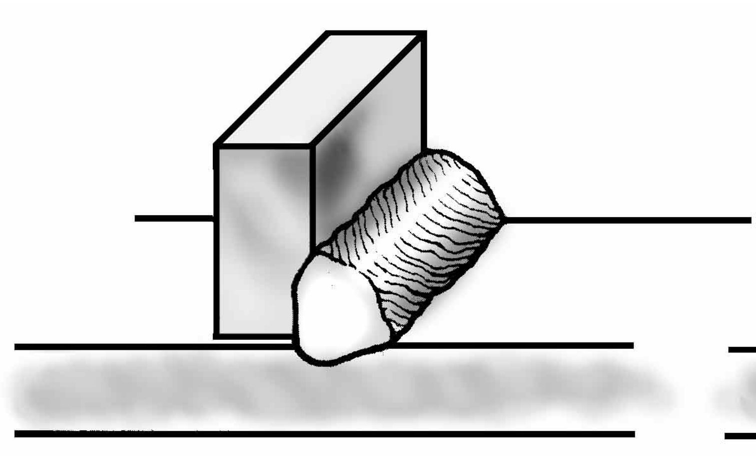
ROLLED ALLOYS
WELDING RA330®

The heat resistant alloy RA330 is readily welded using appropriate practice. To make sound weldments which give lasting performance at red heat, consider the following points:

1. REINFORCED BEAD CONTOUR

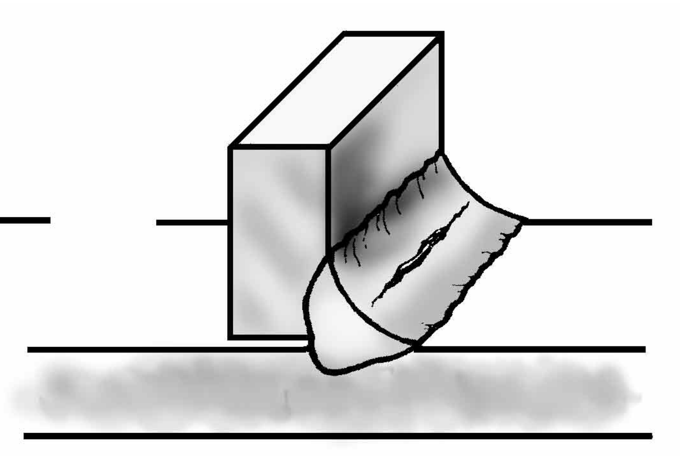
Make convex stringer beads with little or no weave. Broad, flat beads tend to crack down the center.

CONVEX BEAD



Desirable weld bead contour to avoid hot tearing as weld cools.

CONCAVE BEAD



Undesirable bead shape for heat resisting alloys, tends to crack down the center.

2. LOW HEAT INPUT

Keep heat input low and interpass temperatures below 212°F (100°C). Do not preheat RA330, beyond that necessary just to dry the work. Unlike steel, the faster an RA330 welds cools, the less likely it is to crack.

Highly restrained welds are least likely to crack when made with covered electrodes (SMAW). This is because heat input (amount of molten metal deposited per hour) tends to be less with covered electrode. In addition, DC lime type electrodes naturally deposit a strong, reinforced bead contour.

Gas metal arc welding (GMAW) should be done at the lowest current which will give acceptable metal transfer and tie-in. With RA330-04 .045” dia. wire, for example, spray-arc transfer begins at about 190 amperes.

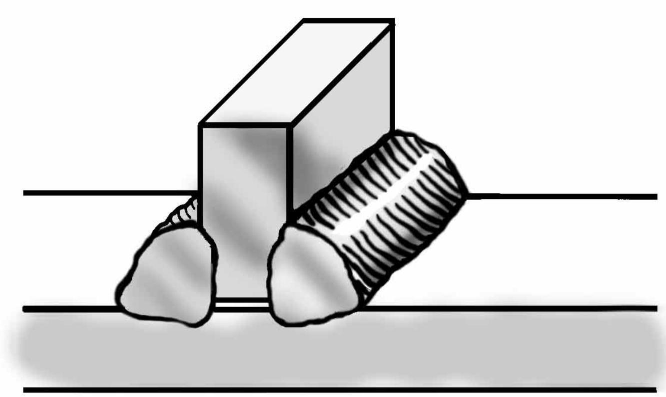
3. USE RA330-04

Choose the right weld rod. Normally this means RA330-04, both for weldability and to match the base metal properties. RA330-80 and RA333-70-16 electrodes, and RA333® wire can be used. Some high nickel weld fillers will also make sound welds in RA330, but at a sacrifice in oxidation resistance. These include 82 and 62 bare wire, and covered electrodes “A” (ENiCrFe-2) and 182.

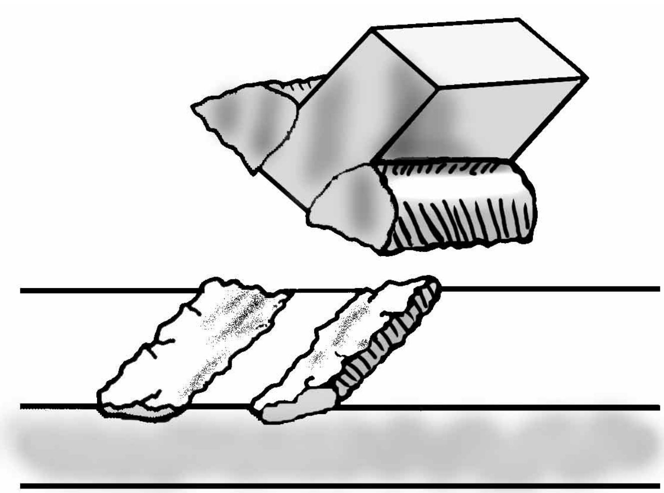
There are certain alloy weld fillers which just aren’t satisfactory for use with RA330 base metal. Specifically, do not use the AWS grades ER330 wire and E330-16 electrodes. Such “Type 330” fillers generally crack and require a great deal of repair when used to join RA330. Stainless electrodes, including 308, 309 and 310, crack when used on RA330. AWS E312 electrodes do make sound welds. But, an E312 weld embrittles severely around 600-1100°F (300-600°C) and is very weak at red heat.

4. FULL PENETRATION JOINTS

Make completely penetrated welds. Lack of adequate penetration is the most common cause of weld failures in service.



This un-welded cavity acts as a crack starter. Repeated thermal expansion and contraction will cause cracks to grow out through the weld.



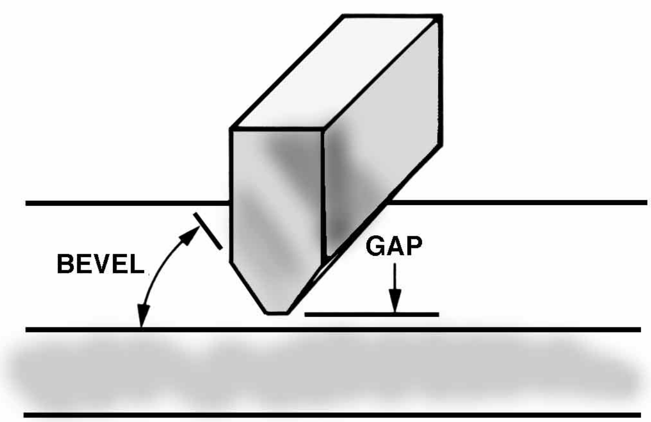
Until it breaks apart completely.

4. FULL PENETRATION JOINTS (continued)

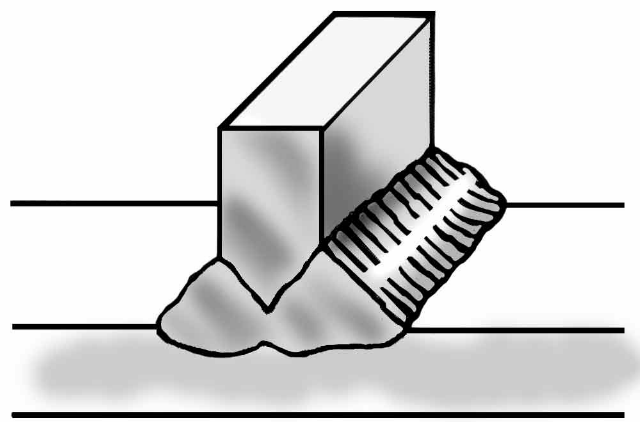
Such failures are aggravated by heavy sections, very high temperature service, the severe thermal shock of quenching, or vibration as may occur in fans.

In carburizing environments, carbon from the atmosphere may deposit in such cavities. As carbon deposits, it pries the cavity open progressively larger, to complete fracture.

Molten salt bath heat treat fixtures may fail very quickly at incompletely penetrated welds. The molten salt easily seeps through minor weld defects and fills the internal cavities. After repeated heat cycles this salt literally forces the joint apart.



To get full penetration in RA330 the joint must be open so that weld metal may be placed at the root. This is achieved by beveling one or both sides, and with a root gap of 1/16 to 1/8”.

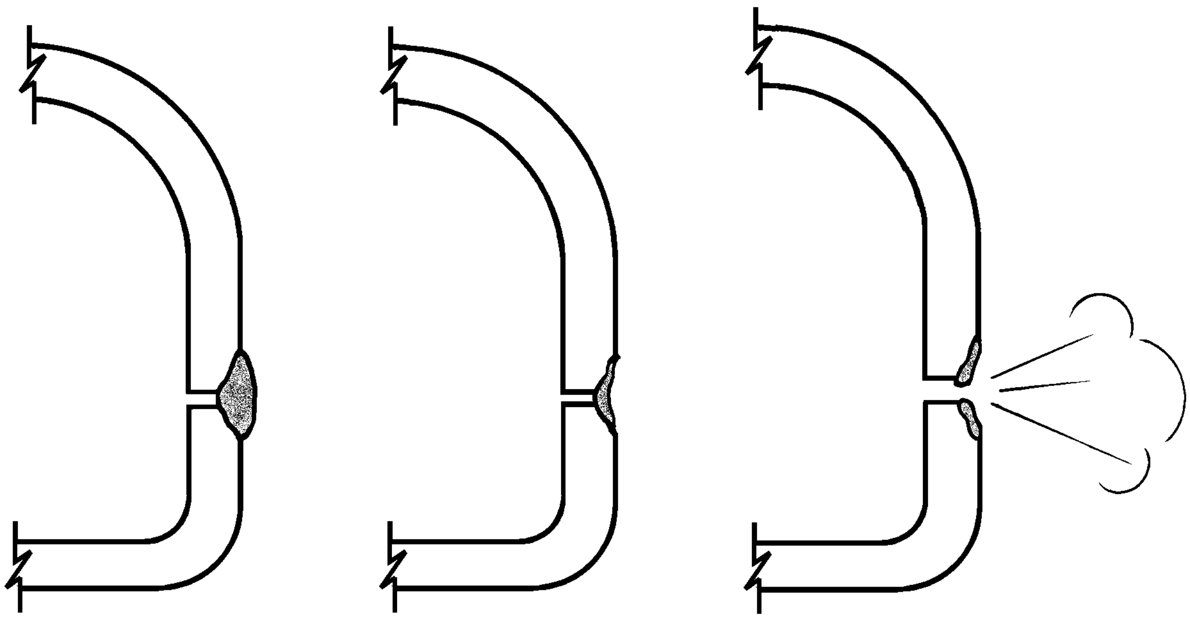


The result of such joint preparation is a fully penetrated weld with optimum strength.

4. FULL PENETRATION JOINTS (continued)

Muffles and radiant tubes, subject to environments above 2000°F (1100°C), require both full penetration welds and the right filler metal for long life. Higher nickel in the weld metal does not ensure better performance. This is because many high nickel weld fillers also contain 2-3% columbium, or as much as 9% molybdenum. Both additions can be extremely detrimental to oxidation resistance at 1800-2200°F (1000-1200°C) working temperatures.

This "weld seam oxidation" problem can be minimized by welding with the 28% chromium electrodes RA 353 MA.



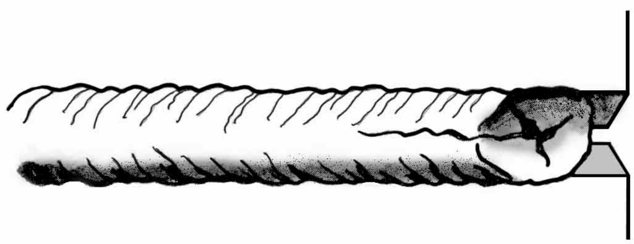
This shallow weld in a D-shaped muffle may

thin by oxidation after long 2000°F (1100°C) service

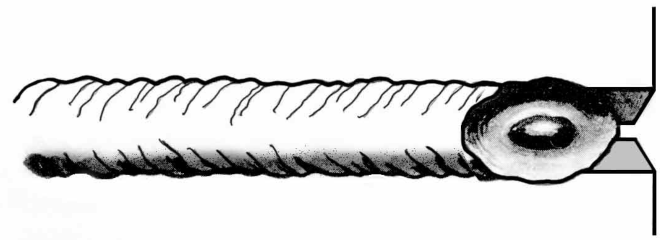
and then leak atmosphere, which may burn with local overheating or melting.

5. FILL CRATERS

Craters at the end of a weld may crack unless filled. The cracks may then run back into previously sound metal. Craters may be filled by back stepping, or reversing direction for about 1/2" at the end of a weld.



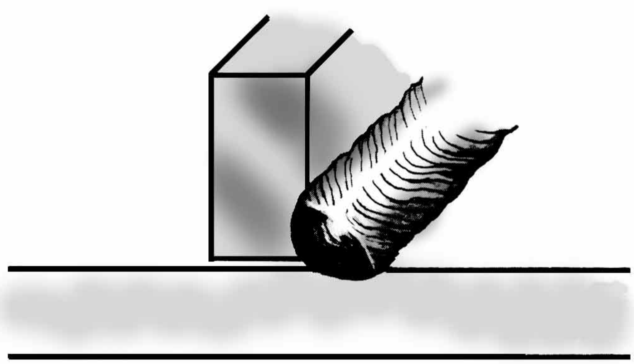
Craters crack



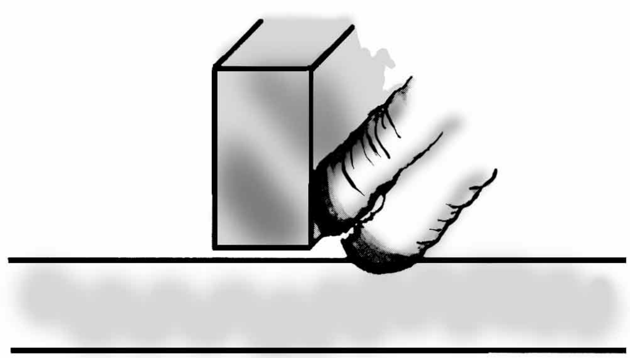
Unless filled or backstepped

6. HEAVY STARTS

Starting beads should be filled in to minimize chances of cracking.



Starts should be as heavy as the rest of the bead.



Thin, weak starting beads may crack.

7. ADD FILLER TO GAS TUNGSTEN ARC WELDS

It is extremely difficult to GTAW RA330 without adding a filler metal designed to resist hot cracking. For example, just fusing the root pass with a GTA torch will usually result in a crack down the center of the bead. The cure is simply to use enough RA330-04 filler wire. Make the weld bead mostly RA330-04, without much dilution by the RA330 base metal.

8. PROPER GAS SHIELDING

Pure argon is often used for GMAW on high nickel alloys. Disadvantages are poor bead tie-in, and a tendency for arc wander. Adding helium to the argon improves bead contour, while a small amount of CO_2 (1/2% to no more than 2-1/2%) will stabilize the arc.

Suggested gases for both spray-arc transfer and pulsed arc include 100% Ar, 75% Ar - 25% He, and 81% Ar - 18% He - 1% CO_2.

For short circuiting arc transfer the most common shielding gas is 90% He - 7-1/2% Ar - 2-1/2% CO_2. Others include 68% Ar - 30% He - 2% CO_2, 81% Ar - 18% He - 1% CO_2, and 75% Ar - 25% He.

Manual GTAW requires 100% argon shielding. Helium may be added to increase heat input and travel speed in automatic welding.

DO NOT USE 95% AR - 5% O_2 or 75% Ar - 25% CO_2 SHIELDING GAS WITH RA330.

9. CLEANLINESS — BEFORE AND AFTER

Copper, brass, lead, aluminum, zinc or other low melting alloys smeared on the base metal may cause both weld bead cracking and base metal heat affected zone cracking. Sources of metallic contamination include soft metal hammers, metallic zinc paint, Kirksite forming dies and, on occasion, the copper back-up bar. All machining or forming lubricants must also be removed prior to welding.

Welding over scale on hot rolled annealed (HRA) alloy, or steel, will increase incidence of weld defects. It is cheaper to remove the scale first, or purchase pickled materials, than to grind out and repair weld the defects.

Remove the slag! Welding fluxes with high fluoride contents are extremely corrosive at high temperature. “Corrosion” includes disrupting the protective oxide scale so that the alloy carburizes rapidly in heat-treat service. It is good practice to remove all traces of flux before exposing the weldment to high temperature service.

10. THE RIGHT CURRENT

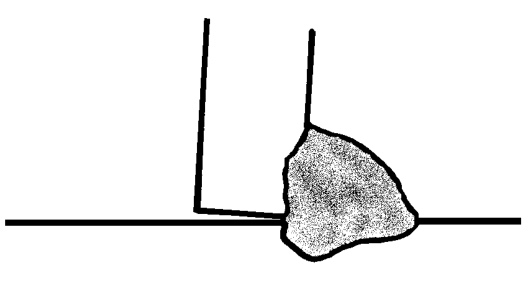
DC lime type electrodes, such as RA330-04-15, work only with direct current (DC). If they are connected to alternating current (AC) it will be very difficult to keep the arc from extinguishing. The use of an AC source with DC lime electrodes will be extremely unsatisfactory if not impossible.

AC-DC electrodes, such as RA330-80-16 or RA333-70-16, may be used with either alternating (AC) or direct (DC) current. Still, AC-DC electrodes operate at their best with direct current, electrode positive (reverse polarity).

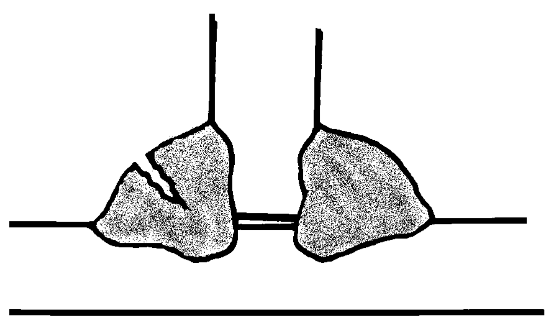
11. THE MATTER OF RESTRAINT

Weld metal shrinks—a lot—as it freezes. Either the base metal or the weld bead must move or stretch to accommodate this shrinkage. During and immediately after solidification, weld beads have low ductility and may tear if stretched too far.

In a complex assembly, each weld completed stiffens the fabrication. This further restricts movement of the base metal during the next weld.

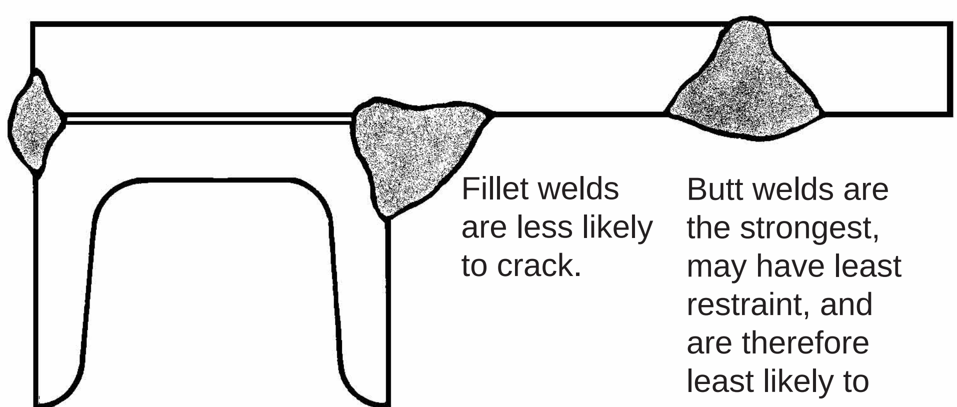


This first fillet weld on plate is easily made.



But the second fillet needs more care to avoid center cracks.

Edge welds are naturally restrained and the most likely to crack.



Fillet welds are less likely to crack.

Butt welds are the strongest, may have least restraint, and are therefore least likely to hot crack.

When cracking is a problem, consider making the most difficult joint in the assembly first (such as the edge weld) and the easiest last.

12. DISSIMILAR METAL WELDING

As a rough guide, when joining two different alloys use the weld filler meant for the more highly alloyed base metal. For example, when joining RA330 to RA309, RA330-04 weld metal is appropriate. Another weld filler, 617, can be used for a variety of dissimilar metal joints, intended to operate under 2000°F (1100°C). Differences in thermal expansion of the two materials should be taken into account to minimize thermal stresses in high temperature service. This is one reason that joints involving austenitic alloy to Cr-Mo steel boiler tubes are commonly made with ENiCrFe-3 electrodes.

Weld procedures should be qualified before going into production with any dissimilar metal weld.

SUGGESTED WELD FILLERS FOR DISSIMILAR METAL JOINTS
Heat Resistant Alloys

Base Metals	Carbon or Low Alloy Steel[A]	Stainless (304, 316, 309, 310)	RA 253 MA®	RA 602 CA™	Cast Alloys[B] HH	Cast Alloys[B] HK, HT, HP
RA330® RA800H/AT	182, 82, RA330-04	RA330-04	RA333	617[C] 6225 Al RA333	RA330-80-15, RA330-04	RA330-80-15, RA330-04, RA333
RA 353 MA®	182, RA82 RA 353 MA	RA 353 MA	RA 353 MA	617[C] 6225 Al	RA330-80-15 RA 353 MA	RA330-80-15 RA 353 MA
RA333®	182, RA333	RA333, RA82, 182	RA333	617[C] 6225 Al	RA333	RA333
RA601	82, 182	82,182	RA333	S 6025 6225 Al	RA333	RA333
RA600	82, 182	RA82,182	RA330-04	82, 182 S 6025	182, RA330-80-15	RA330-80-15, RA333, RA330-04
RA 602 CA™	82 182	82 182	617	S 6025 6225 Al	617[C]	617[C]
RA 253 MA®	309	RA 253 MA 309	RA 253 MA RA333	617[C]	RA 253 MA	RA330-80-15, RA333
RA446	309	309	309	309	309 RA 253MA	RA330-80-15

Notes:

A. When joining to carbon steel, be certain to grind all mill scale and rust from the steel in and near the weld joint. Preheat only as necessary for the carbon steel grade involved.

B. RA330-80-15 DC lime electrodes are particularly useful for welding the cast heat resistant alloys. Note that the high carbon content, 0.85%, of RA330-80 weld beads does preclude their passing conventional bend tests.

C. At this writing, 2002, there is limited experience with RA 602 CA in dissimilar metal welds. Alloy 617 (ERNiCrCoMo-1) has been used to join RA 602 CA, although it does lack the oxidation resistance of RA 602 CA.

13. REPAIR WELDING

Heat resistant alloy equipment is often repair welded to extend its useful service life. Success or failure of the repair procedure depends on how badly the alloy has been embrittled by service conditions, on how experienced the shop is in repair welding and, frankly, on a certain degree of luck.

A pocket magnet is a useful first guide to the possibility of repair welding a particular area. Wrought austenitic heat resisting alloys are non-magnetic as supplied. Strong magnetism usually means the alloy is heavily carburized on the surface. The alloy can also become magnetic from severe intergranular oxidation such as may occur in salt pots or in the skirts of sand sealed retorts. In either case, it is difficult to repair weld highly magnetic areas.

Remove all scale in the area to be welded and grind highly magnetic surfaces down to sound metal. Cracks should be ground out, although with highly carburized material grinding itself may cause cracking.

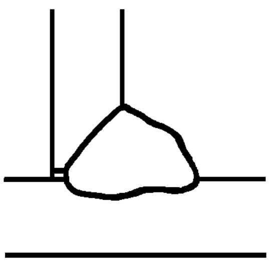
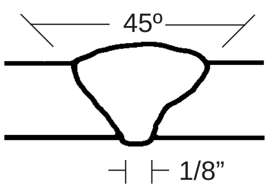
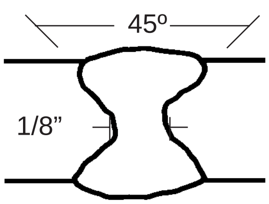
Use small diameter covered electrodes with DCRP at as low a current as will maintain a stable arc. Some shops feel that peening each pass reduces weld shrinkage stress, hence reduces chances of base metal cracking next to the weld.

Choice of electrodes depends on what will best stick to the individual job in question. This may sound crude, but because of sub-surface oxidation the weld metal will not always wet or tie-in to the old base metal For this reason, coated electrodes are preferred for repairing used heat resistant alloy equipment. The coating helps flux away internal oxides and scale that might have been missed during joint preparation.

Various nickel alloys such as RA333-70-16, RA330-04-15 and ENiCrFe-3 are used successfully for weld repair. AWS E312, and the “magic” trade named varieties of 312, should be avoided. These 29Cr-9Ni welds soon break in high temperature service.

Many shops have found RA333-70-16 electrodes exceptionally useful for repairing components which have been carburized. RA333 electrodes develop a very fluid weld puddle at relatively low current. Lower heat in turn avoids cracking of alloy parts embrittled from service. In use, the RA333 weld may outlast the original part.

ELECTRODE AND GMAW WIRE CONSUMPTION FOR VARIOUS JOINT DESIGNS

JOINT DESIGN	PLATE THICKNESS, INCHES	APPROXIMATE WEIGHT, IN POUNDS, OF		
		METAL DEPOSITED PER LINEAL FOOT WITH REINFORCEMENT	ELECTRODES REQUIRED (A)	GMAW WIRE REQUIRED (B)
SINGLE FILLET 	1/8 3/16 1/4 3/8 1/2 5/8	0.032 0.072 0.13 0.29 0.52 0.80	0.064 0.144 0.26 0.58 1.03 1.61	0.038 0.085 0.15 0.34 0.60 0.94
"V" GROOVE 	1/4 3/8 1/2	0.37 0.62 0.85	0.73 1.23 1.7	0.43 0.73 1.00
DOUBLE "V" GROOVE 	1/2 5/8 3/4 1	0.77 0.95 1.32 1.83	1.53 1.90 2.63 3.65	0.90 1.12 1.55 2.16

(A) Assumes 50% deposition efficiency
(B) Assumes 85% deposition efficiency

TYPICAL OPERATING PARAMETERS

COVERED ELECTRODES (SMAW)

Diameter, inch	Current, DCRP (electrode positive) amperes
3/32	40-70
1/8	70-100
5/32	100-135
3/16	125-180

GAS TUNGSTEN ARC WELDING (GTAW, or TIG)

2% Thoriated Tungsten electrode dia., inch	Direct Current Straight Polarity (electrode negative), amperes	Voltage	Shielding Gas Argon or argon-helium mixes, CFH
.040	25-80	10-14	25
.062	50-145	12-16	25
.094	135-235	12-20	25

GAS METAL ARC WELDING (GMAW, OR MIG)

Spray arc transfer wire dia., inch	Minimum current, DCRP, for spray transfer, amperes	Volts
0.035	160	26-30
0.045	190	26-30

Shielding gas 100% argon

Short circuiting arc transfer Wire dia., inch	Current, DCRP amperes	Volts
0.035	75-120	18-22
0.045	100-140	18-22

HEAT RESISTANT ALLOY WELDING CONSUMABLES

Nominal Composition (balance iron)

Grade	UNS	AWS	Cr	Ni	C	Si	Mn	Mo	Co	W	Other	Ferrite Number
RA330-04 wire	N08334	—	19	35	.25	.8	5.2	—	—	—	—	0
RA330-04-15	W88334	—	17.5	33.5	.22	.8	5.2	—	—	—	—	0
RA330-80-15	W88338	—	17.5	33.5	.85	.8	2.2	—	—	—	—	0
RA333® wire	N06333*	—	25	45	.05	1	3	3	3	3	—	0
RA333-70-16	W86333*	—	25	45	.05	1	2.5	3	3	3	—	0
RA602 CA wire	—	ERNiCrFe-12	25	63	.18	.03	.05	—	—	—	2.2 Al .08 Y	0
RA602 CA covered electrodes	—	ENiCrFe-12	25	62	.2	.5	.1	—	—	—	2.3 Al .1 Ti	0
RA 353 MA® wire	—	—	28	34	.04	.7	1.7	—	—	—	.15 N .03 Ce	0
RA 353 MA-15	—	—	26	35	.08	.5	1.5	—	—	—	—	0
RA 253 MA® wire	S30815	—	21	10	.07	1.6	.6	—	—	—	.16 N .05 Ce	7
RA 253 MA-16	W30816	—	21.5	10.5	.05	1.6	.7	—	—	—	.17 N Ce	7
RA309-16	W30910	E309	23	13	.1	.5	1.9	—	—	—	—	7
RA310-15	W31010	E310	26	20	.1	.4	1.8	—	—	—	—	0
RA82 wire	N06082	ERNiCr-3	19	72	.04	.2	.3	—	—	—	2.7 Cb .5 Ti	0
182	W86182	ENiCrFe-3	16	65	.04	.6	7.8	—	—	—	2 Cb .2 Ti	0

*Except manganese

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Bulletin No.201 1/03 5C