RA330® Data Sheet

Since 1953, RA330® has been the workhorse of the thermal processing industry. Good strength, carburization resistance and oxidation resistance up to 2100°F makes RA330 the alloy of choice for demanding high temperature applications in the past, present and future.




The Global Leader in Specialty Metals

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RA330® is the workhorse of the heat resistant alloys. It has good strength, carburization and oxidation resistance to 2100°F. These properties are enhanced by a nominal 1.25% silicon addition. RA330 has been designed to withstand the thermal shock of liquid quenching. It finds wide application in high temperature industrial environments where good resistance to the combined effects of carburization and thermal cycling is a prime requisite. RA330 remains fully austenitic at all temperatures and is not subject to embrittlement from sigma phase formation.

RA330 is worked by forming and machining procedures similar to those used with the austenitic stainless steels or nickel-chromium alloys. Forming at room temperature is suggested whenever possible. Heat treatment is not necessary after most forming or welding operations. When required, the suggested full anneal is 1900-2050°F, followed by a rapid air cool or water quench. RA330 may be readily welded using RA330-04 weld fillers. Do not use AWS ER330. Keep interpass temperatures low, do not preheat, do use reinforced stringer beads. Machinability rating 20-25% of AISI B1112.

Specifications

UNS: N08330 **W. Nr./EN:** 1.4886, 10095 **AMS:** 5592, 5716 **ASTM:** B 536, B 511, B 512, B 535, B 546, B 710, B 739
ASME: SB-536, SB-511, SB-535, SB-710

Chemical Composition, %

	Cr	Ni	Mn	Si	Cu	P	S	C	Fe
MIN	18.0	34.0	–	1.0	–	–	–	0.04	–
MAX	20.0	37.0	2.0	1.5	1.0	0.03	0.03	0.08	balance

Features

- Oxidation resistant to 2100°F
- Resistant to carburization and nitriding
- Resistant to thermal shock
- Good strength at elevated temperature
- Metallurgical stability
- Chloride ion stress corrosion cracking resistance

Applications

- Muffles, retorts
- Bar frame heat treating baskets
- Quenching fixtures
- Radiant tubes
- Heat exchangers
- Salt pots, both neutral and cyanide
- Furnace fans and shafts
- Conveyors
- Hot pressing platens
- Tube hangers for crude oil heaters and steam boilers
- Furnace containers for carburizing, carbonitriding, annealing, and malleablizing

Physical Properties

Density: 0.287 lb/in³ **Melting Range:** 2450 - 2540°F **Permeability, Annealed:** μ= 1.009 at H=2810 oersted

Specific Heat
Physical Properties

Temperature, °F	100	300	500	700	900	1100	1300	1500	1700	1900	2000
Btu/lb °F	0.117	0.119	0.122	0.124	0.126	0.129	0.131	0.134	0.136	0.139	0.140

Thermal Conductivity [6]
Physical Properties

Temperature, °F	75	1000	1200	1400	1500	1600	1800	2000
Btu-ft/ft² • hr • °F	7.2	12.8	13.2	13.7	14.0	14.2	14.7	15.1

Electrical Resisivity [7,8]
Physical Properties

Temperature, °F	75	1000	1200	1400	1600	1800	2000
ohm • circ mil/ft	616	665	680	720	745	765	830

Mean Coefficient of Thermal Expansion
Physical Properties

Temperature, °F	200	300	400	500	600	700	1000	1100	1250	1500	1600	1700	1800
in/in°F x 10^{-6}	8.3	8.4	8.6	8.7	8.9	9.0	9.3	9.4	9.6	9.7	9.8	9.9	10.0

Typical Properties, Mill Annealed
Mechanical Properties

Temperature, °F	70
Ultimate Tensile Strength, ksi	85.0
0.2% Yield Strength, ksi	39.0
Elongation, %	47
Reduction of Area, %	65
Hardness, Rockwell B	70 - 85
ASTM Grain Size	4 - 7
Erichsen Cup Depth, 0.025 in sheet	10
Poisson's Ratio	0.297

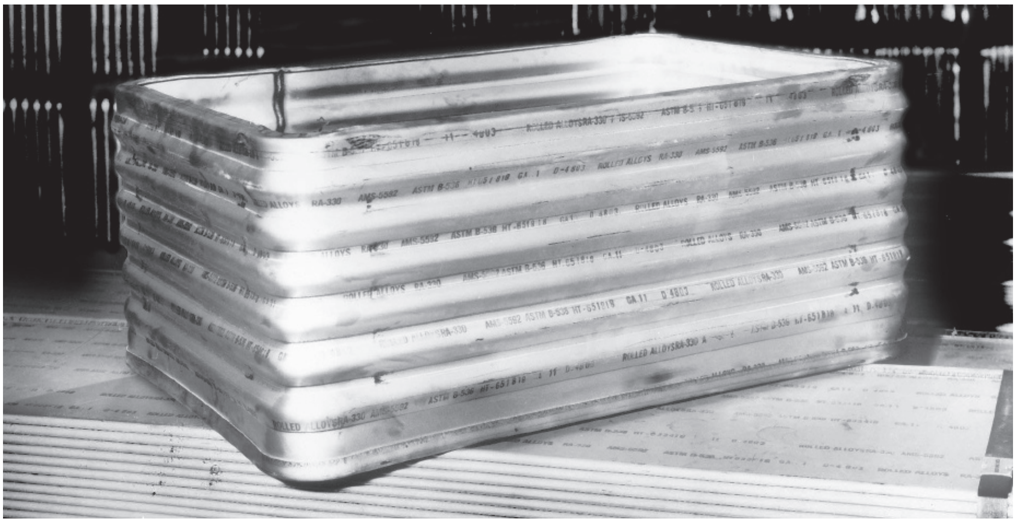
Short Time Elevated Temperature Tensile Properties
Mechanical Properties

Average of Multiple Tests, Mill Annealed Sheet, Plate and Bar

Temperature, °F	200	300	400	500	600	700	1000	1100	1200	1500	1600	1800	2000
Ultimate Tensile Strength, ksi	79.2	76.2	75.3	74.3	74.4	75.1	71.0	66.4	56.7	26.8	21.1	10.4	3.2
0.2% Yield Strength, ksi	35.6	33.1	31.6	29.8	29.6	29.2	25.0	24.2	22.0	17.3	15.4	8.5	2.0
Elongation, %	46	46	43	43	45	47	46	46	43	56	79	79	28
Reduction of Area, %	62	60	59	58	56	55	52	54	54	76	76	60	27

Effect of Elevated Temperature Exposure, Mill Annealed Bar[10]
Mechanical Properties

Temperature, °F	75	75	75	1400	1400
Aging Temperature, °F	–	1400	1400	–	1400
Aging Time, hours	–	100	1000	–	1000
Ultimate Strength, ksi	85.0	88.2	88.5	35.0	–
0.2% Offset Yield Strength, ksi	34.9	34.3	32.6	18.8	–
Elongation, %	47.5	40.5	40.5	65.0	–
Reduction of Area, %	70.0	60.5	60.5	59.0	–
Hardness, Rockwell B	76.5	79.0	83.0	–	–
Charpy V-notch Impact Energy, ft-lb	240	–	96	167	130



Maximum Allowable Design Stresses
Mechanical Properties

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Plate only

Temperature, °F	100	200	300	400	500	600	700	750	800	850	900	950	1000
Stress, ksi	20.0	20.0	19.6	19.4	18.9	18.5	18.1	17.7	17.4	17.0	16.7	16.1	12.7

Temperature, °F	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650
Stress, ksi	10.0	7.8	6.0	4.7	3.8	3.1	2.4	1.8	1.5	1.1	0.9	0.68	0.48

Design stress intensity values, ksi, in tension. U.S. Customary units govern. NOTES: G5, G29, H1, T12

Weldment Tensile Properties
Mechanical Properties

Temperature, °F	1100	1100	1200	1200
Specimen	Weldment	½" Plate	Weldment	½" Plate
Ultimate Tensile Strength, ksi	69.2	69.1	61.4	58.9
0.2% Offset Yield Strength, ksi	28.1	23.5	34.4	22.4
Elongation in 4D, %	34.1	43.7	35.7	49.0
Reduction of Area, %	51.5	52.5	47.9	54.2

Dynamic Modulus of Elasticity
Mechanical Properties

Temperature, °F	75	200	400	600	800	1000	1200	1400	1600	1800
Dynamic Modulus of Elasticity, psi x 10^6	28.5	28.0	27.0	26.0	25.0	23.8	22.3	21.0	19.5	18.0

Cryogenic Tensile Properties, Mill Annealed
Mechanical Properties

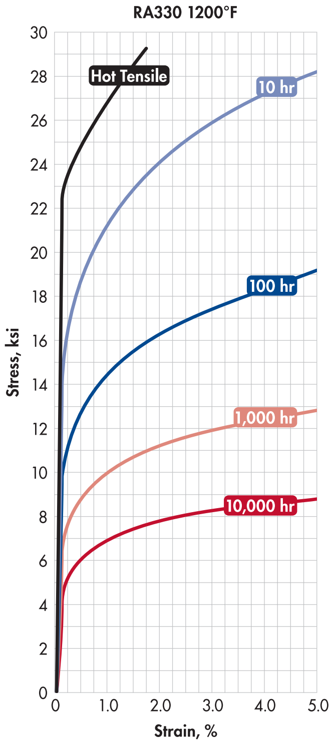
Temperature, °F	0	-50	-100	-200	-320
Ultimate Tensile Strength, ksi	87.0	90.5	94.5	105.2	131.5
0.2% Offset Yield Strength, ksi	40.0	42.7	44.8	53.8	64.4
Elongation, %	44	43	48	55	52.5

Cryogenic Charpy V-notch Properties[9]
Mechanical Properties

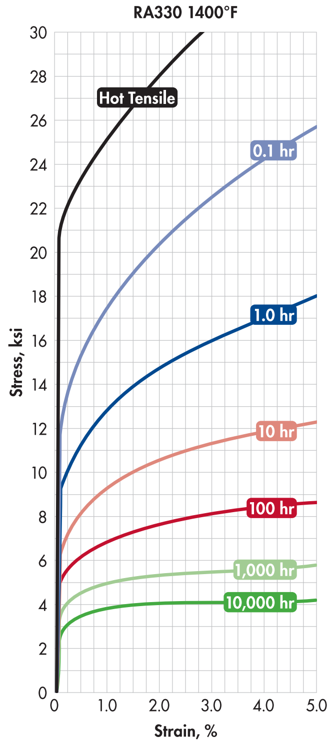
Weld Metal Specimens RA330-04-15 DC Lime Electrodes

Temperature, °F	-200	-250	-320
Charpy V-notch, ft-lb	54.7	42.4	40.4
Lateral Expansion, mils	44.0	32.7	30.0

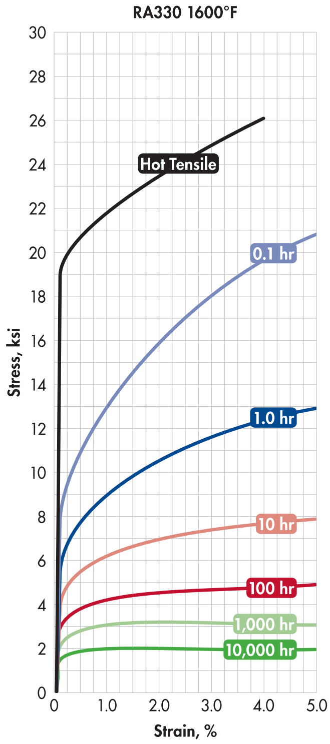
Isochronous Stress-Strain
Mechanical Properties



Average isochronous stress-strain curve



Average isochronous stress-strain curve



Average isochronous stress-strain curve

Hardness of Cold Rolled RA330[11]
Mechanical Properties

Effect of Annealing Temperature

Temperature, °F	as rolled	1400	1500	1600	1700	1800	1900	2000
Hardness 10%, Cold Reduction, Rb	95	94	90	88	87	87	69	68
Hardness 20%, Cold Reduction, Rb	101	97	95	92	89	85	70	68
Hardness 40%, Cold Reduction, Rb	105	102	102	92	81	81	71	68
Hardness 60%, Cold Reduction, Rb	108	101	91	82	83	82	71	–

Starting material: 11 gage hot rolled annealed sheet

Compressive Strength, Mill Annealed
Mechanical Properties

Short Time Elevated Temperature

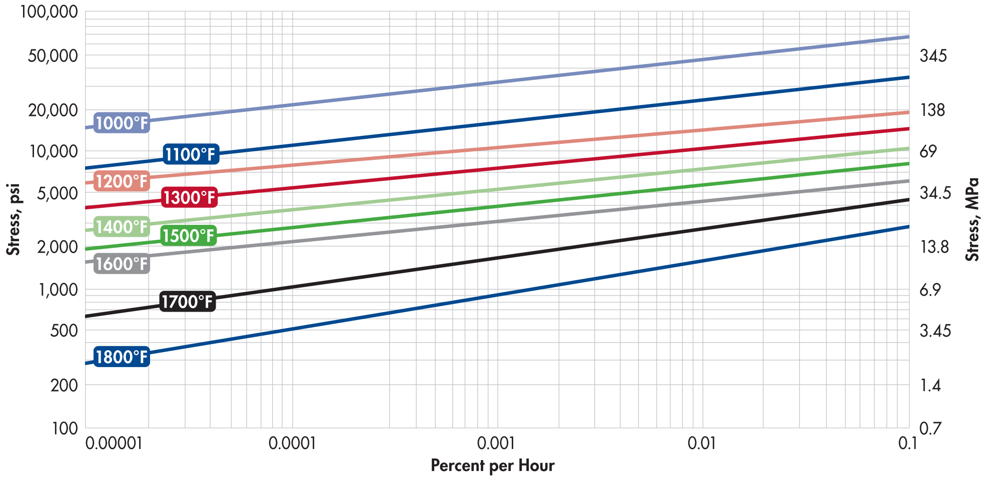
Test Temperature, °F	1400	1500	1600	1700	1800	1900
0.2% Offset Yield Strength, ksi	19.9	17.7	15.6	11.5	7.9	5.9

Hot Hardness, Mill Annealed
Mechanical Properties

Temperature, °F	70	1400	1600	1800
Brinell Hardness Number	145	56.8	29.0	16.5

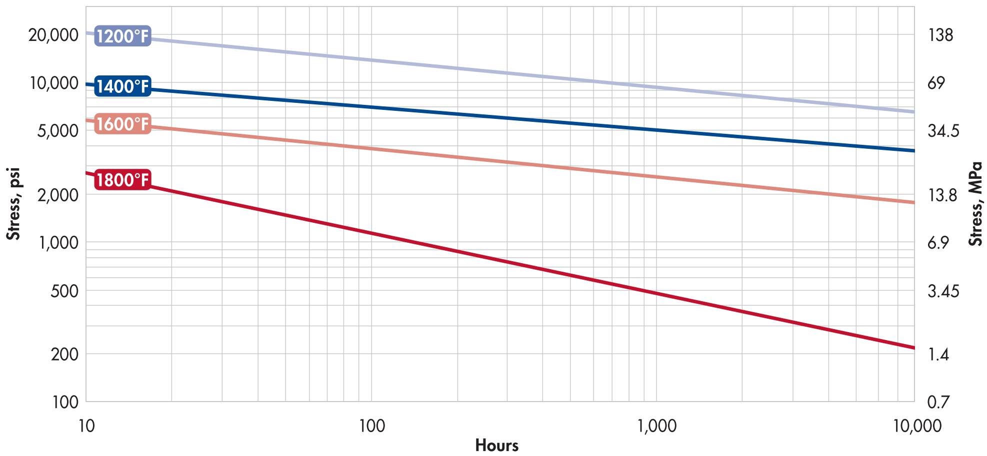
Note: Brinell type hardness testing was employed. Testing was performed with both the penetrator and specimen at the testing temperature. All loads were applied for five minutes. These loads for given testing temperatures are as follows: 1400°F – 2000 kg, 1600°F – 1000 kg, 1800°F – 500 kg. Lesser loads were used at higher temperatures to reduce the tendency for the softer material to deform excessively.

Stress for Secondary Creep Rate
Creep-Rupture Properties

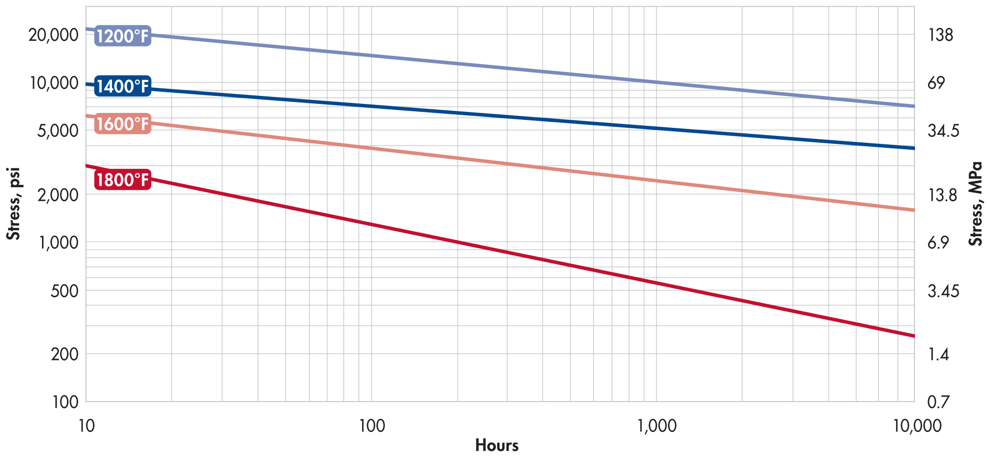


Temperature, °F	1000	1100	1200	1300	1400	1500	1600	1700	1800
0.00001%/hr, ksi	14.5	7.4	5.8	3.9	2.6	1.9	1.5	0.52	0.29
0.0001%/hr, ksi	21.0	10.5	7.6	5.3	3.6	2.7	2.1	1.0	0.5

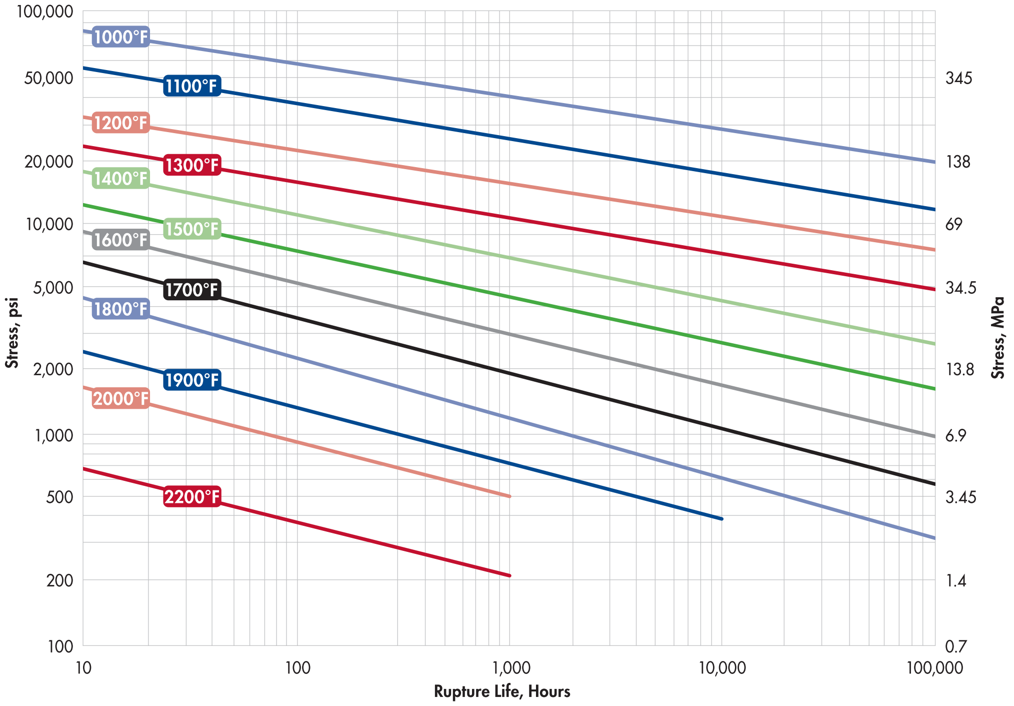
Average 1% Total Creep
Creep-Rupture Properties



Average 2% Total Creep
Creep-Rupture Properties



Average Stress to Rupture, Mill Annealed
Creep-Rupture Properties

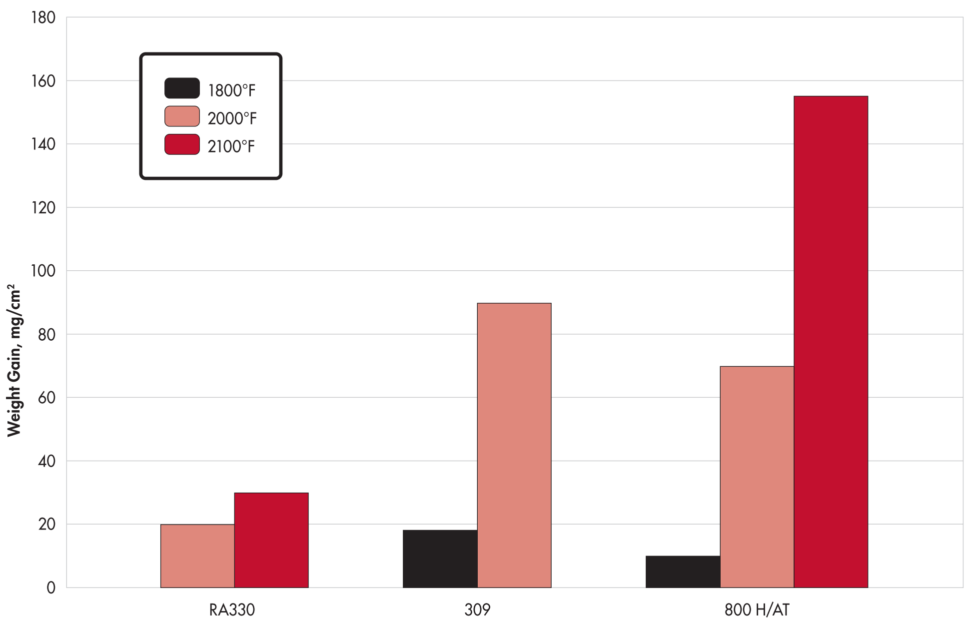


Temperature, °F	1000	1100	1200	1300*	1400	1500	1600	1700*	1800	1900*	2000	2200
100 Hours, ksi	58.0	37.0	22.5	16.0	11.0	7.6	5.2	3.5	2.3	1.4	0.9	0.38
1,000 Hours, ksi	41.0	25.0	16.0	10.5	6.9	4.6	3.0	1.9	1.2	0.75	0.5	0.22
10,000 Hours, ksi	29.0	17.0	11.0	7.2	4.3	2.7	1.7	1.05	0.63	0.4	–	–
100,000 Hours, ksi	20.0	12.0	7.8	4.8	2.7	1.65	1.0	0.58	0.33	–	–	–

**Interpolated by Larson-Miller technique[10]* $T(C + \log t) = \text{constant}$, *using* $C = 14.45$

Cyclic Oxidation
Exposed for 1640 hours,
Cycled every 160 hours

RA330 is highly resistant to oxidation under cyclic conditions, providing excellent service life up to 2100°F. The following laboratory data illustrates the relative performance of RA330 and other materials at elevated temperature.



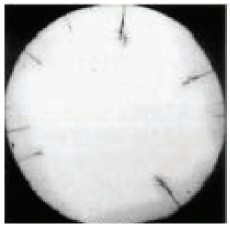
Note: Actual weight gain figures are valid only for the specific conditions of the test. Neither this nor other laboratory oxidation data should be used to quantitatively predict metal wastage in actual service.

Carburization

Carburization resistance of materials used for industrial heating applications is a prime consideration in alloy selection. The 35% nickel content of RA330 has long been considered near the optimum for both mechanical properties[1] and carburization resistance.[2] Silicon, maintained at a nominal 1.25%, is recognized as the one element most potent in conferring resistance to carburization.[2,3,4] Carburization rates are also affected by mechanical and thermal strains which damage the protective scale. Relative carburization resistance of commercial alloys is most reliably studied by exposing the materials to actual service conditions. These samples, cut from a multi-alloy bar frame basket, illustrate the behavior of the alloys in commercial heat treating service:

RA330
35Ni - 19Cr - 1.25Si

600
76Ni - 15.5Cr - 0.2Si



800H/AT
32.5Ni - 21Cr - 0.5Si

The carbon contents of 0.060" surface turnings from these bars are: RA330 0.35%, 600 0.97%, 800 2.40%. Service: 23 months in commercial heat treat shop, 80% carburizing, 15% carbonitriding, balance neutral hardening.

Aqueous Corrosion

RA330 has useful resistance to 10-15% sulfuric acid pickling baths. Heat treating baskets of RA330, required to withstand red heat, have been used to transport the same workload through the pickling bath.

Corrosion in 15% H_2SO_4 plus 0.15% Oakite® PC-10 inhibitor, 160°F

Alloy	RA330	1018 Steel	RA333®	600	Alloy 20
Corrosion Rate, mils/yr	18.8	293	9.85	8.07	5.00

From Rolled Alloys investigation 84-12, baskets to anneal and pickle alloy steel parts.

U-Bend Stress Test

RA330 is highly resistant to chloride ion stress corrosion cracking. This alloy can be a sound engineering choice for those applications where lower alloy materials have failed by stress corrosion cracking.

RA330 Results in U-Bend Stress Corrosion Tests in 45% Boiling Magnesium Chloride, 310°F

Heat Number	624351	624351	624275	624351	624351	624275	624275
Condition	1950°F Annealed	1950°F Annealed	1950°F Annealed	Cold Rolled, 30%	Cold Rolled, 30%	Cold Rolled, 30%	Cold Rolled, 30%
Time to Crack, hours	144	170	NC*	288	216	NC*	NC*

**No Cracking - test discontinued in 350 hours.*

800 H/AT Results in U-Bend Stress Corrosion Tests in 45% Boiling Magnesium Chloride, 310°F

Heat Number	HH0907A	HH0907A	HH5555A	HH5555A	HH0907A	HH0907A	HH5555A
Condition	1950°F Annealed	1950°F Annealed	1950°F Annealed	1950°F Annealed	Cold Rolled, 30%	Cold Rolled, 30%	Cold Rolled, 30%
Time to Crack, hours	<10	<10	<10	<10	<10	<10	<10

Prolonged exposure to temperatures in the 1000 - 1400°F range, or the heat of welding may sensitize RA330 so that it is susceptible to intergranular corrosion in particularly aggressive aqueous environments. Aqueous corrosion resistance may be restored by a full anneal. This sensitization has little or no effect on the alloy's performance at elevated temperatures.

The use of a more highly alloyed weld filler, such as RA333, is preferred where RA330 fabrications are to be used in aqueous corrosion.

Welding

RA330 is readily welded using RA330-04 weld fillers. RA330-04 weld fillers have special elemental additions to avoid hot cracking when welding RA330. Do not use AWS ER330 weld fillers as they have a matching composition and are prone to hot cracking. RA330-04-15 DC lime type electrodes are available from stock in popular sizes. RA330-04 bare welding wire is available as straight lengths for GTAW welding or spooled for GMAW welding. For best results do not preheat, keep interpass temperature low and use reinforced bead contours. Further guidelines for welding RA330 can be found in our RA330 welding manual.

Forming

Forming RA330 is done in the same manner as the conventional austenitic stainless steels. The work hardening rate of RA330 is comparable to that of 304 stainless.

Heavy duty lubricants may be used in cold forming to prevent galling and reduce die wear. Lubricants must be removed prior to welding, annealing or use in high temperature service, to avoid possible hot corrosive attack. Sulfur-chlorinated lubricants, in particular, must be thoroughly removed. Lubricants containing either sulfur or chlorine should not be used for spinning. The spinning operation tends to burnish the lubricant into the surface of the metal, rendering complete removal difficult.

Forming at room temperature is suggested whenever possible. If hot forming or forging is required, the workpiece should be heated uniformly throughout its section to a starting temperature of 2050-2150°F, finishing above 1750°F. Overheating or excessive hold time at starting temperature should be avoided to minimize grain growth. No forming or bending should be performed in the low ductility range of 1200-1600°F. Forming in this temperature range may cause intergranular tearing in austenitic alloys.

Machining

RA330 and other austenitic grades are quite ductile in the annealed condition. However, these chromium-nickel alloys work harden more rapidly and require more power to cut than plain carbon steels. Chips tend to be stringy, cold worked material of relatively high ductility.

Machine tools should be rigid and used to no more than 75% of their rated capacity. Both work piece and tool should be held rigidly; tool overhang should be minimized. Tools, either high speed steel or cemented carbide, should be sharp, and reground at predetermined intervals. Turning operations require chip curlers or breakers.

Feed rate should be high enough to ensure that the tool cutting edge is getting under the previous cut thus avoiding work hardened zones. Slow speeds are generally required with heavy cuts. The machinability rating of RA330 is approximately 20-25% of AISI B1112 steel. Lubricants, such as sulfur-chlorinated petroleum oil are suggested. Such lubricants may be thinned with paraffin oil for finish cuts at higher speeds. The tool should not ride on the work piece as this will work harden the material and result in early tool dulling or breakage. All traces of cutting fluid must be removed prior to welding, annealing or use in high temperature service.

Suggested Machining Speeds

Suggested Speeds, Surface Feet per Minute (ft/min)

Turning [1,5]	30 - 45
Drilling [2]	30 - 45
Reaming [3]	15 - 25
Milling [4]	30 - 40
Treading [5] and Tapping	10 - 15

1. Roughing feeds 0.010 - 0.015 inch per revolution
2. Drilling diameter and feed:

Drilling Diameter, in	1/16 - 1/4	1/4 - 1/2	1/2 - 1 1/2	over 1 1/2
Feed, in/rev	0.001 - 0.0035	0.0035 - 0.005	0.005 - 0.008	0.008 - 0.010

3. Reaming feeds are approximately three times the feed used for a corresponding drill size
4. Feed 0.003 - 0.006 inch per tooth
5. With carbide tools use 100 - 175 sfpm and feeds 0.010 - 0.015 in/rev

Cleaning and Pickling

Machining lubricants or other organic contaminants may be removed from RA330 by alkaline cleaning agents, water-emulsion cleaners or suitable solvents.

Light oxides may be removed by nitric-hydrofluoric acid pickling solution. Heavy hot work or annealing scale may be removed by steel grit blasting, followed by a short pickle in a nitric-hydrofluoric, or sulfuric acid solution to remove the surface iron contamination. Hot water rinse. RA330 is sensitive to intergranular corrosion in nitric-hydrofluoric pickle baths so limit the pickling time to avoid possible intergranular attack (a.k.a. "sugaring").

Heat Treatment

RA330 is a fully austenitic alloy which does not harden by thermal treatment. Increased room temperature strength may be obtained only by cold working. The purposes of annealing RA330 are to remove residual forming stresses or to redissolve precipitated carbides. For most high temperature applications, RA330 fabrications are not annealed after forming or welding.

If the final application requires a full anneal, the suggested procedure is to heat in a low-sulfur atmosphere 1950 - 2050°F long enough to ensure a uniform actual metal temperature, followed by a rapid air cooling or quenching to below 800°F. Residual stresses and work hardening from severe forming operations may be removed by an 1850 - 1900°F anneal.

References

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4. Louis H. Wolfe, "Laboratory Investigations of high Temperature Alloy Corrosion and Failures," Materials Performance, Vol. 17, No. 4, 1978.

5. A.O. Schaefer, Editor, "Report No. FE-1784-48," The Metals Properties Council, Inc., February 27, 1979.

6. Dynatech Report No. RLD-1, Dynatech R/D Company, December, 1984.

7. Unpublished data, Surface Combustion Div., June 5, 1975.

8. Private communication of April 20, 1972, Carpenter Technology Corporation, Tube Division.

9. E. R. Szumachowski/H. F. Reid, "Cryogenic Toughness of SMA Austenitic Stainless Steel Weld Metals: Part-Role of Ferrite," Welding Research Supplement, Welding Journal, Vol. 57, No. 11, November 1978.

10. Private communications of January 10 and June 22, 1972, Crucible Inc., Materials Research Center.

11. G. R. Rundell/A. E. Nehrenberg, "Annealing Temperatures Required to Soften Cold Worked RA330 and RA333, Report No. RA 145," Simonds Saw and Steel Co., June 1, 1964.

12. F. R. Larson/James Miller, "A Time-Temperature Relationship for Rupture and Creep Stresses," Transactions of the ASME, July, 1952.

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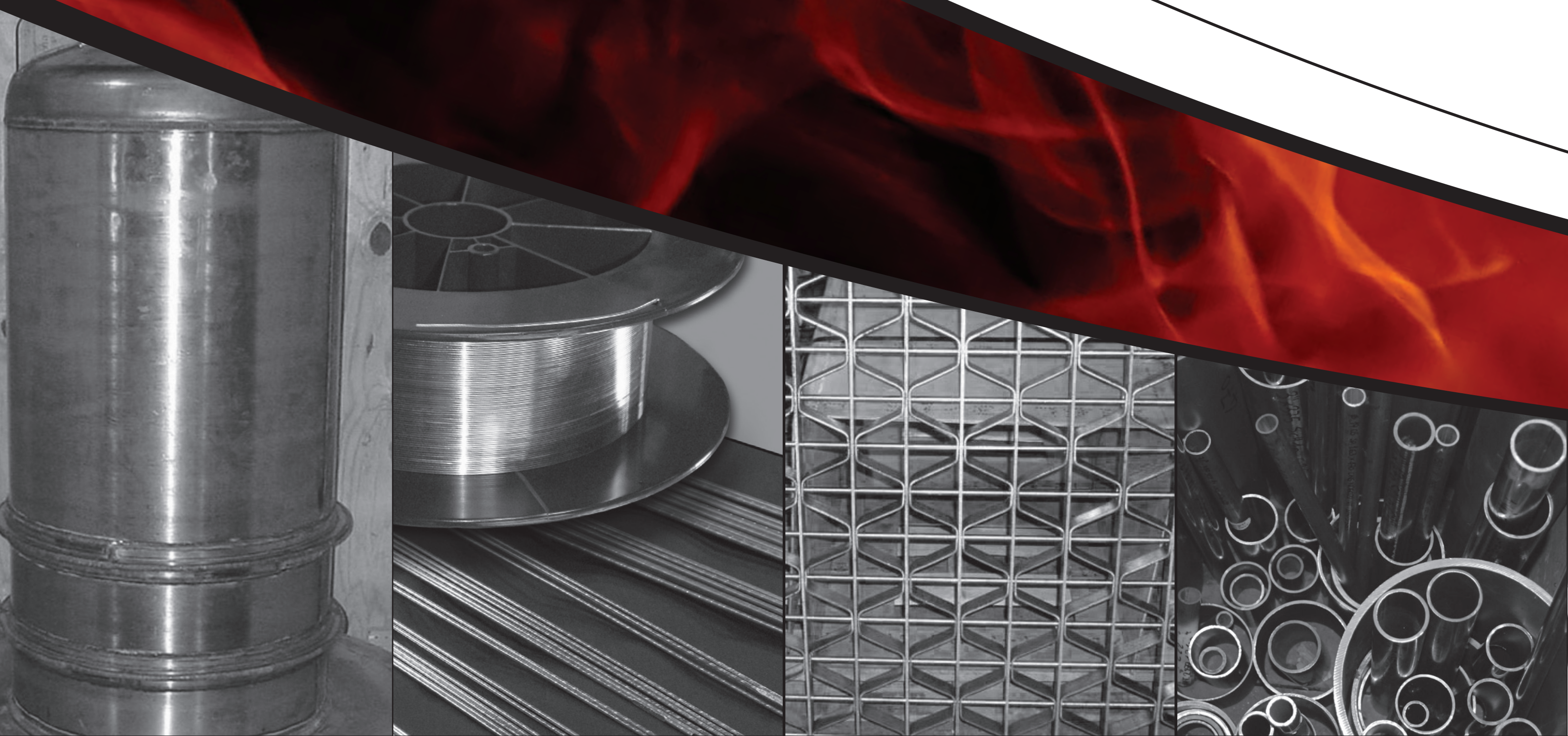

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Bulletin No. 107USe 12/14