HAYNES International

HAYNES® 242® ALLOY

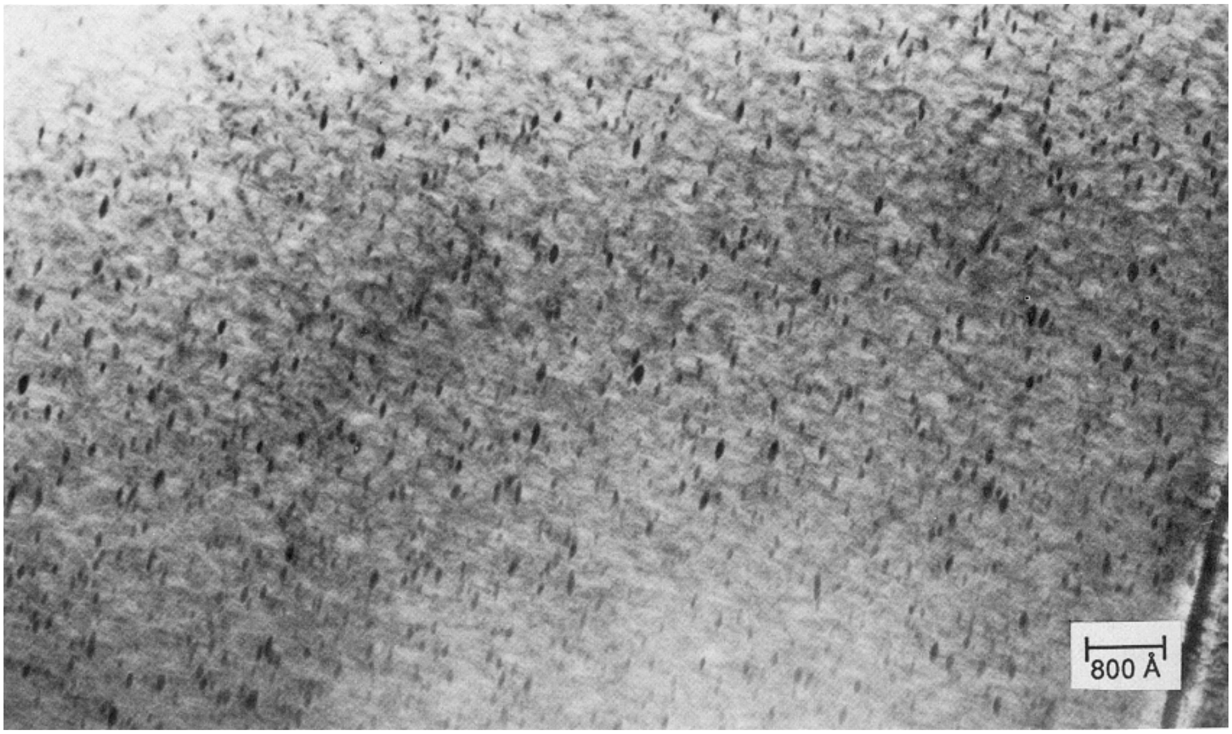
An age-hardenable Ni-Mo-Cr alloy that combines high-temperature strength, low thermal expansion characteristics and good oxidation-resistance for service to 1400°F (760°C). Also resistance to high-temperature fluorine and fluoride environments.

Contents

H-3079E

NEW LONG-RANGE-ORDER STRENGTHENING MECHANISM

HAYNES® 242™ alloy derives its age-hardened strength from a unique long-range-ordering reaction which essentially doubles the un-aged strength while preserving excellent ductility. The ordered $Ni_2(Mo,Cr)$-type domains are less than a few hundred Angstroms in size, and are visible only with the use of electron microscopy.



Transmission electron micrograph showing long-range-ordered domains (dark lenticular particles) in 242™ alloy. (Courtesy Dr. Vijay Vasudevan, University of Cincinnati). Sample was solution heat treated at 2012°F (1100°C) and aged for 100 hours at 1200°F (650°C).

PRINCIPAL FEATURES

Excellent High-Temperature Strength, Low Thermal Expansion Characteristics, and Good Oxidation Resistance

HAYNES® 242™ alloy is an age-hardenable nickel-molybdenum-chromium alloy which derives its strength from a long-range-ordering reaction upon aging. It has tensile and creep strength properties up to 1300°F (705°C) which are as much as double those for solid solution strengthened alloys, but with high ductility in the aged condition. The thermal expansion characteristics of 242 alloy are much lower than those for most other alloys, and it has very good oxidation resistance up to 1500°F (815°C). Other attractive features include excellent low cycle fatigue properties, very good thermal stability, and resistance to high-temperature fluorine and fluoride environments.

Fabrication

HAYNES 242 alloy has very good forming and welding characteristics in the annealed condition. It may be forged or otherwise hot-worked by conventional techniques, and it is readily cold formable. Welding may be performed in the annealed condition by standard gas tungsten arc (GTAW) or gas metal arc (GMAW) techniques. Use of matching composition filler metal is suggested. For further information on forming and fabrication, contact Haynes International.

Heat Treatment

HAYNES 242 alloy is furnished in the annealed condition, unless otherwise specified. The alloy is usually annealed in the range of 1900-2050°F (925-1120°C), depending upon specific requirements, followed by an air cool (or more rapid cooling) before aging. A water quench is recommended for heavy section components.

Aging is performed at 1200°F (650°C) for a period of 24-48 hours, followed by an air cool.

Available in Convenient Forms

HAYNES 242 alloy is produced in the form of reforge billet, bar, plate, sheet, and wire welding products, all in various sizes. Other forms may be produced upon request.

Applications

HAYNES 242 alloy combines properties which make it ideally suited for a variety of component applications in the aerospace industry. It will be used for seal rings, containment rings, duct segments, casings, fasteners, rocket nozzles, pumps, and many others. In the chemical process industry, 242 alloy will find use in high-temperature hydrofluoric acid vapor-containing processes as a consequence of its excellent resistance to that environment. The alloy also displays excellent resistance to high-temperature fluoride salt mixtures. The high strength and fluorine environment-resistance of 242 alloy has also been shown to provide for excellent service in fluoroelastomer process equipment, such as extrusion screws.

CHEMICAL COMPOSITION, PERCENT

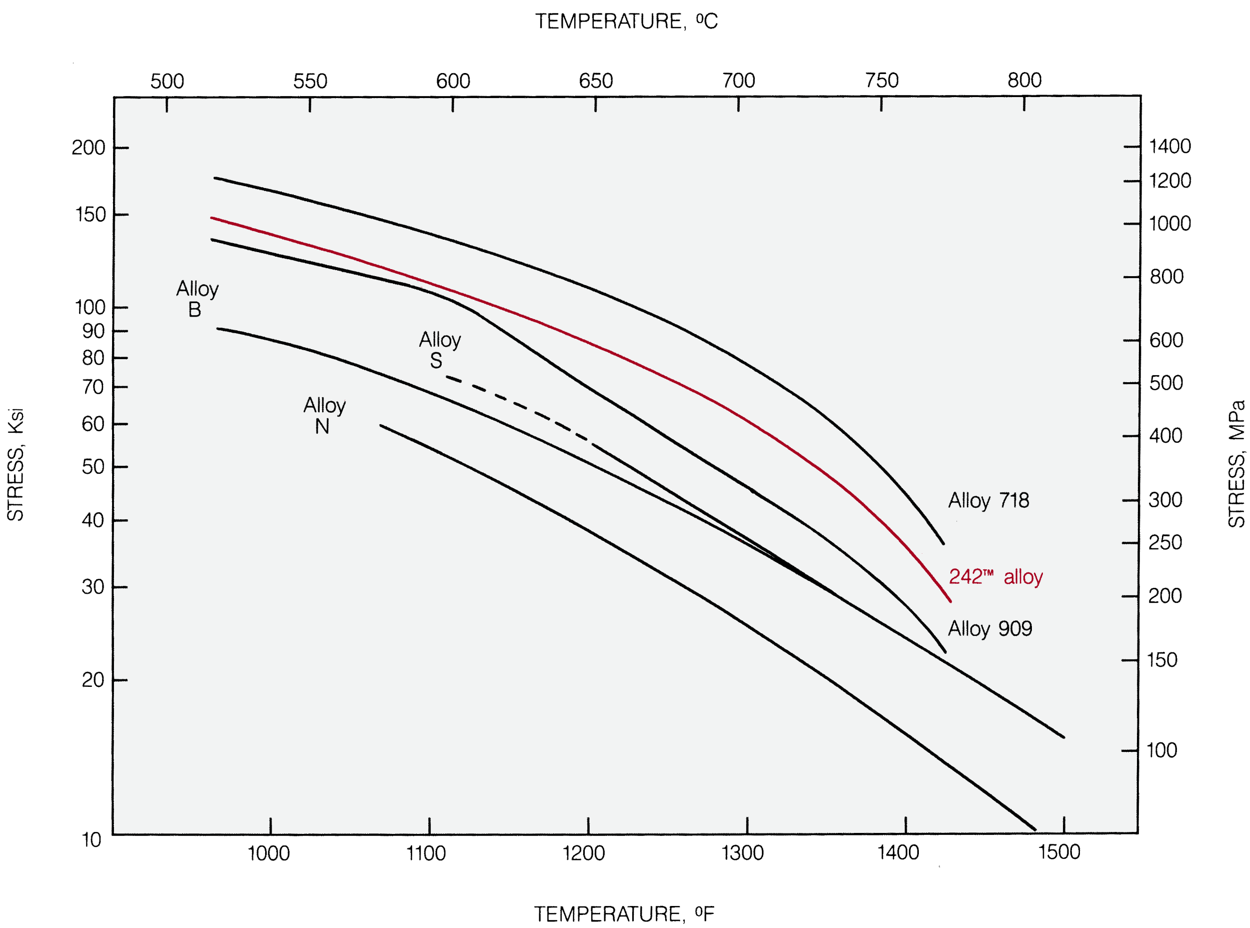
Ni	Mo	Cr	Fe	Co	Mn	Si	Al	C	B	Cu
65[a]	24.0-26.0	7.0-9.0-	2.0*	2.5*	0.80*	0.80*	0.50*	0.03*	0.006*	0.50*

[a] As balance
*Maximum

STRESS-RUPTURE STRENGTH

HAYNES® 242™ alloy is an age-hardenable material which combines excellent strength and ductility in the aged condition with good fabricability in the annealed condition. It is particularly effective for strength-limited applications up to 1300°F (705°C), where its strength is as much as double that for typical solid-solution strengthened alloys. It may be used at higher temperatures, where its solid-solution strength is still excellent, but oxidation resistance limits such uses to about 1500-1600°F (815-870°C).

COMPARISON OF 100 HOUR STRESS-RUPTURE STRENGTHS*



*Alloy B and Alloy N sheet products. All others hot forged or rolled plate, bar, and rings.

STRESS-RUPTURE STRENGTH (continued)

HOT-ROLLED PLATE – ANNEALED AND AGED

Test Temperature °F (°C)	Approximate Initial Stress, Ksi (MPa) Required to Cause Rupture in Specified Time		
	10 Hrs.	100 Hrs.	1000 Hrs.
1000 (540)	160 (1105)	140 (965)	120 (825)
1100 (595)	130 (895)	110 (760)	93 (640)
1200 (650)	105 (725)	90 (620)	75 (515)
1300 (705)	86 (595)	69 (475)	35 (240)
1400 (760)	62 (425)	29 (200)	17 (115)
1500 (815)	26 (180)	16 (110)	11 (76)
1600 (870)	15 (105)	11 (74)	–

TENSILE PROPERTIES

BAR AND RINGS – ANNEALED AND AGED

Test Temperature	Ultimate Tensile Strength		0.2% Yield Strength		Elongation in 4D	Reduction in Area
°F (°C)	Ksi	MPa	Ksi	MPa	%	%
Room	187.4	1290	122.4	845	33.7	45.7
200 (95)	180.7	1245	110.4	760	31.7	47.0
400 (205)	173.5	1195	102.3	705	33.0	51.8
600 (315)	168.6	1160	96.5	665	33.4	48.4
800 (425)	161.3	1110	86.3	595	37.6	45.9
1000 (540)	156.3	1080	78.3	540	38.3	49.9
1200 (650)	144.9	1000	82.7	570	33.2	41.1
1400 (760)	106.2	730	44.9	310	44.3	54.1
1600 (870)	72.5	500	44.8	310	49.7	85.1
1800 (980)	42.0	290	30.6	210	54.0	97.8

COMPARISON OF YIELD STRENGTHS AND ELONGATIONS*

HAYNES® 242™ alloy exhibits much higher yield strength than typical solid-solution-strengthened nickel-base alloys, such as HASTELLOY® S alloy, but also possesses excellent ductility in the fully heat-treated condition. This can translate into excellent containment characteristics for gas turbine rings and casings, particularly when coupled with 242 alloy's lower expansion coefficient and excellent ductility retention following thermal exposure. This combination is also well suited for a range of fastener and bolting applications up to 1300°F (705°C).

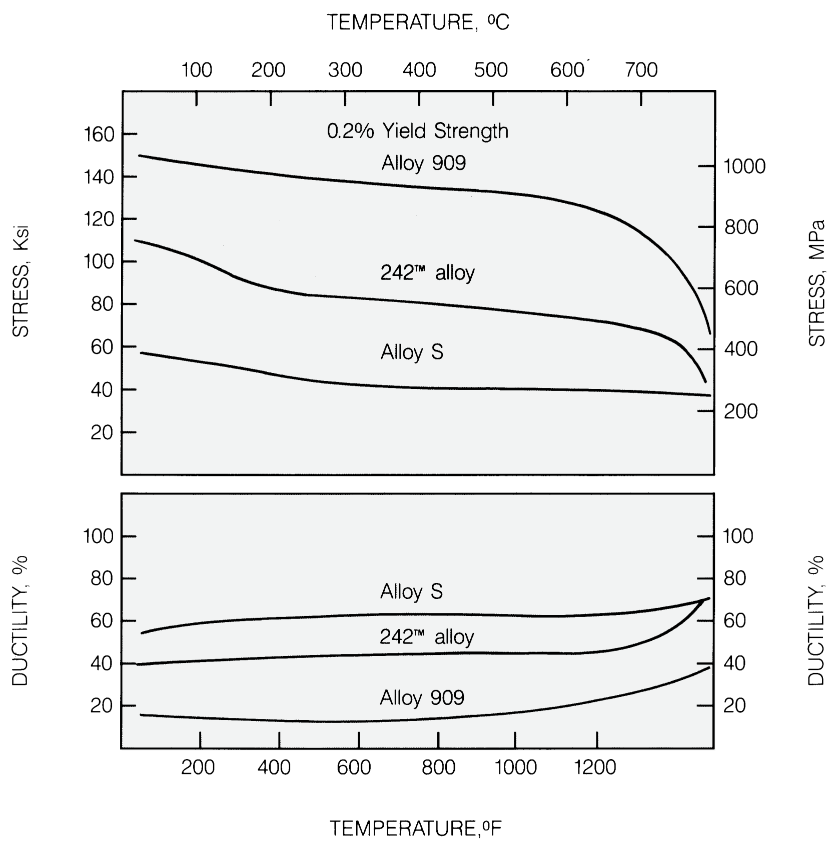


*Plate material or manufacturer's data.

TENSILE PROPERTIES (continued)

HOT-ROLLED PLATE – ANNEALED AND AGED[(a)]

Test Temperature °F (°C)	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	0.2% Yield Strength Ksi	0.2% Yield Strength MPa	Elongation in 4D %	Reduction in Area %
75 (25)	193	1330	126	868	36	–
400 (205)	176	1213	101	696	43	52
800 (425)	165	1137	91	627	45	52
1000 (540)	164	1130	89	613	44	51
1100 (595)	160	1102	89	613	44	51
1200 (650)	141	971	87	599	29	31
1300 (705)	118	813	73	503	28	30

COLD-ROLLED SHEET – ANNEALED AND AGED[(a)]

Test Temperature °F (°C)	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	0.2% Yield Strength Ksi	0.2% Yield Strength MPa	Elongation in 4D %	Reduction in Area %
75 (25)	187	1288	120	827	38	–
1000 (540)	165	1137	106	730	31	–
1100 (595)	150	1034	102	703	18	–
1200 (650)	135	930	96	661	14	–
1300 (705)	109	751	83	572	10	–

(a) Average of two tests per heat, two heats of each product form.
Solution Annealed + Aged 1200°F-48 hr.

TENSILE PROPERTIES (continued)

COLD-REDUCED SHEET – AS COLD-WORKED AND COLD-WORKED PLUS AGED

HAYNES® 242 alloy has excellent strength and ductility as a cold-reduced and directly aged product. Coupled with its low thermal expansion characteristics, this makes it an excellent choice for fasteners and springs.

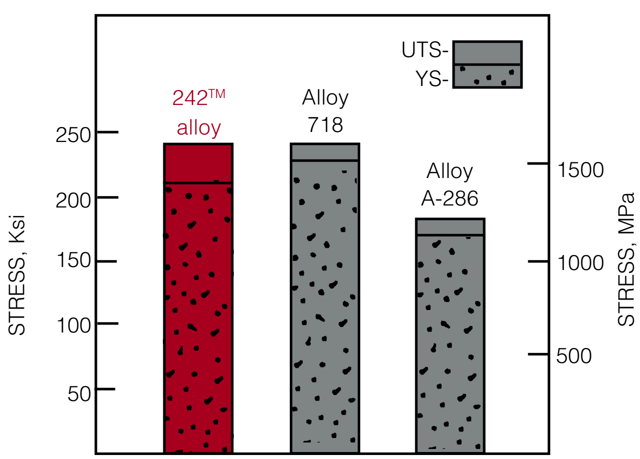
	Test Temperature °F (°C)	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	0.2% Yield Strength Ksi	0.2% Yield Strength MPa	Elongation in 2 in. (50 mm) %
M.A.	Room	137.6	950	65.3	450	47
M.A. + 20% C.W.	Room	169.6	1170	139.5	960	20
M.A. + 40% C.W.	Room	217.9	1500	181.3	1250	8
M.A. + Age	Room	192.0	1325	130.0	895	32
M.A. + 20% C.W. + Age	Room	209.5	1445	173.0	1195	21
M.A. + 40% C.W. + Age	Room	244.7	1685	219.7	1515	11
M.A. + 40% C.W. + Age	1100 (595)	201.9	1390	191.4	1320	11
M.A. + 40% C.W. + Age	1200 (650)	198.7	1370	145.9	1005	8
M.A. + 40% C.W. + Age	1300 (705)	183.7	1265	134.3	925	11
M.A. + 40% C.W. + Age	1400 (760)	156.0	1075	94.1	650	32

*M.A. = Solution Anneal; C.W. = Cold Work; Age = Standard Aging Treatment.

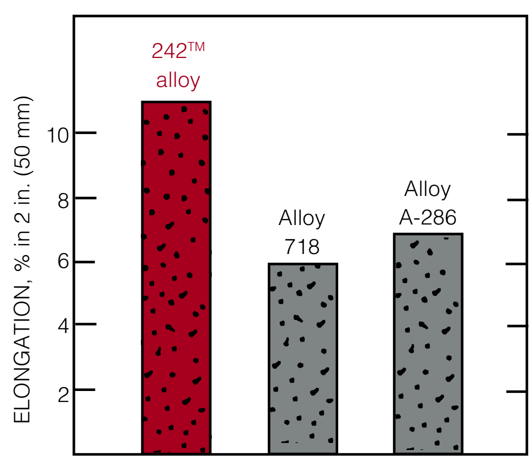
COMPARATIVE FASTENER ALLOY TENSILE PROPERTIES*

HAYNES 242 alloy compares very favorably with other cold-worked and directly aged fastener alloys. The graphs below present comparative room temperature tensile properties for 40% cold-reduced and aged sheet product.

Ultimate and Yield Strength



Elongation

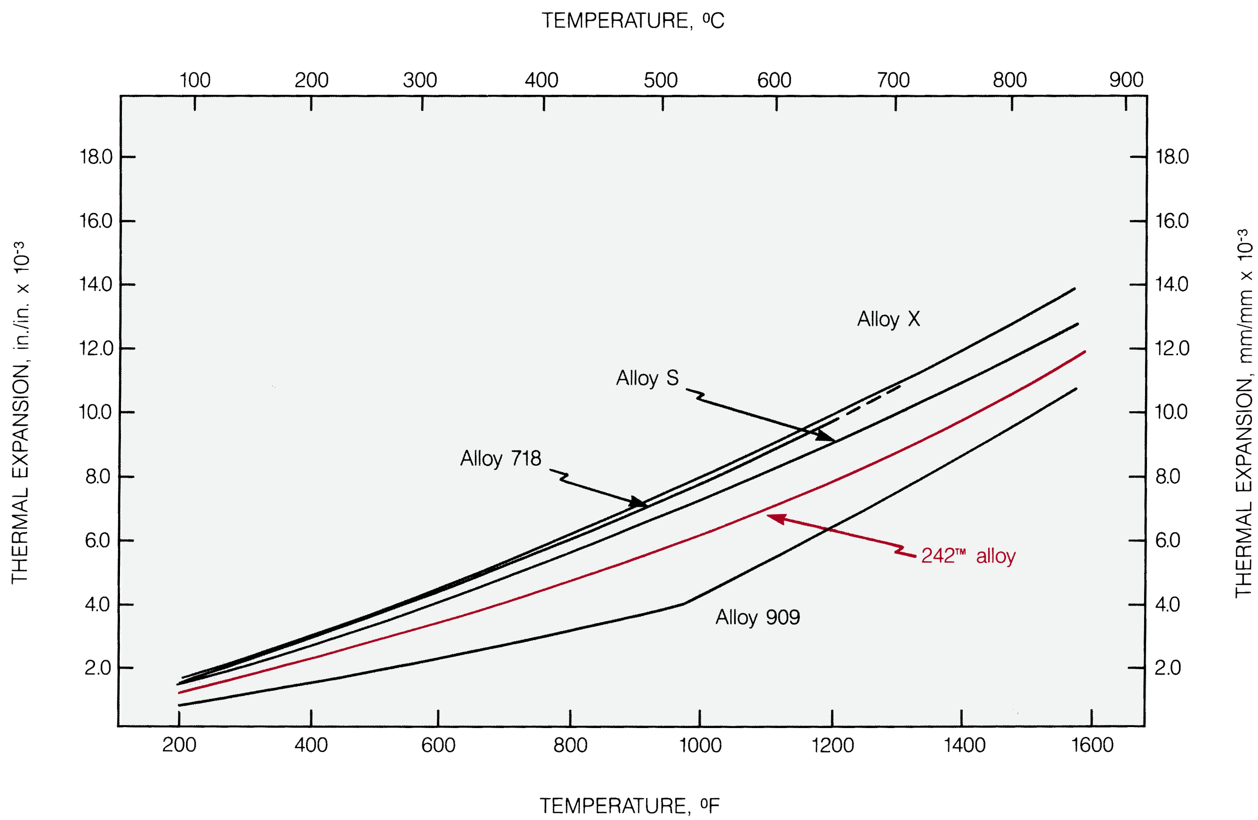


*Alloys cold-rolled to 40% reduction. 242 alloy aged 1200°F (650°C)/24 hours/AC; alloy 718 aged 1325°F (720°C)/8 hours/FC to 1150°F (620°C)/8 hours/AC; alloy A-286 aged 1200°F (650°C)16 hours/AC.

COMPARISON OF THERMAL EXPANSION CHARACTERISTICS

HAYNES® 242™ alloy exhibits significantly lower thermal expansion characteristics than most nickel-base high-temperature alloys in the range of temperature from room temperature to 1600°F (870°C). Although its expansion is greater than that for alloy 909 below 1000°F (540°C), at higher temperatures, the difference narrows considerably.

TOTAL THERMAL EXPANSION, ROOM TO ELEVATED TEMPERATURE



MEAN COEFFICIENT OF THERMAL EXPANSION

The following compares the mean coefficient of expansion for several alloys:

	Mean Coefficient of Expansion From RT to Temperature, in./in.-°F (mm/mm-°C) x 10^{-6}				
Material	1000°F (540°C)	1100°F (595°C)	1200°F (650°C)	1300°F (705°C)	1400°F (760°C)
Alloy 909	5.0 (9.0)	5.4 (9.7)	5.8 (10.4)	6.2 (11.2)	6.6 (11.9)
242™ alloy	6.8 (12.2)	6.8 (12.3)	7.0 (12.6)	7.2 (13.0)	7.7 (13.9)
Alloy B	6.7 (12.0)	6.7 (12.0)	6.7 (12.0)	6.9 (12.4)	7.1 (12.8)
Alloy N	7.3 (13.1)	7.4 (13.3)	7.5 (13.5)	7.6 (13.7)	7.8 (14.0)
Alloy S	7.4 (13.2)	7.5 (13.5)	7.6 (13.7)	7.8 (14.0)	8.0 (14.4)
Alloy X	8.4 (15.1)	8.5 (15.3)	8.6 (15.5)	8.6 (15.7)	8.8 (15.8)

LOW CYCLE FATIGUE PROPERTIES

STRAIN-CONTROLLED LCF PROPERTIES (HOT-ROLLED PLATE)

The following LCF properties were generated from hot-rolled and fully heat-treated plate. Testing was performed in the transverse direction utilizing a smooth, round bar specimen geometry. The specimens were tested by fully reversed axial strain cycling, R-ratio of -1.0, and a cycle frequency of 20 cpm (0.33 Hz) at a strain range of 1%.

Cycles to Failure at 1200°F (650°C), N_F			
HAYNES® 242™ alloy	HASTELLOY® X alloy	HAYNES 188 alloy	HAYNES HR-120® alloy
2000	4000	2100	3600

STRESS-CONTROLLED NOTCHED LCF PROPERTIES (HOT-ROLLED RINGS)

The following test results were generated from hot-rolled and fully heat-treated rings destined for actual gas turbine engine part applications. Testing was performed in the tangential direction utilizing a round test bar geometry with a double notch design (K_t=2.18). Loading was uniaxial cycling with an R-ratio of 0.05 stress and a cycle frequency of 20 cpm (0.33 Hz).

Maximum Stress		Cycles to Failure at 1200°F (650°C), N_F	
Ksi	MPa	242™ alloy	Alloy 909
110	760	845	2,835
100	690	12,220	22,568
95	655	32,587	13,796
90	620	76,763	59,679; 40,525
85	585	297,848	47,707; 43,701
80	550	304,116*	129,573**

* No crack observed at 198,030 cycles. 8 mil (200µm) crack observed at 200,000 cycles.
**No crack observed at 45,800 cycles. 8 mil (200µm) crack observed at 47,770 cycles.

HIGH-TEMPERATURE HARDNESS PROPERTIES

The following are results from standard vacuum furnace hot hardness tests. Values are given in originally measured DPH (Vickers) units and conversions to Rockwell C/B scale in parentheses.

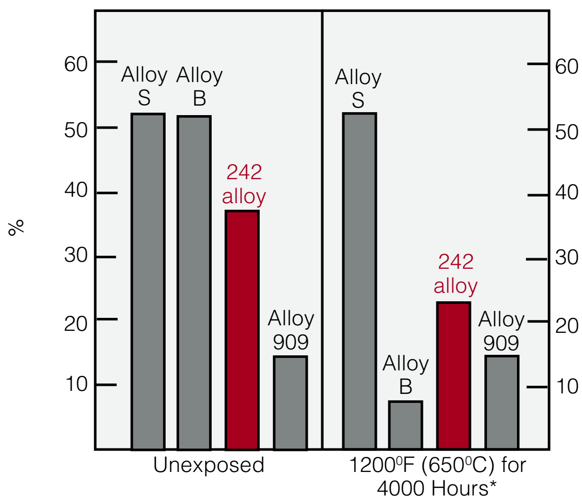
	Vickers Diamond Pyramid Hardness (Rockwell C/B Hardness)				
Material	800°F (425°C)	1000°F (540°C)	1200°F (650°C)	1400°F (760°C)	1600°F (870°C)
242™ alloy	271 (R_C 26)	263 (R_C 24)	218 (R_B 95)	140 (R_B 75)	78
Alloy 6B	269 (R_C 26)	247 (R_C 22)	225 (R_B 98)	153 (R_B 81)	91
Alloy 25	171 (R_B 87)	160 (R_B 83)	150 (R_B 80)	134 (R_B 74)	93
Alloy 188	170 (R_B 86)	159 (R_B 83)	147 (R_B 77)	129 (R_B 72)	89
230® alloy	142 (R_B 77)	139 (R_B 76)	132 (R_B 73)	125 (R_B 70)	75
556™ alloy	132 (R_B 73)	129 (R_B 72)	118 (R_B 67)	100 (R_B 55)	67

THERMAL STABILITY

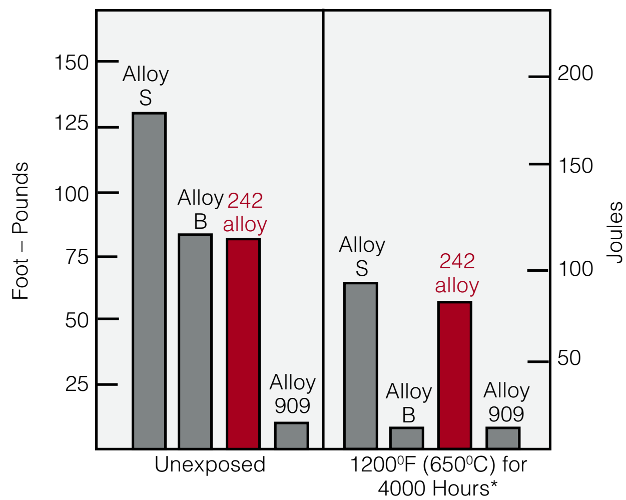
HAYNES® 242™ alloy has excellent retained ductility and impact strength after long-term thermal exposure at temperature. Combined with its high strength and low thermal expansion characteristics, this makes for very good containment properties in gas turbine static structures. The graphs below show the retained room-temperature tensile elongation and impact strength for 242 alloy versus other relevent materials after a 4000 hour exposure at 1200°F (650°C).

COMPARATIVE RETAINED DUCTILITY AND IMPACT STRENGTH

Room-Temperature Tensile Elongation



Room Temperature Impact Strength



*Alloy 909 data for 1000 hours.

ROOM-TEMPERATURE PROPERTIES AFTER EXPOSURE AT 1200°F (650°C)*

Exposure Time Hours	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	0.2% Yield Strength Ksi	0.2% Yield Strength MPa	Elongation in 2 in. (50 mm) %	Reduction in Area %	Charpy V-Notch Ft.-lbs.	Charpy V-Notch Joules
0	179	1235	110	760	39	44	66	90
1000	194	1340	119	820	28	38	41	56
4000	196	1350	122	840	25	37	31	42
8000	193	1330	121	835	24	39	26	35

*Samples machined from plate after exposure. Duplicate tests.

TYPICAL PHYSICAL PROPERTIES

	Temp., °F	British Units	Temp., °C	Metric Units
Density	Room	0.327 lb/in^3	Room	9.05 g/cm^3
Melting Range	2350-2510		1290-1375	
Electrical Resistivity	Room	48.0 µohm-in	Room	122.0 µohm-cm
	200	48.5 µohm-in	100	123.4 µohm-cm
	400	49.3 µohm-in	200	125.1 µohm-cm
	600	50.0 µohm-in	300	126.7 µohm-cm
	800	50.6 µohm-in	400	128.0 µohm-cm
	1000	51.1 µohm-in	500	129.5 µohm-cm
	1200	51.7 µohm-in	600	130.6 µohm-cm
	1400	52.4 µohm-in	700	132.0 µohm-cm
	1600	51.3 µohm-in	800	132.4 µohm-cm
	1800	50.4 µohm-in	900	129.8 µohm-cm
			1000	127.6 µohm-cm
Thermal Diffusivity	Room	4.7 x 10^{-3} in^2/sec	Room	30.5 x 10^{-3} cm^2/sec
	200	5.1 x 10^{-3} in^2/sec	100	32.9 x 10^{-3} cm^2/sec
	400	5.6 x 10^{-3} in^2/sec	200	35.9 x 10^{-3} cm^2/sec
	600	6.1 x 10^{-3} in^2/sec	300	39.0 x 10^{-3} cm^2/sec
	800	6.6 x 10^{-3} in^2/sec	400	41.9 x 10^{-3} cm^2/sec
	1000	7.2 x 10^{-3} in^2/sec	500	45.0 x 10^{-3} cm^2/sec
	1200	7.9 x 10^{-3} in^2/sec	600	48.1 x 10^{-3} cm^2/sec
	1400	7.2 x 10^{-3} in^2/sec	700	51.2 x 10^{-3} cm^2/sec
	1600	7.0 x 10^{-3} in^2/sec	800	44.2 x 10^{-3} cm^2/sec
	1800	7.6 x 10^{-3} in^2/sec	900	46.6 x 10^{-3} cm^2/sec
			1000	49.6 x 10^{-3} cm^2/sec
Thermal Conductivity	Room	75.7 BTU-in/ft^2 hr.-°F	Room	11.3 W/m-K
	200	83.6 BTU-in/ft^2 hr-°F	100	12.6 W/m-K
	400	96.1 BTU-in/ft^2 hr-°F	200	14.2 W/m-K
	600	108.5 BTU-in/ft^2 hr-°F	300	15.9 W/m-K
	800	120.9 BTU-in/ft^2 hr-°F	400	17.5 W/m-K
	1000	133.3 BTU-in/ft^2 hr-°F	500	19.2 W/m-K
	1200	145.7 BTU-in/ft^2 hr-°F	600	20.9 W/m-K
	1400	158.2 BTU-in/ft^2 hr-°F	700	22.5 W/m-K
	1600	170.6 BTU-in/ft^2 hr-°F	800	24.2 W/m-K
	1800	183.0 BTU-in/ft^2 hr-°F	900	25.8 W/m-K
			1000	27.5 W/m-K

TYPICAL PHYSICAL PROPERTIES (continued)

	Temp., ^{0}F	British Units	Temp., ^{0}C	Metric Units
Specific Heat	Room	0.092 BTU/lb-^{0}F	Room	386 J/Kg-k
	200	0.097 BTU/lb-^{0}F	100	405 J/Kg-K
	400	0.100 BTU/lb-^{0}F	200	419 J/Kg-K
	600	0.103 BTU/lb-^{0}F	300	431 J/Kg-K
	800	0.106 BTU/lb-^{0}F	400	439 J/Kg-K
	1000	0.110 BTU/lb-^{0}F	500	451 J/Kg-K
	1200	0.118 BTU/lb-^{0}F	600	470 J/Kg-K
	1400	0.144 BTU/lb-^{0}F	700	595 J/Kg-K
	1600	0.146 BTU/lb-^{0}F	800	605 J/Kg-K
	1800	0.150 BTU/lb-^{0}F	900	610 J/Kg-K
			1000	627 J/Kg-K
Mean Coefficient of Thermal Expansion	70-200	6.0 microinches/in-^{0}F	25-100	10.8 µm/m-^{0}C
	70-400	6.3 microinches/in-^{0}F	25-200	11.3 µm/m-^{0}C
	70-600	6.5 microinches/in-^{0}F	25-300	11.6 µm/m-^{0}C
	70-800	6.7 microinches/in-^{0}F	25-400	11.9 µm/m-^{0}C
	70-1000	6.8 microinches/in-^{0}F	25-500	12.2 µm/m-^{0}C
	70-1100	6.8 microinches/in-^{0}F	25-600	12.3 µm/m-^{0}C
	70-1200	6.9 microinches/in-^{0}F	25-650	12.4 µm/m-^{0}C
	70-1300	7.2 microinches/in-^{0}F	25-700	13.0 µm/m-^{0}C
	70-1400	7.7 microinches/in-^{0}F	25-750	13.7 µm/m-^{0}C
	70-1600	8.0 microinches/in-^{0}F	25-800	14.0 µm/m-^{0}C
	70-1800	8.3 microinches/in-^{0}F	25-900	14.5 µm/m-^{0}C
			25-1000	15.0 µm/m-^{0}C

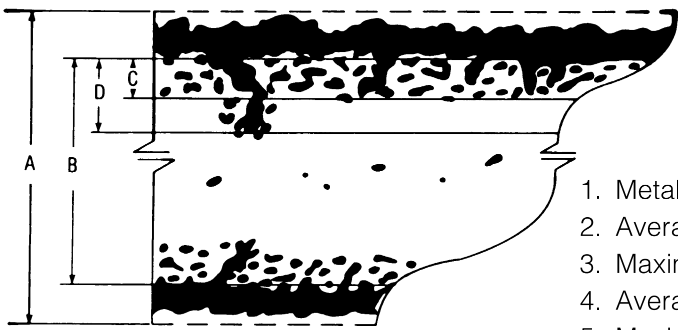
DYNAMIC MODULUS OF ELASTICITY

Temp., ^{0}F	Dynamic Modulus of Elasticity, 10^6 psi	Temp., ^{0}C	Dynamic Modulus of Elasticity, GPa
Room	33.2	Room	229
200	32.7	100	225
400	31.8	200	219
600	30.8	300	213
800	29.7	400	206
1000	28.6	500	199
1200	27.6	600	193
1400	25.7	700	185
1600	24.0	800	172
1800	22.4	900	163
		1000	152

OXIDATION RESISTANCE

HAYNES® 242™ alloy exhibits very good oxidation resistance at temperatures up to 1500°F (815°C), and should not require protective coatings for continuous or intermittent service at these temperatures. The alloy is not specifically designed for use at higher temperatures, but can tolerate short-term exposures.

SCHEMATIC REPRESENTATION OF METALLOGRAPHIC TECHNIQUE USED FOR EVALUATING OXIDATION TESTS



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

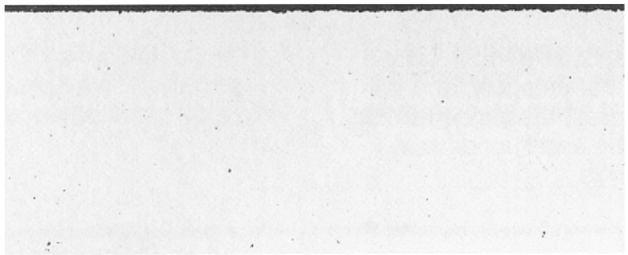
COMPARATIVE BURNER RIG OXIDATION-RESISTANCE AT 1400°F (760°C) FOR 500 HOURS

	Metal Loss		Average Metal Affected		Maximum Metal Affected	
Alloy	Mils	µm	Mils	µm	Mils	µm
HASTELLOY® N alloy	0.7	18	0.8	20	1.2	30
242™ alloy	1.1	28	1.2	30	1.6	41
HASTELLOY B alloy	1.8	46	2.6	66	2.8	71
Alloy 909	0.3	8	10.8	275	12.8	325

Oxidation Test Parameters

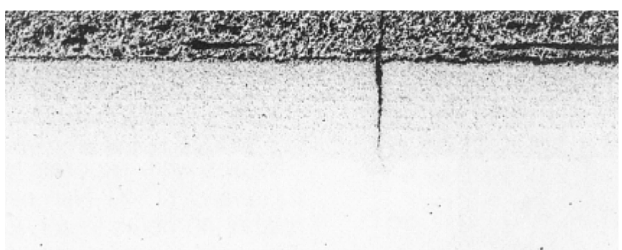
Burner rig oxidation tests were conducted by exposing samples 3/8 inch x 2.5 inches x thickness (9mm x 64mm x thickness), in a rotating holder, to the products of combustion of No. 2 fuel oil burned at a ratio of air to fuel of about 50:1. (Gas velocity was about 0.3 mach). Samples were automatically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

BURNER RIG OXIDATION-RESISTANCE (continued)



HAYNES® 242™ alloy
Average Metal Affected = 1.2 Mils (30 µm)

HASTELLOY® B alloy
Average Metal Affected = 2.6 Mils (66 µm)



Alloy 909
Average Metal Affected = 10.8 Mils (275 µm)

Microstructures shown relate to the burner rig oxidation test data shown on the page opposite for three of the materials evaluated. The black area shown at the top of the pictures for 242™ alloy and alloy B represent thickness loss during the test. The alloy 909 apparently exhibited only minor thickness loss. This is believed to be a consequence of the sample actually swelling during the exposure due to oxygen absorption. The sample also developed a very thick, coarse scale and extensive internal oxidation. There was also evidence of significant cracking in the alloy 909 specimen due to the thermal cycling, even though the test samples were not constrained.

COMPARATIVE OXIDATION-RESISTANCE IN FLOWING AIR AT 1500°F (815°C) FOR 1008 HOURS*

	Metal Loss		Average Metal Affected	
Alloy	Mils	µm	Mils	µm
242™ alloy	0.0	0	0.5	13
HASTELLOY® S alloy	0.0	0	0.5	13
HASTELLOY X alloy	0.1	3	1.1	28
HASTELLOY N alloy	0.4	10	1.2	30
HASTELLOY B alloy	7.2	183	8.2	208
Alloy 909	4.4	112	19.4	493

*Coupons exposed to flowing air at a velocity of 7.0 feet/minute (2.1m/minute) past the samples. Samples cycled to room temperature once-a-day.

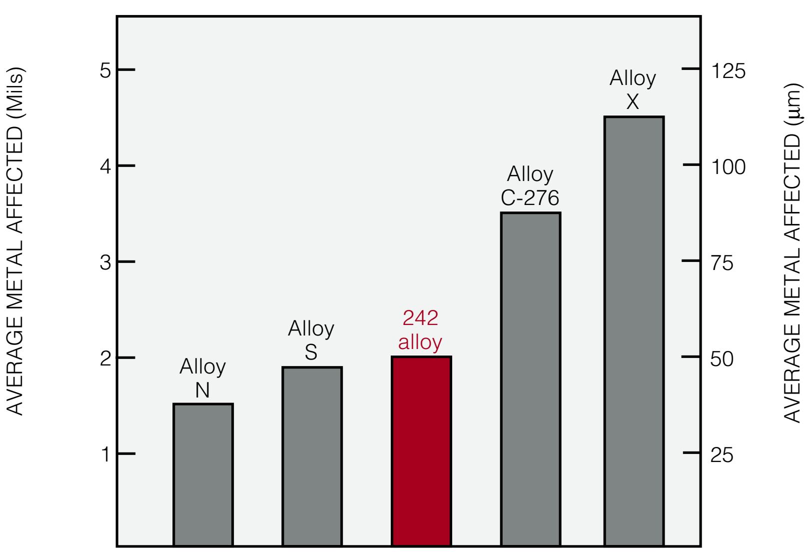
RESISTANCE TO HIGH-TEMPERATURE FLUORIDE ENVIRONMENTS

Research has shown that materials which have high molybdenum content and low chromium content are generally superior to other materials in resisting high-temperature corrosion in fluorine-containing environments. HAYNES® 242™ alloy is in that category, and displays excellent resistance to both fluoride gas and fluoride salt environments.

COMPARATIVE RESISTANCE TO 70% HF AT 1670°F (910°C) FOR 136 HOURS

Alloy	Thickness Loss Mils	Thickness Loss mm
242™ alloy	12.6	0.3
HASTELLOY® S alloy	15.8	0.4
HASTELLOY N alloy	15.8	0.4
Alloy 625	47.2	1.2
230® alloy	70.9	1.8
C-22® alloy	78.7	2.0
Alloy 600	141.7	3.6

COMPARATIVE RESISTANCE TO KCl-KF-NaF MIXED SALTS



Samples were exposed to a mixture of KCl-KF-NaF salts for a total of 40 hours in service. Temperature was cycled from 1290 to 1650°F (700-900°C) during the course of the exposure.

RESISTANCE TO NITRIDING

HAYNES® 242™ alloy have very good resistance to nitriding environments. Tests were performed in flowing ammonia at 1800°F (980°C) for 168 hours. Nitrogen absorption was determined by chemical analysis before and after exposure and knowledge of the specimen area.

Alloy	Nitrogen Absorption (mg/cm^2)
HAYNES® 214 alloy	0.3
HAYNES 242™ alloy	0.7
Alloy 600	0.9
HAYNES 230® alloy	1.4
HASTELLOY® X alloy	3.2
Alloy 800H	4.0
Type 316 Stainless Steel	6.0
Type 304 Stainless Steel	7.3
Type 310 Stainless Steel	7.7

RESISTANCE TO SALT-SPRAY CORROSION

HAYNES 242 alloy exhibits good resistance to corrosion by sodium-sulfate-containing sea water environment at 1200°F (650°C). Tests were performed by heating specimens to 300°F (150°C), spraying with a simulated sea water solution, cooling and storing at room temperature for a week, heating to 1200°F (650°C) for 20 hours in still air; cooling to room temperature, heating and spraying again at 300°F (150°C), and storing at room temperature for a week.

Alloy	Metal Loss		Maximum Metal Affected	
	Mils	µm	Mils	µm
HASTELLOY® S alloy	0.10	2.5	0.20	5.1
HAYNES® 242™ alloy	0.15	3.8	0.30	7.6
HASTELLOY B alloy	0.20	5.1	0.30	7.6
Alloy 909	0.40	10.2	1.20	30.5

RESISTANCE TO HYDROGEN EMBRITTLEMENT

Notched room-temperature tensile tests performed in hydrogen and air reveal that 242 alloy is roughly equivalent to alloy 625 in resisting hydrogen embrittlement, and appears to be superior to many important materials. Tests were performed in MIL-P27201B grade hydrogen, with a crosshead speed of 0.005 in./min. (0.13 mm/min.).

Alloy	Hydrogen Pressure		Kt	Ratio of Notched Tensile Strength Hydrogen/Air
	Psig	MPa		
Waspaloy alloy	7,000	48	6.3	.78
Alloy 625	5,000	34	8.0	.76
242™ alloy	5,000	34	8.0	.74
Alloy 718	10,000	69	8.0	.46
Alloy R-41	10,000	69	8.0	.27
Alloy X-750	7,000	48	6.3	.26

AQUEOUS CORROSION RESISTANCE

Although not specifically designed for use in applications which require resistance to aqueous corrosion, 242™ alloy does exhibit resistance in some media which compares favorably with that exhibited by traditional corrosion-resistant alloys. Data shown for 242 alloy was generated for samples tested in the mill annealed condition.

Corrosive Media	Temperature °F (°C)	Exposure Hours	Corrosion Rate, Mils/year (mm/year) 242™ alloy	alloy B-2	C-22® alloy	alloy N
5% HF	175 (79)	24	14 (0.36)	12 (0.30)	25 (0.64)	20 (0.51)
48% HF	175 (79)	24	32 (0.81)	25 (0.64)	27 (0.69)	31 (0.79)
70% HF	125 (52)	24	35 (0.89)	66 (1.68)	32 (0.81)	48 (1.22)
10% HCl	Boiling	24	22 (0.56)	7 (0.18)	400 (10.16)	204 (5.18)
20% HCl	Boiling	24	41 (1.04)	15 (0.38)	380 (9.65)	–
55% H_3PO_4	Boiling	24	3 (0.08)	4 (0.10)	9 (0.23)	–
85% H_3PO_4	Boiling	24	4 (0.10)	4 (0.10)	120 (3.05)	–
10% H_2SO_4	Boiling	24	2 (0.05)	2 (0.05)	11 (0.28)	46 (1.17)
50% H_2SO_4	Boiling	24	5 (0.13)	1 (0.03)	390 (9.91)	–
99% ACETIC	Boiling	24	<1 (<0.03)	1 (0.03)	Nil	–

FABRICATION AND WELDING

HAYNES® 242 alloy has excellent forming and welding characteristics. It may be hot-worked at temperatures in the range of about 1800-2250°F (980-1230°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, 242 alloy is also readily formed by cold-working. All hot- or cold-worked parts should be annealed at 1900-2050°F (925-1120°C) and cooled by air cool or faster rate before aging at 1200°F (650°C) in order to develop the best balance of properties.

The alloy can be welded by a variety of processes, including gas tungsten arc, gas metal arc, and shielded metal arc. High heat input processes such as submerged arc and oxyacetalyne welding are not recommended.

Welding Procedures

Welding procedures common to most high-temperature, nickel-base alloys are recommended. These include use of stringer beads and an interpass temperature less than 200°F (95°C). Preheat is not required. Cleanliness is critical, and careful attention should be given to the removal of grease, oil, crayon marks, shop dirt, etc. prior to welding. Because of the alloy's high nickel content, the weld puddle will be somewhat "sluggish" relative to steels. To avoid lack of fusion and incomplete penetration defects, the root opening and bevel should be sufficiently open.

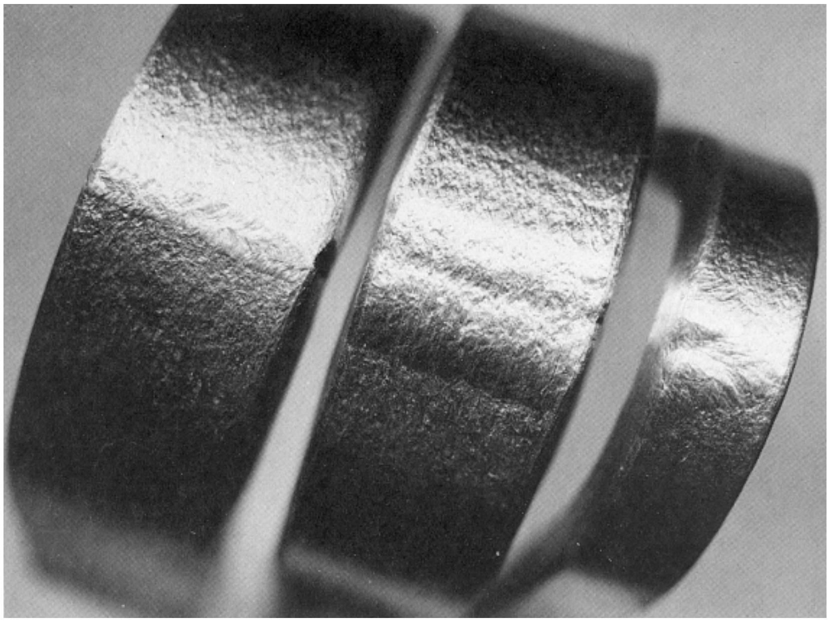
Filler Metals

HAYNES 242 alloy should be joined using matching filler metal. If shielded metal arc welding is used, HASTELLOY® W alloy coated electrodes are suggested.

Post-Weld Heat Treatment

HAYNES 242 alloy is normally used in the fully-aged condition. However, following forming and welding, a full solution anneal is recommended prior to aging in order to develop the best joint and overall mechanical properties.

FABRICATION AND WELDING (continued)



Typical root, face, and side bends (L to R) for welded 242™ alloy 0.5-inch (13 mm) plate and matching filler metal. Bend radius was 1.0 inch (25 mm).

HEALTH AND SAFETY INFORMATION

Welding can be a safe occupation. Those in the welding industry, however, should be aware of the potential hazards associated with welding fumes, gases, radiation, electric shock, heat, eye injuries, burns, etc. Also, local, municipal, state, and federal regulations (such as those issued by OSHA) relative to welding and cutting processes should be considered.

Nickel-, cobalt-, and iron-base 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) H3095 and H1072 for the product.

Inhalation of metal dust or fumes generated from welding, cutting, grinding, melting, or dross handling of these alloys may cause adverse health effects such as reduced lung function, nasal and mucous membrane irritation. Exposure to dust or fumes which may be generated in working with these alloys may also cause eye irritation, skin rash and effects on other organ systems.

The operation and maintenance of welding and cutting equipment should conform to the provisions of American National Standard ANSI/AWS Z49.1, "Safety in Welding and Cutting". Attention is especially called to Section 7 (Protection of Personnel) and 8 (Health Protection and Ventilation) of ANSI/AWS Z49.1. Mechanical ventilation is advisable and, under certain conditions such as a very confined space, is necessary during welding or cuttiing operations, or both, to prevent possible exposure to hazardous fumes, gases, or dust that may occur.

MACHINING GUIDELINES

HAYNES® 242™ alloy may be machined in either the solution-annealed or aged conditions. Carbide tools are recommended. In the annealed condition (R_B 95-100 typical hardness) the alloy is somewhat "gummy". Better results may be achieved by performing machining operations on material in the age-hardened condition (R_C 35-39 typical hardness). Finish turning has been successfully done employing carbide tools with a depth of cut in the range of 0.010-0.020 inch (0.25-0.50 mm), rotation speeds of 200-400 rpm, 40-80 sfm, and a water-base lubricant.

STANDARD PRODUCTS
By Brand or Alloy Designation:

HAYNES International

HASTELLOY® Corrosion-Resistant Alloys

B-3®, C-4, C-22®, C-22HS®, C-276, C-2000®, G-30®, G-35®, G-50®, HYBRID-BC1™, and N

HASTELLOY® High-Temperature Alloys

S, W, and X

HAYNES® High-Temperature Alloys

25, R-41, 75, HR-120®, HR-160®, HR-224™, 188, 214®, 230®, 230-W®, 242®, 263, 282®, 556®, 617, 625, 625SQ®, 718, X-750, MULTIMET®, NS-163™, and Waspaloy

Corrosion-Wear Resistant Alloy

ULTIMET®

Wear-Resistant Alloy

6B

HAYNES® Titanium Alloy Tubular

Ti-3Al-2.5V

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

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