HAYNES International HIGH-TEMPERATURE ALLOYS

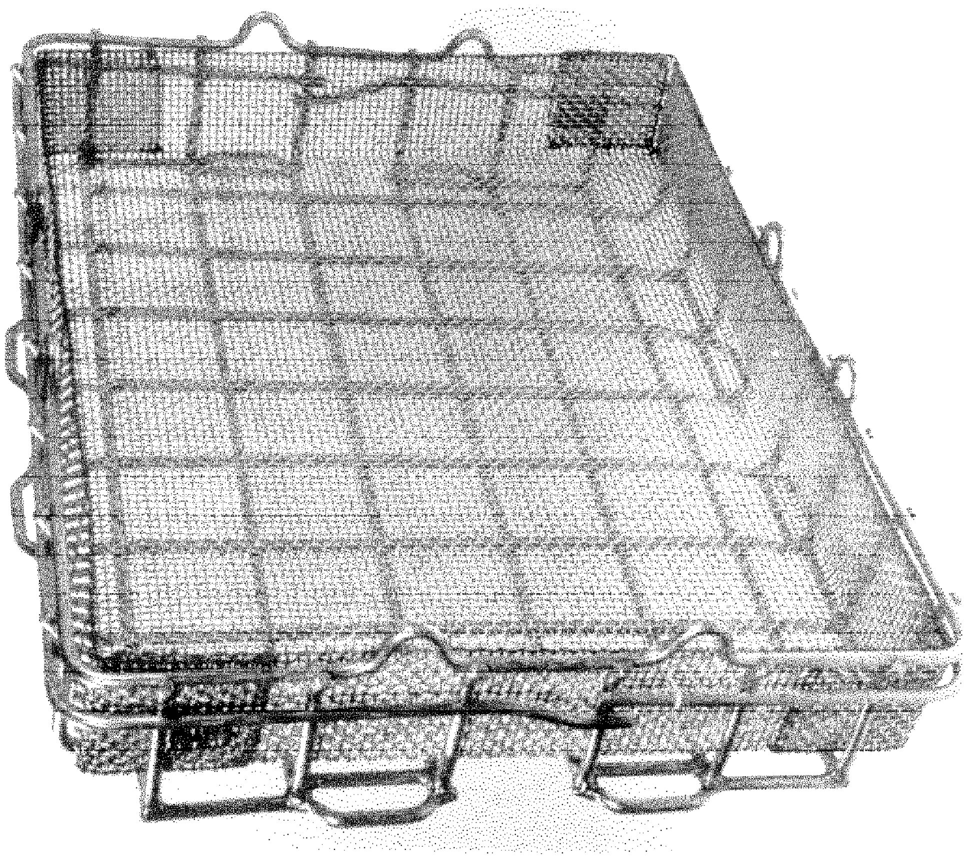
HAYNES® HR-120™ alloy

A solid-solution-strengthened, heat-resistant alloy that provides excellent strength at elevated temperature combined with very good resistance to carburizing and sulfidizing environments.

Contents

H-3125B

TYPICAL APPLICATION



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

PRINCIPAL FEATURES

HAYNES® HR-120™ 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 deg. F (1095 deg. C) 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 carburizing and 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

HEAT-TREATMENT

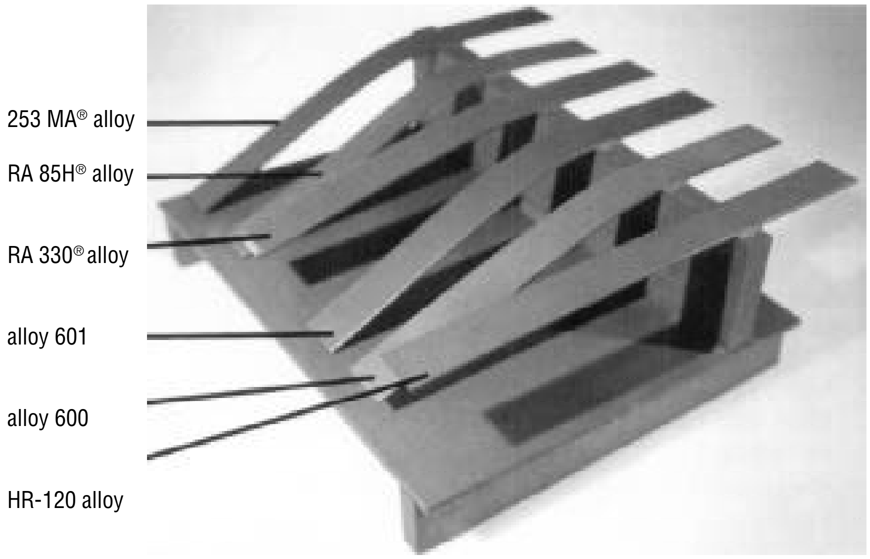
HAYNES HR-120 alloy is furnished in the solution annealed condition, unless otherwise specified. Depending on the product form, the alloy is solution annealed at a temperature ranging from 2150 to 2250 deg. F (1175 to 1230 deg. C) and rapidly cooled.

NOMINAL CHEMICAL COMPOSITION, WEIGHT PERCENT

Fe	Ni	Co	Cr	Mo	W	Cb	Mn	Si	N	Al	C	B
33[a]	37	3*	25	2.5*	2.5*	0.7	0.7	0.6	0.20	0.1	0.05	0.004

*Maximum [a] As balance

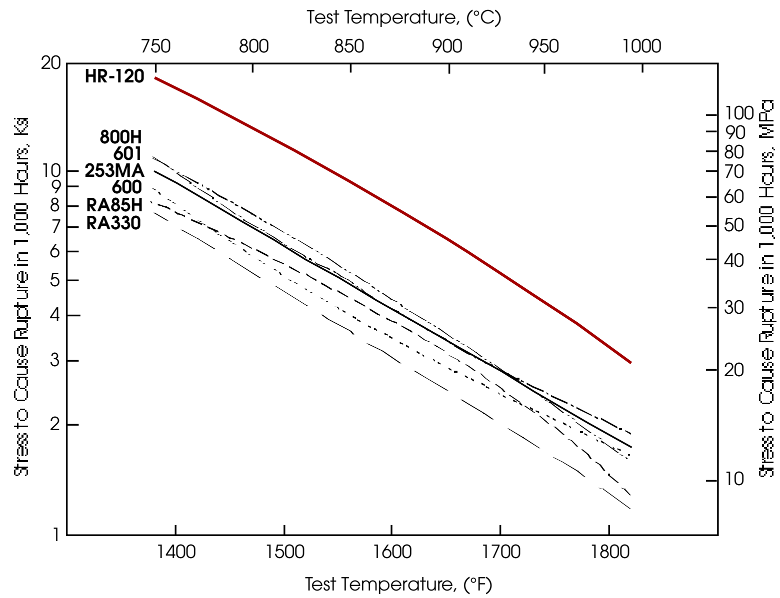
CANTILEVERED BEAM CREEP TEST

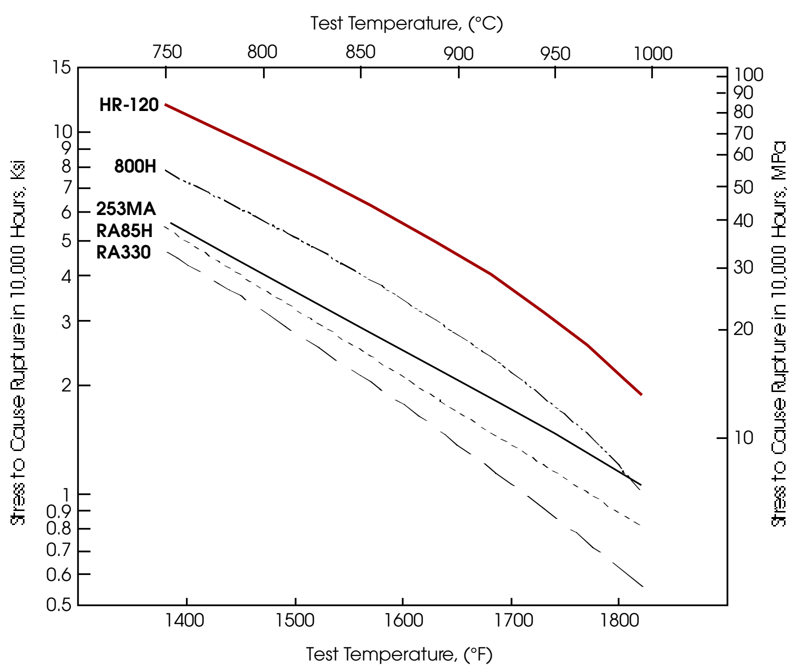


Furnace Temperature: 2000°F (1090°C)
Time in Furnace: 100 Hours
Maximum Bending Stress: 800 psi (5.5 MPa)

Creep deformation is an important contributing factor to the distortion of many high temperature components. The cantilevered beam test provides visual demonstration of creep deformation. The alloys tested were allowed to deform under their own weight in a 2000 deg. F (1095 deg. C) furnace for 100 hours. The maximum bending stresses for the 0.125-inch (3 mm) sheet products were calculated to be 800 psi (5.5 MPa). Only the HR-120 alloy was capable of carrying its own weight!

COMPARATIVE STRESS-RUPTURE STRENGTH





COMPARATIVE STRESS RUPTURE STRENGTH

Material	Approximate Stress Required To Cause Rupture in 10,000 Hours					
	1400°F (760°C)		1600°F (870°C)		1800°F (980°C)	
	Ksi	MPa	Ksi	MPa	Ksi	MPa
HAYNES HR-120 alloy	12.0	83	5.8	40	1.9	13
HASTELLOY® alloy X	10.0	69	3.9	27	1.4	10
RA 333® alloy	9.2	63	3.1	21	1.05	7
800HT® alloy	7.3	50	3.5	24	1.2	8
Alloy 600	6.8	47	2.3	16	1.15	8
253 MA alloy	5.2	36	2.5	17	1.15	8
RA 85H alloy	5.1	35	2.1	14	0.9	6
Type 309 Stainless	4.5	31	1.5	10	0.8	5
INCOLOY® DS	4.4	31	1.9	13	0.9	6
RA 330 alloy	4.3	30	1.7	12	0.63	4
Type 310 Stainless	4.0	28	1.5	10	1.0	7
Type 446 Stainless	1.1	8	0.45	3	0.23	2

COMPARATIVE 1% CREEP STRENGTH

Material	Approximate Stress Required To Cause 1% Creep in 10,000 Hours					
	1400°F (760°C)		1600°F (870°C)		1800°F (980°C)	
	Ksi	MPa	Ksi	MPa	Ksi	MPa
HAYNES HR-120 alloy	10.0	69	5.1	35	1.1	8
HASTELLOY alloy X	7.5	52	3.1	21	1.0	7
RA 333 alloy	5.3	37	2.5	17	0.8	5
800HT alloy	-	-	-	-	-	-
Alloy 600	4.0	28	2.0	14	0.6	4
253 MA alloy	4.2	29	1.8	12	0.5	3
RA 85H alloy	3.8	26	1.7	12	0.8	5
Type 309 Stainless	2.2	15	-	-	-	-
INCOLOY DS alloy	-	-	-	-	-	-
RA 330 alloy	3.6	25	1.9	13	0.17	1
Type 310 Stainless	2.9	15	-	-	-	-
Type 446 Stainless	-	-	-	-	-	-

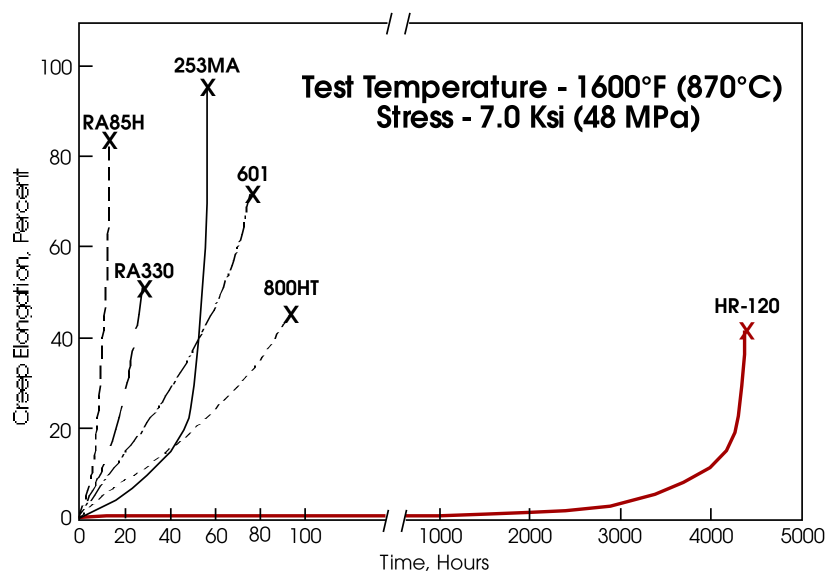
COMPARATIVE STRESS RUPTURE LIFE

The following are stress rupture life predictions, for selected combinations of temperature and stress, based upon standard log-log plot or Larson-Miller parameter extrapolations. All data are for solution-annealed plate or bar except where indicated.

Material	Estimated Stress Rupture Life (Hours) 1400°F/15.0 Ksi (760°C/105 MPa)	1600°F/4.5 Ksi (870°C/31 MPa)	1800°F/2.0 Ksi (980°C/14 MPa)
HAYNES HR-120 alloy	1700	38,500	10,000
HASTELLOY alloy X	900	5,000	2,100
RA 333 alloy	300	1,500	800
800H alloy	130	1,200	920
Alloy 600**	15	280	580
253 MA alloy	140	900	720
RA 85H alloy	30	500	250
Alloy 601	50	1,200	1,000
Type 304 Stainless	10	100	72
RA 330 alloy	30	230	130
Type 310 Stainless*	50	80	50
Type 446 Stainless	<1	<1	<1

*Sheet **Mill Annealed

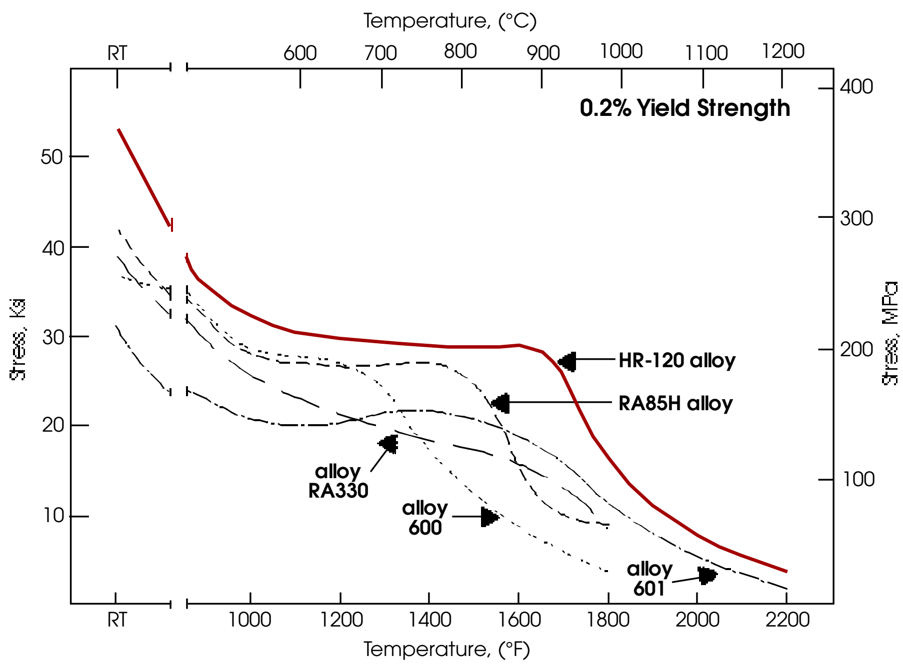
Often the equipment operator is seeking to extend component life at elevated temperature. While comparing stress to cause rupture and stress to cause 1 percent creep for a given amount of hours can demonstrate a relative ranking for materials considered, an alternative perspective can be gained by examining the data presented in the above table. Comparative creep curves for various alloys are displayed below. The difference in life between stronger and weaker alloys when tested at the same temperature and stress can be as much as several orders of magnitude. This difference may sometimes be a consequence of seemingly small differences in the stress to produce failure or a finite level of creep in the same amount of hours, as shown in the previous tables on page 6.



AVERAGE TENSILE DATA, SOLUTION HEAT-TREATED (PLATE)

Test Temperature °F	(°C)	Ultimate Tensile Strength Ksi	MPa	Yield Strength at 0.2% Offset Ksi	MPa	Elongation in 2 in. (50.8 mm) %
ROOM		106.5	735	45.6	375	50
1000	(540)	80.4	555	25.7	175	61
1200	(650)	73.0	505	24.9	170	60
1400	(760)	64.1	440	25.4	175	50
1600	(870)	47.5	325	27.0	185	51
1800	(980)	27.9	190	19.4	135	81
2000	(1095)	15.1	105	9.1	63	89
2200	(1205)	4.9	34	3.9	27	89

COMPARATIVE YIELD STRENGTHS (PLATE)



THERMAL STABILITY

Average Room-Temperature Tensile Data
1,000 Hour Thermal Exposures

Condition	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	Yield Strength at 0.2% Offset Ksi	Yield Strength at 0.2% Offset MPa	% Elongation*
Solution Heat-treated	106	735	46	375	50
Aged at 1200°F/1000 hrs	110	760	51	350	35
Aged at 1400°F/1000 hrs	105	725	49	340	24
Aged at 1600°F/1000 hrs	104	715	47	325	21
Aged at 1800°F/1000 hrs	105	725	44	305	50

*Elongation in 1.4 inches

ENVIRONMENTAL RESISTANCE

HAYNES HR-120 alloy exhibits good resistance to oxidizing environments and can be used at temperatures up to 2000 deg. F (1205 deg. C). The following are comparative static oxidation test results at 1800 deg. F (1095 deg. C) and 2000 deg. F (1205 deg. C) for 1008 hours.

	1800°F (980°C)				2000°F (1090°C)			
	Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
Material	mils	mm	mils	mm	mils	mm	mils	mm
Alloy 600	0.3	0.008	0.09	0.023	1.1	0.028	1.6	0.041
601 alloy	0.5	0.013	1.3	0.033	1.2	0.030	2.6	0.066
RA 330 alloy	0.4	0.010	4.3	0.109	0.8	0.020	6.7	0.170
Alloy 800H	0.9	0.023	1.8	0.046	5.4	0.140	7.4	0.190
HR-120 alloy	0.3	0.008	3.7	0.094	1.2	0.030	7.7	0.190
253 MA alloy	1.3	0.033	2.9	0.074	0.7	0.018	8.2	0.210
RA 85H alloy	0.5	0.013	8.2	0.210	2.9	0.074	25.9	0.660

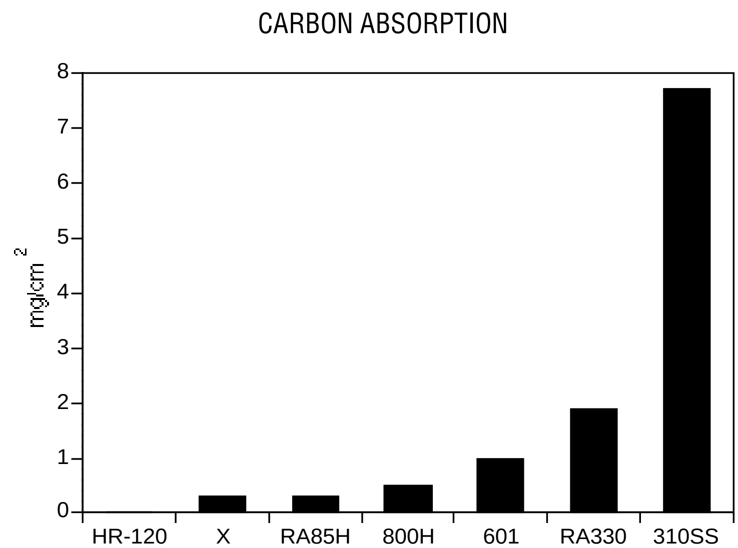
Metal Affected = Metal Loss + Internal Attack

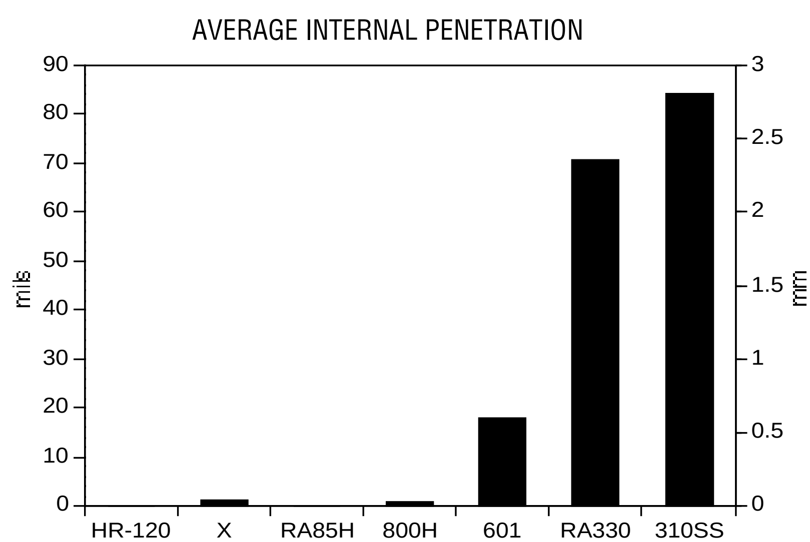
Flowing air at a velocity of 7.0 feet/minute
(2 meters/minute) past the samples.

CARBURIZATION RESISTANCE

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

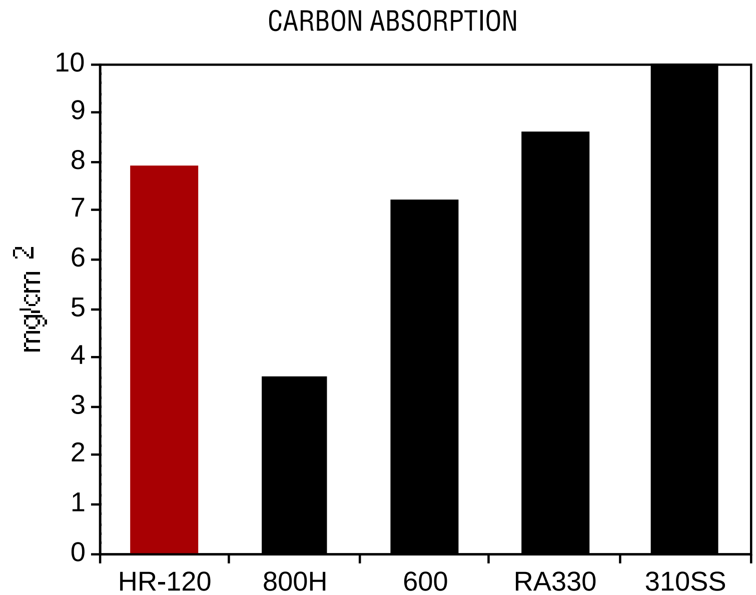
Carburization Resistance of Various Alloys at 1800°F (982°C) for 500 Hours in Graphite

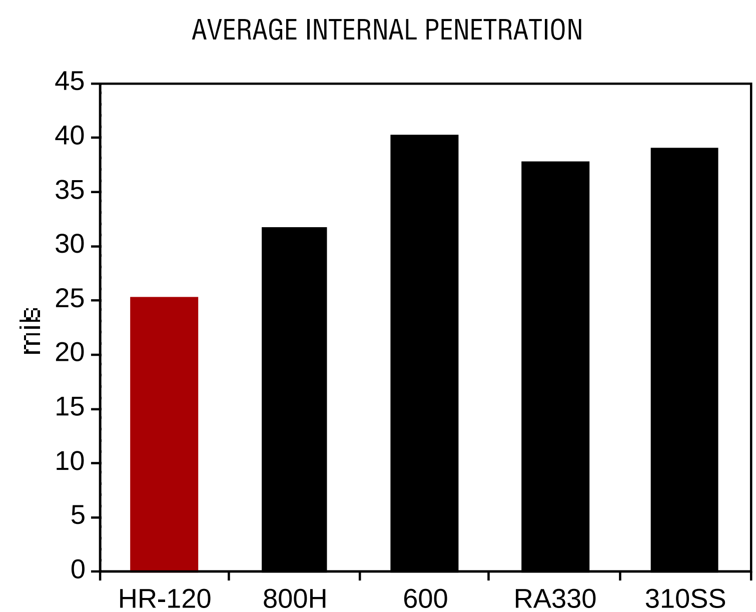




CARBURIZATION RESISTANCE (continued)

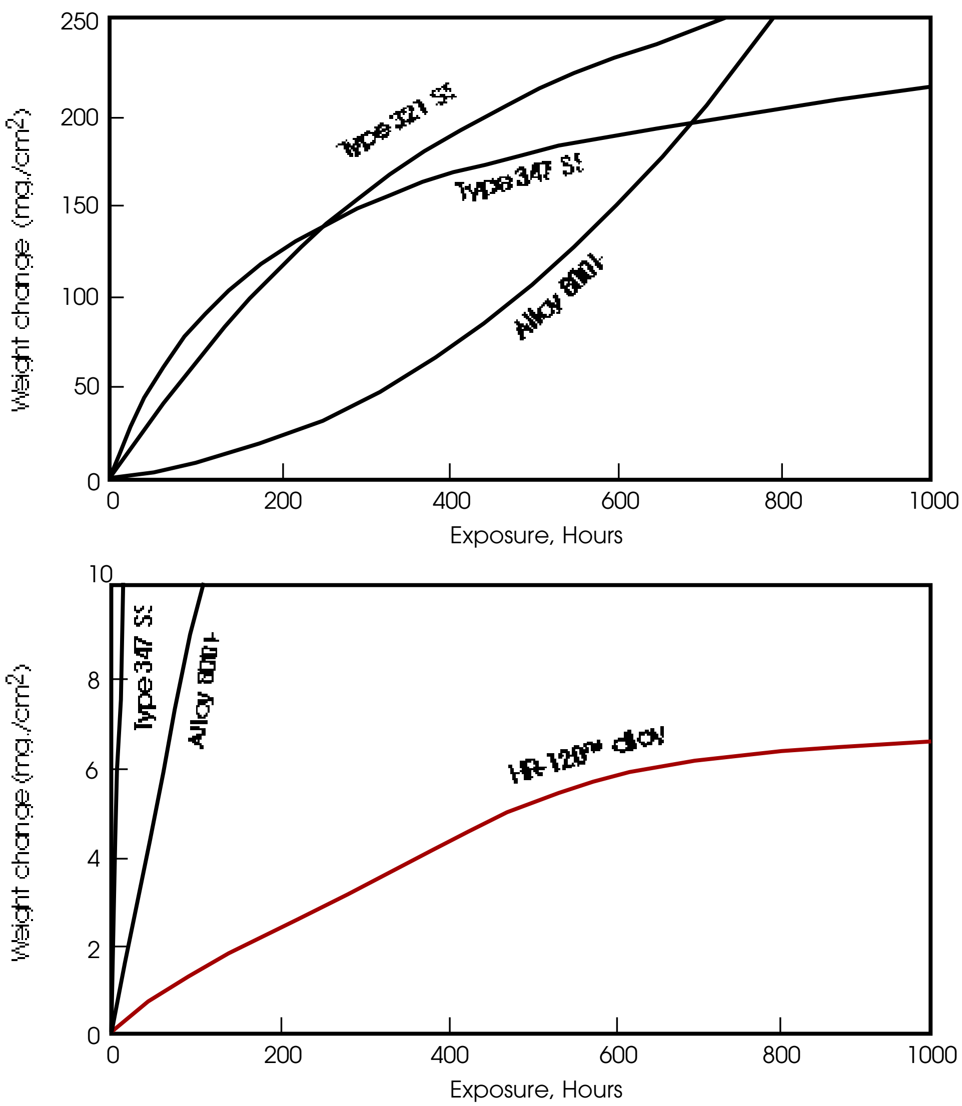
Carburization Resistance of Various Alloys at 1800°F (982°C) for 55 Hours in Ar-5%H_2-1%CH_4





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 deg. F (700 deg. 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.

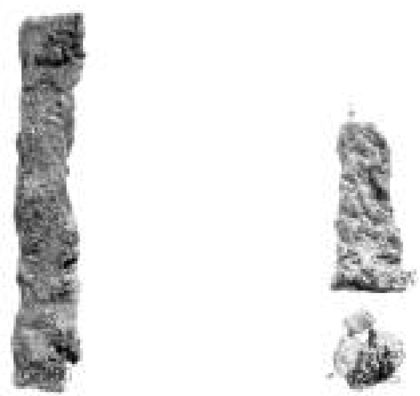


H_2+7%CO+1.5%H_2O+0.6%H_2S at 1290°F (700°C)
$Po_2=1x10^{-23}$ atm.
$Ps_2=1x10^{-9}$ atm.
$a_c=0.3-0.4$

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 deg. F (900 deg. C) for 500 hours with a two-minute cooling cycle to less than 400 deg. F (205 deg. 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, RA 330, 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.

HR-120 | 800H | RA 330



RA 85H | 253MA

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

TYPICAL PHYSICAL PROPERTIES

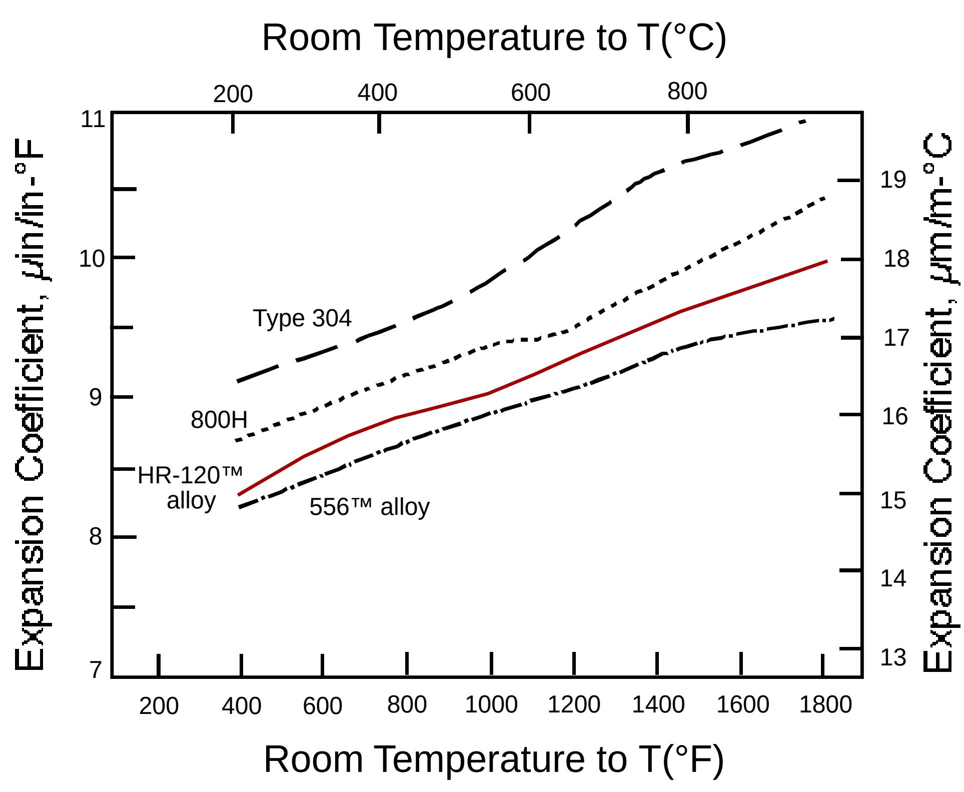
	Temp., °F	British Units	Temp., °C	Metric Units
Density	Room	0.291 lb/in.^{3}	Room	8.07 g/cm.^{3}
Melting Temperature	2375		1300	
Electrical Resistivity	Room	41.4 microhm-in.	Room	105.2 microhm-cm
	200	42.4 microhm-in.	100	107.8 microhm-cm
	400	44.4 microhm-in.	200	112.5 microhm-cm
	600	45.4 microhm-in.	300	114.9 microhm-cm
	800	46.3 microhm-in.	400	116.7 microhm-cm
	1000	47.3 microhm-in.	500	119.3 microhm-cm
	1200	48.2 microhm-in.	600	121.4 microhm-cm
	1400	48.8 microhm-in.	700	123.1 microhm-cm
	1600	49.4 microhm-in.	800	124.5 microhm-cm
	1800	50.0 microhm-in.	900	125.7 microhm-cm
	2000	50.3 microhm-in.	1000	126.6 microhm-cm
	2200	50.7 microhm-in.	1100	127.8 microhm-cm
			1200	128.7 microhm-cm
Thermal Diffusivity	Room	4.7 x 10^{-3} in.^{2}/sec.	Room	30.4 x 10^{-3} cm^2/sec.
	200	5.0 x 10^{-3} in.^{2}/sec.	100	32.4 x 10^{-3} cm^2/sec.
	400	5.4 x 10^{-3} in.^{2}/sec.	200	34.8 x 10^{-3} cm^2/sec.
	600	5.8 x 10^{-3} in.^{2}/sec.	300	37.2 x 10^{-3} cm^2/sec.
	800	6.3 x 10^{-3} in.^{2}/sec.	400	39.7 x 10^{-3} cm^2/sec.
	1000	6.7 x 10^{-3} in.^{2}/sec.	500	42.2 x 10^{-3} cm^2/sec.
	1200	7.1 x 10^{-3} in.^{2}/sec.	600	44.7 x 10^{-3} cm^2/sec.
	1400	7.4 x 10^{-3} in.^{2}/sec.	700	46.9 x 10^{-3} cm^2/sec.
	1600	7.5 x 10^{-3} in.^{2}/sec.	800	48.1 x 10^{-3} cm^2/sec.
	1800	7.8 x 10^{-3} in.^{2}/sec.	900	48.8 x 10^{-3} cm^2/sec.
	2000	8.2 x 10^{-3} in.^{2}/sec.	1000	50.7 x 10^{-3} cm^2/sec.
	2200	8.6 x 10^{-3} in.^{2}/sec.	1100	52.9 x 10^{-3} cm^2/sec.
			1200	55.5 x 10^{-3} cm^2/sec.
Thermal Conductivity	Room	78 Btu-in./ft.^{2} hr.-°F	Room	11.4 W/m-k
	200	84 Btu-in./ft.^{2} hr.-°F	100	12.7 W/m-k
	400	96 Btu-in./ft.^{2} hr.-°F	200	14.1 W/m-k
	600	108 Btu-in./ft.^{2} hr.-°F	300	15.4 W/m-k
	800	121 Btu-in./ft.^{2} hr.-°F	400	17.1 W/m-k
	1000	134 Btu-in./ft.^{2} hr.-°F	500	18.7 W/m-k
	1200	150 Btu-in./ft.^{2} hr.-°F	600	21.0 W/m-k
	1400	168 Btu-in./ft.^{2} hr.-°F	700	23.3 W/m-k
	1600	180 Btu-in./ft.^{2} hr.-°F	800	24.9 W/m-k
	1800	191 Btu-in./ft.^{2} hr.-°F	900	26.2 W/m-k
	2000	205 Btu-in./ft.^{2} hr.-°F	1000	28.0 W/m-k
	2200	216 Btu-in./ft.^{2} hr.-°F	1100	29.6 W/m-k

PHYSICAL PROPERTIES (continued)

	Temp., °F	British Units	Temp., °C	Metric Units
Specific Heat	Room	0.112 Btu/lb.-°F	Room	467 J/Kg-K
	200	0.116 Btu/lb.-°F	100	483 J/Kg-K
	400	0.121 Btu/lb.-°F	200	500 J/Kg-K
	600	0.125 Btu/lb.-°F	300	522 J/Kg-K
	800	0.130 Btu/lb.-°F	400	531 J/Kg-K
	1000	0.135 Btu/lb.-°F	500	558 J/Kg-K
	1200	0.144 Btu/lb.-°F	600	607 J/Kg-K
	1400	0.152 Btu/lb.-°F	700	647 J/Kg-K
	1600	0.159 Btu/lb.-°F	800	655 J/Kg-K
	1800	0.164 Btu/lb.-°F	900	660 J/Kg-K
	2000	0.167 Btu/lb.-°F	1000	663 J/Kg-K
	2200	0.169 Btu/lb.-°F	1100	667 J/Kg-K
			1200	671 J/Kg-K
Dynamic Modulus of Elasticity	Room	28.6 10^6 psi	Room	197 GPa
	200	28.2 10^6 psi	100	194 GPa
	400	27.2 10^6 psi	200	188 GPa
	600	26.3 10^6 psi	300	182 GPa
	800	24.9 10^6 psi	400	174 GPa
	1000	23.6 10^6 psi	500	165 GPa
	1200	22.5 10^6 psi	600	159 GPa
	1400	21.3 10^6 psi	700	152 GPa
	1600	20.0 10^6 psi	800	143 GPa
	1800	18.8 10^6 psi	900	136 GPa
			1000	128 GPa

MEAN COEFFICIENT OF THERMAL EXPANSION

	Temp., °F	British Units	Temp., °C	Metric Units
Mean Coefficient of Thermal Expansion	78-200	7.95 microinches/in.-°F	25-100	14.3 m/m-°C
	78-400	8.29 microinches/in.-°F	25-200	14.9 m/m-°C
	78-600	8.56 microinches/in.-°F	25-300	15.3 m/m-°C
	78-800	8.80 microinches/in.-°F	25-400	15.8 m/m-°C
	78-1000	8.98 microinches/in.-°F	25-500	16.1 m/m-°C
	78-1200	9.24 microinches/in.-°F	25-600	16.4 m/m-°C
	78-1400	9.52 microinches/in.-°F	25-700	16.9 m/m-°C
	78-1600	9.72 microinches/in.-°F	25-800	17.3 m/m-°C
	78-1800	9.87 microinches/in.-°F	25-900	17.6 m/m-°C
			25-1000	17.8 m/m-°C



WELDING

HAYNES HR-120 alloy is readily weldable by Gas Tungsten Arc (TIG), Gas Metal Arc (MIG), and Shielded Metal Arc (SMAW) welding processes. Many of the alloy's welding characteristics are similar to those for the HASTELLOY alloys and the same precautions apply. Submerged Arc Welding is not recommended as this process is characterized by high heat input which could result in distortion and hot cracking. Any start/stop cracking should be removed by grinding prior to further welding. Do not attempt to remelt or "wash-out" welding cracks.

Base Metal Preparation

The joint surface and adjacent area should be thoroughly cleaned before welding. All grease, oil, crayon marks, sulfur compounds and other foreign matter should be removed. It is preferable, but not mandatory that the alloy be in the solution-annealed condition when welded.

Filler Metal Selection

HAYNES 556 filler metal and MULTIMET® 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.

Preheating, Interpass Temperatures and Post-Weld Heat Treatment

Preheat should not be used so long as the base metal to be welded is above 32 deg. F (0 deg. C). Interpass temperatures should be less than 200 deg. F (95 deg. 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 normally required for HR-120 alloy.

Nominal Welding Parameters

Nominal welding parameters are provided as a guide for performing typical operations. These are based on welding conditions used in our laboratory and should be considered only as a guideline.

SHIELDED METAL ARC WELDING

Electrode Diameter, in. (mm)	Arc Voltage, volts	Welding Current, amps
3/32 (2.4)	22-24	55-75
1/8 (3.2)	22-24	80-100
5/32 (4.0)	22-25	125-150
3/16 (4.8)	24-26	150-180

GAS TUNGSTEN ARC WELDING

Joint Thickness, in. (mm)		Tungsten Electrode* Diameter, in. (mm)		Filler Wire Diameter, in.	Welding Current, amps	Arc Voltage, volts
1/32-1/16	(0.8-1.6)	1/16	(1.6)	1/16	15-60	9-12
16/-1/8	(1.6-3.2)	1/16 or 3/32	(1.6 or 2.4)	1/16 or 3/32	50-95	9-12
1/8-1/4	(3.2-6.4)	3/32 or 1/8	(2.4 or 3.2)	3/32 or 1/8	75-130	10-13
>1/4	(6.4)	3/32 or 1/8	(2.4 or 3.2)	3/32 or 1/8	95-150	10-13

*2% Thoriated tungsten
Shielding gas 100% Argon, flow rate~25 ft^3/hr (12 L/min)

GAS METAL ARC WELDING

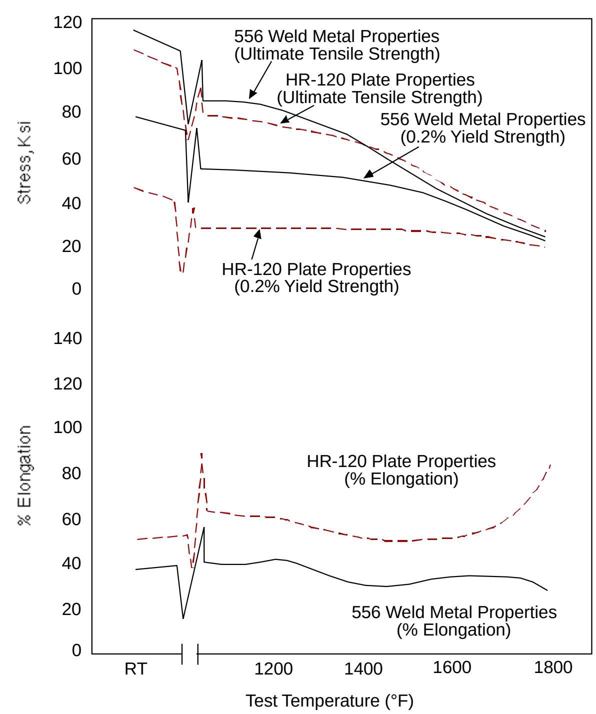
	Wire Diameter, in. (mm)	Shielding* Gas	Welding Current, amps	Arc Voltage, volts	Travel Speed in. (mm)/min
Short Circuiting Transfer	0.035 (0.9)	75%Ar-25%He	70-90	18-20	8-10 (200-250)
	0.045 (1.1)	75%Ar-25%He	100-150	19-22	8-10 (200-250)

*Flow Rate~35 cu. ft./hr. (16 L/min)
POLARITY: SMAW and GMAW-DCRP-Electrode Positive
GTAW DCSP-Electrode Negative

TENSILE PROPERTIES OF 556 WELD METAL (GMAW)

Test Temperature		Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Elongation in 2 in. (50.8mm)
°F	°C	Ksi	MPa	Ksi	MPa	%
Room	Room	115.4	795	77.2	530	37
1200	650	81.0	560	53.3	380	39
1400	760	66.3	455	49.5	340	26
1600	870	40.2	270	36.8	255	34
1800	980	24.0	165	23.6	165	30

TENSILE PROPERTIES OF 556 WELD METAL (GMAW) VS. HR-120 PLATE



WELDING (continued)

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	2T Radius Guided Bend Test 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 Ksi	Tensile Strength MPa	Fracture Location
GTAW	556 Filler Metal	111.0	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

HEALTH AND SAFETY

Nickel-, cobalt-, and iron-base alloys 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 in any particular product, refer to the Material Safety Data Sheets (MSDS) available from Haynes.

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 or nasal and mucus membrane irritation. Exposure to dust or fumes, which may be generated by working 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 Z49.1-88, “Safety In Welding and Cutting”. Attention is especially called to Sections 4 (Protection of Personnel) and 5 (Ventilation) of ANSI Z49.1. Mechanical ventilation is advisable and, under certain conditions such as a very confined space, is necessary during welding or cutting operations to reduce exposure to hazardous fumes, gases, or dust.

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.

DETAILED MACHINING INFORMATION

Listed below are specific comments that deal with various machining operations.

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"	250 RPM (max)	0.002 inch/rev.
1/4"	250 RPM (max)	0.003 inch/rev.
1/2"	250 RPM	0.005 inch/rev.
1"	150 RPM	0.011 inch/rev.
1-1/2"	100 RPM	0.013 inch/rev.
2"	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.

TAPPING

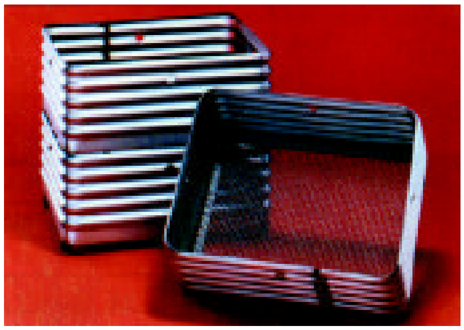
HAYNES HR-120 alloy is tapped using the same tooling and conditions as used with type 316 stainless steel. High speed steel taps work well. Cutting speed can be up to 20 sfpm for taps above 1/2 inch diameter. For small diameter taps (less than 1/2 inch diameter) cutting speeds should be reduced substantially.

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 ON HEAT-RESISTANT ALLOYS

Physical Property*		HAYNES® HR-120™ alloy	HAYNES 214™ alloy	HAYNES 230™ alloy	HAYNES 556™ alloy	HASTELLOY® X alloy	Alloy 600	Alloy 601	RA330® alloy	253MA® alloy	Alloy 800H	Type 304 Stainless	Type 310 Stainless	Type 316 Stainless
Density, lb./in. ^{3}		.291	.291	.319	.297	.297	.304	.291	.289	.282	.287	.287	.285	.287
Incipient Melting Point	°F	2375	2475	2375	2425	2300	2470	2375	2450	2500	2475	2550	2550	2500
Electrical Resistivity µ ohm-in.	70°F	41.4	53.5	49.2	37.5	45.2	40.6	46.9	39.9	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	43.0	40.6	43.0	34.6	41.7	34.5
	800°F	46.3	54.3	50.7	43.5	48.4	43.0	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	47.3	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/ft. ^{2}-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	-	(230)	203	-	-	-	-	-	-
Mean Coefficient of Thermal Expansion, µ in./in.-°F (RT to Temp.)	400°F	7.9	7.4	7.2	8.2	7.9	7.7	8.0	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	9.0	8.6	8.6	8.9	9.6	10.1	9.6	10.2	9.7	10.3
	1400°F	9.5	9.0	8.3	9.2	8.8	8.9	9.2	9.7	10.3	9.9	10.7	10.0	10.4
	1600°F	9.7	9.6	8.6	9.4	9.0	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	10.0	10.8	(10.5)	11.0	10.7	10.7
	2000°F	-	11.1	(9.2)	9.6	(9.4)	(9.5)	10.2	(10.2)	(11.1)	-	11.4	11.0	-
Modulus of Elasticity psi x 10 ^{6}	70°F	28.6	31.6	30.6	29.7	29.8	31.1	30.0	28.5	29.0	28.4	27.9	29.0	28.5
	400°F	27.2	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	24.9	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	21.3	23.9	24.1	21.8	23.3	24.3	22.5	21.0	20.2	21.1	19.4	20.5	20.0
	1600°F	20.0	22.3	23.1	20.9	22.2	22.8	20.5	19.5	-	20.0	-	19.2	-
	1800°F	18.8	20.2	21.9	20.1	20.4	21.0	18.4	18.0	17.6	18.7	-	-	-
	2000°F	-	19.0	-	-	-	-	16.2	-	-	17.2	-	-	-

( ) Estimated
*Manufacturer's laboratory or published data.

Mechanical Property*		HAYNES® HR-120™ alloy	HAYNES 214™ alloy	HAYNES 230™ alloy	HAYNES 556™ alloy	HASTELLOY® X alloy	Alloy 600	Alloy 601	RA330® alloy	253MA® alloy	Alloy 800H	Type 304 Stainless	Type 310 Stainless	Type 316 Stainless
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	106.5	138.9	125.4	116.4	107.5	96.0	102.0	85.0	104.0	82.0	85.0	82.7	103.9
	1200°F	73.0	114.9	977	83.1	78.5	65.0	74.0	55.7	64.6	59.0	43.0	54.0	60.5
	1400°F	64.1	97.4	87.7	68.5	66.6	38.0	43.0	34.0	49.8	39.0	27.6	35.1	39.0
	1600°F	47.5	66.4	63.1	49.3	49.6	20.0	22.0	18.7	30.8	21.0	17.5	19.1	24.6
	1800°F	27.9	16.7	35.2	30.7	31.1	11.0	13.0	10.7	-	11.0	**7.4	10.5	14.0
	2000°F	15.1	9.0	19.5	16.1	16.5	(5.1)	6.5	-	-	5.0	-	4.3	7.1
	2200°F	4.9	5.0	9.4	-	-	-	**5.2	-	-	-	-	-	-
0.2% Yield Strength, Ksi	70°F	45.6	82.2	57.4	54.6	49.4	41.0	35.0	42.0	50.8	35.0	27.9	35.1	36.7
	1200°F	24.9	75.9	39.5	30.6	30.3	30.0	25.4	21.5	24.1	16.9	11.0	20.7	20.5
	1400°F	25.4	73.6	42.5	29.3	31.0	26.0	26.8	18.8	22.4	18.5	10.5	19.3	17.9
	1600°F	27.0	50.4	37.3	27.9	28.4	11.0	19.2	15.9	18.1	18.5	7.4	12.2	10.6
	1800°F	19.4	8.4	21.1	18.5	17.9	6.0	10.9	9.0	-	8.1	-	6.4	-
	2000°F	9.1	4.2	10.8	8.7	9.1	(3.1)	5.1	-	-	3.3	-	3.1	-
	2200°F	3.9	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	60	33	55	57	64	49	46	51	44	38	37	21	40
	1400°F	50	23	53	53	58	70	72	65	44	43	31	19	49
	1600°F	51	34	65	69	75	80	90	69	-	87	35	28	59
	1800°F	81	86	83	84	95	115	100	74	-	100	**38	24	41
	2000°F	89	89	83	95	98	(120)	120	-	-	108	-	-	85
	2200°F	89	92	109	-	-	-	121	-	-	-	-	-	-
Stress to Rupture in 1,000 Hours, Ksi	1200°F	38.0	-	42.5	38.0	34.0	20.0	28.0	-	23.0	23.8	14.1	17.0	20.5
	1400°F	17.0	25.0	20.0	17.5	15.0	8.1	9.8	7.0	9.2	9.8	7.4	7.4	8.8
	1600°F	8.0	8.9	9.5	7.5	6.0	3.5	4.4	3.1	4.4	4.8	3.0	3.3	3.4
	1800°F	3.5	1.8	3.0	3.0	2.4	1.8	2.2	1.3	1.9	1.9	1.2	1.4	1.3
	2000°F	.8	.9	**1.0	-	**0.8	(0.9)	1.0	0.7	1.0	-	-	-	-

( ) Estimated
*Manufacturer's laboratory or published data.
**Limited data.
RA330 is a registered trademark of Rolled Alloys, Inc.
253MA is a registered trademark of Avesta Jernverks Aktiebolag.

COMPARATIVE COST OF HEAT-RESISTANT ALLOYS*

The initial premium for higher cost alloy construction is often recovered via improved equipment performance, minimizing repair replacement and down-time and increasing throughput rates and cycle times. Comparative costs of a wide range of heat-resistant alloys are presented below. These tabulations represent average composits of 1991/1992 pricing information supplied by prominent alloy suppliers in the United States...[1]

Alloys	Relative Cost
304 SS	1.00 (Basis)
309 SS	1.6
446 SS	1.7
310 SS	2.0
253MA, RA85H	2.3
800H, 330	2.6-3.0
HR-120	3.5
600, 601	3.8-4.3
333	5.1
X	4.8-5.6
556	8.5
HR-160®	12

*1991-1992 prices/lb., 1/4-in. plate.

[1] "Alloy Selection for Waste Incineration Facilities", G. Sorell, 1992 Incineration Conference.

AVAILABILITY (HAYNES HR-120 alloy)

Sheet	Plate	Round Bar*
inch	inch	inch
0.125 (11 Gauge)	3/16	1/4
	1/4	3/8
	5/16	1/2
	3/8	5/8
	1/2	3/4
		1

*annealed and pickled

Weld Consumable	Alloy	Available Sizes, in.*
Cut Lengths	556	0.035, 0.045, 0.062, 0.094, 0.125
Layer-Wound Coils	556	0.035, 0.045, 0.062
Structural Wire	HR-120	0.045, 0.062, 0.080, 0.120, 0.135, 0.187

* Not all sizes shown are stocked
(Other sizes can be produced as required by the customer.)

TRADEMARKS

STANDARD PRODUCTS

HAYNES International

By Brand or Alloy Designation:

HASTELLOY® Family of Corrosion-Resistant Alloys

B-2, B-3™, C-4, C-22™, C-276, D-205™, G-3, G-30®, G-50™, H-9M™ and N

HASTELLOY Family of Heat-Resistant Alloys

S, W, and X

HAYNES® Family of Heat-Resistant Alloys

25, 31, R-41, 75, HR-120™, 150, 188, 214™, 230™, 230-W™, 242™, 263, 625, 718, X-750, MULTIMET® and WASPALOY

HAYNES Family of High-Temperature-Corrosion-Resistant Alloys

HR-160® and 556™

Corrosion-Wear Resistant Alloy

ULTIMET™

Wear-Resistant Alloy

6B

Super Stainless Steel

FERRALIUM® 255

HAYNES Titanium Alloy Tubular

Ti-3Al-2.5V

Standard Forms:

Bar, Billet, Remelt Materials, Plate, Sheet, Strip, Coils, Seamless or Welded Pipe & Tubing, Welding Wire and Coated Electrodes

Properties Data:

The data and information in this publication are based on work conducted principally by Haynes International, Inc. and occasionally supplemented by information from the open literature, and are believed to be reliable. However, we do not make any warranty or assume any legal liability or responsibility for its accuracy, completeness or usefulness, nor do we represent that its use would not infringe upon private rights. Any suggestions as to uses and applications for specific alloys are opinions only and Haynes International, Inc. makes no warranty of results to be obtained in any particular situation. For specific concentrations of elements present in a particular product and a discussion of the potential health effects thereof, refer to the Material Safety Data Sheet supplied by Haynes International, Inc.

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