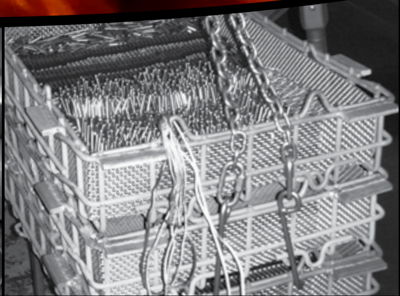
RA 253 MA® Data Sheet

RA 253 MA has provided the solution to the demand for a heat resistant stainless steel with superior strength for over thirty years. It has twice the strength as 309 and 310 stainless above 1600°F and great oxidation resistance up to 2000°F. RA 253 MA can decrease distortion and increase the service life of your equipment.






The Global Leader in Specialty Metals

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RA 253 MA® is a lean austenitic heat resistant alloy with high strength and outstanding oxidation resistance. RA 253 MA obtains its heat resistant properties by advanced control of microalloying additions. The use of rare earth metals in combination with silicon gives superior oxidation resistance to 2000°F. Nitrogen, carbon and to some extent, rare earth and alkali metal oxides, combine to provide creep rupture strength superior to other heat resistant stainless steels.

Specifications

UNS: S30815 **W. Nr./EN:** 1.4835 **ASTM:** A 240, A 276, A 312, A 358, A 409, A 473, A 479, A 813, A 814
ASME: SA-240, SA-479, SA-312, SA-249

Chemical Composition, %

	Cr	Ni	Mn	Si	C	N	Ce	Fe
MIN	20.0	10.0	–	1.4	0.05	0.14	0.03	–
MAX	22.0	12.0	0.8	2.0	0.1	0.2	0.08	balance

Features

- Excellent oxidation resistance through 2000°F
- High creep-rupture strength
- Excellent resistance to thermal shock
- Good weldability

Applications

- Pulverized coal burners in power boilers
- Petrochemical, refinery and steam tube hangers
- Radiant tubes for steel/aluminum annealing
- Recuperates
- Thermal oxidizers
- Expansion bellows
- Furnace fans, dampers
- Fluidized bed combustor cyclones
- Rotary kilns and calciners
- Refractory anchors

Physical Properties

Density: 0.282 lb/in³ **Melting Range:** 2500-2610°F **Poisson's Ratio:** 0.31

Temperature, °F	70	200	400	600	800	1000	1200	1400	1600	1800
Coefficient of Thermal Expansion, in/in°F x 10^{-6}	–	9.06	9.34	9.59	9.81	9.97	10.14	10.3	10.5	10.8
Modulus of Elasticity, Dynamic, psi x 10^6	29.0	–	26.8	–	24.4	–	21.7	20.2	18.7	17.6
Thermal Conductivity, Btu • ft/ft² • hr °F	8.38	–	10.1	–	11.7	–	13.0	14.0	–	16.6
Thermal Conductivity, W/m • K	14.5	–	17.5	–	20.2	–	22.5	24.2	–	28.7
Specific Heat, Btu/lb • F	0.105	–	0.117	–	0.130	–	0.142	0.149	–	0.164
Specific Heat, J/Kg • K	440	–	490	–	544	–	595	624	–	687
Electrical Resistivity, ohm • circ mil/ft	505	–	622	–	745	–	830	851	–	871

Sulfidation Resistance

RA 253 MA has good resistance to hot SO_2 bearing atmospheres, meaning sulfidation under oxidizing conditions. However, RA 253 MA is not resistant to reducing sulfidizing atmospheres, when sulfur is present as H_2S. Note that even though the atmosphere may be oxidizing, the partial pressure of oxygen can be extremely low under solid sulfate deposits. Local sulfidation attack under the deposit can then occur.

Alloy	RA 253 MA	RA333®	309	310	RA330®
Depth of Attack, mils	8.0	8.0	18.0	20.0	24.0

Test samples exposed to an atmosphere containing 13.6% SO_2 at 1850°F for 1860 hours exhibited the above depths of intergranular oxidation and sulfidation.

Carburization Resistance

RA 253 MA has only fair resistance to carburization. Carburization resistance is primarily dependent on the nickel content of a material. Service experience has shown 309 stainless to be slightly better.

Coupons were exposed for 15 weeks to simulated bake cycles 1700-1950°F in "green mix" used for production of carbon electrodes. Room temperature tensile tests showed the following ductility:

Alloy	RA 253 MA	302B	800H	RA330
Nickel, Weight %	11.0	9.0	32.0	35.0
Retention of Ductility, Reduction of Area, %	0.5	0	1.4	16.6

Hot Salt Corrosion

Sodium and potassium neutral or chloride salts cause hot corrosion of heat resistant alloys. Traditionally the most resistant alloys have been considered to be those highest in nickel. Exposure in salts for heat treating high speed steel indicate that RA 253 MA may be comparable to alloy 600.

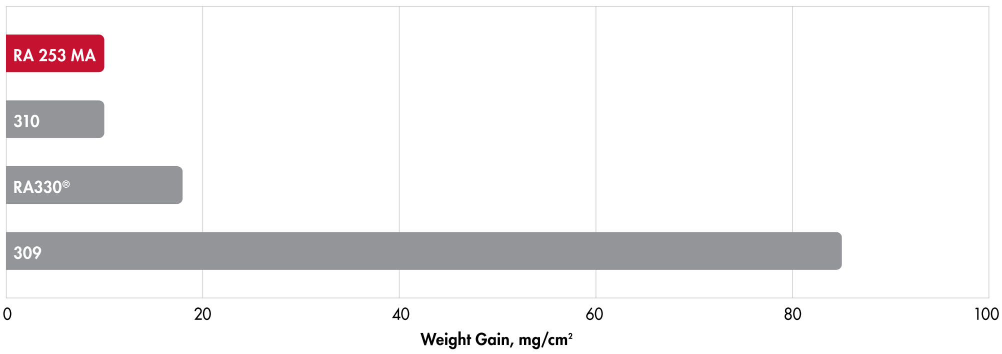
Metallic pots for neutral heat treating salts are commonly made of 309 or RA330. The service life of the pot is primarily determined by maintenance, not alloy. Pots must be desludged and rectified regularly. When changing pots, every bit of old spilled salt must be removed from the furnace refractory.

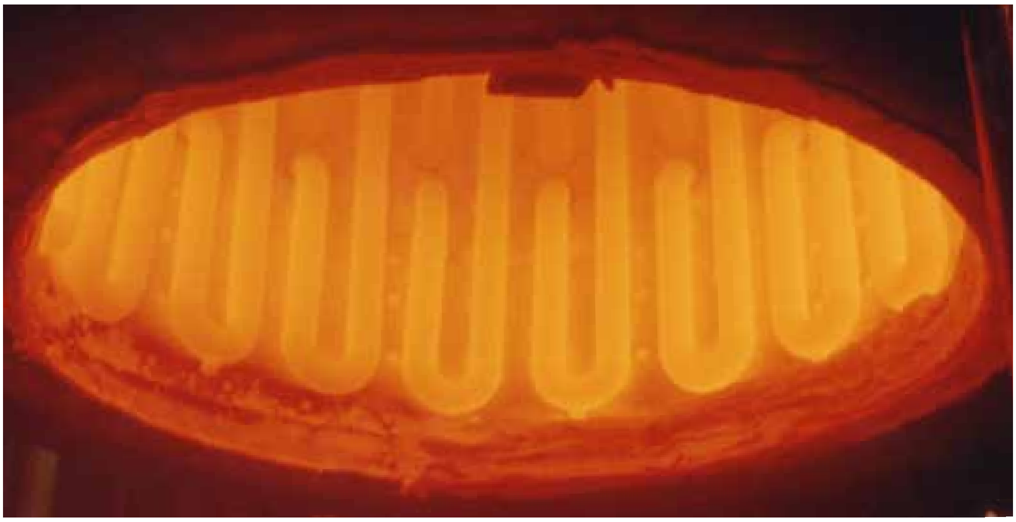
Alloy	RA 253 MA	600	309	RA330
Nickel, Weight %	11.0	76.0	13.0	35.0
Depth of IGA, mils	6.9	7.5	12.5	13.8

Plate samples exposed 210 - 252 cycles in preheat salts 1300 and 1500°F, high heat salt 2200°F, quench in 1100°F salt.

Oxidation

RA 253 MA has exceptional oxidation resistance up to roughly 2000°F, above this temperature its oxidation resistance is reduced. A combination of rare earths and silicon is responsible for the excellent oxidation resistance of this 21% Cr alloy. The rare earths increase diffusion rate of the silicon to the scale-metal interface. This promotes the development of a continuous SiO_2 subscale, which in turn slows further oxide growth. Rare earth metals also improve adhesion and elasticity of the oxide scale, even under cyclic conditions. These rare earths, primarily cerium, increase the number of nucleation sites for the oxide. This results in a fine grained chromia and silica scale. The 2000°F Cyclic Oxidation testing is shown below.





Mechanical Properties

Typical Elevated Temperature Tensile Properties

Temperature, °F	122	212	392	572	752	932	1112	1292	1472	1562	1652
Ultimate Tensile Strength, ksi	96.2	90.2	83.8	82.4	79.7	75.7	69.0	56.0	56.4	36.9	24.8
0.2% Yield Strength, ksi	44.2	39.3	32.2	29.3	29.1	25.1	24.2	23.0	21.5	14.6	11.6
Elongation, %	51	48	46	46	46	44	43	44	–	–	–
Reduction of Area, %	68	65	65	64	60	62	63	58	76	88	92

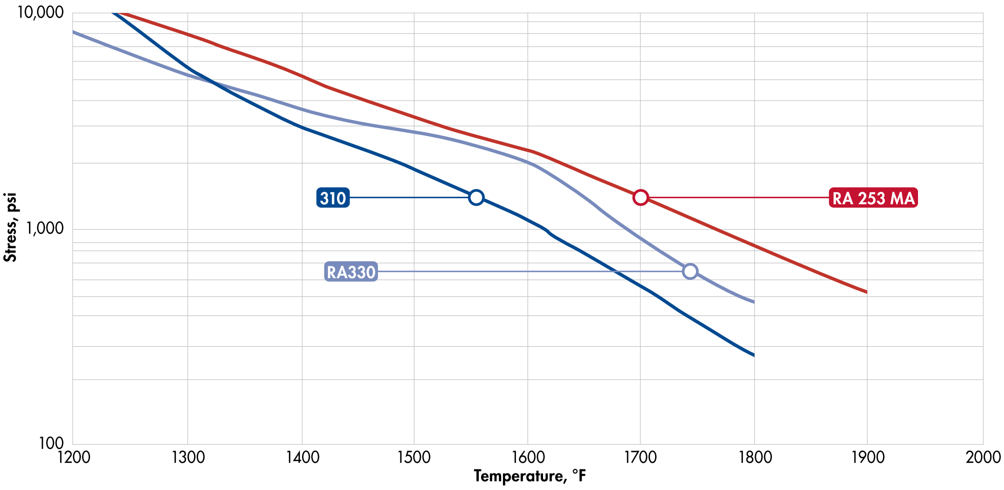
Data for 1562°F and above are from a single heat, other data is an average of 2 to 5 heats. Note: Above approximately 1000°F, short time tensile properties are not a suitable criteria for design. At these temperatures, metals are not elastic and deform slowly over time. Design calculations should utilize time dependent properties such as creep or rupture data.

Creep-Rupture

RA 253 MA maintains excellent creep rupture strength up to its upper use limit of 2000°F. Additions of nitrogen, carbon and cerium all enhance its high temperature strength well above 309 or 310 stainless steels. Above 1600°F, RA 253 MA offers twice the creep strength of types 309 and 310 stainless steel and is actually stronger than the 35% nickel alloy RA330. Over 2.6 million hours of creep and rupture testing were used to generate the graphs and tables below and on the following page. Some tests were run as long as 30,000 hours.

Minimum Creep Rate

0.0001% per Hour



Minimum Creep Rate
Creep-Rupture Properties

Temperature, °F	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
0.0001% per Hour, ksi	18.0	11.6	7.7	5.0	3.35	2.3	1.5	0.89	0.49	0.25*
0.00001% per Hour, ksi	12.0	8.2	5.7	3.8	2.55	1.75	1.15	0.55	0.32*	0.15*

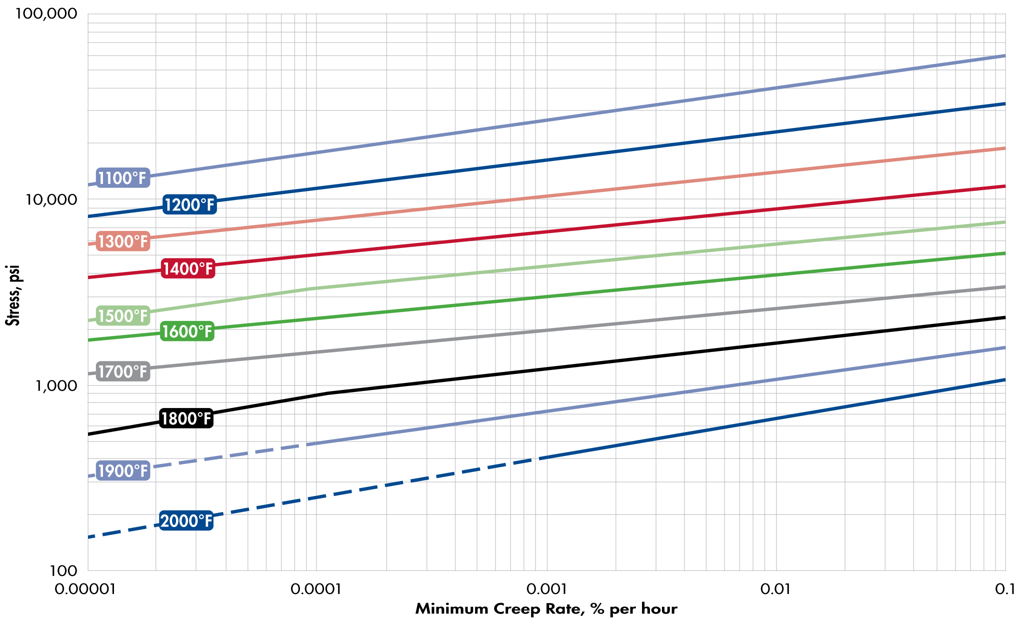
** Extrapolated*

Average Stress to Rupture in Indicated Times
Creep-Rupture Properties

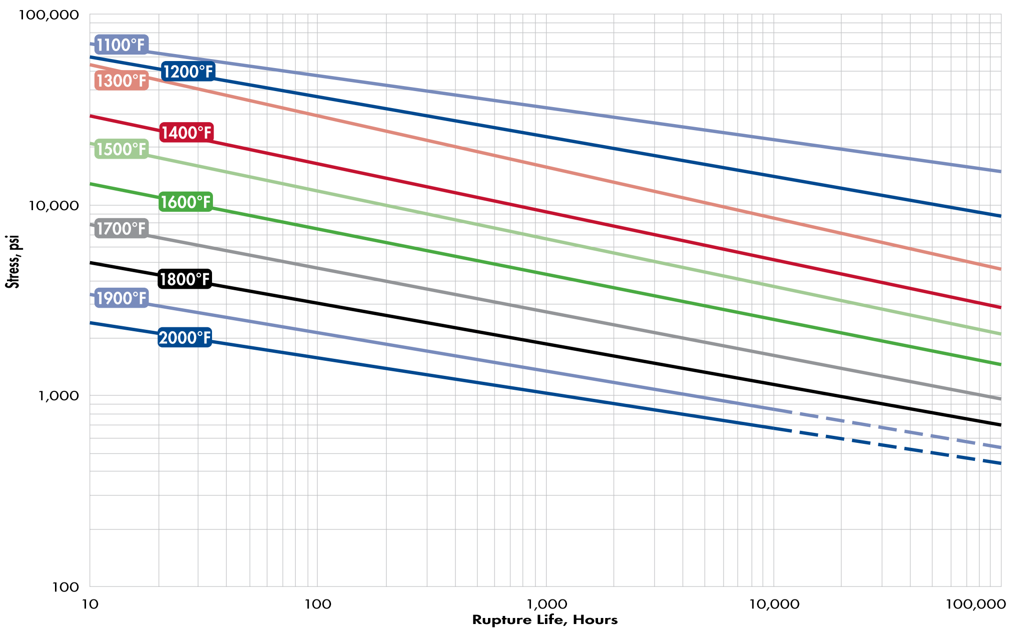
Temperature, °F	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
1,000 hours, ksi	32.0	23.0	16.0	9.2	6.6	4.4	2.8	1.85	1.35	1.03
10,000 hours, ksi	22.0	14.0	8.5	5.2	3.75	2.50	1.65	1.15	0.86	0.68
100,000 hours, ksi	15.0	8.7	4.6	2.9	2.1	1.45	0.97	0.7	054*	0.44*

** Extrapolated*

Minimum Creep Rate
Creep-Rupture Properties



Average Stress to Rupture
Creep-Rupture Properties



Sigma Phase Embrittlement

Like other high chromium austenitic stainless steels, RA 253 MA loses room temperature toughness and ductility after long term exposure to the 1100-1600°F temperature range. The effect is primarily on room temperature properties. While operating in the creep-rupture range the metal will have greater ductility and toughness. Austenite stability in RA 253 MA is enhanced by the nitrogen addition, so that formation of embrittling sigma phase is retarded. Charpy impact values after aging at intermediate temperatures are provided below for RA 253 MA alloy and type 310 stainless steel for reference.

Aged Charpy V-notch Impact Properties

RA 253 MA

Aging Temperature, °F	Annealed Condition	1292	1472	1652
Time, hours	–	20,000	20,000	20,000
Impact Strength, ft-lb	110.0	3.0	4.0	42.0

310

Aging Temperature, °F	Annealed Condition	1292	1472	1652
Time, hours	–	20,000	20,000	20,000
Impact Strength, ft-lb	69.0	3.0	3.0	27.0

Welding

RA 253 MA should be welded with matching welding consumables, which are referred to as RA 253 MA. These are carried in inventory by Rolled Alloys in bare wire for GMAW and GTAW processes, covered electrodes for SMAW and flux core wire for the FCAW process. Use of the matching filler ensures that the weld joint matches the strength and corrosion resistance of the RA 253 MA base metal. Use of columbium containing filler metals, such as alloy 82, is not suggested due to embrittling phases formed with welding RA 253 MA.

RA 253 MA base metal is listed in ASME Section IX as P number 8 group 2. RA 253 MA weld wire does not meet AWS classifications.

Preheating and post-heating are not required for welding RA 253 MA. The chemistry of RA 253 MA welding wire and covered electrodes is balanced to have roughly a 4 to 12 Ferrite Number. This ferrite provides RA 253 MA weld fillers with excellent resistance to hot cracking. In that respect, RA 253 MA behaves like other stainless weld fillers, such as 309.

The unique addition of cerium to RA 253 MA, both in the base metal and in the weld fillers, is to enhance oxidation resistance. Cerium also makes the weld bead appear a little rough. This is a characteristic of weld fillers containing rare earths and is not amenable to improvement by welding procedure. While this has not been a problem in service, a few customers prefer to weld RA 253 MA with RA333 weld fillers.

Interpass temperatures should be kept below 300°F to minimize the likelihood of solidification cracking. Maintaining a low welding heat input with a maximum of 1.5 kJ/mm is suggested.

SMAW
Shielded Metal Arc Welding
Welding Properties

C	Si	Mn	Cr	Ni	N
0.08	1.5	0.7	22.0	10.5	0.18

RA 253 MA-17 AC/DC titania electrodes (UNS W30816) may be used with either alternating current or with direct current. For DC welding use reverse polarity (electrode positive), and maintain the arc length as short as possible. A short arc minimizes loss of cerium through the arc and improves penetration. Stringer beads with only a slight weave, not more than twice the electrode diameter are preferred. Starts and craters should be filled in to minimize the possibility of cracking.

All welding flux must be removed from each deposit, between passes and after the final pass. Residual welding flux may corrode the material when placed in high temperature service.

RA 253 MA electrodes and flux cored wires are packaged in hermetically sealed containers to assure freedom from contamination and moisture absorption. After opening, electrodes should be stored at 150-250°F to prevent the coating from absorbing moisture. Electrodes damaged by exposure to atmospheric humidity should be reconditioned for two to four hours at 500-600°F. It is important to heat and cool slowly. Porosity and excessive weld spatter may result if electrodes are not completely dry.

Electrode Diameter, in	3/32	1/8	5/32
Amperage	45-70	70-110	100-140
Volts	24-30	24-30	24-30

The lower end of the current range is used for out-of-position welding.

FCAW
Flux Core Arc Welding
Welding Properties

C	Ce	Si	Mn	Cr	Ni	N
0.06	0.005	1.4	1.0	22.0	10.0	0.15

The recommended shielding gas for flux cored welding with RA 253 MA consumables is a mixture of 75% argon and 25% carbon dioxide. Shield gas flow rate should be 40 cubic feet per hour. Wire extension should be 0.5 to 1 inch. Unused wire should be stored in a moisture resistant holding environment to prevent moisture pickup by the flux.

Electrode Diameter, in	0.045
Amperage	100-270
Volts	23-35

GTAW
Gas Tungsten Arc Welding
Welding Properties

C	Si	Mn	Cr	Ni	N
0.07	1.6	0.7	21.0	10.0	0.15

100% argon shielding gas is preferred for manual GTAW. Helium may be added to increase speed in automatic welding. Electrodes should be 2% thoriated tungsten (AWS EWTh-2) with direct current straight polarity (electrode negative). For good arc control, grind the electrode tip to a 30 to 60 degree point, with a small flat at the tip. Grind lines should be parallel to the electrode, not circumferential. Finish grind on a 120 grit wheel. Adjust the arc on clean scrap metal, with no scale. Shielding gas flow should be 25 cubic feet per hour.

Electrode Diameter, in	0.062	0.094	0.125
Amperage	80-110	130-160	160-200
Volts	10-12	16-18	17-19

GMAW
Gas Metal Arc Welding
Welding Properties

C	Si	Mn	Cr	Ni	N
0.07	1.6	0.6	21.0	10.0	0.15

Spray Arc

Electrode Diameter, in	0.035	0.045
Amperage	190-240	210-250
Volts	25-29	26-30

Pulsed Arc

Electrode Diameter, in	0.045
Amperage	I_{PEAK} = 340-380, I_{BKG} = 100-160
Frequency, Hz	100-120

Shielding Gas - 68% Ar, 30% He, 2% CO_2 Gas Flow Rate - 25-34 ft^3/hr

Transfer Mode	Shielding Gas Composition
Spray Arc	100% Argon
	81% Argon, 18% Helium, 1% Carbon Dioxide
Globular/Short Circuit	75% Argon, 25% Helium
	90% Argon, 7.5% Helium, 2.5% Carbon Dioxide
	81% Argon, 18% Helium, 1% Carbon Dioxide
Out of Position	68% Argon, 30% Helium, 2% Carbon Dioxide

**Do not use 98% Ar 2%O_2 for welding RA 253 MA. Never use 75% Ar 25% CO_2 for any stainless or heat resistant alloy using the GMAW process.*

SAW
Submerged Arc Welding
Welding Properties

RA 253 MA is sub-arc welded using the neutral basic AVESTA FLUX 805 (Basicity index 1.7). This is an agglomerate type welding flux characterized by neat deposit surfaces, a smooth transition zone between the parent and weld metal, easy slag removal and excellent resistance to moisture absorption during storage. Flux consumption of between 0.5 to 0.8 pounds of flux per pound of wire is typical.

Correct joint geometry must be used to avoid hot cracking in sub-arc welding. This means that the width of the joint must be greater than the depth. The width to depth ratio should be between 2 and 3. Interpass temperatures should be kept below 200°F for the SAW process.

Direct Current Reverse Polarity (DCRP)

Electrode Diameter, in	0.062	0.094	0.125
Current, amps	225-300	300-400	400-450
Voltage, volts	29-33	29-33	29-33
Wire Stickout, in	0.75	1.0	1.0
Travel Speed, in/min	8-12	16-24	16-24

Dissimilar Metal Welding

Base Metal 1	RA 253 MA	RA 253 MA	RA 253 MA	RA 253 MA	RA 253 MA
Base Metal 2	Mild Steel	304,316, 309	310	RA330, RA333, 800H, 600, 601	RA 602 CA
Filler Metal	309	RA 253 MA or 309	RA 253 MA	RA333	RA 602 CA or RA333

Forming

RA 253 MA may be formed, sheared, and machined, however, alloying with nitrogen results in a high yield point (54,000 psi typical). For this reason, greater force is required and more spring-back may be anticipated than with 304 or 309 stainless. All traces of forming lubricants must be removed prior to welding, annealing, or use in high temperature service.

Forming at room temperature is suggested whenever possible. If hot bending is required, the work piece should be heated uniformly throughout its section to 2000°F, finishing above 1650°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

Heat resistant austenitic alloys are generally more difficult to machine than conventional austenitic stainless steels. Since RA 253 MA is alloyed with nitrogen and rare earth metals, both higher cutting forces and a more rapid tool wear should be expected.

Use the most stable machine tools available. Stainless steels generate high cutting forces and large loads on the tools and the set-up. The set-up of the tools and the work piece must be rigid. The work piece must be adequately supported to avoid deflections by the cutting forces. Extensions on tools should be kept as small as possible. Long tool extensions and/or unstable cutting conditions severely increase the risk of vibration and tool failure.

Always use tools with sharp cutting edges. It is important that the cutting edge is sharp but it must also be strong enough to withstand the cutting forces. Change the insert or regrind the tool at more frequent intervals than for carbon steels. A blunt cutting edge produces higher cutting forces and a thicker strain hardened layer than a sharp edge. This applies especially to high alloy stainless steels. For cemented carbide tools, it is important that the edge chamfer is small enough to give a cutting edge that is effectively "sharp". Do not use a larger nose radius than necessary as this may cause vibrations.

Use a depth of cut that is deep enough to let the cutting edge work below the strain hardened layer created by previous passes or operations. Use the correct cutting speed. Too slow of a cutting speed increases the risk of built-up edge formation, tool failure and may result in a poor surface finish of the machined surface.

When cutting fluid is used it should always be applied liberally to the cutting zone. If possible use cutting oils and emulsions with EP-additives.

The machining data given below represents general guidelines or starting values. These may need to be adjusted to the actual conditions of a specific machining operation. They are based on a tool life of approximately 15 minutes for cemented carbide tools and approximately 40 minutes for high-speed steel tools.

Turning, Longitudinal and Face Turning

	Cutting Speed, ft/min	Feed, in/turn	Depth of Cut, in	Cemented Carbide Grade
Cemented Carbide Roughing	295-395	0.012-0.024	0.08-0.20	C5, C6
Cemented Carbide Finishing	395-525	0.002-0.012	0.02-0.08	C6, C7
High Speed Steels Finishing	46-59	0.002-0.008	0.02-0.08	–

Drilling

Twist with High Speed Steels

Drill Diameter, in	1/32, 1/8	1/4	3/8	5/8	3/4	1 1/4	1 1/2
Cutting Speed, ft/min	16-26	16-26	26-33	26-33	26-33	26-33	26-33
Feed, in/rev	0.0015	0.003	0.005	0.008	0.010	0.012	0.013

Heat Treatment

Solution annealing of RA 253 MA is performed at 1920-2100°F for one hour per inch of thickness, rapid air cool or water quench. Plate is most commonly annealed at about 1960-2000°F.

About 70% of residual stresses may be relieved by holding between 1560-1740°F for about 15 minutes followed by an air cool.

After severe cold work (more than 10-20% cold work) it is desirable to solution anneal for maximum creep rupture strength. This is appropriate for service above 1450°F.

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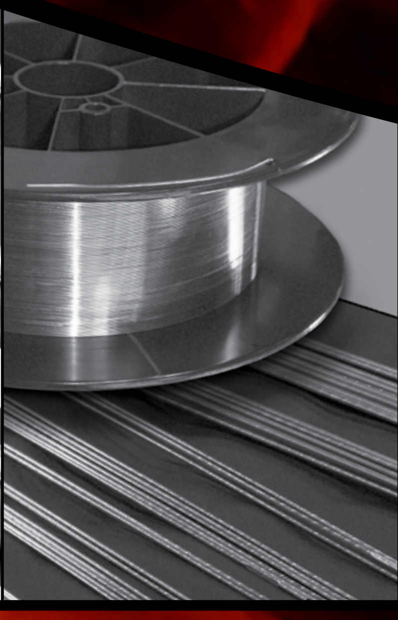

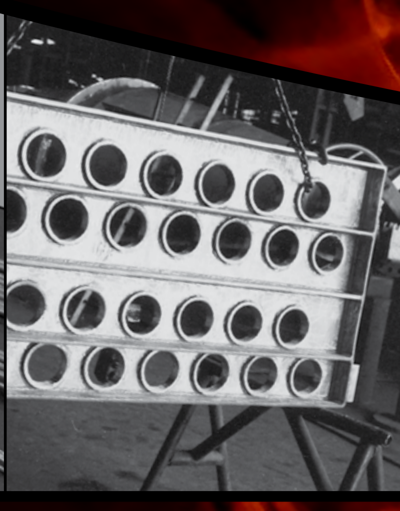

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