HAYNES® 242® alloy

Principal Features

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

HAYNES® 242® alloy (UNS N10242) 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 1200 - 1300°F (649 - 704°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 (816°C). Other attractive features include excellent low cycle fatigue properties, very good thermal stability, and resistance to high-temperature fluorine and fluoride environments. HAYNES® 244® alloy has been developed as an upgrade from 242® alloy, with enhanced tensile and creep properties up to 1400°F (760°C), as well as a lower coefficient of thermal expansion.

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.

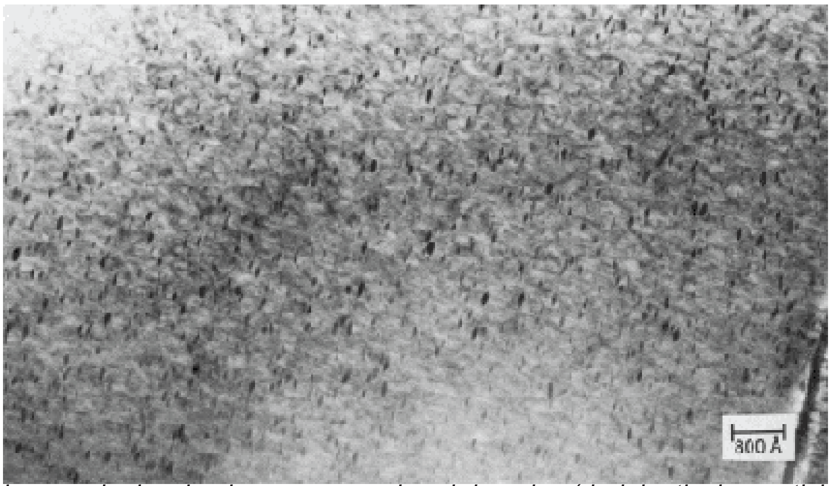
Applications

HAYNES® 242® alloy combines properties which make it ideally suited for a variety of component applications in aero and industrial gas turbine engines. It may 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.

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.

Principal Features Continued



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).

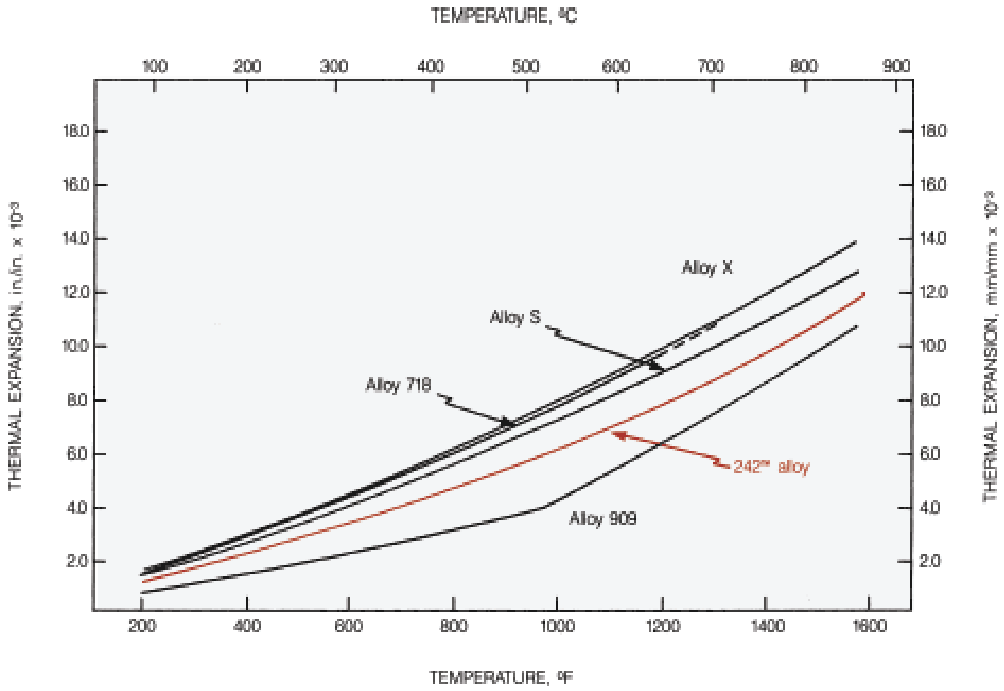
Nominal Composition

	Weight %
Nickel:	Balance
Molybdenum:	25
Chromium:	8
Iron:	2 max.
Cobalt:	1 max.
Manganese:	0.8 max.
Silicon:	0.8 max.
Aluminum:	0.5 max.
Carbon:	0.03 max.
Boron:	0.006 max.

Thermal Expansion

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 (871°C). Although its expansion is greater than that for alloy 909 below 1000°F (538°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									
	1000°F	538°C	1100°F	593°C	1200°F	649°C	1300°F	704°C	1400°F	760°C
Alloy	in./in/-°F x10⁻⁶	mm/mm-°C x10⁻⁶	in./in/-°F x10⁻⁶	mm/mm-°C x10⁻⁶	in./in/-°F x10⁻⁶	mm/mm-°C x10⁻⁶	in./in/-°F x10⁻⁶	mm/mm-°C x10⁻⁶	in./in/-°F x10⁻⁶	mm/mm-°C x10⁻⁶
909	5.0	9.0	5.4	9.7	5.8	10.4	6.2	11.2	6.6	11.9
242®	6.8	12.2	6.8	12.3	7.0	12.6	7.2	13.0	7.7	13.9
B	6.7	12	6.7	12.0	6.7	12.0	6.9	12.4	7.1	12.8
N	7.3	13.1	7.4	13.3	7.5	13.5	7.6	13.7	7.8	14.0
S	7.4	13.2	7.5	13.5	7.6	13.7	7.8	14.0	8.0	14.4
X	8.4	15.1	8.5	15.3	8.6	15.5	8.6	15.7	8.8	15.8

Tensile Properties

Bar and Rings - Annealed and Aged

Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		Elongation	Reduction in Area
°F	°C	ksi	MPa	ksi	MPa	%	%
RT	RT	122.4	845	187.4	1290	33.7	45.7
200	93	110.4	760	180.7	1245	31.7	47
400	204	102.3	705	173.5	1195	33	51.8
600	316	96.5	665	168.6	1160	33.4	48.4
800	427	86.3	595	161.3	1110	37.6	45.9
1000	538	78.3	540	156.3	1080	38.3	49.9
1200	649	82.7	570	144.9	1000	33.2	41.1
1400	760	44.9	310	106.2	730	44.3	54.1
1600	871	44.8	310	72.5	500	49.7	85.1
1800	982	30.6	210	42	290	54	97.8

*RT= Room Temperature

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).

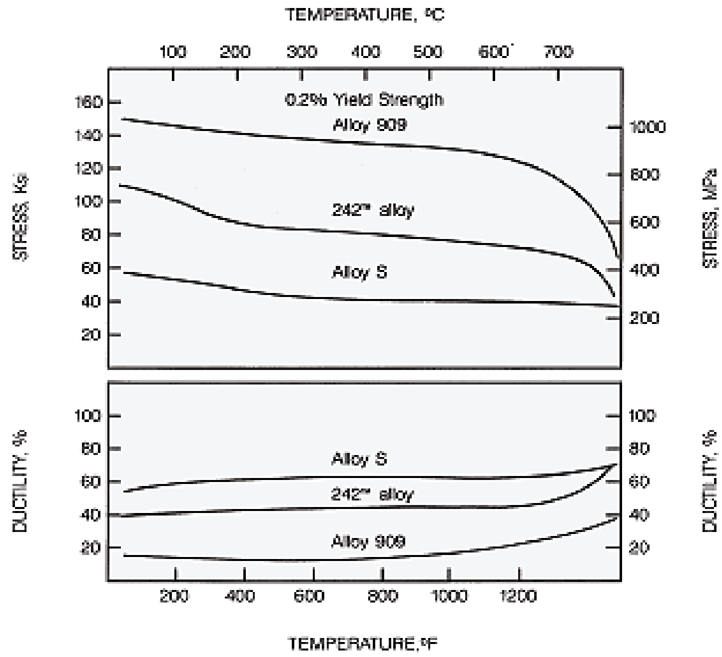


Plate material or manufacture's data

Tensile Properties Continued

Hot-Rolled Plate - Annealed and Aged[a]

Test Temperature		Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation	Reduction in Area
°F	°C	ksi	MPa	ksi	MPa	%	%
RT	RT	126	868	193	1330	36	-
400	204	101	696	176	1213	43	52
800	427	91	627	165	1137	45	52
1000	538	89	613	164	1130	44	51
1100	593	89	613	160	1102	44	51
1200	649	87	599	141	971	29	31
1300	704	73	503	118	813	28	30
1400	760	48	331	94	648	93	71

Cold-Rolled Sheet- Annealed and Aged[a]

Test Temperature		Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	120	827	187	1288	38
1000	538	106	730	165	1137	31
1100	593	102	703	150	1034	18
1200	649	96	661	135	930	14
1300	704	83	572	109	751	10
1400	760	57	393	92	634	98

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

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		0.2% Yield Strength		Ultimate Tensile Strength		Elongation
-	°F	°C	ksi	MPa	ksi	MPa	%
M.A.	RT	RT	65.3	450	137.6	950	47
M.A. + 20% C.W.	RT	RT	139.5	960	169.6	1170	20
M.A. + 40% C.W.	RT	RT	181.3	1250	217.9	1500	8
M.A. + Age	RT	RT	130	895	192	1325	32
M.A. + 20% C.W. + Age	RT	RT	173	1195	209.5	1445	21
M.A. + 40% C.W. + Age	RT	RT	219.7	1515	244.7	1685	11
M.A. + 40% C.W. + Age	1100	595	191.4	1320	201.9	1390	11
M.A. + 40% C.W. + Age	1200	649	145.9	1005	198.7	1370	8
M.A. + 40% C.W. + Age	1300	705	134.3	925	183.7	1265	11
M.A. + 40% C.W. + Age	1400	760	94.1	650	156	1075	32

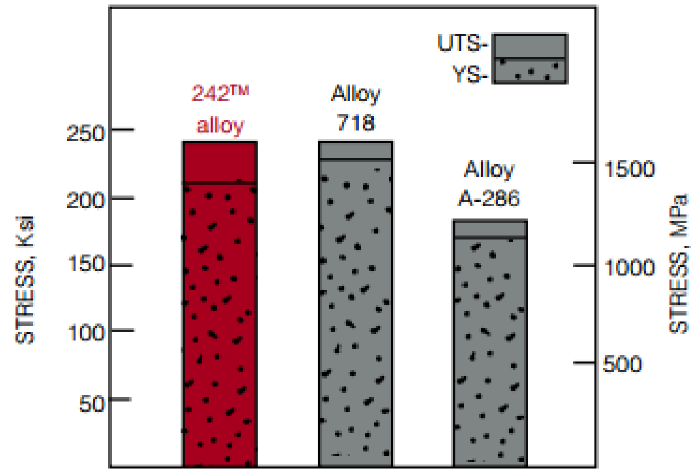
RT= Room Temperature
M.A.= Solution Anneal
C.W. = Cold Work
Age = Standard aging treatment

Tensile Properties Continued

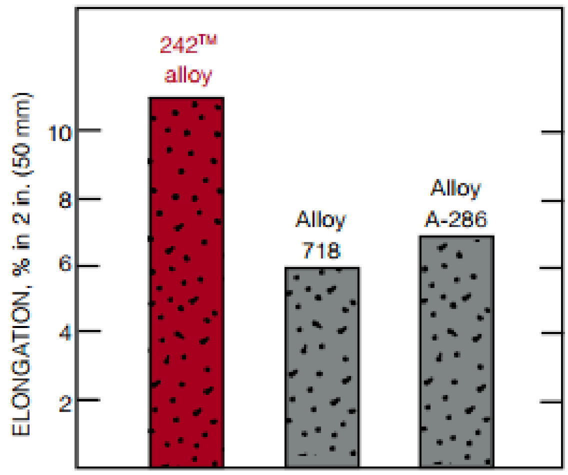
Comparative Fastener Alloy Tensile Properties*

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

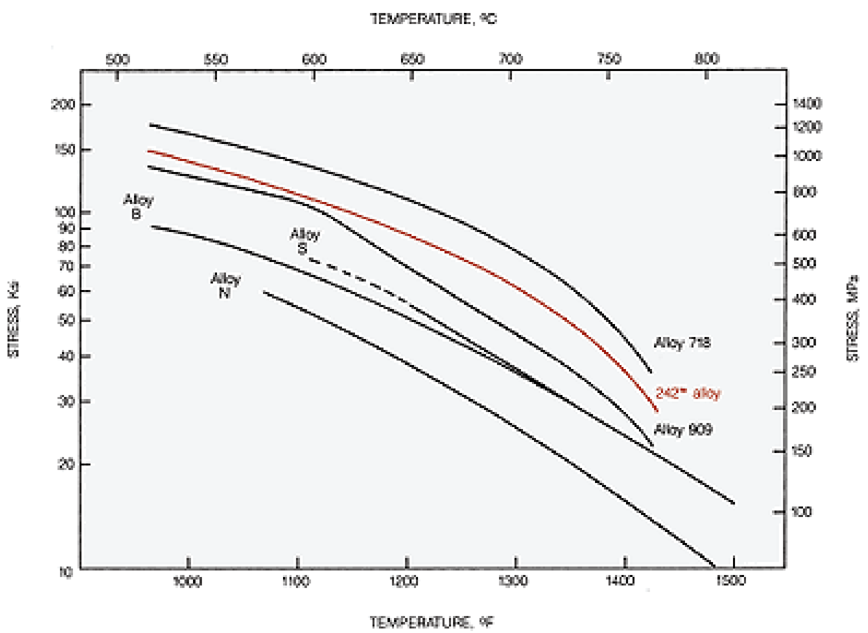


*Alloys cold-rolled to 40% reduction. 242® alloy aged 1200°F (650°C)/24 hours/AC; alloy 718 aged 1325°F (720°C)/8 hours/FC to 1150°F (620°C)/8 hours/AC; alloy A-286 aged 1200°F (650°C)/16 hours/AC.

Creep-Rupture Strength

HAYNES® 242® alloy is an 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.

Creep-Rupture Strength Continued

242® Plate, Age-Hardened

Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in							
			10 Hours		100 Hours		1,000 Hours		10,000 Hours	
°F	°C	%	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
1000	538	0.5	-	-	-	-	-	-	-	-
		1	-	-	-	-	-	-	-	-
		R	153	1055	138	952	122	841	109	752
1100	593	0.5	-	-	-	-	-	-	75	517
		1	-	-	-	-	-	-	79	545
		R	126	869	112	772	100	690	85	586
1200	649	0.5	-	-	82	565	62	427	38	262
		1	-	-	85	586	66	455	42	290
		R	105*	724*	91	627	75	517	48	331
1300	704	0.5	72	496	48	331	33	228	13*	90*
		1	75	517	53	365	37	255	17*	117*
		R	87*	600*	66	455	44	303	25	172
1400	760	0.5	24	165	12	83	-	-	-	-
		1	27	186	15	103	8	55	-	-
		R	46	317	29	200	18	124	-	-

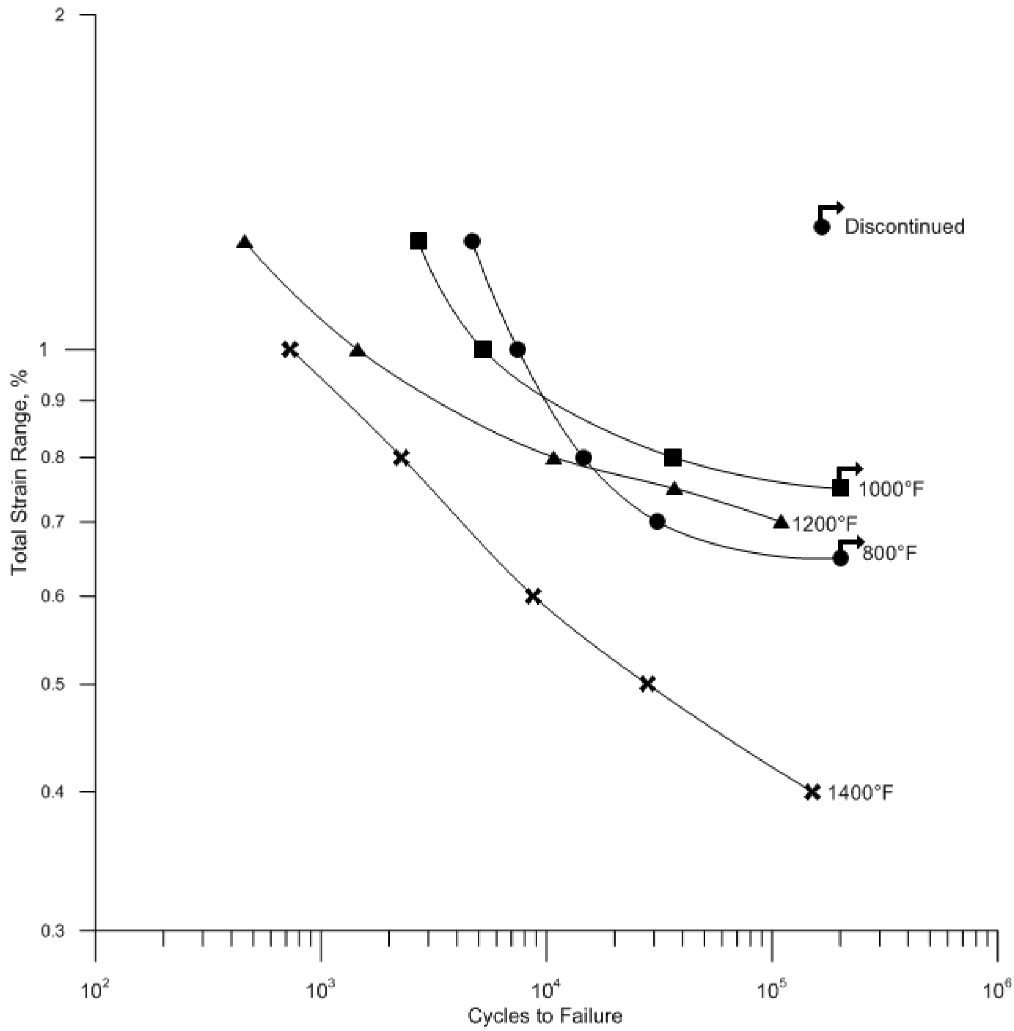
*Significant extrapolation

242® Sheet, Age-Hardened

Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in					
			10 Hours		100 Hours		1,000 Hours	
°F	°C	%	ksi	MPa	ksi	MPa	ksi	MPa
1000	538	0.5	-	-	-	-	-	-
		1	-	-	-	-	-	-
		R	-	-	133	917	125	862
1100	593	0.5	-	-	-	-	97	669
		1	-	-	-	-	102	703
		R	-	-	117	807	110	758
1200	649	0.5	-	-	79	545	58	400
		1	-	-	82	565	62	427
		R	110*	758*	90	621	69	476
1300	704	0.5	59	407	44	303	33	228
		1	64	441	47	324	35	241
		R	80	552	57	393	41	283
1400	760	0.5	21	145	12*	83*	-	-
		1	24	165	14	97	-	-
		R	41	283	25	172	15	103

Fatigue Properties

HAYNES® 242® 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 1400°F (425 to 760°C). Samples were machined from plate. Tests were run with fully reversed strain (R = -1) at a frequency of 20 cpm (0.33 Hz).



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), NF	
ksi	**MPa**	**242®**	**909**
110	760	**845**	2,835
100	690	**12,220**	22,568
95	655	**32,587**	13,796
90	620	**76,763**	55,679; 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.

Impact Strength

Product	Condition	Average Impact Strength	
		ft-lb	J
Plate	Solution Annealed	194	263
Plate	Age Hardened*	91	123
Ring	Annealed + Aged*	51	69

*Aged at 1200°F (649°C) / 24 h / air cool.

Hot Hardness Data

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/BW scale.

Alloy	800°F (425°C)		1000°F (540°C)		1200°F (650°C)		1400°F (760°C)		1600°F (870°C)	
	Vickers	Rockwell	Vickers	Rockwell	Vickers	Rockwell	Vickers	Rockwell	Vickers	Rockwell
242®	**271**	**26 HRC**	**263**	**24 HRC**	**218**	**95 HRBW**	**140**	**75 HRBW**	**78**	**-**
6B	269	26 HRC	247	22 HRC	225	98 HRBW	153	81 HRBW	91	-
25	171	87 HRBW	160	83 HRBW	150	80 HRBW	134	74 HRBW	93	-
188	170	86 HRBW	159	83 HRBW	147	77 HRB	129	72 HRBW	89	-
230®	142	77 HRBW	139	76 HRBW	132	73 HRB	125	70 HRBW	75	-
556®	132	73 HRBW	129	72 HRBW	118	67 HRB	100	56 HRBW	67	-

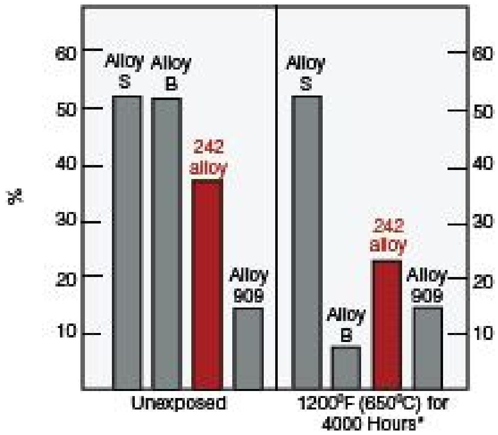
HRC = Hardness Rockwell “C”.
HRBW= Hardness Rockwell “B”, Tungsten Indentor.

Thermal Stability

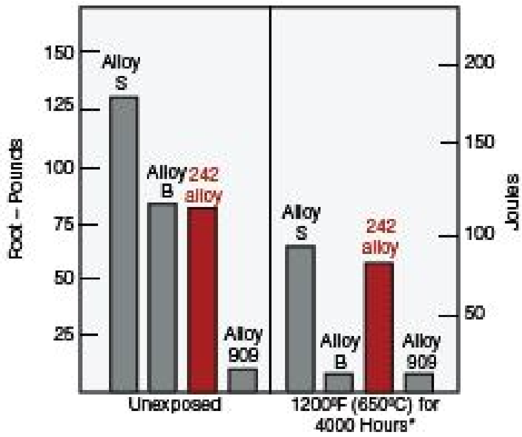
HAYNES® 242® alloy has excellent retained ductility and impact strength after long-term thermal exposure at temperature. Combined with its high strength and low thermal expansion characteristics, this makes for very good containment properties in gas turbine static structures. The graphs below show the retained room-temperature tensile elongation and impact strength for 242® alloy versus other relevant 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 (649°C)*

Exposure Time	0.2% Yield Strength		Ultimate Tensile Strength		Elongation	Reduction of Area	Charpy V-Notch	
h	ksi	MPa	ksi	MPa	%	%	ft.-lbs.	J
0	110	758	179	1234	39	44	66	89
1000	119	820	194	1338	28	38	41	56
4000	122	841	196	1351	25	37	31	42
8000	121	834	193	1331	24	39	26	35

*Samples age hardened 1200°F (649°C) 24 h. Duplicate tests.

Physical Properties

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

RT= Room Temperature

Physical Properties Continued

Physical Property	British Units		Metric Units	
Specific Heat	RT	0.092 Btu/lb-°F	RT	386 J/Kg-ºC
	200°F	0.097 Btu/lb-°F	100°C	405 J/Kg-ºC
	400°F	0.100 Btu/lb-°F	200°C	419 J/Kg-ºC
	600°F	0.103 Btu/lb-°F	300°C	431 J/Kg-ºC
	800°F	0.106 Btu/lb-°F	400°C	439 J/Kg-ºC
	1000°F	0.110 Btu/lb-°F	500°C	451 J/Kg-ºC
	1200°F	0.118 Btu/lb-°F	600°C	470 J/Kg-ºC
	1400°F	0.144 Btu/lb-°F	700°C	595 J/Kg-ºC
	1600°F	0.146 Btu/lb-°F	800°C	605 J/Kg-ºC
	1800°F	0.150 Btu/lb-°F	900°C	610 J/Kg-ºC
	-	-	1000°C	627 J/Kg-ºC
Mean Coefficient of Thermal Expansion	70-200°F	6.0 µin/in-°F	25-100°C	10.8 µm/m-°C
	70-400°F	6.3 µin/in-°F	25-200°C	11.3 µm/m°C
	70-600°F	6.5 µin/in-°F	25-300°C	11.6 µm/m-°C
	70-800°F	6.7 µin/in-°F	25-400°C	11.9 µm/m-°C
	70-1000°F	6.8 µin/in-°F	25-500°C	12.2 µm/m-°C
	70-1100°F	6.8 µin/in-°F	25-600°C	12.3 µm/m-°C
	70-1200°F	6.9 µin/in-°F	25-650°C	12.4 µm/m-°C
	70-1300°F	7.2 µin/in-°F	25-700°C	13.0 µm/m-°C
	70-1400°F	7.7 µin/in-°F	25-750°C	13.7 µm/m-°C
	70-1600°F	8.0 µin/in-°F	25-800°C	14.0 µm/m-°C
	70-1800°F	8.3 µin/in-°F	25-900°C	14.5 µm/m-°C
	-	-	25-1000°C	15.0 µm/m-°C
Dynamic Modulus of Elasticity	RT	33.2 x 10^6 psi	RT	229 GPa
	200°F	32.7 x 10^6 psi	100°C	225 GPa
	400°F	31.8 x 10^6 psi	200°C	219 GPa
	600°F	30.8 x 10^6 psi	300°C	213 GPa
	800°F	29.7 x 10^6 psi	400°C	206 GPa
	1000°F	28.6 x 10^6 psi	500°C	199 GPa
	1200°F	27.6 x 10^6 psi	600°C	193 GPa
	1400°F	25.7 x 10^6 psi	700°C	185 GPa
	1600°F	24.0 x 10^6 psi	800°C	172 GPa
	1800°F	22.4 x 10^6 psi	900°C	163 GPa
	-	-	1000°C	152 GPa

RT= Room Temperature

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.

Comparative Oxidation-Resistance in Flowing Air at 1500°F (815°C) for 1008 Hours*

Alloy	Metal Loss		Average Metal Affected	
-	mils	µm	mils	µm
242®	**0**	**0**	**0.5**	**13**
S	0	0	0.5	13
X	0.1	3	1.1	28
N	0.4	10	1.2	30
B	7.2	183	8.2	208
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.

Comparative Oxidation Resistance in Flowing Air, 10 Months (7200 h), Cycled Every Two Months**

	800°F (427°C)				1000°F (538°C)				1200°F (649°C)			
	Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
Alloy	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm
718	0	0	0	0	0	0	0.1	3	0	0	0.2	5
242®	**0**	**0**	**0**	**0**	**0**	**0**	**0.1**	**3**	**0**	**0**	**0.3**	**8**
263	0	0	0	0	0	0	0.1	3	0	0	0.3	8

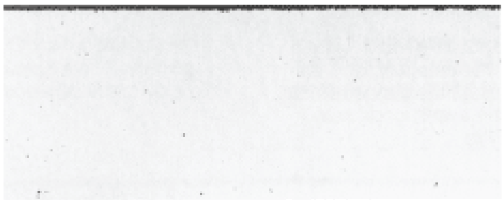
** Coupons exposed to flowing air at a velocity of 7.0 feet/minute (2.1m/minute) past the samples. Samples cycled to room temperature once every two months.

Comparative Burner Rig Oxidation-Resistance at 1400°F (760°C) for 500 Hours***

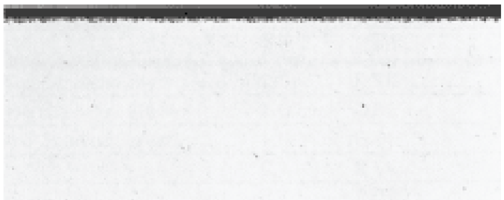
Alloy	Metal Loss		Average Metal Affected	
	mils	µm	mils	µm
N	0.7	18	0.8	20
242®	**1.1**	**28**	**1.2**	**30**
B	1.8	46	2.6	66
909	0.3	8	10.8	275

***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.

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 above 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.

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

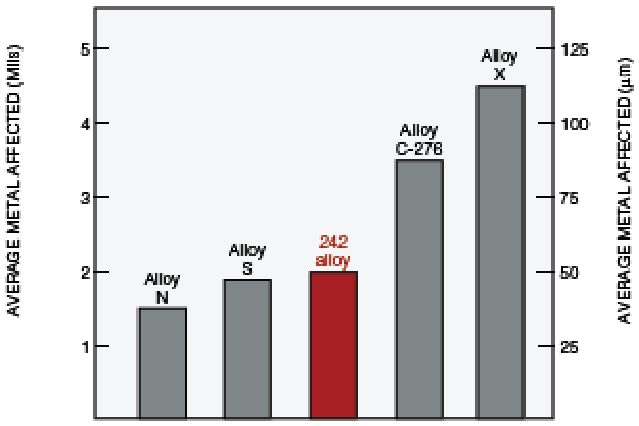
Resistance to High-temperature Fluoride Environments

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	mm
242®	**12.6**	**0.3**
S	15.8	0.4
N	15.8	0.4
625	47.2	1.2
230®	70.9	1.8
C-22®	78.7	2
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 Molten Salt

Samples were partially submerged in molten flux at 1250°F for 1200 hours. Flux consisted of boric acid, boron elemental, potassium fluoride, potassium tetraborate tetrahydrate, potassium fluoborate, potassium hydrogen difluoride, and potassium pentaborate.

Alloy	Corrosion Rate	
	mils / 24 h	µm / 24 h
242®	**0.5**	**13**
N	0.6	15
C-276	0.9	23

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)
214®	0.3
242®	0.7
600	0.9
230®	1.4
X	3.2
800H	4.0
316 SS	6.0
304 SS	7.3
310 SS	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
S	0.1	2.5	0.2	5.1
242®	0.15	3.8	0.3	7.6
B	0.2	5.1	0.3	7.6
909	0.4	10.2	0.2	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		Stress Concentration Factor	Ratio of Notched Tensile Strength
	psi	MPa	Kt	Hydrogen/Air
Waspaloy	7,000	48	6.3	0.78
625	5,000	34	8	0.76
242®	5,000	34	8	0.74
718	10,000	69	8	0.46
R-41	10,000	69	8	0.27
X-750	7,000	48	6.3	0.26

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		Exposure	Corrosion Rate, Mils/year (mm/year)							
				242®		B-2		C-22®		N	
-	°F	°C	h	mils	mm	mils	mm	mils	mm	mils	mm
5% HF	175	79	24	**14**	**0.36**	12	0.3	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% HC	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	0.1	9	0.23	-	-
85% H_3PO_4	Boiling		24	**4**	**0.1**	4	0.1	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	-	-

Solution Annealed Tensile

Room temperature tensile properties of material in mill annealed condition

Form	0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation	Reduction of Area
	ksi	MPa	ksi	MPa	%	%
Sheet	60.7	419	131.8	909	65.6	-
Plate	60.3	416	131.1	904	65.5	71.6
Bar	60.5	417	131.0	903	66.5	77.1

Hardness and Grain Size

Solution Annealed Room Temperature Hardness

Form	Hardness, HRBW	Typical ASTM Grain Size
Sheet	92	5 - 6.5
Plate	94	4 - 6.5
Bar	90	3.5 - 6

HRBW= Hardness Rockwell "B", Tungsten Indentor.

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

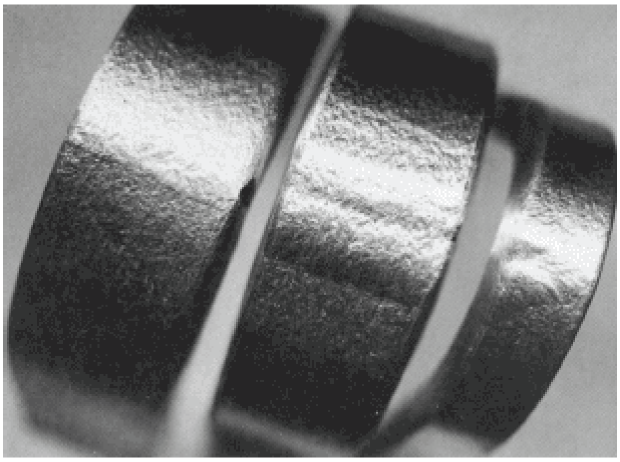
Welding procedures common to most high-temperature, nickel-base alloys are recommended. These include use of stringer beads and an interpass temperature less than 200°F (95°C). Preheat is not required. Cleanliness is critical, and careful attention should be given to the removal of grease, oil, crayon 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.

Postweld 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.



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).

Machining

HAYNES® 242® alloy may be machined in either the solutionannealed or aged conditions. Carbide tools are recommended. In the annealed condition (RB 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 (RC 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 waterbase lubricant.

Specifications and Codes

Specifications

HAYNES® 242® alloy (N10242)	
Sheet, Plate & Strip	SB 434/B 434 P= 44
Billet, Rod & Bar	SB 573/B 573 B 472 P= 44
Coated Electrodes	-
Bare Welding Rods & Wire	SFA 5.14, F= 44 (ERNiMo-12) A 5.14 (ERNiMo-12)
Seamless Pipe & Tube	SB 622/B 622 P= 44
Welded Pipe & Tube	SB 619/B 619 SB 626/B 626 P= 44
Fittings	SB 366/B 366 P= 44
Forgings	SB 564/B 564 P= 44
DIN	-
Others	-

Specifications and Codes Continued

Codes

			HAYNES® 242® alloy (N10242)
ASME	Section I		-
	Section III	Class 1	-
		Class 2	-
		Class 3	-
	Section IV	HF-300.2	-
	Section VIII	Div. 1	1000°F (538°C)[1]
		Div. 2	-
	Section XII		-
	B16.5		-
	B16.34		-
	B31.1		-
	B31.3		-
MMPDS			-

[1]Approved material forms: Plate, Sheet, Bar, Forgings, fittings, welded pipe/tube, seamless pipe/tube