RA2205 Duplex Stainless

ROLLED ALLOYS

The world's heat, corrosion, titanium, and aerospace alloy specialists.

RA2205 DUPLEX STAINLESS

CONTENTS

DESCRIPTION

RA2205 stainless is a duplex (two-phase) alloy. It contains about 45-70% austenite in a matrix of ferrite. RA2205 stainless is resistant to chloride stress corrosion cracking, and has good general corrosion resistance. RA2205 stainless is quite strong, with a yield strength about twice that of austenitic stainless.

SPECIFICATIONS:

UNS S31803, S32205 EN, and W. Nr., 1.4462

RA2205 Chemistry Range

Ni	Cr	Mo	C	N	Mn	Si	P	S	Fe
4.50	22.0	3.00	.030	.14	2.00	1.00	.030	.020	remain
6.50	23.0	3.50	max	.20	max	max	max	max	

Minimum Mechanical Properties

Tensile Strength		0.2% Yield Strength		Elongation %	Hardness, Brinell
psi	(MPa)	psi	(MPa)		
90,000	(620)	65,000	(448)	25	290 max

ASME 2001 Section VIII, Div. 1, Maximum Allowable Stress Values *

Temperature °F	-20 to 100	200	300	400	500	600
Design stress ksi	25.7	25.7	24.8	23.9	23.3	23.1

Note G32 This steel may be expected to develop embrittlement after service at moderately elevated temperatures; See Appendix 6. For P-No. 10H Gr. 1 materials, exposure to temperatures in the range of 1100F to 1700F for relatively short periods of time may result in severe loss of ductiliy due to sigma formation; see 6-340 and 6-360

For external pressure design, use Chart No. HA-5, in Section IID

Section IIA SA-182 Flanges, Fittings and Valves, SA-240 Plate, Sheet & Strip SA-479 Bar, SA-789 Seamless and Welded Tube, SA-790 Seamless and Welded Pipe, SA-815 Piping Fittings. Section VIII Div. 2 case 2067-2,. ASTM A 923 Detecting Detrimental Intermetallic Phase.

RA2205 is P No. 10H, Group 1, ASME Section IX

WELDING CONSUMABLES

GMAW, GTAW and SAW bare wire produced to AWS A5.9, ER2209 (UNS S39209)

Nominal Chemistry: 22.5 Cr; 8.5 Ni; 3.1 Mo; 1.6 Mn; 0.4Si; 0.14 N

SMAW covered electrodes produced to AWS A5.4, E2209 (UNS W39209)

Nominal Chemistry: 22.5 Cr; 9.5 Ni; 3.1 Mo; 0.9 Mn; 0.14 N

FCAW gas-shielded flux cored wire produced to AWS A5.22, E2209T0-1 (UNS W39239)

Nominal Chemistry: 22.5 Cr; 9.0 Ni; 3 Mo; 1.3 Mn; 0.10 N

FORGING

Heat RA2205 uniformly to 2050-2100°F (1120-1150°C). Do not forge at temperatures below 1700°F (930°C). Reheat as often as necessary. Hammer forging is preferred. Dies should have generous radii. Cool forgings in air and anneal, followed by water quench.

Hot tearing or surface checking are possible if the initial forging temperature is too high. As with other high chromium alloys, RA2205 can be sensitive to coarse grinding marks on the forging billet.

In order to dissolve undesirable precipitates occurring from the hot forming operations, and to restore the austenite-ferrite balance, the finished forging should be heat treated at 1950°F (1070°C) minimum for 10 minutes minimum, or 30 minutes per inch (25mm) of thickness, water quenched. Rapid heat-up rate is desired to avoid developing second phases. This alloy has very low strength at the annealing temperature, so the workpiece should be well supported in the furnace. It is important to cool to below 700°F (370°C) as quickly as possible. If the cooling rate is too slow, it will lead to decreased corrosion resistance and lowered impact strength.

COLD FORMING

RA2205 stainless can be readily formed and cold worked using techniques and designs similar to the basic austenitic stainless steel grades. However, due to higher strength and slightly lower ductility, bend radii must be more generous than those used for austenitic materials. Power requirements for forming operations will be greater due to the higher yield strength of RA2205 stainless as compared to standard austenitic stainless.

RA2205 stainless plate can normally be press brake bent over a radius equal to twice the plate thickness. As with other stainless and nickel alloys, bending over a sharp male die may cause the material to crack.

Annealing may be required after 25% cold deformation.

MACHINING

Because of its high strength, RA2205 is generally more difficult to machine than austenitic stainless. With HSS tools the machinability of RA2205 is similar to that of 316L stainless, while with carbide tools the rating is about 65% that of 316L. The following is abstracted from MACHINING GUIDELINES 2205, by Bélla Leffler, Avesta Sheffield AB.

Use the most stable machine tools available. 2205 generates high cutting forces and large loads on tools and set-up. The set-up of tools and workpiece must be rigid. The workpiece must be adequately supported in order to avoid deflections by the cutting forces. Extensions on tools should be kept as small as possible, to avoid 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. 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 vibration.

Use a depth of cut sufficient to let the cutting edge work below the strain hardened layer created by the previous pass. Use the correct cutting speed. A cutting speed which is too low increases the risk of built-up edge formation, tool failure and may result in a poor surface finish of the machined part. 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. 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 parameters given below consist of general guidelines or starting values that may need to be adjusted to the actual conditions of a specific machining operation. These data are based on a tool life of approximately 15 minutes for cemented carbide tools and approximately 40 minutes for high speed tools.

TURNING, Longitudinal and face turning

	Cemented Carbide Tools		HSS tools
	Roughing	**Finishing**	**Finishing**
Cutting Speed, surface ft/min	295-394	394-525	49-66
Feed, inch/rev	0.012-0.024	0.002-0.012	0.002-0.008
Depth of Cut, inch	0.08-0.2	0.02-0.08	0.02-0.08
ISO Cemented Carbide Grade	P 20—P 35	P 10—P 15	- -
~American Industry Standard	C6—C5	C7—C6	

Notes: Use coated cemented carbide inserts with positive chipbreaker styles. Us as small an entering angle as possible during roughing. Use cutting fluid. When roughing, SPUN and TPUN geometries may be used with good results. When face turning large workpieces, use a tougher cemented carbide grade.

MILLING, Face milling with cemented carbide tools

	Roughing	Finishing
Cutting Speed, surface ft/min	164—262	262—361
Feed, inch/tooth	0.008—0.016	0.004—0.008
Depth of Cut, inch	0.080—0.20	0.040—0.080
ISO Cemented Carbide Grade	P 20—P 40	P 10—P 25
~American Industry Standard	C6—C5	C7—C6

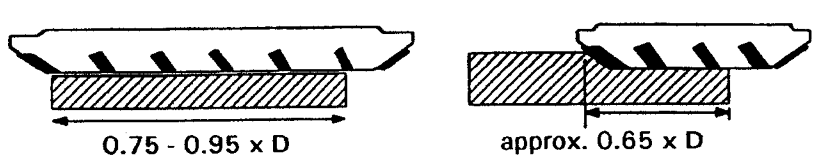
Notes: The feed should give an average chip thickness of not less than 0.004”. The feeds given in the table are valid for a milling cutter with an entering angle of 45°. For other entering angles the feed should be adjusted. The feed value should be multiplied by the correction factor. Use a milling cutter with positive geometry (positive-negative or positive-positive).

Climb milling techniques are preferred. Milling should generally be performed without the use of any coolant. Use inserts with positive chipbreaker styles. For finishing, use inserts with positive chipbreaker styles and sharp cutting edges. When rough milling workpieces with irregular shapes,the use of round inserts with may positive chipbreakers yield better results.

Correction Factors For Entering angles other than 45°

Entering angle	Correction factor
45°	0.9
60°	0.8
90°	0.7

If possible use the following radial cutting depths (D = cutter diameter)



Coolant may be used at low cutting speeds or when a very good surface finish is desired. For longer tool life, reduce the table feed when the tool enters or leaves the workpiece. Observe the chip flow. If the chips stick to the inserts, the cutting speed is unsuitable. Try increasing the cutting speed.

TWIST DRILLING WITH HSS DRILLS

Drill diameter, inch	Cutting speed, surface feet per minute	Feed, inch/revolution
1/32—1/8	20—26	0.002
3/16	33—39	0.004
3/8	33—39	0.008
5/8	33—39	0.010
3/4	33—39	0.012
1 3/16	33—39	0.014
1 1/2	33—39	0.016

NOTES: Suitable drill point geometry: point angle 130°, clearance angle 9—15°, helix angle 40°. Cutting fluid: 10% emulsion. The cutting fluid flow should be ample and directed at the tool. When drilling with short “NC drills” the feed may be increased by up to 15%. For TiN or TiCN coated drills the cutting speed may be increased by up to 10%. When drilling holes deeper than 4 x D, remove chips by periodic withdrawal of the drill. The use of drills equipped with internal cooling fluid channels is advantageous for drilling deep holes. For best tool life and good tolerances, use drills equipped with a self centering drill point geometry.

For large diameter drills web thinning may be advantageous. When using drills equipped with internal cooling fluid channels, the cutting speed may be increased by up to 20%.

HEAT TREATMENT

Solution annealing is performed in the range 1870-2010°F (1020-1100°C). Fixture the workpiece to minimize distortion, as this alloy has low strength at the annealing temperature. The aim point for RA2205 stainless is 1950°F (1066°C) for at least 10 minutes, or 30 minutes per inch (25mm) of thickness, followed by a water quench. If the cooling is too slow, the corrosion resistance of RA2205 stainless will be markedly decreased. Furnace cooling of RA2205 stainless is definitely not recommended, and would result in quite unacceptable mechanical and corrosion properties.

TUBE BENDING AND ROLLING

RA2205 stainless tubes can be bent to a minimum bend radius of 2 times the tube outside diameter (O.D.). This is an inside radius of 1-1/2 times O.D., and a centerline-to-centerline leg spacing of 4 times O.D. Unlike copper alloy or titanium tubes, RA2205 stainless tubes may be rolled to the full thickness of the tubesheet. No provision need be made for staying back from the inside face of the tubesheet. Grooving the tubesheet hole will not increase the pull-out strength of the rolled-in tube. High alloy stainlesses do not flow into the grooves when rolled.

RA2205 stainless tubes may be successfully expanded using 3, 4 or 5-roller expanders. Selection of the number of rolls is largely a matter of personal preference. However, 5-roller expanders tend to be more forgiving when operator skills vary.

WELDING

HEAT INPUT

In welding duplex alloys such as RA2205 it is important to maintain the proper austenite-ferrite balance in the weld metal and in the heat affected zone (HAZ). This is accomplished by using a weld filler metal enriched in nickel, by base metal with 0.14% minimum nitrogen, and by control of welding heat input, preheat, and interpass temperature as appropriate.

RA2205 should be welded with fairly high heat input, comparable to that used for common stainless (e.g., 304L or 316L). Do NOT treat RA2205 like a nickel alloy—low heat input and tiny stringer beads are undesirable when welding a duplex stainless. This heat input assists transformation of excess HAZ ferrite back to austenite as the weldment cools. High heat also minimizes chromium nitride precipitates in the ferrite. The suggested range is 15 to 63.5 kJ/inch (0.6 to 2.5kJ/mm). The lower end of the range is used with covered electrodes in the flat position. Higher heat is required for vertical SMAW welds.

When a very low heat input (less than 15 kJ/inch) welding process must be used for plate 5/8" and thicker, preheating 200-300°F (100-150°C) is suggested. The purpose is to prevent rapid cooling and too high a ferrite content. Maximum weld interpass temperature should be 300°F (150°C). This is critical for welding RA2205. Measure interpass temperature with a contact pyrometer. Take care not to contaminate the joint with temperature measuring crayons.

Heat input in kJ/inch is calculated:

$$\frac{\text{Voltage x Amperage x 6}}{\text{Travel Speed (inch/minute) x 100}}$$

The arc should always be struck at a point within the joint itself. An arc scar is essentially an autogenous weld, rapidly cooled, and will be nearly 100% ferrite. Any arc scars on the base metal should be removed by fine grinding.

FILLER METALS

Enriched nickel weld fillers have been developed to further assure proper phase balance in RA2205 stainless weldments. The higher nickel, 8% in bare wire, 9.5% in covered electrodes, and 9% in flux cored wire, promotes transformation of ferrite to austenite as the weld bead cools. These enriched nickel weld fillers are designated RA2209, to distinguish them from the lower nickel RA2205 base metal. In addition to nickel, it is desirable to have 0.14% minimum nitrogen to achieve phase balance. The AWS requirements are not sufficient in this respect, being only 0.08-0.20% N.

When it is required to maximize both toughness and critical pitting temperature of a weld bead, the over-alloyed duplex 2507 (Avesta P100, Sandvik 25.10.4.L) GTAW wire may be used for the root pass (process side).

Nickel alloy weld fillers have markedly lower erosion resistance than duplex stainless and ought generally be avoided except where required for dissimilar metal welds. High columbium levels in weld fillers such as ERNiCrMo-3 may deplete nitrogen from the adjacent RA2205 base metal.

WELDING PROCESS VS PROPERTIES

Choice of welding process affects both impact toughness and critical pitting temperature (CPT), in opposite directions.

In order of increasing impact toughness: SMAW AC/DC, FCAW, SMAW DC-basic, SAW, GMAW argon shielding, GMAW 95Ar 3He $2N_2$ shielding, and GTAW.

In order of increasing pitting resistance (CPT): GTAW, GMAW, SAW, FCAW, SMAW DC-basic, SMAW AC/DC.

SHIELDED METAL ARC (SMAW)

Use stringer beads with RA2209PW nickel enriched covered electrodes in the flat position. A slight weave, not exceeding two times the diameter of the electrode, may be used. Weaving is unavoidable in vertical welds.

Maintain as short an arc length as possible. A "long arc" or increased gap between electrode and workpiece may result in weld porosity and excessive oxides in the weld. Avoid welding in the presence of direct drafts of air, wind, or fans.

Remove all slag from each filler pass by use of chipping tools, fine grinding or stainless wire brushes. Do NOT use carbon steel brushes!

RA2209 covered electrodes must be kept dry to avoid porosity and hydrogen embrittlement of the weld. Store these electrodes in a non-humid environment at 100°F (38°C) or higher and use while they are still warm, from a heated quiver.

COVERED ELECTRODES (SMAW)

Electrodes which have absorbed moisture may be dried out by baking in an electric oven for about 3 hours at 480°F (250°C). If the electrodes are baked too hot, or too long, the arc characteristics will change undesirably.

Typical SMAW Parameters

Electrode dia		Current,	Voltage
inch	mm	amperes	
3/32	2.4	60-80	22-28
1/8	3.2	80-110	22-28
5/32	4.0	100-160	22-28
3/16	4.8	130-180	22-28

GAS METAL ARC WELDING (GMAW)

RA2205 plate is GMA welded using either the spray arc or pulsed-arc transfer mode. Short circuiting arc transfer is used for welding thin sheets and for out-of-position welding. Pulsing arc transfer provides some of the benefits of spray arc at a lower average heat input, which permits the method to be used on sheet gauges and in all positions. Heat inputs should be maintained around 20-45 kJ/inch (0.8-1.8 kJ/mm). The upper end of the range is not critical.

Appearance—on duplex stainless the gas metal arc process makes a ropey looking weld bead with a dirty gray oxide color. While unattractive, this is quite normal for GMAW using RA2209 wire. Do clean this oxide off between weld passes.

Shielding gas is normally 100% welding grade argon having a nominal purity of 99.996% and a dew point of -77°F (-60°C). 2% nitrogen may be added. Helium may be added if desired to flatten the bead contour. Argon-25% helium is desirable to get good edge fusion when welding very heavy plate with small diameter wire. A newer gas mixture with desirable characteristics is 95%Ar 3%He 2%N_2. Do not add oxygen or hydrogen. Oxygen or hydrogen contamination lowers impact toughness in duplex stainless weldments.

Typical GMAW Parameters

Spray-arc transfer, 100% argon shielding at 24-36 SCFH (11-17 liter/min)

Wire dia.,		Direct Current	Voltage
inch	mm	Reverse Polarity,	range
0.035	0.9	170-200	24-28
0.045	1.14	180-260	27-31
0.062	1.6	230-350	26-32

SUBMERGED ARC WELDING (SAW)

When sub-arc welding RA2205 stainless, use a highly basic flux, such as Avesta Flux 805. Do not use acid fluxes meant for 18-8 stainless. Heat inputs in the range 45-55 kJ/inch (1.8-2.2kJ/mm) are preferred.

Typical SAW Parameters

Wire size		DCRP Current	Voltage
inch		mm	amperes
3/32	2.4	250-450	28-32
1/8	3.2	300-500	29-34
5/32	4.0	400-600	30-35

FLUX CORED ARC WELDING (FCAW)

The enriched nickel flux cored wire developed for use with RA2205 is designated E2209TO-1 in AWS A5.22, with the UNS number W39239.

Shielding gases used are either 75% argon, 25% carbon dioxide or 100% carbon dioxide. Argon-CO_2 offers the best weldability in the horizontal position while 100% CO_2 is preferred for vertical welding.

The use of flux cored welding can reduce fabrication costs, as compared to using solid wire. Fabricators should be aware, before quoting the job, that some end users may not permit flux cored welding of pressure boundary joints.

Typical FCAW Parameters With 0.045” (1.14mm) dia. wire are:

	75% Ar - 25% CO_2, horizontal position	100% CO_2, vertical position
Amperes	150-250	60-110
DCRP (electrode positive)		
Volts	22-38	20-24

Use stringer beads with very little weave. Weaving will tend to trap slag at the edges of the bead. Allow the metal to cool down below 300°F (150°C) between passes.

GAS TUNGSTEN ARC WELDING (GTAW)

With GTAW, use straight stringer beads. Limit dilution of the weld bead by RA2205 base metal. This is particularly important in tack welding and during the root pass. If there is any problem with tack welds or root cracking it is probably due to insufficient weld filler or too low a heat input. Both conditions promote high ferrite contents, and reduced ductility, in the bead.

2% thoriated tungsten electrodes (AWS EWTh-2) are used, 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.

Typical GTAW Parameters

2% Thoriated Tungsten electrode diameter, inch	mm	Direct Current Straight Polarity (electrode negative), amperes	Voltage	Shielding Gas* Argon or argon-2% nitrogen, or argon-helium mixes CFH	liter/min
.040	1.0	25-80	10-14	25	12
.062	1.6	50-145	12-16	25	12
.094	2.4	135-235	12-16	25	12

For light gages, 3/16" (4.8mm) and thinner, heat input should be 20-50 kJ/inch (0.8-2.0kJ/mm) to ensure sufficient austenite in the finished weld bead.

* Do not use hydrogen in the shielding gas. This may hydrogen embrittle the weld. Helium may be added to get deeper penetration and faster speeds in automatic welding.

DISSIMILAR METAL WELDS

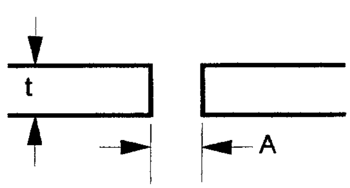
To join RA2205 stainless to:	Suggested Filler Metal
carbon and low alloy steel	E316L, E309LMo, E309L*
austenitic stainless (304,316, etc.)	E316L, E309LMo, E2209, ER2209
other duplex stainless (2507, alloy 255)	E2209, ER2209, 2507
AL-6XN® alloy, 20Cb-3® stainless, 625, C-276, C22 or 686	alloys C-276, C-22 or 686 CPT®

*the use of 2209 duplex stainless weld metal on carbon steel may result in a weld with a hard, brittle martensitic zone of about Rockwell C35.

WELD JOINT DESIGNS

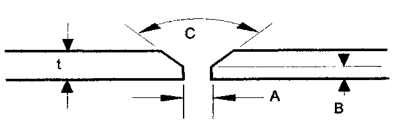
RA2209 enriched nickel weld fillers flow much like 316L stainless. For this reason joints need to be more open at the root, than with carbon steels. A J-or U-preparation may be needed with RA2205 where a V would suffice with carbon steel. Avoid feather-edge roots—these promote high dilution and may result in high FN welds of low toughness. The following are a few suggested joint designs, intended to achieve full penetration welds.

JOINT DESIGN 1. Square Butt



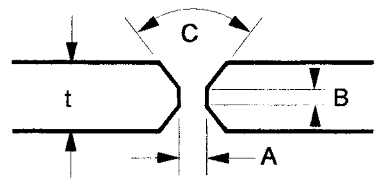
Maximum t = 1/8 inch (3mm)
Gap A - 1/16 to 3/32 inch (1.6 to 2.4mm)

JOINT DESIGN 2. Single "V" Joint



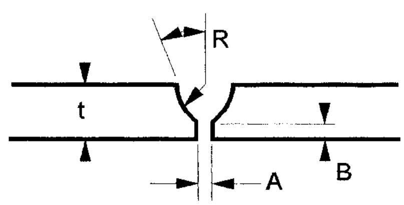
Maximum t = 5/8 inch (16mm)
Gap A = 1/16 to 1/8 inch (1.6 to 3mm)
Land B = 1/16 to 3/32 inch (1.6 to 2.4mm)
Angle C = 60 - 75°

JOINT DESIGN 3. Double "V" Joint



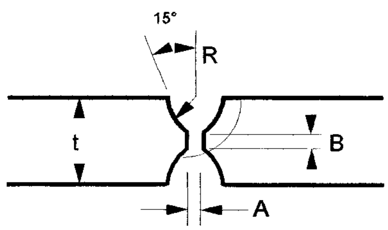
Gap A = 1/16 to 1/8 inch (1.6 to 3mm)
Land B – 1/16 to 1/8 inch (1.6 to 3mm)
t = 1/2 inch or greater (13mm
Angle C = 60 – 75°

JOINT Design 4. Single "U" Joint



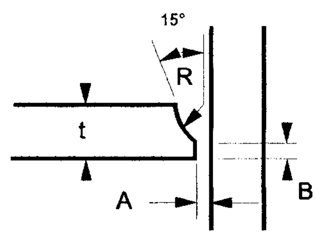
Gap A = 1/16 to 1/8 inch
Land B = 1/16 to 1/8 inch (1.6 to 3mm)
Radius R = 1/4 to 3/8 inch (1.6 to 3mm)
For single groove welds on heavy plate 3/4" (20mm) and over. Reduces the amount of time and filler required to complete weld.

JOINT DESIGN 5. Double "U" Joint



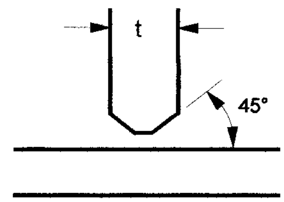
Gap A = 1/16 to 1/8 inch (1.6 to 3mm)
Land B = 1/16 to 1/8 inch (1.6 to 3 mm)
Radius R = 1/4 to 3/8 inch (6.4 to 9.5mm)
Minimum t = 3/4 inch (20mm)

JOINT DESIGN 6. "J" Groove Joint



Gap A = 1/16 to 1/8 inch (1.6 to 3mm)
Land B = 1/16 to 1/8 inch (1.6 to 3mm)
Radius R = 1/4 to 3/8 inch (6.4 to 9.5mm)
For single groove welds on plates thicker than 3/4" (20mm). Reduces the amount of time and filler metal required to complete the weld.

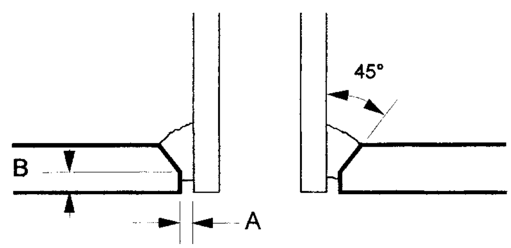
JOINT DESIGN 7. "T" Joint



t = greater than 1/4 inch (6.4mm)

For joints requiring maximum penetration. Full penetration welds give maximum strength and avoid potential crevice corrosion sites.

JOINT DESIGN 8. For Openings such as Manways, Viewports, and Nozzles.



Gap A = 1/16 to 1/8 inch (1.6 to 3mm)
Land B = 1/16 to 1/8 inch (1.6 to 3mm)

REPAIR WELDING

Separate procedures should be qualified for weld repair. The critical issue is the total exposure time of the metal to the "red heat" zone. A maximum cumulative time of 5 minutes in the 1300-1800°F (700-980°C) range is suggested. After this time intermetallic phase precipitation will begin to lower both the corrosion resistance and the notch impact toughness of the weldment. This 5 minutes is the sum of all original welding time and repair welding time to a particular heat affected zone, in addition to the cooling time after plate annealing at the steel mill. At 15 minutes total time the detrimental effects on notch impact toughness and corrosion resistance may become significant.

Weld repair must ONLY be performed with the use of filler metal. That is, a "wash pass" with GTAW torch only is absolutely prohibited. Such a GTAW pass would cool rapidly, developing a very high ferrite structure with reduced properties.

QUALITY ASSURANCE

It is important to both the fabricator and to the end user that quality requirements for duplex fabrication be both relevant to the service and practical to achieve. Mandatory should be NDT, both visual and radiograph, macro geometry of the weld, tensile test and Charpy V-notch testing. Other testing might include hardness, microstructure, corrosion per ASTM G 48 and other NDT such as ultrasonic. Suggestions:

Prior to fabrication a weld procedure should be written and approved by the end user. Both the procedure, and each individual welder's performance, should be qualified by weldment impact testing as covered by paragraph UHA-51, ASME Section VIII, Division 1. Typically, RA2205 weldments should exceed average 35 foot-pound (47 joule) at room temperature and 20 ft-lb (27 joule) at -20°F (°C). The choice of test temperature ought be chosen with the lowest expected service temperature in mind. Location of test specimen is important. Low Charpy values may indicate a high ferrite content, or the presence of sigma phase.

Ferric chloride pitting corrosion testing per ASTM G 48 is sensitive to intermetallic phases. However a reduced critical pitting temperature measured by G 48 is not specifically definitive for sigma, as formation of secondary austenite, common in the middle few passes of a mult-pass weld, can also lower pitting resistance. Unless it is in the root pass exposed to corrosive service this secondary austenite is of no practical consequence. Loss of nitrogen during welding can also lower critical pitting temperature.

Magnetic or metallographic tests for phase balance, and metallography for sigma are questionable. The phase balance issue of interest might be local areas of high ferrite, but these will get lost in magnetic measurements of a material that is already 50% ferritic. Agreement among laboratories with respect to ferrite measurement by point count metallographic methods may be only plus or minus 6 Ferrite Number (FN). Metallography for sigma is very subjective, with agreement among laboratories only on the order of a factor of 2. Volume percent of sigma may be less important than particle size.

ASTM A 923, Detecting Detrimental Intermetallic Phase, was written to ensure that the base metal was adequately annealed at the steel mill. It is also appropriate for material which has been annealed after hot or cold forming. A 923 does not address welding and is inappropriate to use as a quality control specification for weldments. Nevertheless, in the absence of a good duplex welding specification, portions of A 923 are commonly used anyway.

FERRITE MEASUREMENT

If it is considered important to measure the ferrite level in duplex stainless weldments a magnetic method is the suggested means. Magnetic measurement of ferrite is expressed as a Welding Research Council Ferrite Number (FN). This is the only agreed upon means of ferrite measurement in duplex stainless weld metal. There is currently no agreement among laboratories regarding a metallographic method of measuring actual volume per cent ferrite in duplex stainless weld metal itself.

The definitive instrument for ferrite measurement in welds is the Magne-Gage®. With the addition of counterweights it may be used up to 140 FN. This instrument is available from: Magne-Gage Sales and Services, 629 Packer Street, Avoca Pennsylvania 18641 phone 570-457-3477, FAX 570-457-3467. www.magne-gage.com At the high ferrite levels of duplex stainless, Magne-Gage readings are sensitive to vibration. Weld test specimens should be finished smooth with 400 or 600 grit paper, rather than the file finish used for austenitic stainlesses.

A more recent development is the Feritscope® MP30, calibrated to 80 FN. This pocket-size instrument is completely portable and convenient for shop or field use. The Feritscope MP30 is available from: Fischer Technology, Inc., 750 Marshall Phelps Road, Windsor, Connecticut. 06095-2199, phone 860-683-0781, fax 860-688-8496 www.fischer-technology.com

With either instrument the best that can be achieved is to measure the average ferrite level of the region. Given a base metal that is half ferrite, magnetic measurements cannot distinguish any small fully ferritic regions, such as might be present in the HAZ.

James Kelly
Director of Technology
February, 2004

This chart is intended as guidance for what alloys might be tested in a given environment. It must NOT be used as the major basis for alloy selection, or as a substitute for competent corrosion engineering work.

Alloy selection for corrosive process environments is a complex process. It should include experience with similar equipment, extensive testing in the exact corrosive environment of interest, and detailed knowledge of the various alloys to be considered. Oftentimes minor contaminants can cause major changes in corrosion rates. One example is contamination of organic chlorides with small amounts of water. This can permit the organic compound to hydrolyze, forming hydrochloric acid. The HCl in turn, may aggressively pit or stress corrode the standard 18-8 stainless steels. Other examples are the alloys B-2, 200, and 400, which contain no chromium. While they have excellent corrosion resistance in reducing environments, they have little or no resistance to oxidizing environments. Unexpected failures may therefore arise from contamination by small amounts of oxidizing salts (e.g., $FeCl_3$, $CuCl_2$ or $NaClO_3$), or sometimes even dissolved oxygen. Titanium behaves in the opposite manner, and requires the presence of oxidizing species for best resistance to HCl.

Alloy Performance Guide

ENVIRONMENT	Not Suggested	Good	Better	Best
CHLORIDES (pitting, crevice corrosion)	304L	RA20 RA333® 316L, 200(a), RA600	RA904L™ 400(a) RA2205	AL-6XN® RA625 C-276 Titanium
CHLORIDE STRESS CORROSION CRACKING	304L 316L	904L RA2205	AL-6XN RA20 RA330	200, 400, RA600, RA333®, RA625
HYDROCHLORIC ACID	Titanium(b) RA600, RA20, RA2205	200(a) 400(a)	59 C-22 C-276 686	Zirconium(a) alloy B-2(a) Tantalum Titanium(b)
HYDROFLUORIC ACID	200, RA600, Ta, RA2205, etc.	Copper(a)	400(a) Silver(a)	Gold, Platinum
SULPHURIC ACID	Titanium RA600	316L 200(a) RA2205	904L AL-6XN, RA333 400(a), RA625	RA20 Tantalum
PHOSPHORIC ACID (commercial)	200, 400 316L		904L RA2205	AL-6XN, RA625 RA20
NITRIC ACID	904L, AL-6XN 200, 400, RA600	304L RA20 RA2205	RA333(c) RA625	Zirconium Tantalum
CAUSTIC	316L Tantalum	RA20 RA2205	RA600, RA625 400	200(a)

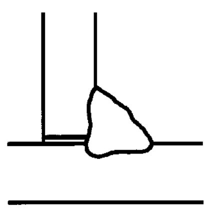
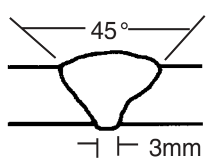
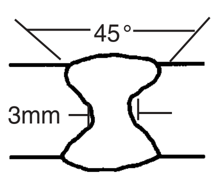
(a) presence of oxygen or oxidizing salts may greatly increase corrosion

(c) Stabilize annealed 1700-1800°F 1 hour

(b) Titanium has excellent resistance to hydrochloric acid containing oxidizers such as $FeCl_3$, HNO_3, etc. However, titanium has very poor resistance to pure, reducing, HCl.

Electrode and GMAW or GTAW Wire Consumption for Various Joint Designs

Filler metal requirements range from about 2-1/2 to 5 percent of the weight of plate involved in a fabrication. Estimated weight of covered electrodes and spooled wire for various joint configurations is given below.

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

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

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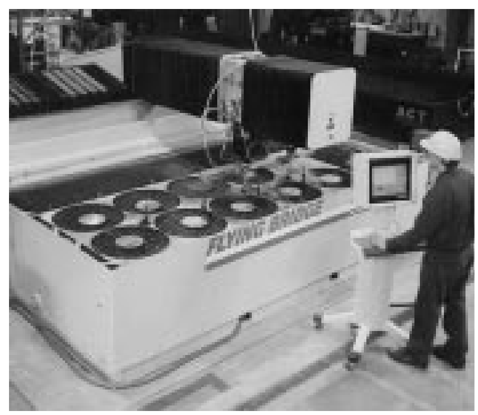

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