HAYNES® Waspaloy alloy

HAYNES® Waspaloy alloy (UNS N07001) is a gamma-prime strengthened, age-hardenable alloy with very good strength in the 1000-1650°F (540-900°C) temperature range. Widely used for forged and fabricated gas turbine and aerospace components.

Principal Features

HAYNES® Waspaloy alloy (UNS N07001) is an age-hardenable, nickel-based superalloy with very good strength at temperatures up to about 1800°F (980°C). It is widely used as a wrought material for forged and fabricated gas turbine and aerospace components. Its strength is generally comparable to HAYNES® R-41 alloy, and is superior to that of alloy 718 at temperatures above 1200-1300°F (650-705°C). Waspaloy alloy can be cold-formed in the annealed condition, and may also be hot-formed at temperatures of 1900°F (1040°C) or above. Weldability us somewhat limited by susceptibility to strain age cracking under conditions of heavy restraint. The alloy exhibits good resistance to gas turbine combustion environments at temperatures up to about 1600°F (870°C). Waspaloy alloy is now being replaced in many applications by HAYNES® 282® alloy, due to the superior fabricability and creep-strength of 282® alloy.

Nominal Composition

Weight %

Nickel:	58 Balance
Cobalt:	13.5
Iron:	2 max.
Chromium:	19
Molybdenum:	4.3
Aluminum:	1.5
Titanium:	3
Carbon:	0.08
Manganese:	0.1 max.
Silicon:	0.15 max.
Boron:	0.006
Zirconium:	0.05

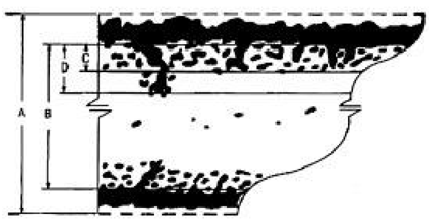
Heat Treatment

Wrought HAYNES® Waspaloy alloy is furnished in the solution annealed condition unless otherwise specified. After component fabrication, the alloy would normally again be solution annealed at 1950 to 2000°F (1066 to 1093°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 three-step age-hardening treatment to optimize the microstructure and induce age-hardening. The first step is 1825°F (996°C) for 2 hours followed by air cooling. The second step is 1550°F (843°C) for 4 hours followed by air cooling. The final step is 1400°F (760°C) for 16 hours followed by air cooling.

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

Alloy	1600°F (871°C)				1700°F (927°C)				1800°F (982°C)			
	Metal Loss		Avg. Met. Aff.		Metal Loss		Avg. Met. Aff.		Metal Loss		Avg. Met. Aff.	
	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
Râ€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.

Alloy	1600°F (871°C), 1000 hours, 30 minute cycles				1800°F (982°C), 1000 hours, 30 minute cycles			
	Metal Loss,		Avg. Met. Aff.		Metal Loss,		Avg. Met. Aff.	
	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
Râ€41	1.2	30	4.4	112	5.8	147	12.1	307

Typical Tensile Properties

Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		4D Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	130.4	899	189.2	1304	24.5
400	204	118.9*	820*	183.2*	1263*	24.4*
800	427	120.4*	830*	171.6*	1183*	22.6*
1000	538	117.8	812	170.4	1175	22.0
1200	649	113.8	784	164.9	1137	31.9
1400	760	102.4	706	119.2	822	32.8
1500	816	75.0	517	91.9	633	39.7
1600	871	51.8	357	66.2	456	48.0
1700	927	30.5	210	43.1	297	57.7
1800	982	19.2	132	25.2	174	57.8
2000	1093	4.5*	31*	7.4*	51*	135.5*

* Limited data
Samples were age hardened by treating at 1825°F (995°C)/2 Hr./AC + 1550°F (845°C)/4 Hr./AC + 1400°F (760°C)/16 Hr./AC

Thermal Stability

Condition	Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		4D Elongation
	°F	°C	ksi	MPa	ksi	MPa	%
Solution Annealed	RT	RT	64.3	443	128.8	888	50.1
Age Hardened*	RT	RT	129.4	892	189.9	1309	24.9
	1200	649	114	786	166.1	1145	31.8
	1400	760	103.7	715	119.6	825	34.5
	1500	816	75.9	523	92.1	635	40.6
	1600	871	52.6	363	66.9	461	45.7
Age Hardened* + 1200°F/8000h	RT	RT	137.8	950	197	1358	21.8
	1200	649	120.7	832	171.3	1181	29.7
Age Hardened* + 1400°F/8000h	RT	RT	115.2	794	178.2	1229	19
	1400	760	80.2	553	110.3	760	32.1
Age Hardened* + 1500°F/8000h	RT	RT	93.2	643	160.4	1106	22.2
	1500	816	51.1	352	79.9	551	31.3
Age Hardened* + 1600°F/8000h	RT	RT	66	455	115.7	798	13
	1600	871	30.5	210	49.9	344	29.2

*Samples were age hardened by treating at 1825°F (995°C)/2 Hr./AC + 1550°F (845°C)/4 Hr./AC + 1400°F (760°C)/16 Hr./AC

Creep and Stress-Rupture Strength

HAYNES® Waspaloy Sheet, Age Hardened*

Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in			
			100h		1,000h	
°F	°C	%	ksi	MPa	ksi	MPa
1200	649	1	81	558	67	462
		R	92	634	80	552
1300	704	1	63	434	46	317
		R	75	517	57	393
1400	760	1	41	283	28	193
		R	53	365	35	241
1500	816	1	25	172	16	110
		R	32	221	20	138
1600	871	1	15	103	7.0	48
		R	19	131	10	69
1700	927	1	6.4	44	3.0	21
		R	10	69	4.8	33

*Samples were age hardened by treating at 1825°F (995°C)/2 Hr./AC + 1550°F (845°C)/4 Hr./AC + 1400°F (760°C)/16 Hr./AC

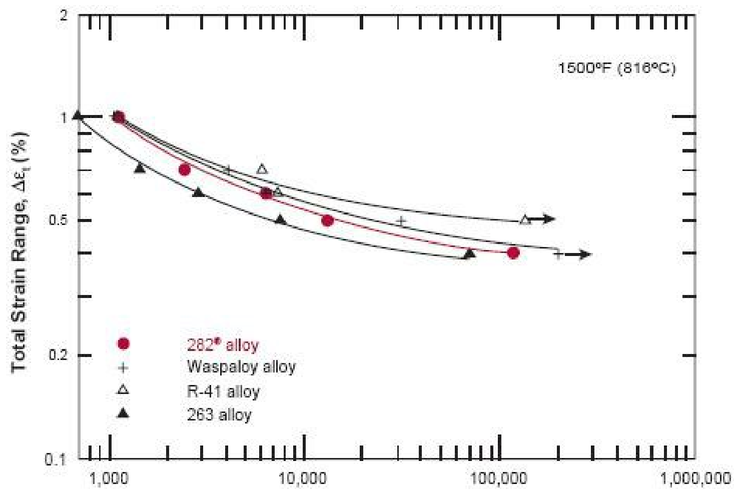
Physical Properties

Physical Property	British Units		Metric Units	
Density	RT	0.296 lb/in^3	RT	8.20 g/cm^3
Melting Temperature	2425-2475°F	-	1330-1360°C	-
Thermal Conductivity	400°F	88 Btu-in/ft^2-hr-°F	200°C	12.6 W/m-°C
	800°F	112 Btu-in/ft^2-hr-°F	400°C	15.7 W/m-°C
	1000°F	125 Btu-in/ft^2-hr-°F	600°C	19.1 W/m-°C
	1200°F	139 Btu-in/ft^2-hr-°F	700°C	20.9 W/m-°C
	1400°F	152 Btu-in/ft^2-hr-°F	800°C	22.7 W/m-°C
	1600°F	167 Btu-in/ft^2-hr-°F	900°C	24.5 W/m-°C
Mean Coefficient of Thermal Expansion	70-800°F	7.6 µin/in -°F	20-500°C	13.9 x 10^{-6}m/m·°C
	70-1000°F	7.8 µin/in -°F	20-600°C	14.3 x 10^{-6}m/m·°C
	70-1200°F	8.1 µin/in -°F	20-700°C	14.8 x 10^{-6}m/m·°C
	70-1400°F	8.4 µin/in -°F	20-800°C	15.4 x 10^{-6}m/m·°C
	70-1600°F	8.9 µin/in -°F	20-900°C	16.4 x 10^{-6}m/m·°C
	70-1800°F	9.7 µin/in -°F	20-1000°C	17.8 x 10^{-6}m/m·°C
Dynamic Modulus of Elasticity	70°F	30.9 x 10^6 psi	20°C	213 GPa
	400°F	29.5 x 10^6 psi	200°C	204 GPa
	800°F	27.7 x 10^6 psi	400°C	192 GPa
	1000°F	26.7 x 10^6 psi	600°C	180 GPa
	1200°F	25.6 x 10^6 psi	700°C	172 GPa
	1400°F	24.3 x 10^6 psi	800°C	164 GPa
	1600°F	22.9 x 10^6 psi	900°C	155 GPa
	1800°F	21.1 x 10^6 psi	1000°C	146 GPa

RT= Room Temperature

Low Cycle Fatigue

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*

Fabrication

Solution Annealed Room Temperature Hardness

Form	Hardness	Typical ASTM Grain Size
Sheet	93 HRBW	5 - 6.5
Plate	29 HRC	5.5 - 6.5

All samples tested in solution-annealed condition
HRBW = Hardness Rockwell "B", Tungsten Indentor.
HRC = Hardness Rockwell "C".

Waspaloy, Solution Annealed, Room Temperature Tensile

Form	Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		4D Elongation
	°F	°C	ksi	MPa	ksi	MPa	%
Sheet	RT	RT	60.8	419	131.9	909	52.2
Plate	RT	RT	87.6	604	154.7	1067	42.3

Welding

For welding HAYNES® Waspaloy alloy, please review the General Welding and Joining Guidelines. In addition to those guidelines, there are some additional considerations when welding Waspaloy alloy.

HAYNES® Waspaloy alloy is a precipitation-strengthened alloy and requires a postweld heat treatment (PWHT) to develop suitable properties. Postweld heat treatment for Waspaloy alloy consists of two parts: a solution anneal, which is followed by a three-step aging treatment. Details can be found here . During PWHT, the gamma-prime phase (Ni_3Al,Ti) precipitates and the alloy undergoes a slight volumetric contraction. This makes it susceptible to strain-age cracking, which typically occurs upon heating to the solution annealing temperature. To inhibit strain-age cracking, the heating rate to the solution annealing temperature should be as fast as possible, within the capability of the furnace being used.

Filler metal of matching composition is suggested for welding Waspaloy alloy to itself. For filler metal suggestions for welding Waspaloy alloy to other alloys, please refer to the Haynes Welding SmartGuide, or contact Haynes International for further guidance.

Specifications and Codes

Specifications

HAYNES® Waspaloy alloy (N07001)	
Sheet, Plate & Strip	AMS 5544
Billet, Rod & Bar	AMS 5704 AMS 5706 AMS 5707 SB 637/B 637
Coated Electrodes	-
Bare Welding Rods & Wire	AMS 5828
Seamless Pipe & Tube	-
Welded Pipe & Tube	-
Fittings	-
Forgings	AMS 5704 AMS 5706 AMS 5707 SB 637/ B637
DIN	-
Others	-

Codes

HAYNES® Waspaloy alloy (N07001)	
MMPDS	6.3.8

Disclaimer