
		Rupture	22	152	12	83
1700	927	0.5	8.3	57	4.2	29
		1	9	62	5	34
		Rupture	12	83	6	41
1800	982	0.5	3.6	25	-	-
		1	4.2	29	1.8	12
		Rupture	5.5	38	2.5	1

*2100°F (1149°C)
**1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC

Creep and Stress-Rupture Strength Continued

Solution Annealed* + Age Hardened 282® Plate**

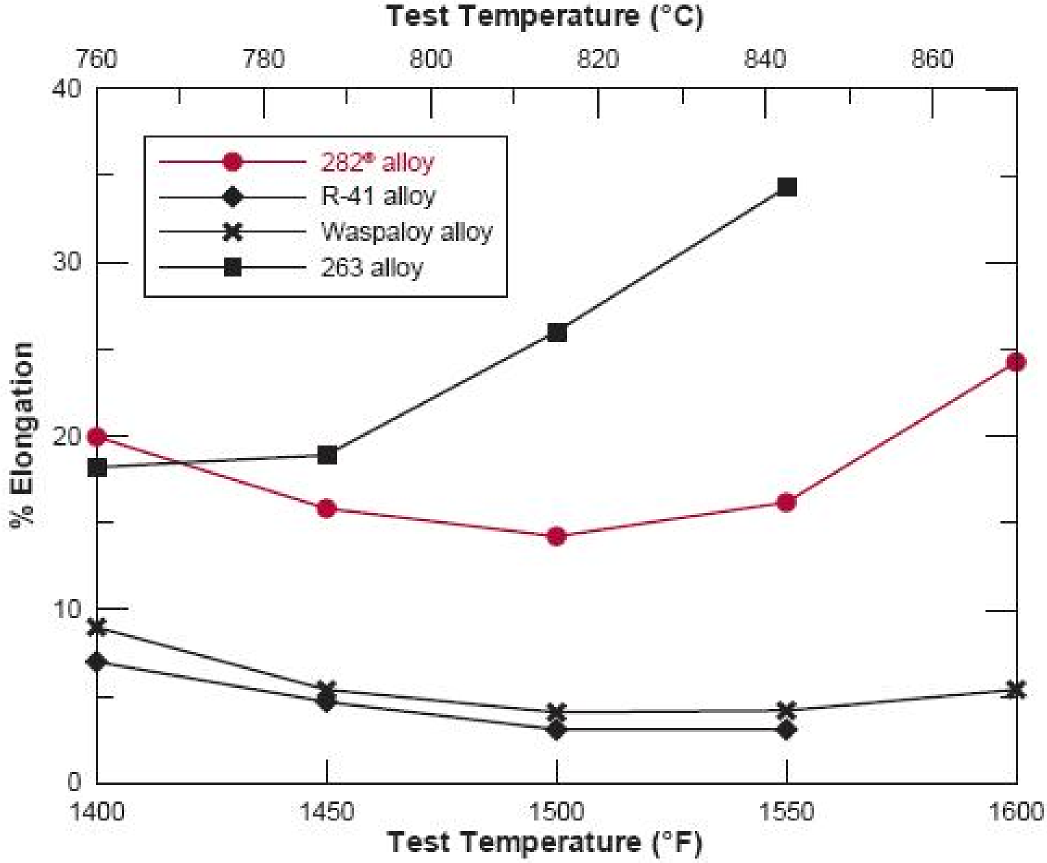
Test Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in:					
			100 h		1,000 h		10,000 h	
°F	°C	%	ksi	MPa	ksi	MPa	ksi	MPa
1200	649	0.5	-	-	81	558	-	-
		1	-	-	82	565	-	-
		Rupture	-	-	85	586	64	441
1300	704	0.5	73	503	53	365	-	-
		1	75	517	55	379	-	-
		Rupture	80	552	61	421	45	310
1400	760	0.5	49	338	35	241	-	-
		1	50	345	36	248	-	-
		Rupture	57	393	41	283	27	186
1500	816	0.5	32	221	20	138	-	-
		1	34	234	22	152	-	-
		Rupture	38	262	25	172	14	97
1600	871	0.5	18	124	11	76	-	-
		1	19	131	12	83	-	-
		Rupture	23	159	14	97	8	55
1700	927	0.5	9.4	65	4.8	33	-	-
		1	10	69	5.2	36	-	-
		Rupture	13	90	7	48	3.7	26
1800	982	0.5	4.2	29	1.8	12	-	-
		1	4.6	32	2	14	-	-
		Rupture	6.2	43	3.6	25	-	-

*2075°F (1135°C)
**1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC

Strain-Age Cracking Resistance

Resistance to strain-age cracking is a major attribute of HAYNES® 282® alloy. As indicated in the chart below, 282® alloy approaches the well-known 263 alloy in this regard, and possesses much higher resistance to strain-age cracking than other nickel superalloys in its strength class (Waspaloy and R-41 alloys).

Resistance to Strain-Age Cracking as Measured by the Controlled Heating-Rate Tensile (CHRT) Test



The CHRT test is an excellent measure of the resistance of gamma-prime strengthened superalloys to strain-age cracking. Samples of thickness 0.063” (1.6 mm), originally in the solution annealed condition, are heated to the test temperature at a rate of 25-30°F (14-17°C) per minute, this being representative of a typical post-weld heat treatment. Tests are performed for each alloy over a range of temperatures. The susceptibility to strain-age cracking is related to the minimum tensile elongation observed within that temperature range (the higher the minimum elongation, the greater is the resistance to strain-age cracking).

For further information regarding this test, please refer to:

1. R.W. Fawley, M. Prager, J.B. Carlton, and G. Sines, WRC Bulletin No. 150, Welding Research Council, New York, 1970.
2. M.D. Rowe, “Ranking the Resistance of Wrought Superalloys to Strain-Age Cracking”, Welding Journal, 85 (2), pp. 27-s to 34-s, 2006.

Tensile Properties

Solution Annealed and Age-Hardened Sheet*

Temperature		Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	101.4	699	164.2	1132	30
1000	538	91.6	632	139.3	960	36
1200	649	91.5	631	145.7	1005	27
1300	704	90.5	624	136.5	941	24
1400	760	88.7	612	120.8	833	22
1500	816	82.3	567	100.3	692	24
1600	871	72.6	501	80.5	555	31
1700	927	43.9	303	50.2	346	37
1800	982	18.7	129	24.5	169	61

Solution Annealed and Age-Hardened Plate*

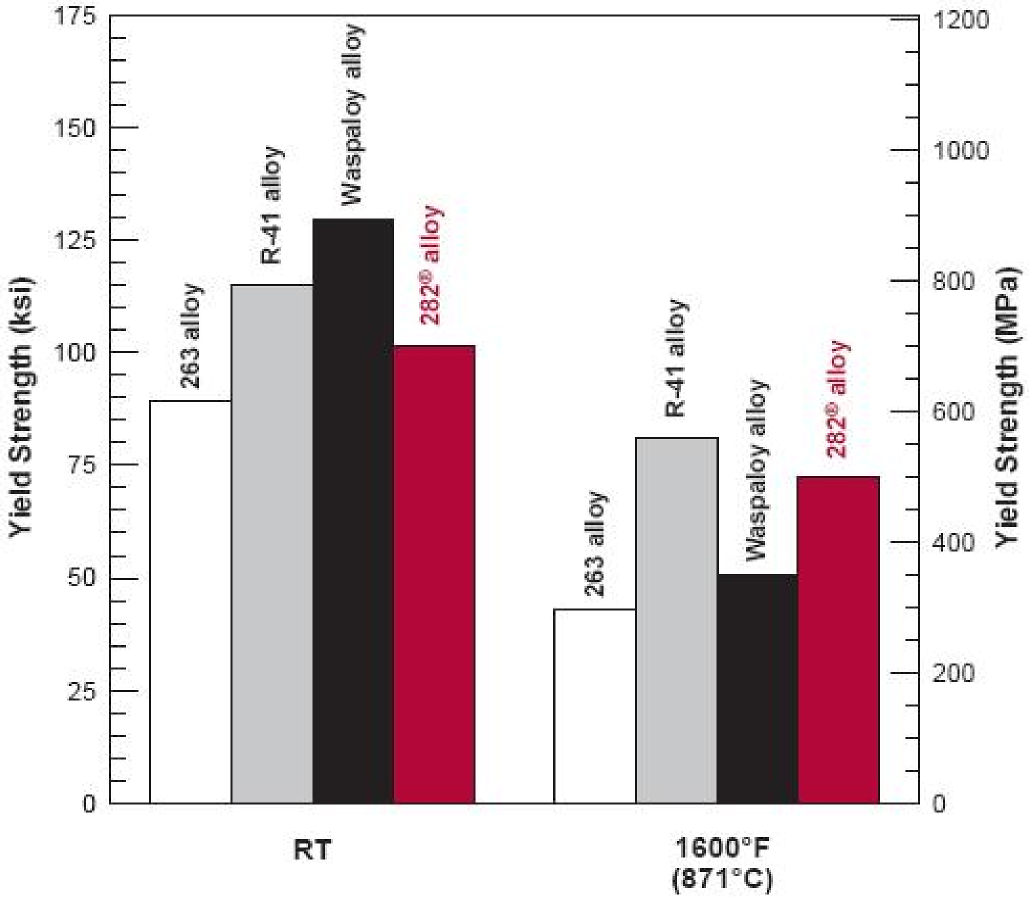
Temperature		Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation	Reduction of Area
°F	°C	ksi	MPa	ksi	MPa	%	%
RT	RT	103.7	715	166.4	1147	30	31
1000	538	94.1	649	143.8	991	34	36
1200	649	93.2	643	152.0	1048	31	31
1300	704	94.2	649	141.8	978	29	28
1400	760	91.1	628	124.2	856	22	24
1500	816	83.4	575	102.8	709	28	31
1600	871	73.6	507	82.1	566	31	42
1700	927	44.9	310	52.1	359	50	69
1800	982	19.1	132	25.3	174	71	91

*Solution Annealing: Sheet at 2100°F (1149°C), Plate at 2075°F (1135°C)
Age-Hardening: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC
RT= Room Temperature

Tensile Properties Continued

Comparative Yield Strengths of Age-Hardened* Sheet Material at Room Temperature and 1600°F (871°C)

At room temperature, HAYNES® 282® alloy has a higher yield strength than 263 alloy, but is not as strong as R-41 and Waspaloy alloys, which contain higher gamma-prime phase contents. However, at higher temperatures typical of gas turbine component applications, 282® alloy exhibits excellent yield strength, surpassing that of 263 and Waspaloy, and approaching that of the less fabricable R-41 alloy.



*Age-hardened (263 alloy: 1472°F (800°C)/8h/AC, Waspaloy alloy : 1825°F (996°C)/2h/AC + 1550°F (843°C)/4h/AC + 1400°F (760°C)/16h/AC, R-41 alloy: 1650°F (899°C)/4h/AC, 282® alloy: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC)

Hardness

Average Room Temperature Hardness of Mill Annealed HAYNES® 282® Alloy

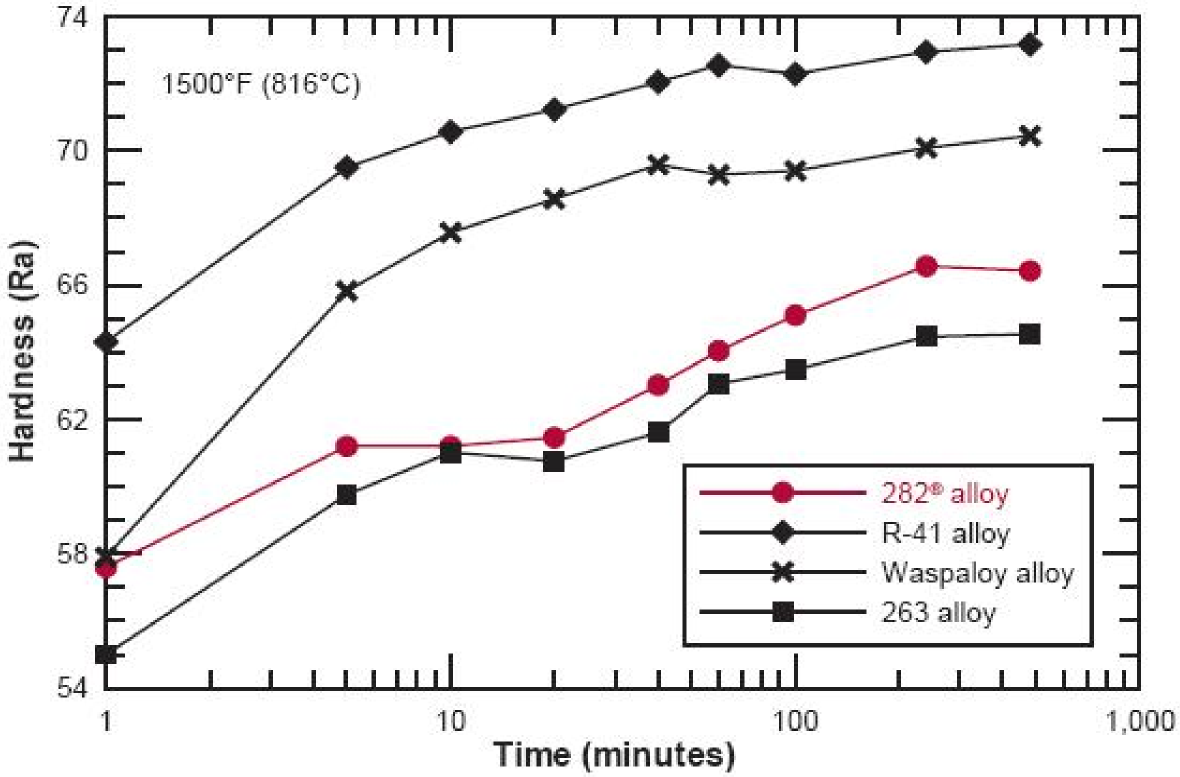
Form	Solution Annealed*	Age-hardened**
-	HRBW	HRC
Sheet	90	30
Plate	93	32
Bar	86	29

*Solution Annealing: Sheet at 2100°F (1149°C), Plate and Bar at 2075°F (1135°C)
**Age-hardening: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC
HRBW = Hardness Rockwell "B", Tungsten Indentor.
HRC = Hardness Rockwell "C".

Aging Kinetics

A key attribute of HAYNES® 282® alloy is its sluggish gamma-prime precipitation kinetics which are highly desirable for improved fabricability for two main reasons. One, the formation of gamma-prime during heat treatment is a key factor in strain age-cracking. Two, it allows sufficient time for the alloy to cool after solution annealing without formation of the gamma-prime phase which would reduce cold formability. The chart below indicates the increase in the room-temperature hardness (an indicator of the precipitation of the gamma-prime phase) with increasing aging time at 1500°F (816°C) for 282® alloy and several other gamma-prime strengthened alloys. 282® alloy was found to have a sluggish response, similar to the readily fabricable 263 alloy. The less fabricable R-41 and Waspaloy alloys hardened much more quickly.

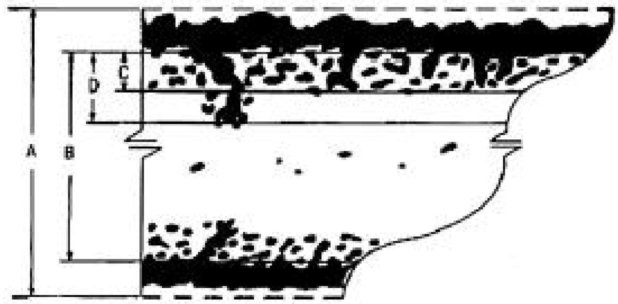
Isothermal Hardening Kinetics
Temperature: 1500°F (816°C), Starting Material: Solution Annealed Sheet



Oxidation Resistance

Static Oxidation Testing

Environment: Flowing Air
Test Duration: 1,008 h
Number of Cycles: 6
Cycle Length: 168 h
Temperatures: 1600, 1700, 1800°F (871, 927, 982°C)
Metal Loss = (A-B)/2
Average Internal Penetration = C
Maximum Internal Penetration = D
Average Metal Affected = Metal Loss + Average Internal Penetration
Maximum Metal Affected = Metal Loss + Maximum Internal Penetration



Comparative Oxidation Resistance in Flowing Air, 1008 Hours

	1600°F (871°C)				1700°F (927°C)				1800°F (982°C)			
	Metal Loss, mils (µm)		Avg. Met. Aff. mils, (µm)		Metal Loss, mils (µm)		Avg. Met. Aff. mils, (µm)		Metal Loss, mils (µm)		Avg. Met. Aff. mils, (µm)	
Alloy	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm
263	0.1	3	0.4	10	0.2	5	0.7	18	0.9	23	5.0	127
282®	**0.2**	**5**	**0.6**	**15**	**0.1**	**3**	**1.1**	**28**	**0.2**	**5**	**1.8**	**46**
R-41	0.2	5	0.8	20	0.2	5	1.5	38	0.2	5	2.9	74
Waspaloy	0.3	8	1.4	36	0.3	8	3.4	86	0.7	18	5.0	127

Dynamic Oxidation Testing (Burner Rig)

Burner rig oxidation tests were conducted by exposing, in a rotating holder, samples 0.375 inch x 2.5 inches x thickness (9.5mm x 64mm x thickness) to the products of combustion of fuel oil (2 parts No. 1 and 1 part No. 2), burned at an air to fuel ratio of about 50:1. The gas velocity was about 0.3 mach. Samples were automatically removed from the gas stream every 30 minutes and fan cooled to less than 500°F (260°C) and then reinserted into the flame tunnel.

	1600°F (871°C), 1000 hours, 30 minute cycles				1800°F (982°C), 1000 hours, 30 minute cycles			
	Metal Loss, mils (µm)		Avg. Met. Aff. mils, (µm)		Metal Loss, mils (µm)		Avg. Met. Aff. mils, (µm)	
Alloy	mils	µm	mils	µm	mils	µm	mils	µm
263	1.4	36	4.0	102	12.5	318	16.1	409
282®	**1.8**	**46**	**4.2**	**107**	**8.0**	**203**	**13.0**	**330**
Waspaloy	1.9	48	4.3	109	9.5	241	13.6	345
R-41	1.2	30	4.4	112	5.8	147	12.1	307

Thermal Stability

Comparative Thermal Stability Data of Gamma-Prime Strengthened Alloys (Sheet)

Room Temperature Tensile Data – Exposed* at 1200°F (649°C) for 1,000 hours

Alloy	0.2% Yield Strength		Ultimate Tensile Strength		Elongation
-	ksi	MPa	ksi	MPa	%
263	113.6	783	166.6	1149	21.3
282®	**112.9**	**778**	**172.8**	**1191**	**25.8**
Waspaloy	136.5	941	196.2	1353	22.6
R-41	141.9	979	189.4	1306	8.9

Room Temperature Tensile Data – Exposed* at 1400°F (760°C) for 1,000 hours

Alloy	0.2% Yield Strength		Ultimate Tensile Strength		Elongation
-	ksi	MPa	ksi	MPa	%
263	92.7	639	160.3	1105	32.4
282®	**104.1**	**718**	**170.5**	**1176**	**22.8**
Waspaloy	112.9	779	182.4	1258	24
R-41	167	1151	197.2	1359	1.9

Room Temperature Tensile Data – Exposed* at 1500°F (816°C) for 1,000 hours

Alloy	0.2% Yield Strength		Ultimate Tensile Strength		Elongation
-	ksi	MPa	ksi	MPa	%
263	71.4	492	144	993	34.7
282®	**91.9**	**634**	**159.8**	**1102**	**22.3**
Waspaloy	103.5	714	170.1	1173	22.8
R-41	137.9	951	177.5	1224	1.8

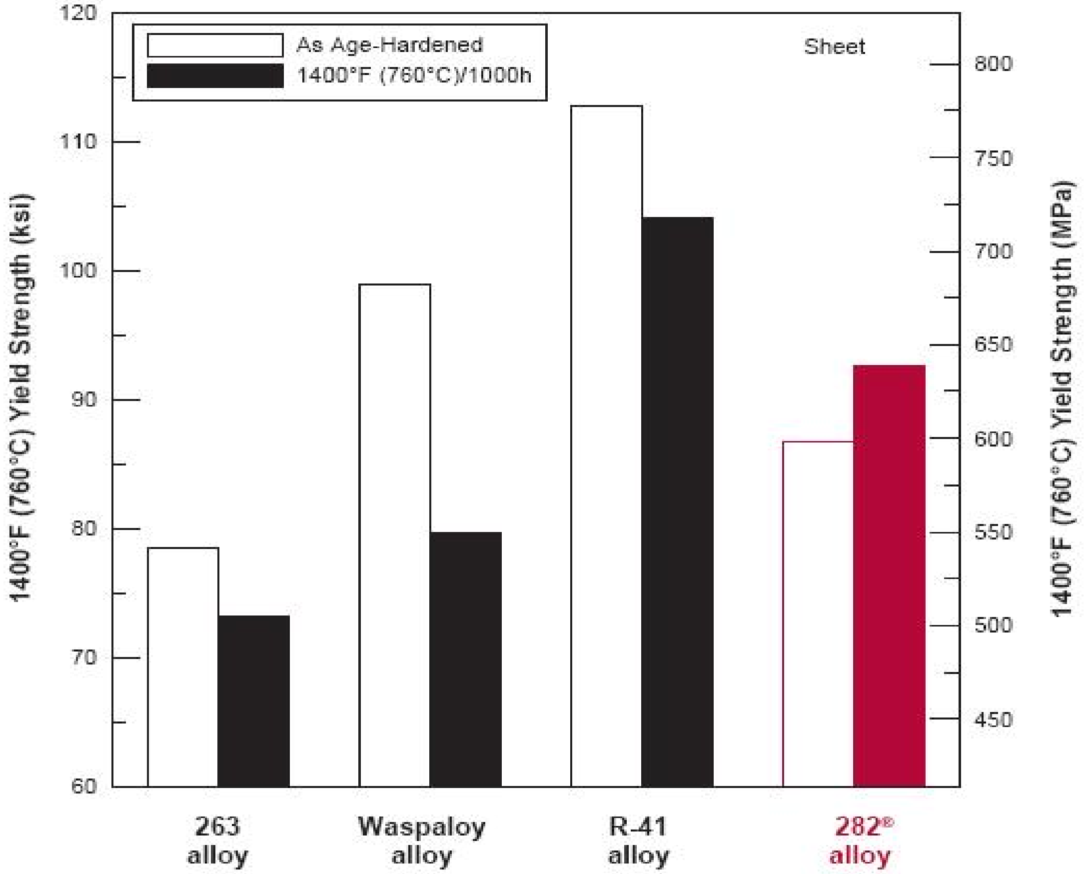
Room Temperature Tensile Data – Exposed* at 1600°F (871°C) for 1,000 hours

Alloy	0.2% Yield Strength		Ultimate Tensile Strength		Elongation
-	ksi	MPa	ksi	MPa	%
263	55	379	125.2	863	40.9
282®	**72.9**	**505**	**141.4**	**975**	**24.2**
Waspaloy	84.6	584	149.3	1030	18.1
R-41	103.8	715	148	1021	2.6

*Thermal exposure was applied to samples in the age-hardened condition (263 alloy: 1472°F (800°C)/8h/AC, Waspaloy alloy : 1825°F (996°C)/2h/AC + 1550°F (843°C)/4h/AC + 1400°F (760°C)/16h/AC, R-41 alloy: 1650°F (899°C)/4h/AC, 282® alloy: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC)

Thermal Stability Continued

Effect of Thermal Exposure on Yield Strength (At the Exposure Temperature)



Room Temperature Properties of HAYNES® 282® Plate after Thermal Exposure*

Exposure Temperature		Duration	0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation	Reduction of Area
°F	°C	h	ksi	MPa	ksi	MPa	%	%
1200	649	0	102	705	167	1152	30	33
		100	116	798	181	1247	27	31
		1,000	118	814	181	1248	26	29
		4,000	120	830	182	1255	26	29
		8,000	119	819	183	1264	24	27
		16,000	118	816	183	1260	23	25
1400	760	0	102	705	167	1152	30	33
		100	110	759	177	1223	27	30
		1,000	108	742	178	1226	26	29
		4,000	103	707	175	1205	21	22
		8,000	100	690	173	1191	20	21
		16,000	96	658	168	1161	20	19
1600	871	0	102	705	167	1152	30	33
		100	90	618	162	1114	31	36
		1,000	77	533	155	1065	30	30
		4,000	71	487	148	1022	32	31
		8,000	69	473	146	1006	32	31
		16,000	66	452	142	978	33	32

*Thermal exposure was applied to samples in the age-hardened condition (1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC)

Physical Properties*

Physical Property	British Units		Metric Units	
Density (Solution Annealed)	0.299 lb/in³	-	8.27 g/cm³	-
Density (Age-Hardened)	0.300 lb/in³	-	8.29 g/cm³	-
Melting Range	2370-2510°F	-	1300-1375°C	-
Gamma-Prime Solvus	1827°F	-	997°C	-
Specific Heat	RT	0.104 Btu/lb.°F	RT	436 J/Kg.°C
	200°F	0.110 Btu/lb.°F	100°C	463 J/Kg.°C
	300°F	0.114 Btu/lb.°F	200°C	494 J/Kg.°C
	400°F	0.118 Btu/lb.°F	300°C	522 J/Kg.°C
	500°F	0.122 Btu/lb.°F	400°C	544 J/Kg.°C
	600°F	0.125 Btu/lb.°F	500°C	563 J/Kg.°C
	700°F	0.128 Btu/lb.°F	600°C	581 J/Kg.°C
	800°F	0.131 Btu/lb.°F	700°C	594 J/Kg.°C
	900°F	0.134 Btu/lb.°F	800°C	650 J/Kg.°C
	1000°F	0.136 Btu/lb.°F	900°C	668 J/Kg.°C
	1100°F	0.138 Btu/lb.°F	1000°C	676 J/Kg.°C
	1200°F	0.140 Btu/lb.°F	-	-
	1300°F	0.142 Btu/lb.°F	-	-
	1400°F	0.150 Btu/lb.°F	-	-
	1500°F	0.156 Btu/lb.°F	-	-
	1600°F	0.158 Btu/lb.°F	-	-
	1700°F	0.160 Btu/lb.°F	-	-
	1800°F	0.161 Btu/lb.°F	-	-
Thermal Conductivity	RT	72 Btu-in/ft²-h°F	RT	10.3 W/m.°C
	200°F	82 Btu-in/ft²-h°F	100°C	12.0 W/m.°C
	300°F	90 Btu-in/ft²-h°F	200°C	14.1 W/m.°C
	400°F	99 Btu-in/ft²-h°F	300°C	16.3 W/m.°C
	500°F	107 Btu-in/ft²-h°F	400°C	18.5 W/m.°C
	600°F	116 Btu-in/ft²-h°F	500°C	20.5 W/m.°C
	700°F	124 Btu-in/ft²-h°F	600°C	22.6 W/m.°C
	800°F	132 Btu-in/ft²-h°F	700°C	24.8 W/m.°C
	900°F	140 Btu-in/ft²-h°F	800°C	26.1 W/m.°C
	1000°F	148 Btu-in/ft²-h°F	900°C	27.3 W/m.°C
	1100°F	156 Btu-in/ft²-h°F	1000°C	28.9 W/m.°C
	1200°F	164 Btu-in/ft²-h°F	-	-
	1300°F	173 Btu-in/ft²-h°F	-	-
	1400°F	177 Btu-in/ft²-h°F	-	-
	1500°F	182 Btu-in/ft²-h°F	-	-
	1600°F	187 Btu-in/ft²-h°F	-	-
	1700°F	192 Btu-in/ft²-h°F	-	-
	1800°F	199 Btu-in/ft²-h°F	-	-

*Age-hardened 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC
RT= Room Temperature

Physical Properties* Continued

Physical Property	British Units		Metric Units	
Thermal Diffusivity	RT	0.112 ft²/h	RT	0.0288 cm²/s
	200°F	0.121 ft²/h	100°C	0.0315 cm²/s
	300°F	0.128 ft²/h	200°C	0.0348 cm²/s
	400°F	0.135 ft²/h	300°C	0.0381 cm²/s
	500°F	0.143 ft²/h	400°C	0.0413 cm²/s
	600°F	0.150 ft²/h	500°C	0.0444 cm²/s
	700°F	0.156 ft²/h	600°C	0.0473 cm²/s
	800°F	0.163 ft²/h	700°C	0.0509 cm²/s
	900°F	0.170 ft²/h	800°C	0.0488 cm²/s
	1000°F	0.176 ft²/h	900°C	0.0498 cm²/s
	1100°F	0.183 ft²/h	1000°C	0.0521 cm²/s
	1200°F	0.190 ft²/h	-	-
	1300°F	0.197 ft²/h	-	-
	1400°F	0.192 ft²/h	-	-
	1500°F	0.190 ft²/h	-	-
	1600°F	0.192 ft²/h	-	-
	1700°F	0.195 ft²/h	-	-
	1800°F	0.200 ft²/h	-	-
Electrical Resistivity	RT	49.7 μohm.in	RT	126.1 μohm.cm
	200°F	50.3 μohm.in	100°C	127.8 μohm.cm
	300°F	50.7 μohm.in	200°C	129.9 μohm.cm
	400°F	51.2 μohm.in	300°C	131.8 μohm.cm
	500°F	51.6 μohm.in	400°C	133.4 μohm.cm
	600°F	52.0 μohm.in	500°C	135.0 μohm.cm
	700°F	52.3 μohm.in	600°C	136.2 μohm.cm
	800°F	52.7 μohm.in	700°C	135.5 μohm.cm
	900°F	53.0 μohm.in	800°C	134.5 μohm.cm
	1000°F	53.5 μohm.in	900°C	132.6 μohm.cm
	1100°F	53.7 μohm.in	1000°C	129.9 μohm.cm
	1200°F	53.4 μohm.in	-	-
	1300°F	53.3 μohm.in	-	-
	1400°F	53.1 μohm.in	-	-
	1500°F	52.9 μohm.in	-	-
	1600°F	52.5 μohm.in	-	-
	1700°F	51.9 μohm.in	-	-
	1800°F	51.3 μohm.in	-	-

*Age-hardened 1850°F(1010°C)/2h/AC + 1450°F(788°C)/8h/AC
RT= Room Temperature

Physical Property	British Units		Metric Units	
Mean Coefficient of Thermal Expansion	RT	-	RT	-
	200°F	6.7 µin/in.°F	100°C	12.1 µm/m.°C
	300°F	6.8 µin/in.°F	200°C	12.4 µm/m.°C
	400°F	6.9 µin/in.°F	300°C	12.8 µm/m.°C
	500°F	7.0 µin/in.°F	400°C	13.1 µm/m.°C
	600°F	7.1 µin/in.°F	500°C	13.5 µm/m.°C
	700°F	7.2 µin/in.°F	600°C	13.7 µm/m.°C
	800°F	7.3 µin/in.°F	700°C	14.2 µm/m.°C
	900°F	7.5 µin/in.°F	800°C	14.9 µm/m.°C
	1000°F	7.5 µin/in.°F	900°C	15.9 µm/m.°C
	1100°F	7.6 µin/in.°F	1000°C	16.9 µm/m.°C
	1200°F	7.8 µin/in.°F	-	-
	1300°F	7.9 µin/in.°F	-	-
	1400°F	8.1 µin/in.°F	-	-
	1500°F	8.4 µin/in.°F	-	-
	1600°F	8.7 µin/in.°F	-	-
	1700°F	9.0 µin/in.°F	-	-
	1800°F	9.3 µin/in.°F	-	-
Dynamic Modulus of Elasticity	RT	31.5 x 10^6 psi	RT	217 GPa
	200°F	31.0 x 10^6 psi	100°C	213 GPa
	300°F	30.6 x 10^6 psi	200°C	209 GPa
	400°F	30.2 x 10^6 psi	300°C	202 GPa
	500°F	29.7 x 10^6 psi	400°C	196 GPa
	600°F	29.2 x 10^6 psi	500°C	190 GPa
	700°F	28.7 x 10^6 psi	600°C	183 GPa
	800°F	28.2 x 10^6 psi	700°C	175 GPa
	900°F	27.7 x 10^6 psi	800°C	166 GPa
	1000°F	27.2 x 10^6 psi	900°C	154 GPa
	1100°F	26.6 x 10^6 psi	1000°C	140 GPa
	1200°F	26.0 x 10^6 psi	-	-
	1300°F	25.4 x 10^6 psi	-	-
	1400°F	24.7 x 10^6 psi	-	-
	1500°F	23.8 x 10^6 psi	-	-
	1600°F	22.9 x 10^6 psi	-	-
	1700°F	21.7 x 10^6 psi	-	-
	1800°F	20.6 x 10^6 psi	-	-
	1100°F	0.346	1000°C	0.363
	1200°F	0.35	-	-
	1300°F	0.353	-	-
	1400°F	0.355	-	-
	1500°F	0.355	-	-
	1600°F	0.355	-	-
	1700°F	0.359	-	-
	1800°F	0.363	-	-

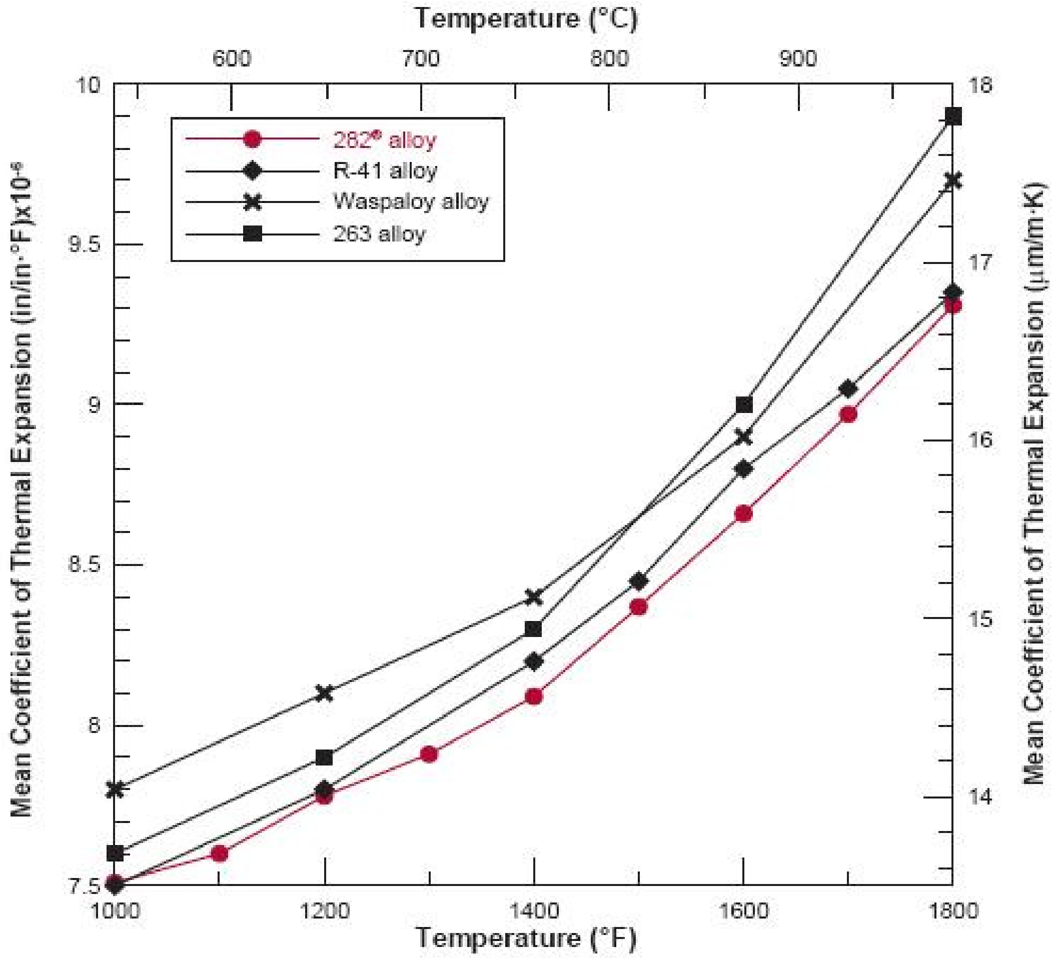
Physical Properties* Continued

Physical Property	British Units		Metric Units	
Dynamic Shear Modulus	RT	11.9 x 10^6 psi	RT	82 GPa
	200°F	11.7 x 10^6 psi	100°C	80 GPa
	300°F	11.5 x 10^6 psi	200°C	78 GPa
	400°F	11.3 x 10^6 psi	300°C	76 GPa
	500°F	11.1 x 10^6 psi	400°C	73 GPa
	600°F	10.9 x 10^6 psi	500°C	71 GPa
	700°F	10.7 x 10^6 psi	600°C	68 GPa
	800°F	10.6 x 10^6 psi	700°C	65 GPa
	900°F	10.4 x 10^6 psi	800°C	61 GPa
	1000°F	10.1 x 10^6 psi	900°C	57 GPa
	1100°F	9.9 x 10^6 psi	1000°C	51 GPa
	1200°F	9.7 x 10^6 psi	-	-
	1300°F	9.4 x 10^6 psi	-	-
	1400°F	9.1 x 10^6 psi	-	-
	1500°F	8.8 x 10^6 psi	-	-
	1600°F	8.4 x 10^6 psi	-	-
	1700°F	8.0 x 10^6 psi	-	-
	1800°F	7.6 x 10^6 psi	-	-
Poisson's Ratio	RT	0.319	RT	0.319
	200°F	0.325	100°C	0.326
	300°F	0.33	200°C	0.335
	400°F	0.335	300°C	0.335
	500°F	0.335	400°C	0.337
	600°F	0.335	500°C	0.341
	700°F	0.337	600°C	0.346
	800°F	0.338	700°C	0.352
	900°F	0.34	800°C	0.355
	1000°F	0.342	900°C	0.357
	1100°F	0.346	1000°C	0.363
	1200°F	0.35	-	-
	1300°F	0.353	-	-
	1400°F	0.355	-	-
	1500°F	0.355	-	-
	1600°F	0.355	-	-
	1700°F	0.359	-	-
	1800°F	0.363	-	-

*Age-hardened 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC
RT= Room Temperature

Physical Properties Continued

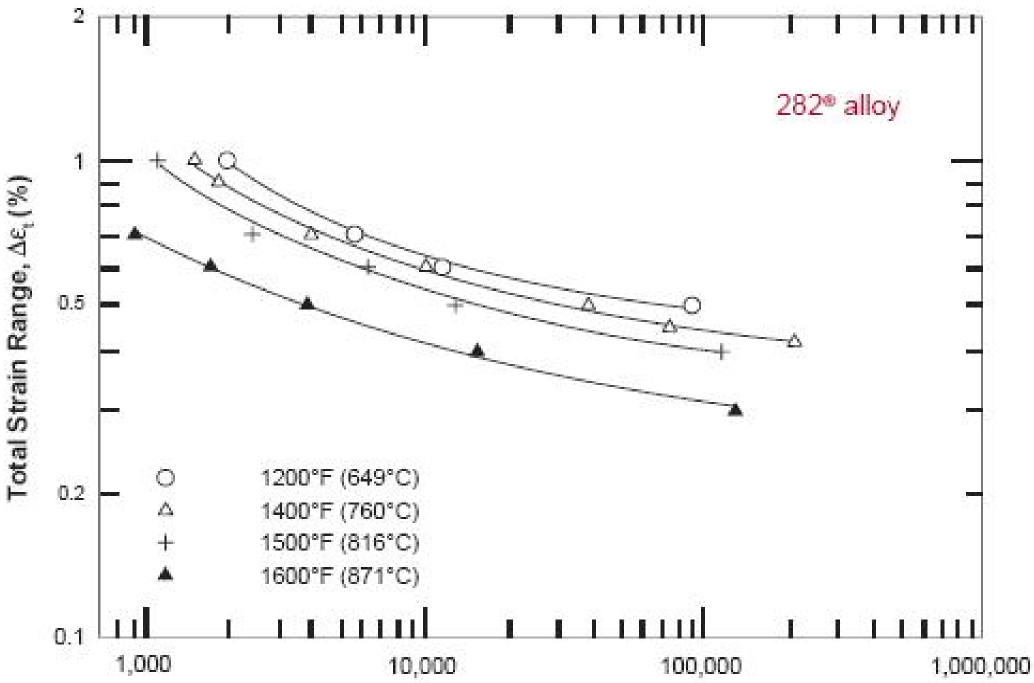
Coefficient of Thermal Expansion of Gamma-Prime Strengthened Alloys* (Sheet)



*Age-hardened (263 alloy: 1472°F (800°C)/8h/AC, Waspaloy alloy: 1825°F (996°C)/2h/AC + 1550°F (843°C)/4h/AC + 1400°F (760°C)/16h/AC, R-41 alloy: 1650°F (899°C)/4h/AC, 282® alloy: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC)

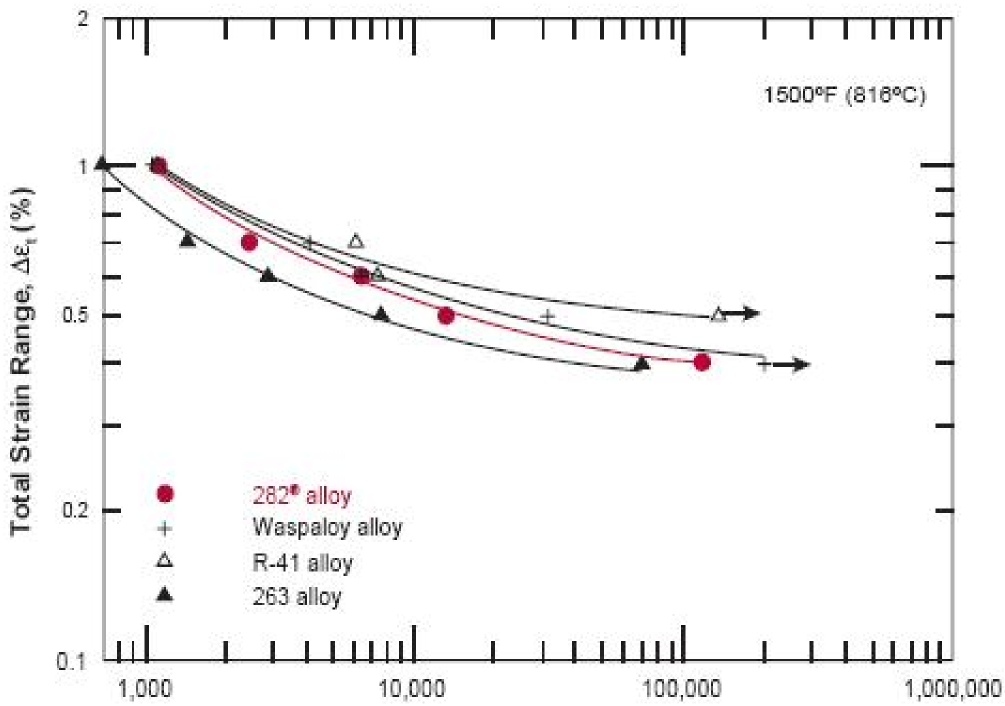
Low Cycle Fatigue

Low-Cycle Fatigue Data – HAYNES® 282® Sheet* (Thickness 0.125”, 3.2 mm)
*Age-hardened at 1850ºF(1010ºC)/2h/AC + 1450ºF(788ºC)/8h/AC



Fully Reversed, R = -1, Waveform = Triangle, Frequency = 0.33Hz

Comparative Low-Cycle Fatigue Data



1500°F (816°C), Fully Reversed, R = -1, Waveform = Triangle, Frequency = 0.33Hz, Material: 0.125"(3.2 mm) Sheet*

Welding

As a result of its high resistance to strain-age cracking, HAYNES® 282® alloy is much more weldable than other alloys of similar strength. The preferred welding processes are gas tungsten arc (GTAW or TIG) and gas metal arc (GMAW or MIG), using 282® alloy bare filler wire. If shielded metal arc welding (SMAW) of HAYNES® 282® alloy is necessary, please contact the technical support group at Haynes International for information on the most appropriate coated electrode. Submerged arc welding (SAW) of HAYNES® 282® alloy is not recommended due to the high heat input and increased weld restraint associated with this process.

Filler Metal Selection

It is recommended that bare, filler metal of a matching composition be used to join HAYNES® 282® alloy to itself, using either the GTAW or GMAW process. HAYNES® 282® alloy filler metal can also be used for dissimilar joining, and/or repair welding, of other age-hardenable, nickel superalloys.

Base Metal Preparation

HAYNES® 282® alloy should be welded in the solution-annealed condition, before it is subjected to the age-hardening treatment. The joint surface and adjacent areas should be thoroughly cleaned, to reveal bright, metallic surfaces, before welding. All grease, oil, crayon marks, sulfur compounds, and other foreign matter should be removed.

Preheating, Interpass Temperatures, and Post-Weld Heat Treatment

Preheating of HAYNES® 282® alloy is not required, as long as the base metal to be welded is above 32°F (0°C). Interpass temperatures should be less than 200°F (93°C). Auxiliary cooling methods may be used between weld passes, provided that these do not introduce contaminants.

After welding, HAYNES® 282® alloy will normally be subjected to its age-hardening treatment, which comprises 2 hours at 1850°F (1010°C), air cool + 8 hours at 1450°F (788°C), air cool. The heat up rate to 1850°F (1010°C) should be as fast as possible, within the capability of the furnace being used.

The use of a full solution anneal (typically at 2075°F/1135°C) after welding and prior to the two step age-hardening treatment is neither required nor prohibited. For heavy section weldments, or complex weldments with high residual stress, a full solution anneal prior to the age-hardening treatment may be advisable.

Nominal Welding Parameters (Sheet)

These are provided as a guide for performing typical operations and are based upon the welding conditions used in the laboratories of Haynes International. For further information, please contact the technical support group.

Welding Continued

Manual Gas Tungsten Arc Welding V-Groove or U-Groove – All thicknesses 0.125” (3.2 mm) or greater	
Technique	Stringer Bead
Current (DCEN), amperes	150-250
Voltage, volts	11 ~ 14
Filler Metal	0.125” (3.2 mm) diameter 282® alloy
Travel Speed, in/min (mm/min)	4-6 (102-152)
Electrode Size – EWTH-2, in (mm)	0.125” (3.2 mm) diameter
Electrode Shape	30° included
Cup Size	#8 or larger
Gas Type	Argon
Shielding Gas Flow, CFH (l/min)	30-35 (14.2-16.5)
Backing Gas Flow, CFH (l/min)	10 (4.7) for root pass
Preheat	Ambient
Maximum Interpass Temperature, °F (°C)	200 (93)

Automatic Gas Tungsten Arc Welding Square Butt Joint – No filler metal added – Material thickness 0.125” (3.2 mm)	
Current (DCEN), amperes	275
Voltage, volts	9.5
Travel Speed, in/min (mm/min)	12 (305)
Electrode Size – EWTH-2, in (mm)	0.125 (3.2) diameter
Electrode Shape	45° included
Cup Size	#8
Shielding Gas Flow, CFH (l/min)	30 (14.2)
Shielding Gas Type	Argon
Backing Gas Flow, CFH (l/min)	10 (4.7)
Backing Gas Type	Argon

Gas Metal Arc Welding Synergic Mode – All thicknesses 0.09” (2.3 mm) or greater	
Wire Type	HAYNES® 282® alloy
Wire Diameter, in (mm)	0.045 (1.1)
Feed Speed, ipm (m/min)	170-190 (4.3-4.8)
Current (DCEP), amperes	175
Voltage, volts	28-32
Stickout, in (mm)	0.5-0.75 (12.7-19.1)
Travel Speed, ipm (mm/min)	9-13 (230-330)
Torch Gas Flow, CFH (l/min)	40 (18.9)
Gas Type	75% Argon + 25% Helium

Welding Continued

Mechanical Properties of HAYNES® 282® Welds

Welded Transverse Tensile Data* For .125" (3.2 mm) Sheet
.125" (3.2 mm) Sheet Autogenously Welded, then with one Cover Pass
Cover Pass - .125" (3.2 mm) Diameter Wire

Condition	Temperature		0.2% Yield Strength		Ultimate Tensile Strength		Fracture Location
-	°F	°C	ksi	MPa	ksi	MPa	-
As Welded	RT	RT	64.7	446	125.4	865	Weld/Weld
As Welded/Aged***	RT	RT	106.3	733	168.2	1160	Base/Weld
As Welded/Solution Annealed**	RT	RT	66.9	461	126.8	874	Base/Base
As Welded/Solution Annealed**/Aged***	RT	RT	98.5	679	152.1	1049	Base/Base
	1000	538	83.7	577	132	910	Base/Base
	1200	649	86.1	594	135.1	932	Base/Weld
	1400	760	83.7	577	120.3	829	Base/Base
	1600	871	70.9	489	77.1	532	Base/Base
	1800	982	19.1	132	24.7	170	Base/Weld

RT= Room Temperature

GTAW Welded Transverse Tensile Data* For .5" (12.7 mm) Plate
0.5" (12.7 mm) Plate GTAW Welded
with .125" (3.2 mm) Diameter Wire

Condition	Temperature		0.2% Yield Strength		Ultimate Tensile Strength		Fracture Location
-	°F	°C	ksi	MPa	ksi	MPa	-
As Welded	RT	RT	75.9	523	130.8	902	Weld/Base
As Welded/Aged***	RT	RT	120.5	831	165.8	1143	Weld/Weld
As Welded/Solution Annealed**	RT	RT	77.2	532	139.5	962	Weld/Weld
As Welded/Solution Annealed**/Aged***	RT	RT	94.3	650	146.1	1007	Weld/Weld
	1000	538	85.4	589	134.3	926	Weld/Weld
	1200	649	86.6	597	137	945	Base/Base
	1400	760	85.3	588	125.7	867	Base/Base
	1600	871	71.9	496	83.4	575	Weld/Weld
	1800	982	20.1	139	26.3	181	Weld/Weld

Welding Continued

GMAW Welded Transverse Tensile Data* For .5" (12.7 mm) Plate
0.5" (12.7 mm) Plate GMAW Welded
with 0.045" (1.1 mm) Diameter Wire

Condition	Temperature		0.2% Yield Strength		Ultimate Tensile Strength		Fracture Location
-	°F	°C	ksi	MPa	ksi	MPa	-
As Welded	RT	RT	77.9	537	130.4	899	Base/Base
As Welded/Aged***	RT	RT	117.5	810	162.4	1120	Weld/Weld
As Welded/Solution Annealed**	RT	RT	78.6	542	141.7	977	Base/Base
As Welded/Solution Annealed**/Aged***	RT	RT	94.4	651	155.8	1074	Base/Base
	1000	538	83.8	578	132	910	Weld/Weld
	1200	649	85.2	587	137.3	947	Weld/Weld
	1400	760	83.7	577	123.6	852	Base/Base
	1600	871	71	490	82	565	Weld/Weld
	1800	982	19.8	137	26.8	185	Weld/Weld

All Weld Metal Tensile Data*
0.5" (12.7 mm) Cruciform GMAW Welded
with 0.045" (1.1 mm) Diameter Wire

Condition	Temperature		0.2% Yield Strength		Ultimate Tensile Strength		Elongation	Reduction of Area
-	°F	°C	ksi	MPa	ksi	MPa	%	%
As Welded	RT	RT	85	586	124.7	860	40	43.8
As Welded/Aged***	RT	RT	105.4	727	151.6	1045	20.3	22.4
As Welded/ Solution Annealed**	RT	RT	81.2	560	132.4	913	40.1	45.5
As Welded/ Solution Annealed**/Aged***	RT	RT	100.9	696	149.3	1029	22.7	20

*Average of two tests
** 2075°F (1135°C)/30 min/AC
***1850°F (1010°C)/2 h/AC + 1450°F (788°C)/8 h/AC
RT= Room Temperature

Comparative Creep-Rupture Properties of Weld Metal to Base Metal

Temperature		Stress		Material	Time to 1% Creep	Time to Rupture
°F	°C	ksi	MPa	-	h	h
1400	760	50	345	Base Metal*	96.8	237.5
				All Weld Metal**	197	364.8
1700	927	7	48	Base Metal*	335.6	792.3
				All Weld Metal**	648	950.5

*Annealed + Age-Hardened
**GMAW Welded + Annealed + Age-Hardened

Heat Treatment and Fabrication

Heat Treatment

Wrought HAYNES® 282® alloy is furnished in the solution annealed condition unless otherwise specifi ed. After component fabrication, the alloy would normally again be solution annealed at 2050 to 2100°F (1121 to 1149°C) for a time commensurate with section thickness and rapidly cooled or water-quenched for optimal properties. Following solution annealing, the alloy is given a two-step age-hardening treatment to optimize the microstructure and induce age-hardening. The first step is 1850°F (1010°C) for 2 hours followed by rapid or air cooling. The second step is 1450°F (788°C) for 8 hours followed by air cooling.

Hot and Cold Working

HAYNES® 282® alloy has excellent forming characteristics. It may be hot-worked at temperatures in the range of about 1750-2150°F (955-1177°C) provided the entire piece is soaked for a time sufficient to bring it uniformly to temperature. Initial breakdown is normally performed at the higher end of the range, while finishing is usually done at the lower temperatures to afford grain refinement.

As a consequence of its good ductility, 282® alloy is also readily formed by cold-working. Intermediate annealing may be performed at 2050 to 2100°F (1121 to 1149°C) for a time commensurate with section thickness and rapidly cooled or water-quenched, to ensure maximum formability. All hot- or cold-worked parts should normally be annealed prior to age-hardening (as described in the "Heat Treatment" section) in order to develop the best balance of properties.

Cold Forming Characteristics

Average Room-Temperature Hardness and Tensile Properties of Solution Annealed HAYNES® 282® alloy

Form	Hardness	0.2% Yield Strength		Ultimate Tensile Strength		Elongation	Reduction of Area
-	Rb	ksi	MPa	ksi	MPa	%	%
Sheet	90	56	384	122	839	59	-
Plate	93	56	384	120	830	60	61
Bar	86	51	348	118	816	62	69

Hardness vs. Cold Work (Sheet)

Alloy	0%	10%	20%	30%	40%	50%
282®	**93 Rb**	**26 Rc**	**33 Rc**	**38 Rc**	**41 Rc**	**43 Rc**
R-41	96 Rb	30 Rc	36 Rc	39 Rc	41 Rc	42 Rc
Waspaloy	94 Rb	26 Rc	32 Rc	37 Rc	39 Rc	41 Rc
263	89 Rb	19 Rc	27 Rc	33 Rc	37 Rc	39 Rc
625	97 Rb	32 Rc	37 Rc	40 Rc	42 Rc	45 Rc

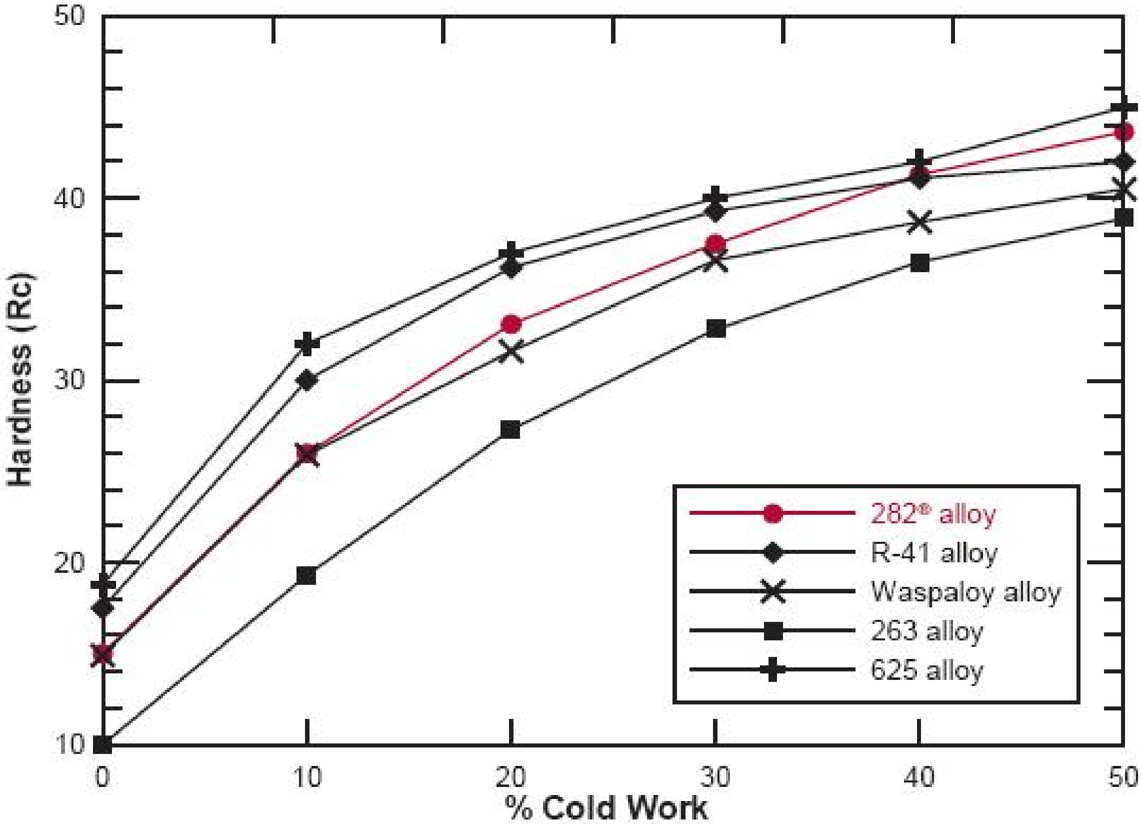
Heat Treatment and Fabrication Continued

Effect of Cold Reduction on Room-Temperature Tensile Properties*

Cold Reduction	0.2% Yield Strength		Ultimate Tensile Strength		Elongation
%	ksi	MPa	ksi	MPa	%
0	55.5	383	121	834	58
10	87.8	605	131.8	909	46.7
20	114.5	790	144.9	999	31.5
30	139.7	963	165.4	1141	15.5
40	158.5	1093	184.2	1270	8.9
50	174.7	1204	200.4	1382	6.6
60	190.4	1312	215.4	1485	5.6

*Based upon rolling reductions taken upon a solution annealed 0.125” (3.2 mm) thick sheet

Hardness of Solution Annealed Sheet Versus % Cold Work



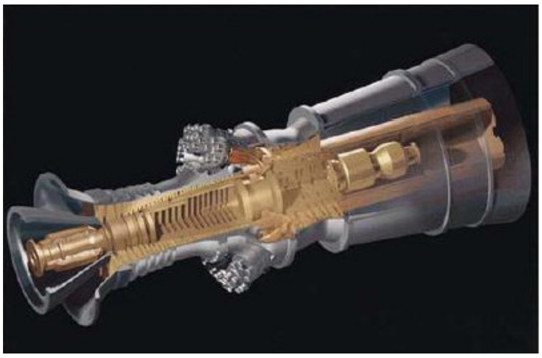
Machining

HAYNES® 282® alloy has similar machining characteristics to other nickel alloys used at high temperatures. Rough machining should be carried out prior to age-hardening. Final machining or finish grinding may be done after age-hardening. Machining guidelines can be found in the Welding and Fabrication brochure on haynesinlt.com. If further information is required, please contact the technical support group at Haynes International.

Typical Applications

HAYNES® 282® alloy is developed for applications in engines for aircraft.

HAYNES® 282® alloy is developed for the transition sections and other hot-gas-path components in land-based gas turbines.



Specifications and Codes

Specifications

HAYNES® 282® alloy (N07208)	
Sheet, Plate & Strip	AMS 5951
Billet, Rod & Bar	B 637 AMS 5915
Coated Electrodes	-
Bare Welding Rods & Wire	-
Seamless Pipe & Tube	-
Welded Pipe & Tube	-
Fittings	-
Forgings	B 637 AMS 5915
DIN	-
Others	-

Codes

HAYNES® 282® alloy (N07208)	
MMPDS	6.3.11