HAYNES® HR-120® alloy

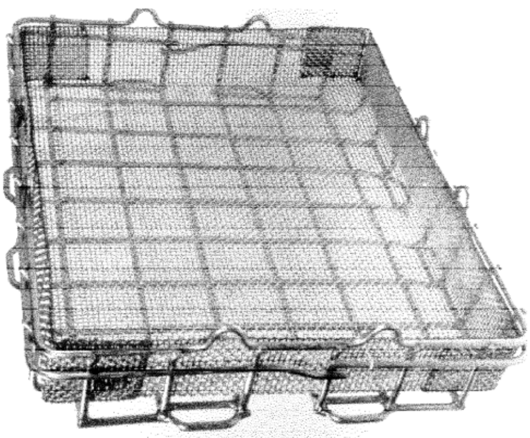
Principal Features

HAYNES® HR-120® (UNS N08120) alloy is a solid-solution-strengthened heat-resistant alloy that provides excellent strength at elevated temperature combined with very good resistance to carburizing and sulfidizing environments. Its oxidation resistance is comparable to other widely used Fe-Ni-Cr materials, such as alloys 330 and 800H, but its strength at temperatures up to 2000 ºF (1095 ºC) is significantly higher, even in comparison to Ni-Cr alloys. The alloy can be readily formed hot or cold, and is commonly welded using HAYNES® 556® filler wire.

Applications

Applications include those which require high strength combined with good resistance to carburizingand sulfidizing environments such as the following:

- Bar Frame Heat Treating Baskets
- Wire Mesh Furnace Belts and Basket Liners
- Muffles, Retorts
- Heat Treating Fixtures
- Waste Incinerators
- Radiant Tubes
- Cast Link Belt Pins
- Recuperators
- Fluidized Bed Components



HR-120® alloy heat treat furnace basket and mesh liner.This 3/8 of an inch diameter rod frame basket has replaced 1/2 in diameter baskets in similiar design in 330 and 600 alloys. The reduction in rod diameter is equivilant to a 43% weight deduction.

Heat-treatment

HAYNES® HR-120® alloy is furnished in the solution annealed condition, unless otherwise specified. Depending on the product form, the alloy is solution annealed at a temperature ranging from 2150 to 2250 °F (1175 to 1230 °C) and rapidly cooled. For more information on heat-treatment, please see our “Welding and Fabrication” brochure.

Applicable Specifications

HAYNES® HR-120® is covered by ASME Section VIII, Division 1. Plate, sheet, strip, bar, forging, tubing, pipe, and fittings are covered by ASME specifications SB 409, SB 408, SB 407, SB 514, SB 366, and SB 564 and ASTM specifications B 409, B 408, B 407, B 514, B 366, and B 564. The UNS number for the alloy is N08120. DIN designations are No. 2.4854 and NiFe33Cr25Co. Sheet, strip, and plate are also covered by AMS specification 5916.

Nominal Composition

Weight %

Iron:	33 (Balance)
Nickle:	37
Cobalt:	3 max.
Chromium:	25
Molybdenum:	2.5 max.
Tungsten:	2.5 max.
Columbium:	0.7
Manganese:	0.7
Silicon:	0.6
Nitrogen:	0.2
Aluminum:	0.1
Carbon:	0.05
Boron:	0.004

Creep Rupture Data

HR-120® Plate, Solution-annealed

Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in:							
			10 h		100 h		1,000 h		10,000 h	
°F	°C	%	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
1200	649	0.5	-	-	-	-	23	159	-	-
		1	-	-	-	-	26.5	183	-	-
		R	68	469	54	372	35	241	23	159
1300	704	0.5	-	-	20.3	140	14	97	-	-
		1	-	-	23.5	162	15.9	110	-	-
		R	45	310	32	221	21.7	150	15	103
1400	760	0.5	19.3	133	14.5	100	10.8	74	8	55
		1	22.2	153	15.8	109	12.3	85	9.5	66
		R	30	207	21.5	148	15.3	105	11	76
1500	816	0.5	13.8	95	10.5	72	8	55	5.7	39
		1	15.3	105	11.4	79	8.4	58	6.2	43
		R	21.8	150	15.3	105	11	76	7.8	54
1600	871	0.5	10.5	72	8.4	58	6.1	42	4.1	28
		1	11.4	79	9.1	63	6.5	45	4.4	30
		R	14	97	10.8	74	7.7	53	5	34
1700	927	0.5	8	55	6	41	3.9	27	2.4	17
		1	8.5	59	6.7	46	4.4	30	2.7	19
		R	11.2	77	7.8	54	5.1	35	3.1	21
1800	982	0.5	5.8	40	3.7	26	2.1	14	1.1	7.6
		1	6.2	43	4.4	30	2.5	17	1.3	9
		R	7.9	54	5.1	35	3.1	21	1.8	12
1900	1038	0.5	4	28	2.3	16	1.1	7.6	-	-
		1	4.7	32	2.5	17	1.2	8.3	0.6	4.1
		R	5.5	38	3.3	23	1.8	12	0.97	6.7
2000	1093	0.5	1.8	12	0.9	6.2	-	-	-	-
		1	-	-	1.1	7.6	-	-	-	-
		R	-	-	2	14	1.1	7.6	0.6	4.1
2100	1149	0.5	0.6	4.1	0.3	2.1	-	-	-	-
		1	-	-	0.42	2.9	-	-	-	-
		R	-	-	1.2	8.3	0.6	4.1	0.3	2.1

Creep Rupture Data Continued

HR-120® Sheet, Solution-annealed, Limited Data

Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in:			
			100 h		1,000 h	
°F	°C	%	ksi	MPa	ksi	MPa
1400	760	1	14.6	101	10.4	72
		R	21.6	149	14.4	99
1500	816	1	11.5	79	8.8	61
		R	14.9	103	10.4	72
1600	871	1	8.2	57	6.6	46
		R	10.3	71	7.2	50
1700	927	1	6	41	4.2	29
		R	7	48	4.3	30
1800	982	1	3.3	23	2.4	17
		R	4.4	30	2.7	19

Tensile Data

Average Tensile Data, Solution Heat-treated Sheet

Test Temperature		Ultimate Tensile Strength		0.2% Offset Yield Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	104.2	718	47.5	328	46.3
1000	538	80	552	28.3	195	53.6
1200	649	73.5	507	27	186	55
1400	760	57.4	396	26.4	182	48
1600	871	32.6	225	24.7	170	67.2
1800	982	17.1	118	13.2	91	74.7
2000	1093	8.8	61	6.4	44	56.1

RT= Room Temperature

Average Tensile Data, Solution Heat-treated Plate

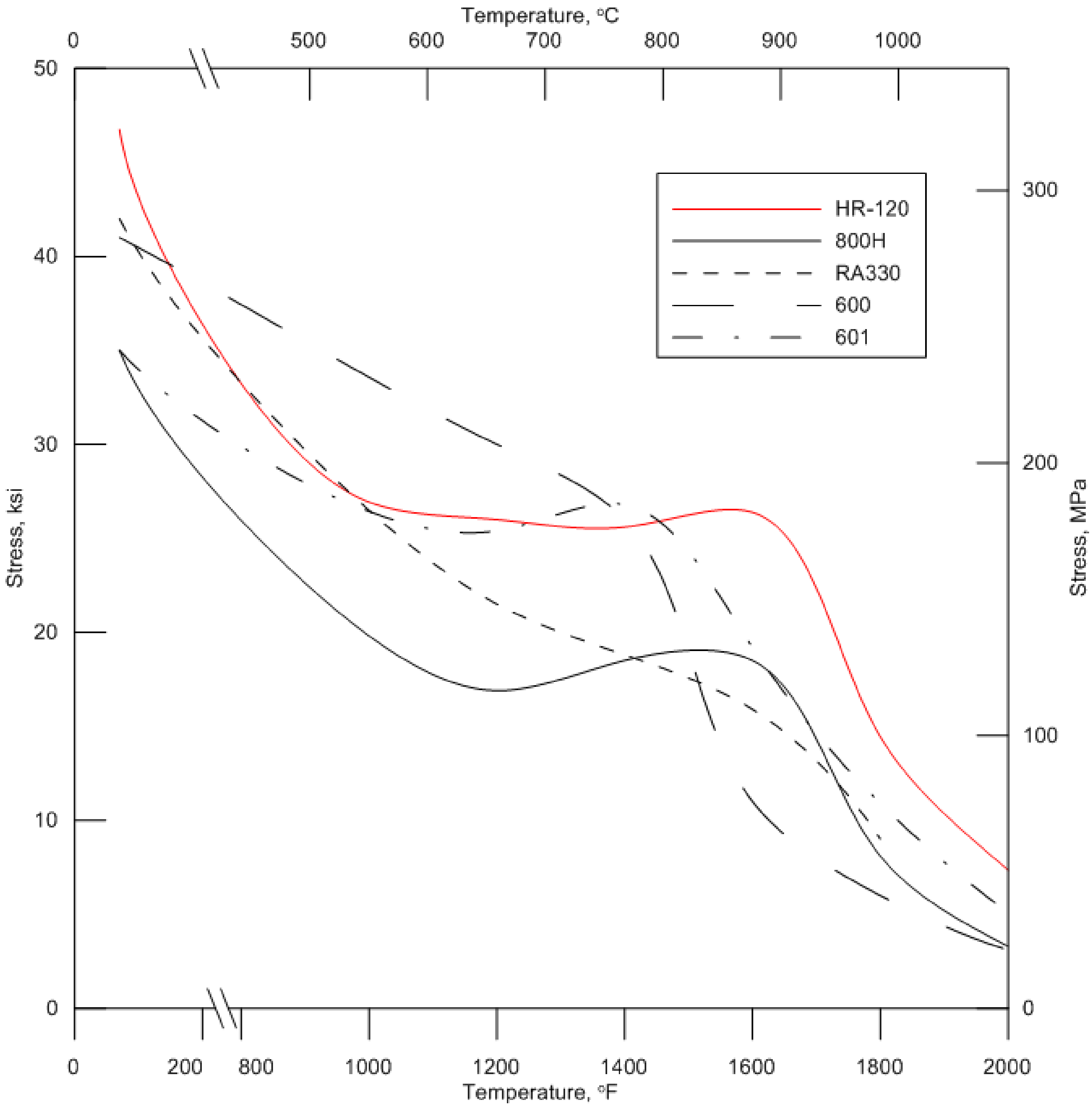
Test Temperature		Ultimate Tensile Strength		0.2% Offset Yield Strength		Elongation	Reduction of Area
°F	°C	ksi	MPa	ksi	MPa	%	%
RT	RT	104.3	719	46.8	322	49.8	63.3
1000	538	80.4	554	26.9	186	58.7	57.7
1200	649	72.9	503	26	179	55.4	59.6
1400	760	59.8	412	25.6	177	51.6	65.6
1600	871	35.8	247	26.4	182	71.1	72.3
1800	892	18.6	128	14.5	100	83.6	77.4
2000	1093	9.6	66	7.4	51	84.1	69.4

RT= Room Temperature

Tensile Data Continued

Comparative Yield Strengths

Temperature	0.2% Yield Strength, ksi				
°F	HR-120®	800H	RA330®	600	601
70	**46.8**	35	42	41	35
1000	**26.9**	-	-	-	-
1200	**26**	16.9	21.5	30	25.4
1400	**25.6**	18.5	18.8	26	26.8
1600	**26.4**	18.5	15.9	11	19.2
1800	**14.5**	8.1	9	6	10.9
2000	**7.4**	3.3	-	3.1 est	5.1



Hardness Data

Solution-annealed Room Temperature Hardness

Form	Hardness, HRB	Typical ASTM Grain Size
Sheet	88	3.5 - 5
Plate	87	0 - 5
Bar	84	0 - 4.5

HRB= Hardness Rockwell "B"

Thermal Stability

Condition	Ultimate Tensile Strength		0.2% Offset Yield Strength		Elongation	Reduction of Area
	ksi	MPa	ksi	MPa	%	%
Solution Heat-treated	108	745	49	338	48.5	69
+ 1200°F/8,000 h	109.2	753	52.5	362	26.2	32.8
+ 1200°F/20,000 h	112.4	775	53.5	369	24.2	34
+ 1200°F/30,000 h	112.7	777	52.3	361	24.6	32.7
+ 1200°F/50,000 h	113	779	53.1	366	23.2	32.5
+1400°F/8,000 h	101.8	702	47.9	330	18.2	17.6
+1400°F/20,000 h	101.2	698	43.3	299	18	17.2
+1400°F/30,000 h	101.5	700	44.8	309	19.7	18.4
+1400°F/50,000 h	99.8	688	44.9	310	14.8*	10.8
+ 1600°F/8,000 h	101	696	44.7	308	22.6	22.6
+ 1600°F/20,000 h	96.9	668	40.9	282	19.4	17.9
+ 1600°F/30,000 h	96.7	667	40.3	278	22	19.5
+ 1600°F/50,000 h	94.3	650	39.8	274	20.1	18.2

*AGL, which tends to be lower; Other data are 4D Elong.

Oxidation Resistance

Static Oxidation

HAYNES® HR-120® alloy exhibits good resistance to oxidizing environments and can be used at temperatures up to 2100°F (1150°C). The following are comparative static oxidation test results at 1600°F (870°C), 1800°F (980°C), 2000°F (1090°C), and 2100°F (1150°C) for 1008 hours.

	1600°F (870°C)				1800°F (980°C)				2000°F (1090°C)				2100°F (1150°C)			
	Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
Alloy	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm
HR-120®	**0.1**	**0**	**0.9**	**0.02**	**0.4**	**0.01**	**2.1**	**0.05**	**1**	**0.03**	**4.4**	**0.11**	**7.9**	**0.2**	**10.1**	**0.26**
253MA	0.2	0.01	0.9	0.02	1.3	0.03	3	0.08	0.7	0.02	8.2	0.21	8.7	0.22	16.5	0.42
800HT	0.1	0	1	0.03	0.5	0.01	4.1	0.1	7.6	0.19	11.6	0.29	11	0.28	15	0.38
601	-	-	-	-	0.4	0.01	1.7	0.04	1.3	0.03	3.8	0.1	2.8	0.07	6.5	0.17
600	-	-	-	-	0.3	0.01	2.4	0.06	0.9	0.02	3.3	0.08	2.8	0.07	4.8	0.12
RA330®	-	-	-	-	0.3	0.01	3	0.08	0.8	0.02	6.7	0.17	-	-	-	-
304SS	-	-	-	-	5.5	0.14	8.1	0.21	NA	NA	>19.6	>0.498	NA	NA	>19.5	>0.498
RA85H	-	-	-	-	0.5	0.01	8.3	0.21	3	0.08	26	0.66	-	-	-	-

Dynamic Oxidation

Burner rig oxidation tests were conducted by exposing samples of 3/8” x 2.5” x thickness (9mm x 64 mm x thickness), in a rotating holder to the products of combustion of 2 parts No. 1 and 1 part No. 2 fuel 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.

1800°F/1000-h/2000-Cycles				
	Metal Loss		Average Metal Affected	
Alloy	mils	µm	mils	µm
556®	3.9	99	6.8	173
HR-120®	**6.3**	**160**	**8.4**	**213**
RA 330®	6.5	165	9.5	241
800H/800HT	8.9	226	13.7	348
310 SS	16.0	406	18.3	465
253MA	16.6	422	17.8	452

Oxidation Resistance Continued

Long-term Oxidation

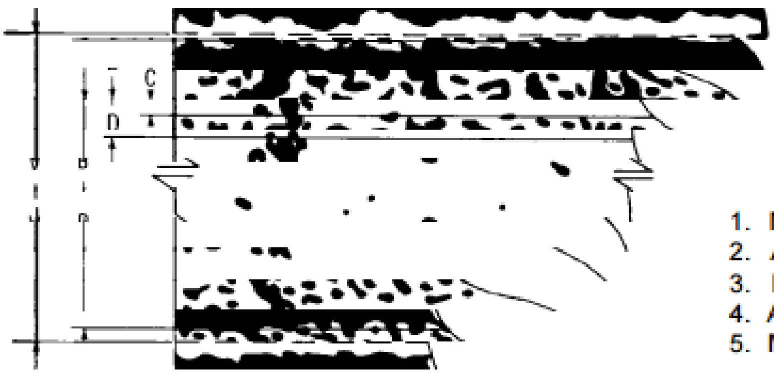
Amount of metal affected for high-temperature plate (0.25”) alloys exposed for 360 days (8,640 hours) in flowing air. Cycled once per month.

Alloy	Exposure Duration		1600°F				1800°F				2000°F				2100°F			
			Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
	h	number of cycles	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm
214®	8640	12	0.1	0	0.2	0.01	0	0	0	0	0	0	0	0	0	0	0	0
230®	8640	12	0.2	0.01	1.4	0.04	0.1	0	2.5	0.06	3.4	0.09	11	0.28	28.5	0.72	34.4	0.87
HR-120®	**8640**	**12**	**0.3**	**0.01**	**1.6**	**0.04**	**0.5**	**0.01**	**3.3**	**0.08**	**18.1**	**0.46**	**23.2**	**0.59**	**33.6**	**0.85**	**44**	**1.12**
556®	8640	12	0.3	0.01	1.9	0.05	0.5	0.01	6.2	0.16	15	0.38	24.1	0.61	-	-	-	-
617	8640	12	0.3	0.01	1.6	0.04	-	-	-	-	-	-	-	-	-	-	-	-
800HT	8640	12	0.4	0.01	2.9	0.07	-	-	-	-	-	-	-	-	-	-	-	-

Water Vapor Testing

Alloy	1008 hours at 1600ºF Cycled 1x/week in air+10% H_2O				1008 hours at 1600ºF Cycled 1x/week in air+20% H_2O				6 months at 1400ºF Cycled 1x/week in air+10% H_2O			
	Meal Loss		Average Metal Affected		Meal Loss		Average Metal Affected		Meal Loss		Average Metal Affected	
	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm
HR-120®	**0.09**	**0.002**	**0.68**	**0.017**	**0.04**	**0.001**	**0.29**	**0.007**	**0.1**	**0.003**	**0.5**	**0.013**
253MA	0.66	0.017	1.59	0.04	0.08	0.002	0.68	0.017	-	-	-	-
347SS	0.86	0.022	1.48	0.038	0.18	0.005	0.88	0.022	0.46	0.012	1.26	0.032
800HT	-	-	-	-	-	-	-	-	0.12	0.003	0.82	0.021

Schematic Representation of Metallographic Technique used for Evaluating Oxidation

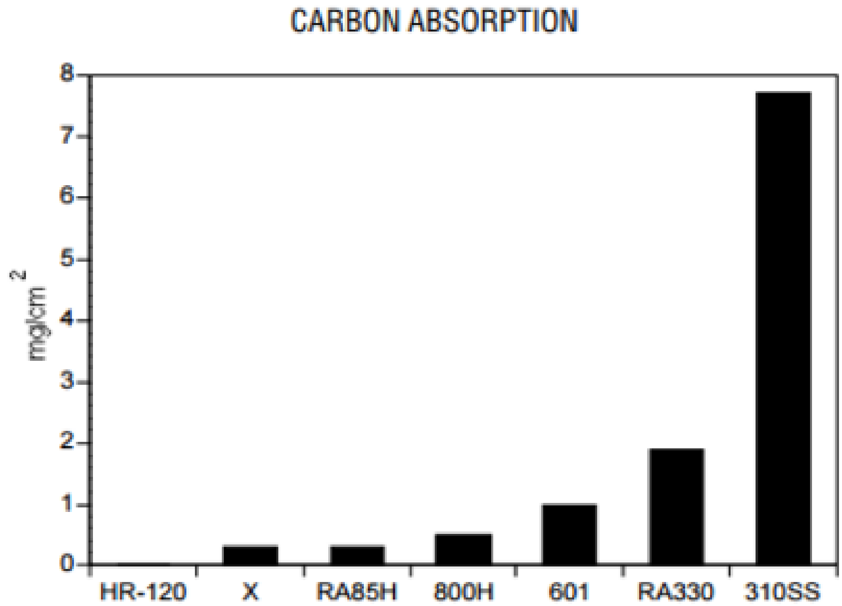


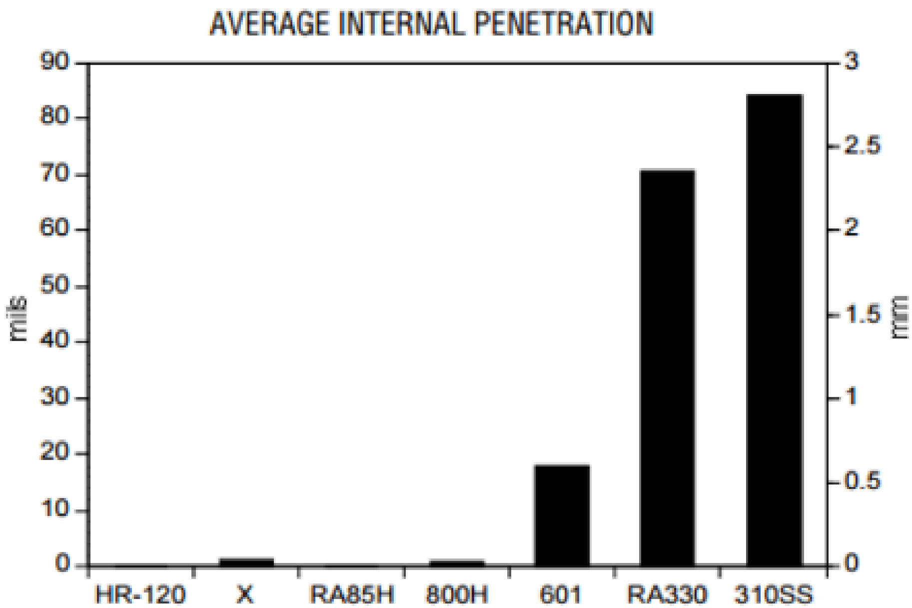
1. Metal Loss = (A-B)/2
2. Average Internal Penetration = C
3. Maximum Internal Penetration = D
4. Average Metal Affected = ((A-B)/2) + C
5. Maximum Metal Affected = ((A-B)/2) + D

Carburization Resistance

HAYNES® HR-120® alloy has good resistance to carburization. Results from 1800°F (982°C) carburization testing show HR-120® alloy to be better than stainless steels. Both pack and gaseous carburization test results are presented.

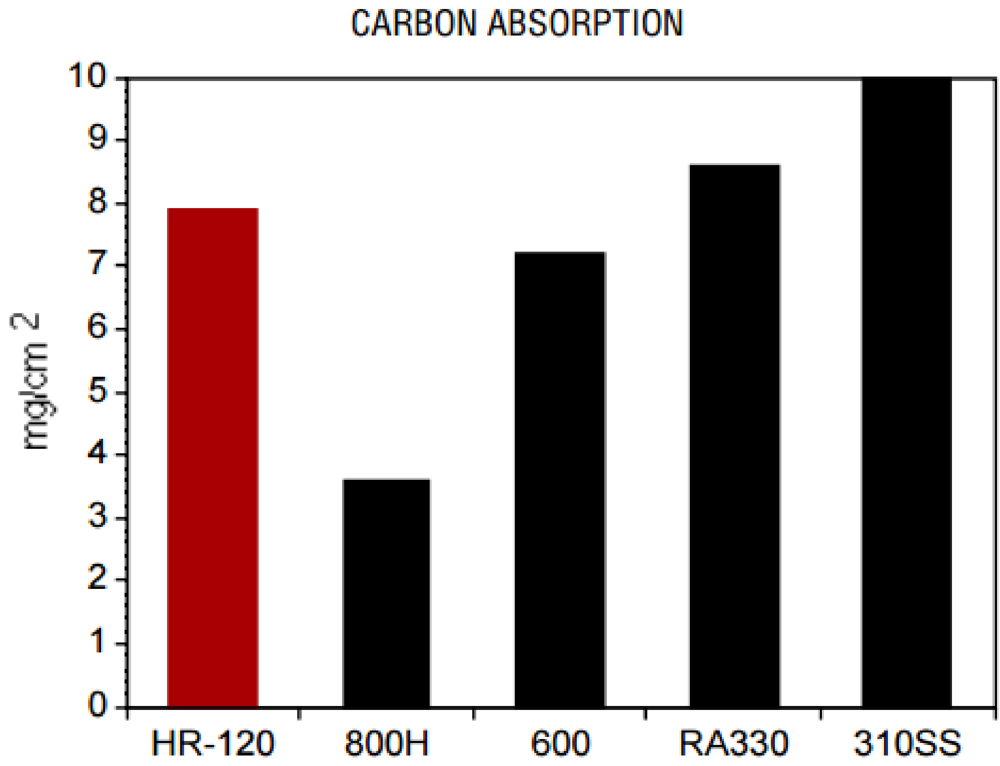
Carburization Resistance of Various Alloys at 1800°F (982°C) for 500 Hours in Graphite

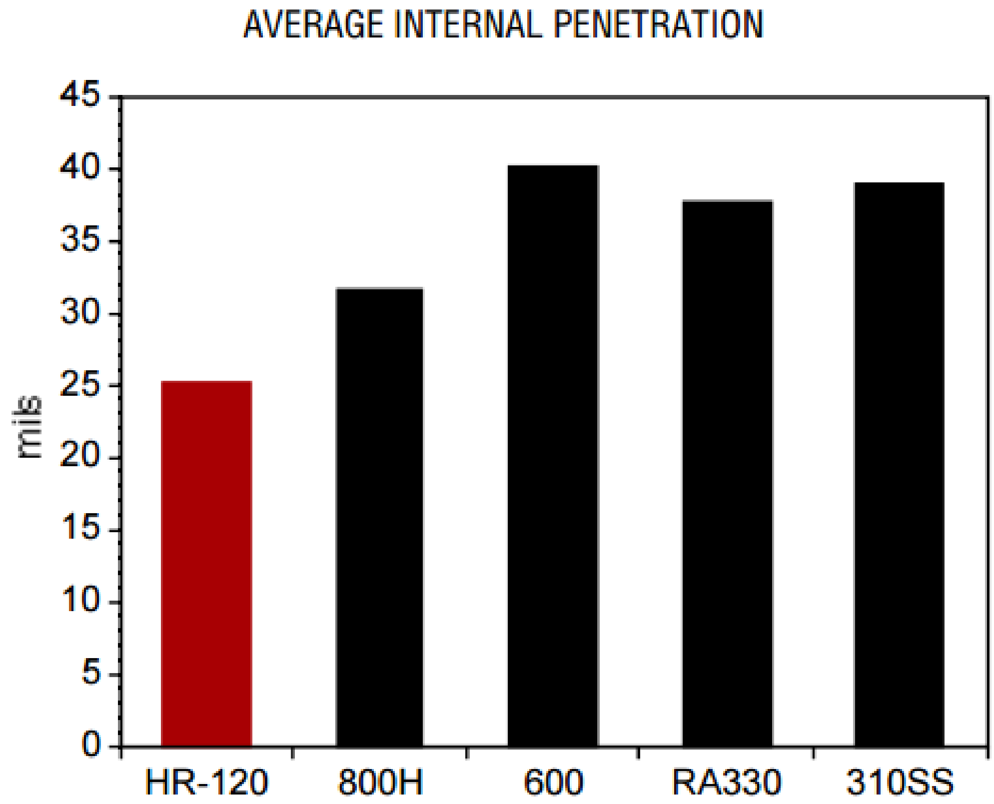




Carburization Resistance Continued

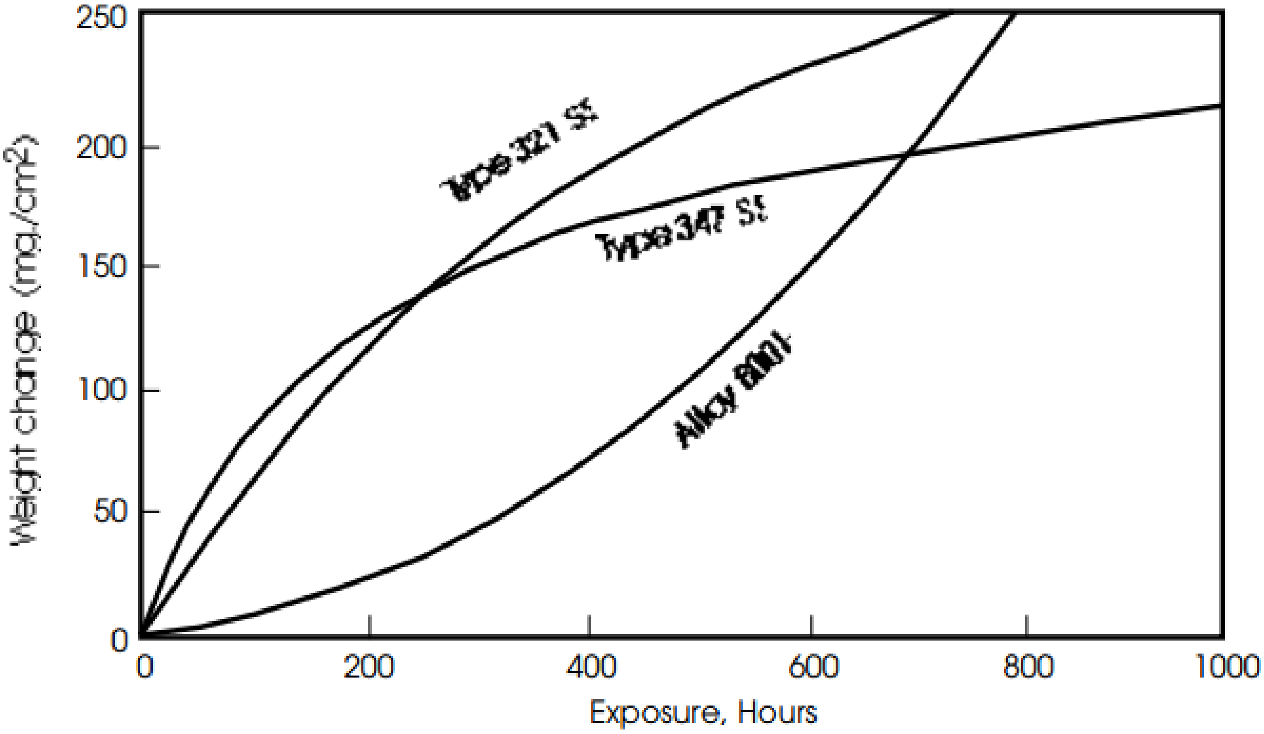
Carburization Resistance of Various Alloys at 1800°F (982°C) for 55 Hours in Ar-5%H_2-1%CH_4

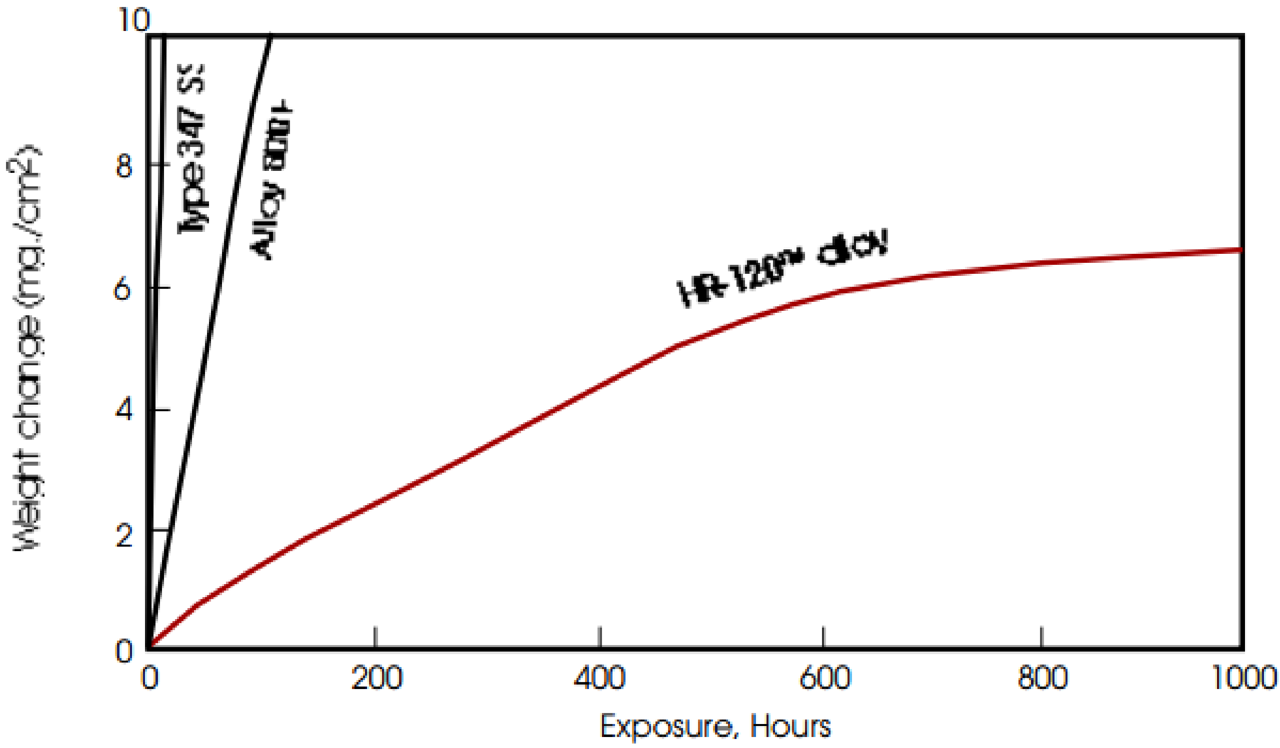




Comparative Sulfidation Resistance

Independent outside testing laboratories have also verified the superior performance of HR-120® alloy in sulfidizing environments. Petten Establishment in the Netherlands found that HR-120® alloy performed significantly better than alloys 800H, 347SS and 321SS at 1290°F (700°C) in hydrogen plus 7 percent carbon monoxide plus 1.5 percent water vapor plus 0.6 percent hydrogen sulfide. The HR-120® alloy was found to be magnitudes better than the other alloys.

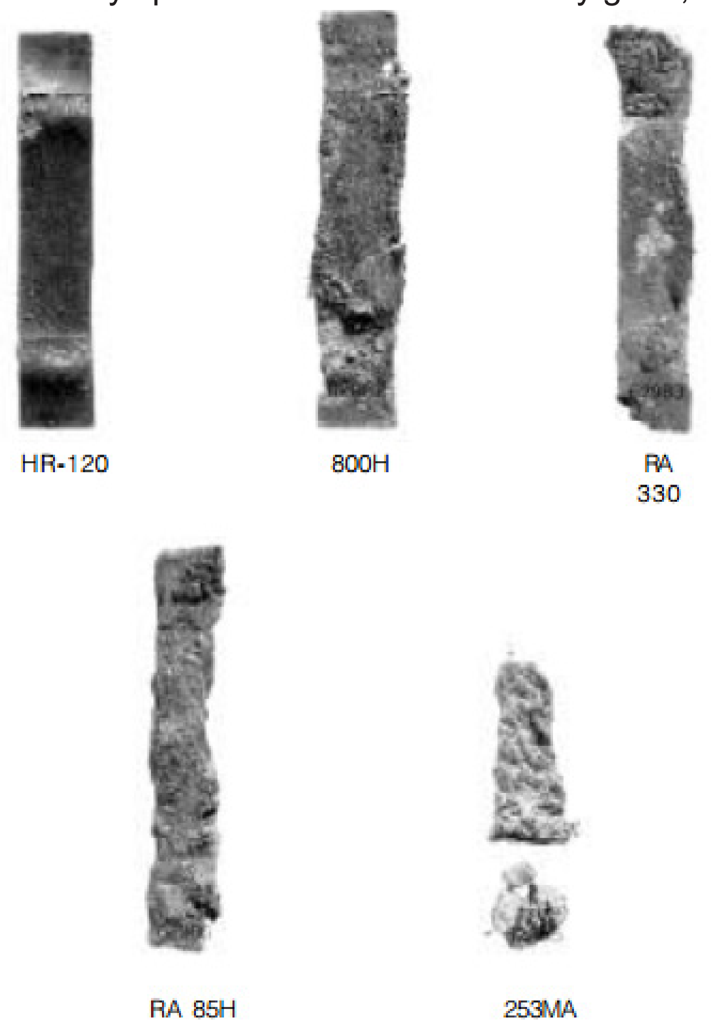




H_2+7%CO+1.5%H_2O+0.6%H_2S at 1290°F (700°C)
$Po_2=1x10^{-23}$ atm.
$Ps_2=1x10^{-9}$ atm.
$a_c=0.3-0.4$

Hot Corrosion Comparison

Hot corrosion is an accelerated oxidation or sulfidation attack due to a molten salt deposit. This form of corrosion is seen in gas turbines as well as in other industrial environments. The hot corrosion resistance of the HR-120® alloy was evaluated by performing laboratory burner rig testing. The burner rig used No. 2 fuel oil with a sulfur content of about 1 weight percent and air to generate the test environment. The air-to-fuel ratio was maintained at 35 to 1. The test was run at 1650°F (900°C) for 500 hours with a two-minute cooling cycle to less than 400°F (205°C) every hour. During testing a synthetic sea salt solution (ASTM D1141-52) was continuously injected into the combustion zone. The following photographs show the appearance of the specimens after testing. Specimens of 253 MA, RA 85H, RA330®, and 800H alloys were either severely corroded or partially destroyed. On the other hand, the HR-120® alloy specimen still looks extremely good, showing little attack.



Hot corrosion test specimens after exposure at 1650°F (900°C) for 500 hours using 50 ppm sea salt injection and 1 percent sulfur fuel.

Hot Corrosion Comparison

Burner Rig Hot Corrosion Data for Alloys at 1650°F (900°C) exposed for 500 hours

Alloy	Time	% S in Fuel	Salt	Metal Loss		Average Metal Affected	
	h		ppm	mils	mm	mils	mm
HR-120®	**500**	**1**	**50**	**0.9**	**0.02**	**5.2**	**0.13**
RA330	500	1	50	1.4	0.04	5.8	0.15
800H	500	1	50	1	0.03	10.3	0.26
253MA	500	1	50	>25	>0.64	>25	>0.64
RA85H	500	1	50	>25	>0.64	>25	>0.64

Physical Properties

Physical Property	British Units		Metric Units	
Density	RT	0.291 lb/in.^{3}	RT	8.07 g/cm.^{3}
Melting Range	2375°F	-	1300°C	-
Electrical Resistivity	RT	41.4 µohm.in	RT	105.2 µohm.cm
	200°F	42.4 µohm.in	100°C	107.8 µohm.cm
	400°F	44.4 µohm.in	200°C	112.5 µohm.cm
	600°F	45.4 µohm.in	300°C	114.9 µohm.cm
	800°F	46.3 µohm.in	400°C	116.7 µohm.cm
	1000°F	47.3 µohm.in	500°C	119.3 µohm.cm
	1200°F	48.2 µohm.in	600°C	121.4 µohm.cm
	1400°F	48.8 µohm.in	700°C	123.1 µohm.cm
	1600°F	49.4 µohm.in	800°C	124.5 µohm.cm
	1800°F	50.0 µohm.in	900°C	125.7 µohm.cm
	2000°F	50.3 µohm.in	1000°C	126.6 µohm.cm
	2200°F	50.7 µohm.in	1100°C	127.8 µohm.cm
	-	-	1200°C	128.7 µohm.cm
Thermal Diffusivity	RT	4.7 x 10^{-3} in^2/s	RT	30.4 x 10^{-3} cm^2/s
	200°F	5.0 x 10^{-3} in^2/s	100°C	32.4 x 10^{-3} cm^2/s
	400°F	5.4 x 10^{-3} in^2/s	200°C	34.8 x 10^{-3} cm^2/s
	600°F	5.8 x 10^{-3} in^2/s	300°C	37.2 x 10^{-3} cm^2/s
	800°F	6.3 x 10^{-3} in^2/s	400°C	39.7 x 10^{-3} cm^2/s
	1000°F	6.7 x 10^{-3} in^2/s	500°C	42.2 x 10^{-3} cm^2/s
	1200°F	7.1 x 10^{-3} in^2/s	600°C	44.7 x 10^{-3} cm^2/s
	1400°F	7.4 x 10^{-3} in^2/s	700°C	46.9 x 10^{-3} cm^2/s
	1600°F	7.5 x 10^{-3} in^2/s	800°C	48.1 x 10^{-3} cm^2/s
	1800°F	7.8 x 10^{-3} in^2/s	900°C	48.8 x 10^{-3} cm^2/s
	2000°F	78.2 x 10^{-3} in^2/s	1000°C	50.7 x 10^{-3} cm^2/s
	2200°F	8.6x 10^{-3} in^2/s	1100°C	52.9 x 10^{-3} cm^2/s
	-	-	1200°C	54.5 x 10^{-3} cm^2/s

Physical Properties Continued

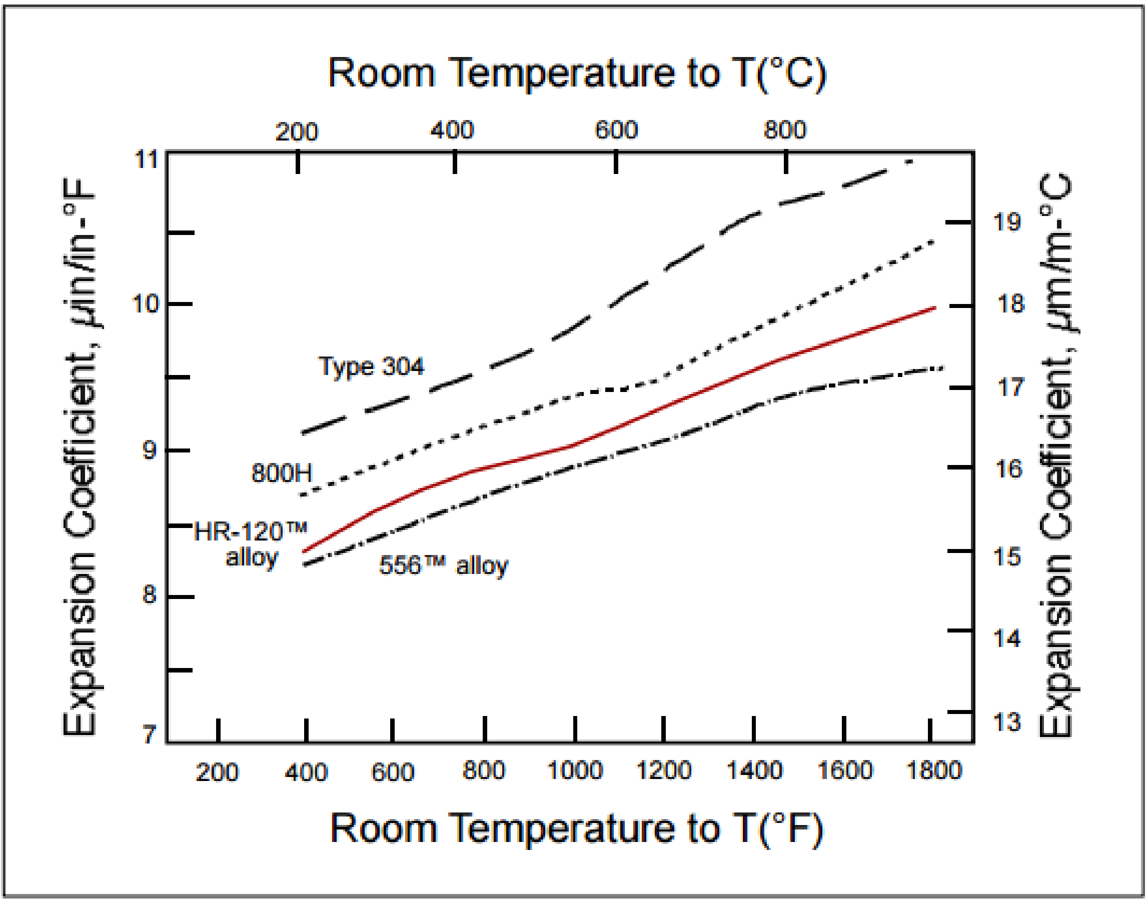
Physical Property	British Units		Metric Units	
Specific Heat	RT	0.112 Btu/lb.°F	RT	467 J/kg-°C
	200°F	0.116 Btu/lb.°F	100°C	483 J/kg-°C
	400°F	0.121 Btu/lb.°F	200°C	500 J/kg-°C
	600°F	0.125 Btu/lb.°F	300°C	522 J/kg-°C
	800°F	0.130 Btu/lb.°F	400°C	531 J/kg-°C
	1000°F	0.135 Btu/lb.°F	500°C	558 J/kg-°C
	1200°F	0.144 Btu/lb.°F	600°C	607 J/kg-°C
	1400°F	0.152 Btu/lb.°F	700°C	647 J/kg-°C
	1600°F	0.159 Btu/lb.°F	800°C	655 J/kg-°C
	1800°F	0.164 Btu/lb.°F	900°C	660 J/kg-°C
	2000°F	0.167 Btu/lb.°F	1000°C	663 J/kg-°C
	2200°F	0.169 Btu/lb.°F	1100°C	667 J/kg-°C
	-	-	1200°C	671 J/kg-°C
Mean Coefficient of Thermal Expansion	78-200°F	7.95 µin/in-°F	25-100°C	14.3 µm/m-°C
	78-400°F	8.29 µin/in-°F	25-200°C	14.9 µm/m-°C
	78-600°F	8.56 µin/in-°F	25-300°C	15.3 µm/m-°C
	78-800°F	8.80 µin/in-°F	25-400°C	15.8 µm/m-°C
	78-1000°F	8.98 µin/in-°F	25-500°C	16.1 µm/m-°C
	78-1200°F	9.24 µin/in-°F	25-600°C	16.4 µm/m-°C
	78-1400°F	9.52 µin/in-°F	25-700°C	16.9 µm/m-°C
	78-1600°F	9.72 µin/in-°F	25-800°C	17.3 µm/m-°C
	78-1800°F	9.87 µin/in-°F	25-900°C	17.6 µm/m-°C
	-	-	25-1000°C	17.8 µm/m-°C
Dynamic Modulus of Elasticity	RT	28.7 x 10^6 psi	RT	198 GPa
	200°F	28.2 x 10^6 psi	100°C	194 GPa
	400°F	27.0 x 10^6 psi	200°C	187 GPa
	600°F	25.9 x 10^6 psi	300°C	179 GPa
	800°F	24.7 x 10^6 psi	400°C	172 GPa
	1000°F	23.7 x 10^6 psi	500°C	165 GPa
	1200°F	22.5 x 10^6 psi	600°C	158 GPa
	1400°F	21.4 x 10^6 psi	700°C	151 GPa
	1600°F	20.2 x 10^6 psi	800°C	143 GPa
	1800°F	18.9 x 10^6 psi	900°C	136 GPa
	2000°F	17.3 x 10^6 psi	1000°C	129 GPa

Physical Properties Continued

Physical Property	British Units		Metric Units	
Dynamic Shear Modulus	RT	11.0×10^6 psi	RT	76 GPa
	200°F	10.7×10^6 psi	100°C	74 GPa
	400°F	10.3×10^6 psi	200°C	71 GPa
	600°F	9.8×10^6 psi	300°C	68 GPa
	800°F	9.3×10^6 psi	400°C	65 GPa
	1000°F	8.9×10^6 psi	500°C	62 GPa
	1200°F	8.4×10^6 psi	600°C	59 GPa
	1400°F	8.0×10^6 psi	700°C	56 GPa
	1600°F	7.5×10^6 psi	800°C	53 GPa
	1800°F	7.0×10^6 psi	900°C	50 GPa
	2000°F	6.3×10^6 psi	1000°C	47 GPa
Poisson's Ratio	RT	0.31	RT	0.31
	200°F	0.31	100°C	0.31
	400°F	0.32	200°C	0.32
	600°F	0.32	300°C	0.32
	800°F	0.33	400°C	0.32
	1000°F	0.33	500°C	0.33
	1200°F	0.34	600°C	0.33
	1400°F	0.34	700°C	0.34
	1600°F	0.35	800°C	0.34
	1800°F	0.36	900°C	0.35
	2000°F	0.37	1000°C	0.36

RT=Room Temperature

Physical Properties Continued



Welding

HAYNES® HR-120® alloy is readily welded by Gas Tungsten Arc Welding (GTAW), Gas Metal Arc Welding (GMAW), Shielded Metal Arc Welding (SMAW), and resistance welding techniques. Submerged Arc Welding (SAW) is not recommended as this process is characterized by high heat input to the base metal and slow cooling of the weld. These factors can increase weld restraint and promote cracking.

Base Metal Preparation

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

Filler Metal Selection

HAYNES® 556® filler metal (AMS 5831, AWS A5.9 ER3556) and MULTIMET® (AMS 5794) coated electrodes are recommended for joining HR-120® alloy. When dissimilar base metals are to be joined, such as HR-120® alloy to a stainless steel, HAYNES® 556® filler metal and MULTIMET® coated electrodes are again recommended. Please see the “Welding and Joining Guidelines” or the Haynes Welding SmartGuide for more information.

Preheating, Interpass Temperatures, and Post- Weld Heat-treatment

Preheat is not required. Preheat is generally specified as room temperature (typical shop conditions). Interpass temperature should be maintained below 200°F (93°C). Auxiliary cooling methods may be used between weld passes, as needed, providing that such methods do not introduce contaminants. Post-weld heat-treatment is not generally required for X alloy. For further information, please see the “Welding and Joining Guidlines” Heat-treatment section.

Nominal Welding Parameters

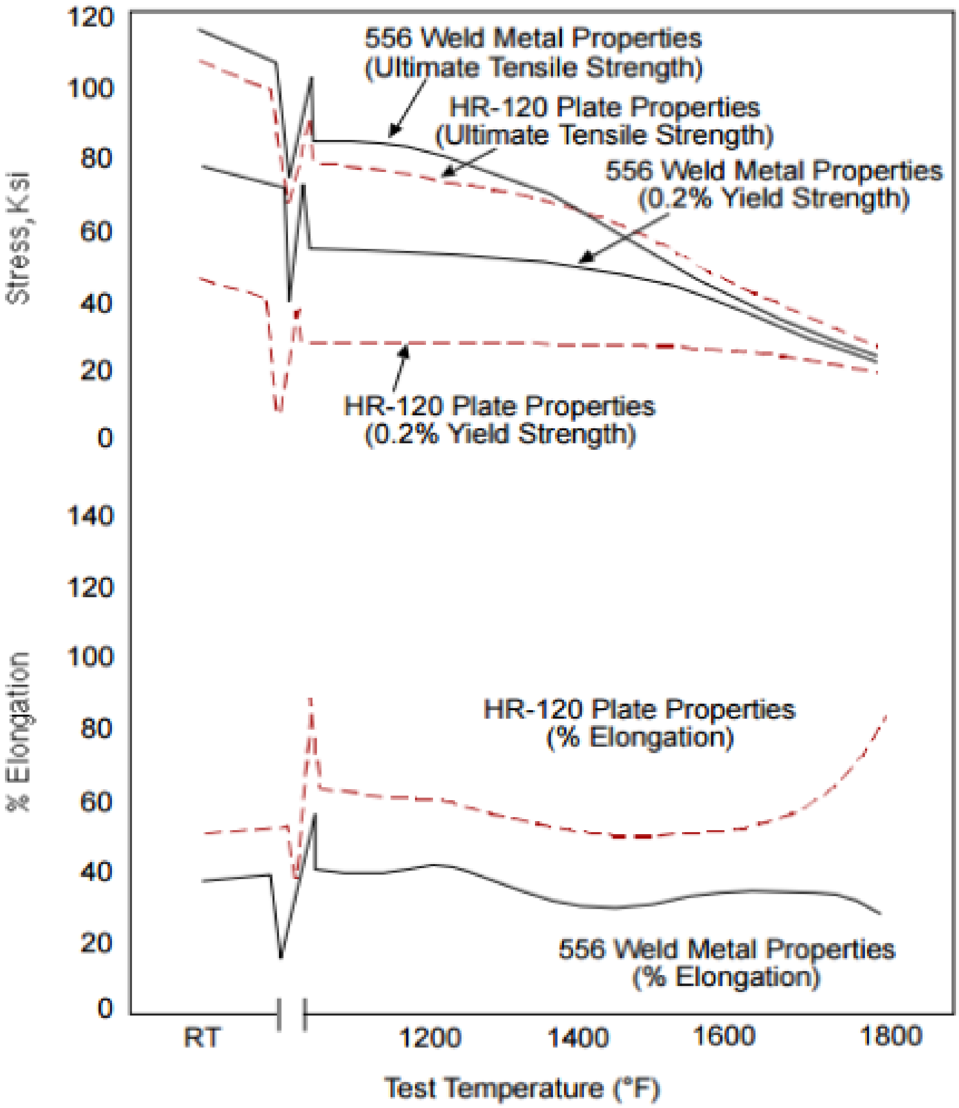
Details for GTAW, GMAW and SMAW welding are given here. Nominal welding parameters are provided as a guide for performing typical operations and are based upon welding conditions used in our laboratories.

Tensile Properties of All Weld Metal (AWM)

Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	77.2	530	115.4	795	37
1200	650	53.3	380	81.0	560	39
1400	760	49.5	340	66.3	455	26
1600	870	36.8	255	40.2	270	34
1800	980	23.6	165	24.0	165	30

RT=Room Temperature

Welding Continued



Welding Continued

Transverse Tensile Tests, HR-120® Base Metal Welded with Haynes 556® filler

Temperature		0.5 Inch Plate		0.125 Inch Sheet	
		UTS		UTS	
°F	°C	ksi	MPa	psi	MPa
RT	RT	106	731	104	717
200	93	97	666	97	665
300	149	91	625	92	632
400	204	87	600	89	612
500	260	86	595	78	540
600	316	85	589	83	571
700	371	84	576	79	547
800	427	84	581	83	570
900	482	82	568	82	564
1000	538	79	544	80	549
1100	593	75	516	77	530
1200	649	71	490	74	507
1300	704	68	471	66	455
1400	760	60	413	55	382
1500	816	47	327	45	312
1600	871	35	241	33	226
1700	927	27	184	26	176
1800	982	20	136	25	174
1900	1038	15	102	16	110
2000	1093	12	84	9	64

Welding Continued

Transverse Tensile Tests, HR-120® Plate Welded with Haynes 556® filler

Temperature		1 Inch Plate		0.5 Inch Plate	
		UTS		UTS	
°F	°C	ksi	MPa	ksi	MPa
RT	RT	110	762	106	731
200	93	102	703	96	661
300	149	96	665	91	629
400	204	93	641	88	609
500	260	90	622	86	590
600	316	89	611	84	582
700	371	89	612	82	564
800	427	89	611	82	563
900	482	87	602	82	568
1000	538	78	538	78	534
1100	593	79	545	75	519
1200	649	75	515	72	497
1300	704	72	497	68	471
1400	760	64	439	60	412
1500	816	53	362	48	329
1600	871	40	279	36	247
1700	927	31	215	27	188
1800	982	24	166	20	141
1900	1038	18	123	15	106
2000	1093	12	84	11	74

Welding Continued

HR-120® Plate and Transverse Weld Room Temperature Charpy Impact Tests 0.5" Plate, Welded with Haynes 556®

Condition	Energy	
	ft-lb	J
Parent Metal	182	247
GMAW SYN Mid Weld	155	211
GMAW SYN HAZ	147	199

Restrained 1/2 inch thick HR-120® plates have been successfully joined using 556® weld wire and MULTIMET® coated electrodes. The results below indicate an absence of hot cracking and microfissuring related weldability problems under the test conditions.

Welding Process	Welding Product	Hot Cracking	2T Radius Guided Bend Test	
-	-	-	Face	Side
GTAW	556® Filler Metal	None	Pass	Pass
GMAW	556® Filler Metal	None	Pass	Pass
SMAW	MULTIMET® Electrodes	None	Pass	Pass

Room Temperature Tensile Strength of Transverse Welded Specimens

Welding Process	Welding Product	Tensile Strength		Fracture Location
-	-	ksi	MPa	-
GTAW	556® Filler Metal	111	765	HR-120® Base Metal
GMAW	556® Filler Metal	109.4	755	HR-120® Base Metal
SMAW	MULTIMET® Electrodes	109.7	755	HR-120® Base Metal

Machining and Grinding

HAYNES® HR-120® alloy can be readily machined using conventional techniques. Generally, the same practices are employed as those used with the 300 series austenitic stainless steels. Some minor adjustments in the machining parameters may be required to obtain optimum results. High speed steel tools are found to be satisfactory, although machining speeds can be substantially increased by using carbide cutting tools. As a general statement, grinding operations with HAYNES® HR-120® alloy are considered equivalent to those of the 300 series stainless steels. As with other alloys, grinding is recommended where a close tolerance is required. Basic "Do's" and "Don'ts" that should be considered during machining are:

Do:

1. Use machine tools that are rigid and overpowered, where possible.

2. Insure work piece and tools are held rigid. In addition, minimize tool overhang.

3. Make sure tools are always sharp. Change to sharpened tools at regular intervals rather than out of necessity. Remember, cutting edges, particularly throw-away inserts, are expendable. Don't try to prove how long they can last. Don't trade dollars in machine times for pennies in tool cost.

4. Use positive rake angle tools for most machining operations. Negative rake angle tools can be considered for intermittent cuts and heavy stock removal.

5. Use heavy, constant, feeds to maintain positive cutting action. If feed slows and the tool dwells in the cut, work hardening occurs, tool life deteriorates and close tolerance is impossible.

6. Avoid conditions such as chatter and glazing. This can cause work hardening of the surface, making subsequent machining difficult.

7. Flood the work with premium-quality sulfochlorinated water soluble oil or water-base chemical emulsion oils with extreme pressure additives. Dilute per the recommendations of the manufacturer.

8. Use heavy-duty sulfochlorinated oil for drilling and tapping. Special proprietary tapping oils can also be used.

9. Use air jet directed on the tool when dry cutting. This can provide substantial increase in tool life.

Don't:

1. Do not make intermittent cuts, if possible. This tends to work harden the surface, making subsequent cuts more difficult.

Machining and Grinding Continued

Detailed Machining Information

Turning, Boring and Facing

The table below represents a typical range of values for normal turning operations. The depth of cut (particularly for roughing operations) is quite large with relatively low feed rates. These parameters are equipment and component dependent. The larger depths of cuts and higher speeds are recommended only when using heavy, overpowered equipment on large rigid components.

Conditions	Roughing	Finishing
Depth of Cut	0.125-0.250 in.	0.020-0.040 in.
Feed Rate	0.008-0.010 ipr	0.006-0.008 ipr
Speed-HSS	30-50 sfpm	40-60 sfpm
Speed-Carbide	100-170 sfpm	140-180 sfpm

Drilling

Standard high-speed steel bits are normally used. For drill bits larger than 3/8", thinning the web may reduce thrust and aid chip control. The following are suggested speed and feed rates for various diameter drills.

Diameter	Speed	Feed Rate
1/8 in	250 RPM (max)	0.002 inch/rev.
1/4 in	250 RPM (max)	0.003 inch/rev.
1/2 in	250 RPM	0.005 inch/rev.
1 in	150 RPM	0.011 inch/rev.
1-1/2 in	100 RPM	0.013 inch/rev.
2 in	75 RPM	0.016 inch/rev.

For other diameters (above 1/2 inch diameter) the spindle speed may be calculated from the following: RPM = 150/Diameter (inches). This results in a cutting speed of about 40 sfpm. For drill diameters smaller than 1/2 inch, speed rates substantially below 40 sfpm are required.

Reaming

Standard fluted reamers of high-speed steel are generally used. Speeds should be about 20-25 sfpm for diameters above 1/2 inch. For small diameter reamers (less than 1/2 inch diameter) cutting speeds should be reduced substantially. Feed rates will range from 0.002 to 0.006 inch/revolution depending upon diameter. If carbide tipped reamers are used, the speed can be increased to 70 sfpm for reamers above 1/2 inch diameter. If chatter occurs, reduce speed.

Machining and Grinding Continued

Tapping

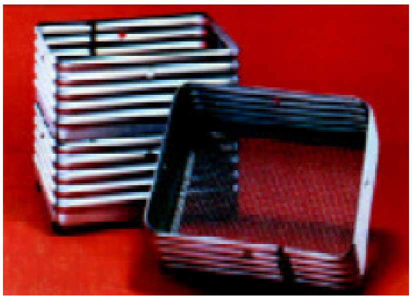
HAYNES® HR-120® alloy is tapped using the same tooling and conditions as used with type 316 stainless steel. High speed steel taps work well. Cutting speed can be up to 20 sfpm for taps above 1/2 inch diameter. For small diameter taps (less than 1/2 inch diameter) cutting speeds should be reduced substantially.

Thread engagement can be reduced because of the high strength of this alloy. Generally, thread engagement of 60 to 75 percent is considered acceptable. Thread engagement is considered a design parameter and therefore should be left to the design engineer. As a general statement, 75 percent thread engagement is common for low strength materials, but only leads to increased tool wear and possible breakage in high strength alloys. It does not increase the holding strength in these alloys.

Milling

High speed steel cutters, with good impact strength, are recommended due to the interrupted nature of the cutting action. A cutting speed of 30 to 40 sfpm with feed rates of 0.002 to 0.005 inch/tooth is generally recommended. If carbide cutters are employed, speeds of 60 to 80 sfpm are possible.

Applications



Corrugated boxes for carburizing furnaces operating at 1750°F. After 14 months of intensive field testing, HR-120® alloy was selected over RA 333 alloy.

HR-120® alloy Retort used to carburize large gears for ships at a commercial heat treat operation. The prior material of construction was Type 330 stainless steel.

Custom designed vacuum furnace basket fabricated in HR-120® alloy channel. The alloy replaced was alloy 601.

HR-120® alloy hazardous waste lifter plates were substituted for plates previously fabricated in Type 316 SS. The facility supervisor reported a substantial increase in equipment uptime and attributed it to the alloy change.

Comparative Data

Mechanical Property*		HR-120®	214®	230®	556®	X	600	601	RA330®	253MA	800H	304 SS	310 SS	316 SS
Annealing Temperature	°F	**2250**	2000	2250	2150	2150	2050	2100	2050	2000	2100	2000	2150	2000
Typical ASTM Grain Size	-	**3 - 6**	3 - 5	5 - 6	5 - 6	5 - 6	2 - 4	2 - 4	4 - 6	3 - 6	2 - 4	2 - 5	3 - 4	5 - 7
Ultimate Tensile Strength, ksi	70°F	**104.3**	138.9	125.4	116.4	107.5	96	102	85	104	82	85	82.7	103.9
	1200°F	**72.9**	114.9	97.7	83.1	78.5	65	74	55.7	64.6	59	43	54	60.5
	1400°F	**59.8**	79.4	87.7	68.5	66.6	38	43	34	49.8	39	2736	35.1	39
	1600°F	**35.8**	66.4	63.1	49.3	49.6	20	22	18.7	30.8	21	17.5	19.1	24.6
	1800°F	**18.6**	16.7	35.2	30.7	31.1	11	13	10.7	-	11	**7.4	10.5	14
	2000°F	**9.6**	9	19.5	16.1	16.5	-5.1	6.5	-	-	5	-	4.3	7.1
	2200°F	**-**	5	9.4	-	-	-	**5.2	-	-	-	-	-	-
0.2% Yield Strength, ksi	70°F	**46.8**	82.2	57.4	54.6	49.4	41	35	42	50.8	35	27.9	35.1	36.7
	1200°F	**26**	75.9	39.5	30.6	30.3	30	25.4	21.5	24.1	16.9	11	20.7	20.5
	1400°F	**25.6**	73.6	42.5	29.3	31	26	26.8	18.8	22.4	18.5	10.5	19.3	17.9
	1600°F	**26.4**	50.4	37.3	27.9	28.4	11	19.2	15.9	18.1	18.5	7.4	12.2	10.6
	1800°F	**14.5**	8.4	21.1	18.5	17.9	6	10.9	9	-	8.1	-	6.4	-
	2000°F	**7.4**	4.2	10.8	8.7	9.1	-3.1	5.1	-	-	3.3	-	3.1	-
	2200°F	**-**	1.4	4.3	-	-	-	**2.0	-	-	-	-	-	-
Tensile Elongation, %	70°F	**50**	43	50	51	53	45	50	45	51	49	61	54	59
	1200°F	**55**	33	55	57	64	49	46	51	44	38	37	21	40
	1400°F	**52**	23	53	53	58	70	72	65	44	43	31	19	49
	1600°F	**71**	34	65	69	75	80	90	69	-	87	35	28	59
	1800°F	**84**	86	83	84	95	115	100	74	-	100	**38	24	41
	2000°F	**84**	89	83	95	98	-120	120	-	-	108	-	-	85
	2200°F	**-**	92	109	-	-	-	121	-	-	-	-	-	-
Stress to Rupture in 1,000 Hours, ksi	1200°F	**38**	-	42.5	38	34	20	28	-	23	23.8	14.1	17	20.5
	1400°F	**17**	25	20	17.5	15	8.1	9.8	7	9.2	9.8	7.4	7.4	8.8
	1600°F	**8**	8.9	9.5	7.5	6	3.5	4.4	3.1	4.4	4.8	3	3.3	3.4
	1800°F	**3.5**	1.8	3	3	2.4	1.8	2.2	1.3	1.9	1.9	1.2	1.4	1.3
	2000°F	**0.8**	0.9	**1.0	-	**0.8	-0.9	1	0.7	1	-	-	-	-

( ) Estimated

*Manufacturer's laboratory or published data

**Limited data

Comparative Data Continued

Physical Property*		HR-120®	214®	230®	556®	X	600	601	RA330	253MA	800H	304 SS	310 SS	316 SS
Density, lb/in³		**0.291**	0.291	0.324	0.297	0.297	0.304	0.291	0.289	0.282	0.287	0.278	0.285	0.287
Incipient Melting Point	°F	**2375**	2475	2375	2425	2300	2470	2375	2450	2500	2475	2250	2550	2500
Electrical Resistivity, µ ohm-in	70°F	**41.4**	53.5	49.2	37.5	45.2	40.6	46.9	29.9	33.1	38.9	28.7	38.2	29.4
	400°F	**44.4**	53.9	49.8	40.5	46.7	41.5	48.2	43	40.6	43	34.6	41.7	34.5
	800°F	**46.3**	54.3	50.7	43.5	48.4	43	49.2	45.6	48.8	46.1	40.6	45.7	39.3
	1200°F	**48.2**	53.5	51.6	45.7	49.5	-	49.5	47.8	54.3	-	45.7	48.4	43.7
	1600°F	**49.4**	49.6	50.3	17.3	49.8	-	50.2	49.1	56.3	-	47.2	50.8	-
	2000°F	**50.3**	47.6	-48.4	48.6	49.7	-	51.1	-	-57.5	-	-	-	-
Thermal Conductivity, Btu-in/ft2-hr °F	70°F	**78**	83	62	77	63	103	78	86	101	80	99	91	90
	400°F	**96**	99	87	107	83	121	100	108	121	103	116	112	108
	800°F	**120**	132	118	135	121	145	126	134	140	127	141	145	132
	1200°F	**150**	175	148	160	152	172	153	162	156	152	167	182	152
	1600°F	**180**	215	179	185	182	200	178	198	184	181	192	213	172
	2000°F	**205**	234	-210	210	-	-203	203	-	-	-	-	-	-
Mean Coefficient of Thermal Expansion, µ in/in-°F (R to Temp.)	400°F	**7.9**	7.4	7.2	8.2	7.9	7.7	8	8.6	9.3	8.8	9.1	8.9	9.1
	800°F	**8.8**	7.9	7.6	8.6	8.2	8.1	8.3	9.1	9.8	9.2	9.6	9.2	9.8
	1200°F	**9.2**	8.6	8.1	9	8.6	8.6	8.9	9.6	10.1	9.6	10.2	9.7	10.3
	1400°F	**9.5**	9	8.3	9.2	8.8	8.9	9.2	9.7	10.3	9.9	10.7	10	10.4
	1600°F	**9.7**	9.6	8.6	9.4	9	9.1	9.5	9.8	10.5	10.2	10.8	10.4	10.5
	1800°F	**9.9**	10.2	8.9	9.5	9.2	9.3	9.8	10	10.8	-10.5	11	40.7	10.7
	2000°F	**-**	11.1	-9.2	9.6	-9.4	-9.5	10.2	-10.2	-11.1	-	11.4	11	-
Modulus of Elasticity, psi x 10⁶	70°F	**28.7**	31.6	30.6	29.7	29.8	31.1	30	28.5	29	28.4	27.9	29	28.5
	400°F	**27**	29.6	29.3	28.2	28.6	29.7	28.5	26.9	26.8	26.6	26.6	26.9	26.9
	800°F	**24.7**	27.4	27.3	25.6	26.7	27.8	26.6	24.9	24.4	24.4	24.1	24.3	24.2
	1200°F	**22.5**	25.3	25.3	23.1	24.7	25.5	24.1	22.4	21.7	22.3	21.1	21.8	21.5
	1400°F	**21.4**	23.9	24.1	21.8	23.3	24.3	22.5	21	20.2	21.1	19.4	20.5	20
	1600°F	**20.2**	22.3	23.1	20.9	22.2	22.8	20.5	19.5	-	20	-	19.2	-
	1800°F	**18.9**	20.2	21.9	20.1	20.4	21	18.4	18	17.6	18.7	-	-	-
	2000°F	**17.3**	19	-	-	-	-	16.2	-	-	17.2	-	-	-

( ) Estimated
*Manufacturer's labroatory or published data

Specifications and Codes

Specifications

HAYNES® HR-120® alloy (N08120)	
Sheet, Plate & Strip	AMS 5916 SB 409/B 409 P= 45
Billet, Rod &Bar	SB 408/B 408 B 472 P= 45
Coated Electrodes	-
Bare Welding Rods & Wire	-
Seamless Pipe & Tube	SB 407/B 407 SB 163/B 163 P= 45
Welded Pipe & Tube	SB 514/B 514 SB 515/B 515 P= 45
Fittings	SB 366/B 366 P= 45
Forgings	SB 564/B 564 P= 45
DIN	No. 2.4854 NiFe33Cr25Co
Others	-

Codes

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(N08120)</th></tr>
<tr><td rowspan="11">ASME</td><td>Section I</td><td colspan="2">-</td></tr>
<tr><td rowspan="3">Section III</td><td>Class 1</td><td>-</td></tr>
<tr><td>Class 2</td><td>-</td></tr>
<tr><td>Class 3</td><td>-</td></tr>
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<tr><td>Div. 2</td><td>-</td></tr>
<tr><td>Section XII</td><td colspan="2">-</td></tr>
<tr><td>B16.5</td><td colspan="2">-</td></tr>
<tr><td>B16.34</td><td colspan="2">-</td></tr>
<tr><td>B31.1</td><td colspan="2">-</td></tr>
<tr><td>B31.3</td><td colspan="2">-</td></tr>
<tr><td colspan="2">MMPDS</td><td colspan="2">6.3.10</td></tr>
</table>

[1]Approved material forms: Plate, Sheet, Bar, Forgings, fittings, welded pipe/tube, seamless pipe/tube
[2]Properties up to 1650°F (899°C) are found in the latest ASME BPV Code, and from 1650°F - 1800°F (899°C - 982°C) in ASME Code Case 2672