



RA 253 MA pier caps fabricated from 3/8-inch plate used to protect refractory piers in a titanium billet furnace

Micro-Alloyed Heat-Resistant Alloy Reduces Costs, Not Performance

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Tough times call for tough decisions. Tight budgets are still common as the economy slowly recovers. In order to stretch budgets further, it has not been too unusual for questions to arise about using stainless steels or even mild steels in place of nickel-based alloys for furnace and heat-treat components.

In most cases, it is accepted that lowering the alloy cost will also lower the performance of the material. This does not always have to be true. There are some opportunities to consider leaner alloys and lower costs while improving performance. Micro-alloyed grades like RA 253 MA® (UNS S30815) have been around since the 1980s but are still unfamiliar to many in the furnace and heat-treat industries.

In 1992, Hamer and McConnell published an article in this same magazine discussing the benefits of micro-alloyed materials.^[1] Some things have changed since then, including the prices of commodities such as nickel. Figure 1 shows the fluctuation in nickel prices over the past 25 years. In 1992, nickel was less than \$4 per pound, but the average for nickel over this decade has exceeded \$7 per pound. While the technical advantages of micro-alloys are still the same, their cost advantages are now even more significant.

What is Micro-Alloying?

Micro-alloying, as the name implies, in-

volves the tightly controlled addition of small amounts of alloying elements to a steel or stainless to provide enhanced properties at minimal cost.

In high-strength, low-alloy (HSLA) steels, the term refers to additions of vanadium, titanium and niobium. In the case of heat-resistant stainless steels and nickel alloys, it refers to the addition of

rare-earth metals (REM) such as cerium, yttrium or lanthanum. These additions work in conjunction with other stable, high-temperature oxide formers to provide oxidation resistance at elevated temperatures and extend the useful operating range of these alloys. RA 253 MA utilizes cerium additions to enhance its oxidation resistance. Other heat-resistant alloys

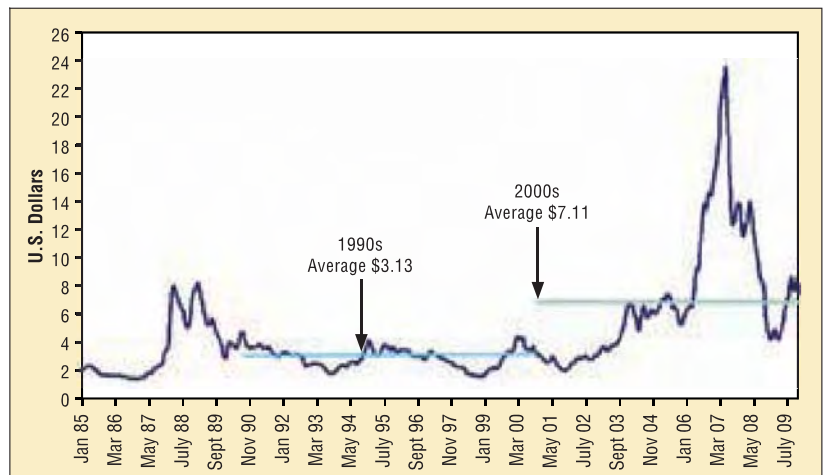


Fig. 1. Average nickel prices from 1985 to present (Source: London Metal Exchange)

such as Haynes 230®, RA 602 CA® and Haynes 214® also utilize rare-earth elements for similar reasons.

Micro-Alloying of RA 253 MA

Development work was started on RA 253 MA alloy in the 1970s at the Avesta Stainless (now known as Outokumpu Stainless) research center in Sweden. The aim at the time was to develop a heat-resistant stainless steel with at least the properties of 310 stainless (UNS S31008) but with lower alloy content. The chemistries of RA 253 MA and 310 stainless are compared in Table 1 along with that of 304, RA330® and alloy 600.

RA 253 MA is very lean in comparison to other heat-resistant alloys. As a result,

it can provide significant cost relief as a replacement to nickel-based alloys.

RA 253 MA, like 310 stainless, is an austenitic stainless steel. Micro-alloying with cerium in conjunction with both nitrogen and high silicon provides a lean heat-resistant alloy with dramatically improved oxidation resistance and high-temperature creep strength. RA 253 MA, like 310, can be operated in air up to 2000°F. A comparison to the maximum operating temperatures of other alloys is shown in Figure 2.

The nitrogen addition in conjunction with cerium and carbon provides the high creep-rupture strength of RA 253 MA. Table 2 shows the minimum creep strengths for several heat-resistant alloys.

RA 253 MA provides strength advantages over even alloy 600.

Even though RA 253 MA is stronger and comparable in oxidation resistance to higher-nickel alloys (up to 2000°F), there are some situations where the lower nickel content will have drawbacks. Nickel is important for resisting embrittlement in nitriding, carburizing and carbonitriding service. Nickel decreases the solubility of carbon and nitrogen in the alloy, and, as a result, high-nickel alloys maintain their ductility in these services for much longer periods of time than RA 253 MA.

The other area is thermal stability. Long-term exposure to temperatures in the 1200-1600°F range can lead to sigma-phase formation. The presence of sigma phase can reduce the room-temperature ductility of an alloy. As a result, straightening and repair welding can be more difficult in alloys with significant sigma phase. Both 310 and RA 253 MA will form sigma phase, whereas RA330 and alloy 600 with

Table 1. Nominal chemistries, weight %

Grade	UNS #	Nickel	Chromium	Silicon	Carbon	Nitrogen	Other
RA 253 MA	S30815	11	21	1.7	0.08	0.17	0.04 Ce
304 SS	S30400	8.3	18.3	0.3	0.02	0.05	1.2 Mn
310 SS	S31008	20	25	0.5	0.05	-	1.6 Mn
RA330	N08330	35	19	1.25	0.05	-	1.5 Mn
Alloy 600	N06600	76	15.5	0.2	0.04	-	-

Extrapolated values in parentheses

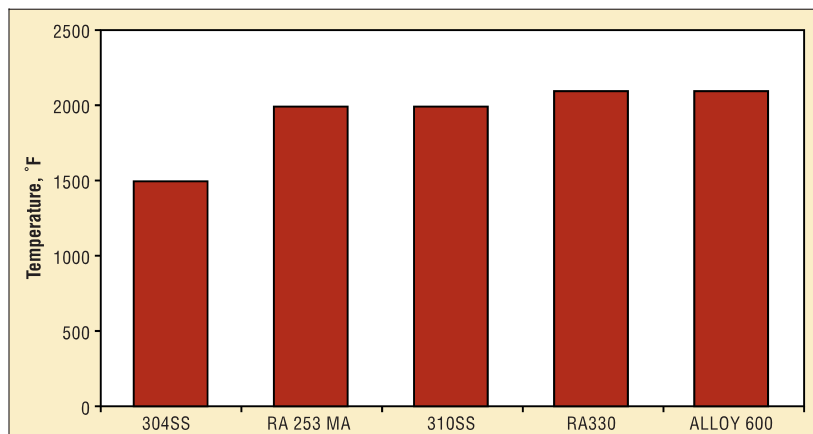


Fig. 3. On top, an RA 253 MA dip tube after six years in service at 1600°F. On bottom, distortion in a dip tube that was typical for 310 stainless after two to three years of service. Dip tubes are 8.5 feet in diameter and 23 feet long and hang vertically.

Table 2. Average stress for 0.0001% per hour minimum creep

Grade	1200°F	1400°F	1600°F	1800°F	2000°F
RA 253 MA	11,600	5,000	2,300	890	(250)
304/L SS	10,800	2,050	-	-	-
310 SS	14,900	3,300	1,100	280	-
RA330	7,600	3,600	2,100	500	-
Alloy 600	-	-	2,000	560	270

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their high nickel and lower chromium contents will not. Solution annealing at 2050°F (when practical) can dissolve the sigma phase and restore room-temperature ductility in RA 253 MA.

Case History #1: Coal-Fired Power Plants

RA 253 MA has been used in the heat-treat and furnace industries, but its most significant use has been in coal-fired power plants to replace 309 and 310 stainless. Here, it has proven its ability to withstand distortion better than other stainless steels. It has been commonly used for pulverized-coal injection nozzles in typical supercritical boilers as well as for cyclones in fluidized-bed boiler systems.

Case History #2: Isothermal Annealing of Forgings

A Midwestern commercial heat-treat shop has been using corrugated boxes manufactured from 11-gauge (0.120-inch) RA 253 MA sheet (Fig. 4). Two different-sized boxes are used. The operation is an “isothermal anneal” of various carbon-steel forgings. The typical annealing temperature for most of the forgings is 1750°F with a maximum temperature of 1800°F. This is followed by fan cool to 1185°F and then a still-air cool. Loads are up to 900 pounds.

Distortion is a problem because the boxes are a rather close fit in the furnace. As the sides bow out, they scrape away at the furnace insulation, which must be replaced. RA330 holds its shape fairly well until it cracks, which is an acceptable failure mode. Alloy 309 distorts very badly, which is not too surprising considering it has about half the creep strength of RA330. RA 253 MA has been the material of choice for the past four years based on its lower initial cost than RA330 and its equal or better resistance to distortion.

Another captive heat-treat shop is also using corrugated RA 253 MA boxes of much larger dimension (Fig. 5). Also made from 11-gauge sheet, these boxes are 72 inches square. The bottoms of the boxes also utilize RA 253 MA round bar, 5/8 inch in diameter. This isothermal anneal is performed at 1600°F followed by controlled cooling to 1250°F.

Case History #3: Steel Wire Annealing

RA 253 MA pipe is being used at one wire manufacturer for the heat treatment of steel wire between 1650 and 1800°F. Twenty-

foot-long annealing tubes made from 1-inch, schedule-40 pipe are used in the furnace. A nitrogen atmosphere fills the tubes. RA 253 MA has been the material of choice for over 10 years after testing side by side with nickel alloys such as RA330, alloy 601, Haynes 230® and alloy 600. The life of RA 253 MA is similar to alloy 601 at about 40% of its cost.



Fig. 4. RA 253 MA corrugated boxes shown cooling down upon exiting an isothermal annealing operation at 1750°F.

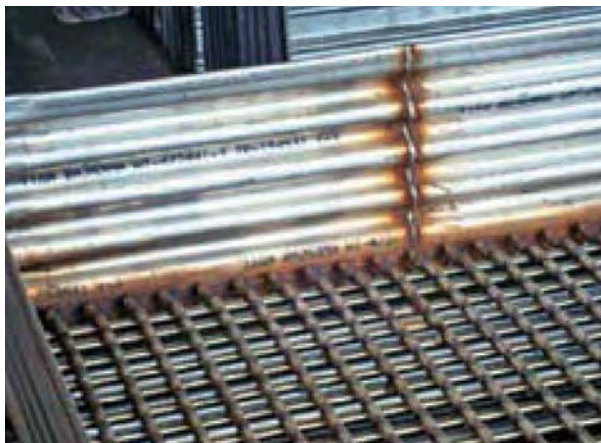


Fig. 5. Close up of corrugated box and fabricated bottom grid, both made from RA 253 MA for an isothermal annealing process at 1600°F.

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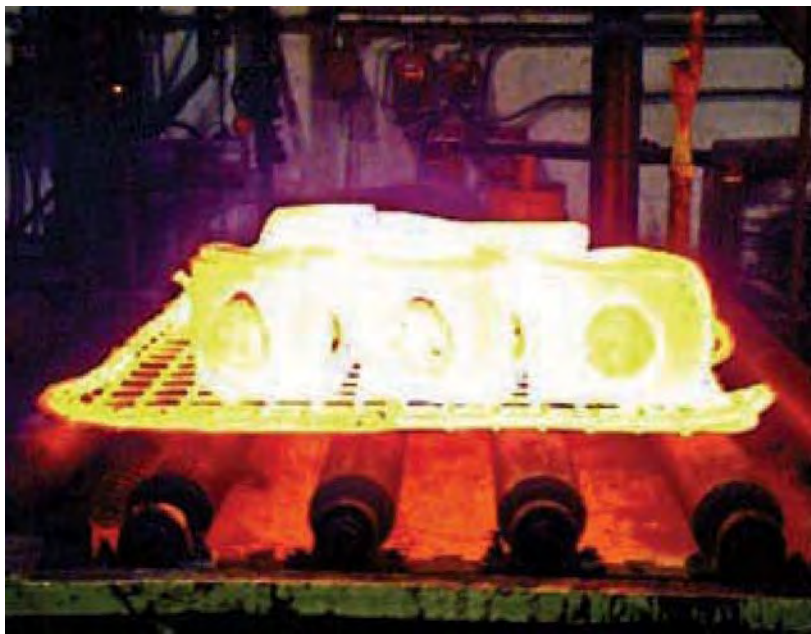


Fig. 6. RA 253 MA bar-frame basket manufactured from 1/2-inch-diameter round bar

Case History #4: Bar-Frame Baskets for Heat Treatment of Castings

A commercial heat-treat shop in the southern U.S. is now using shallow baskets made from 1/2-inch diameter RA 253 MA round bar. The basket is fabricated using pressure welding. The heat treatment of castings in this shop involves heating to 1800°F followed by a water quench. Prior to RA 253 MA being used, the baskets were made of RA330 alloy. RA 253 MA and RA330 both typically last roughly 350 cycles before replacement. During use, both RA 253 MA and RA330 require straightening. The average load on the baskets is 2,500 pounds, and the heat-treatment cycle lasts between four and eight hours.

Case History #5: Pier Caps for Titanium Billet Heat Treatment

Pier caps fabricated from 3/8-inch-thick RA 253 MA plate replaced 1/2-inch-thick type 304 stainless pier caps at this U.S. titanium company. Operating temperatures were typically 1750°F with occasional excursions to 1900°F. The atmosphere in this car-bottom furnace was gas-fired and oxidizing. Cycles varied in length from two to eight hours. The type 304 stainless caps

lasted about three months until oxidation and distortion necessitated their replacement. Type 304 stainless is not suggested for use at temperatures above 1600°F. The lead photo of the RA 253 MA pier caps was taken after eight months, and expectations were for total life for the piers to be in excess of two years. At the time of the photos, the RA 253 MA had already paid back its higher initial cost. **IH**

References:

1. J. Hamer and J. McConnell, *Industrial Heating*, April 1992

253 MA is a trademark of Outokumpu Stainless. RA330 is a registered trademark of Rolled Alloys, Haynes, 230 and 214 are registered trademarks of Haynes International.

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