Alloy 20

FABRICATION

Technology Department

January, 2001

NOTE:

The data and information in this manual are believed to be reliable. However, this material is not intended as a substitute for competent professional engineering assistance, which is a requisite to any specific application. Rolled Alloys makes no warranty and assumes no legal liability or responsibility for results to be obtained in any particular situation.

We acknowledge the assistance of many individuals and corporations in the preparation of this manual. These include R. Stahura of Avesta Welding, Robert Van Deelen formerly of Avesta Sheffield, Avesta Welding AB, Sandvik AB and of course Carpenter Technology Corporation, Reading, Pennsylvania, USA. The column Stainless Q&A in the *Welding Journal,* written by Damien Kotecki of The Lincoln Electric Co. is a continuing source of useful tips.

Technical or commercial questions regarding RA20 stainless may be directed to:

Rolled Alloys, Ltd., Walker Industrial Park, Guide, Blackburn, Lancashire BB1 2QE, United Kingdom Tel +44 (0)1254 582 999 FAX +44 (0)1254 582 666 blackburn@rolledalloys.co.uk

Rolled Alloys, Voorerf 16, 4824 GN Breda, The Netherlands Tel +31 (0)76 548 44 44 FAX +31 (0)76 542 98 88 sales@rolledalloys.nl

For other technical information on RA20, or a current RA20 FABRICATION manual, contact Rolled Alloys Marketing Services in Temperance, Michigan, USA, FAX +1 734.847.3915. Tel +1.734.847.0561 e-mail: marketingservices@rolledalloys.com

Improvements and additions are made from time to time. .

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I. MATERIALS SPECIFICATION

A. RA20 is an austenitic stainless steel developed by Carpenter Technology Corporation for the handling of dilute sulfuric and other reducing acid solutions. The alloy exhibits high resistance to chloride stress corrosion cracking, and to polythionic acid stress corrosion cracking.

The specified chemistry range of RA20 stainless is:

Ni	Cr	Mo	Cu	Nb	Mn	Si	P	S	C	Fe
32.50	19.00	2.00	3.00	8 x C	2.00	1.00	0.035	0.035	0.06	remainder
35.00	21.00	3.00	4.00	1.00	max	max	max	max	max	

Minimum Specified Mechanical Properties

Ultimate Tensile, N/mm^2	0.2% Yield Strength, N/mm^2	Elongation[A] in 50.8mm,%	Hardness Number, max Brinell	Hardness Number, max Rockwell B
551	241	30.0	217	95

[A]Elongation for thickness less than 0.38mm shall be 20.0% minimum, in 25.4mm

Physical Properties

Density 8080 kg/m^3 Melting Point 1380°C

Modulus of Elasticity, 20°C 193 GN/mm^2

Electrical Resistivity, 20°C 1.08 microhm•m

Specific Heat 500 J/kg•K

Thermal Conductivity

Temperature, °C	W/mK
50	12.2
100	13.1
200	14.8
300	16.5
400	18.1

I. MATERIALS SPECIFICATIONS (continued)

Thermal Expansion 20°C to:	Expansion Coefficient 10^{-6}/°C
100	14.7
200	15.1
350	15.7
450	15.9
900	17.15

B. 20Cb-3 stainless is designated as UNS No. N08020 in the Unified Numbering System for alloys. In ASME Section IX 20Cb-3 alloy is P No. 45. The ASME Section III and Section VIII, Division 1 cover the use of 20Cb-3 stainless in welded construction through 427°C (800°F). For external pressure design, use Fig NFN-12 of Section II, Part D.

1999 Addenda ASME Section VIII, Division 1 design stresses for 20Cb-3 are:

For Metal Temperatures not exceeding, °F (°C) — Maximum Allowable Stress Values, ksi (N/mm²)

U.S. CUSTOMARY UNITS GOVERN

	Plate, Bar, Forgings, Seamless Pipe and Tube		Welded Pipe, Welded Tube	
100 (38)	22.9 (158)	22.9 (158)	19.4 (134)	19.4 (134)
200 (93)	20.6 (142)	22.9 (158)	17.5 (121)	19.4 (134)
300 (149)	19.7 (136)	22.9 (158)	16.7 (115)	19.2 (132)
400 (204)	18.9 (130)	22.2 (153)	16.1 (111)	18.8 (130)
500 (260)	18.2 (125)	22.1 (152)	15.5 (107)	18.8 (130)
600 (316)	17.7 (122)	22.1 (152)	15.0 (103)	18.8 (130)
650 (343)	17.5 (121)	22.0 (152)	14.9 (103)	18.7 (129)
700 (371)	17.4 (120)	21.9 (151)	14.8 (102)	18.6 (128)
750 (399)	17.2 (119)	21.8 (150)	14.6 (101)	18.5 (128)
800 (427)	16.8 (116)	21.8 (150)	14.3 (98.6)	18.5 (128)
NOTES:	--	G5	G14	G5, G14

G5 Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed 66 2/3% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction. G14 A factor of 0.85 has been applied in arriving at the maximum allowable stress values in tension for this material. Divide tabulated values by 0.85 for maximum allowable longitudinal tensile stress.

I. MATERIALS SPECIFICATION (continued)

C. Applicable Specifications are:

Alloy Form	Specifications
Plate, sheet & strip	ASTM B 643, A 240 ASME SB-643, SA-240
Seamless pipe & tube	ASTM B 729 ASME SB-729
Welded pipe	ASTM B 464 ASME SB-464
Welded tube	ASTM B 468 ASME SB-468
Bar and wire	ASTM B 473 ASME SB-473
Billets and Bars for Reforging	ASTM B 472
Forged fittings, valves and parts	ASTM B 462, A 182 ASME SB-462, SA-182
Wrought nickel alloy welding fittings	ASTM B 366 ASME SB-366

I. MATERIALS SPECIFICATION (continued)

C. Applicable Specifications (continued)

Alloy Form	AWS	ASME	UNS
1. Bare Welding Rods and Wire	A-5.9 ER320LR	SFA-5.9 ER320LR, F-No. 6	N08022
2. Covered Electrodes	A-5.4 E320LR	SFA-5.4 E320LR, F-No. 5	W88022

The Specified Chemistry Range of ER320LR bare welding wire is:

Ni	Cr	Mo	Cu	Nb	Mn	Si	P	S	C	Fe
32.0	19.0	2.0	3.0	8xC	1.5	--	--	--	--	remainder
36.0	21.0	3.0	4.0	0.40	2.0	0.15	0.015	0.02	0.025	

The Specified Chemistry Range of E320LR-15 basic covered electrodes is:

Ni	Cr	Mo	Cu	Nb	Mn	Si	P	S	C	Fe
32.0	19.0	2.0	3.0	8xC	1.50	--	--	--	--	remainder
36.0	21.0	3.0	4.0	0.4	2.50	0.30	0.20	0.015	0.03	

D. Mill Specification Analysis Sheets should be furnished to the end user for all items used in the equipment fabrication. This includes but is not necessarily limited to the following:

1. All 20Cb-3 stainless materials used
2. All weld filler metal wire, coated electrodes and SAW flux used
3. All bolting materials used in the fabrication and assembly of the equipment that will be exposed to the process environment
4. All "poison pad" material used in the fabrication

II. CODES

A. Some North American and European codes which may be applicable for 20Cb-3 stainless fabrications intended for pressure vessel service include:

1. Latest Edition with Addenda, ASME Boiler and Pressure Vessel Code, Section VIII, Division I. Available from ASME International, 22 Law Drive, P.O. Box 2900, Fairfield, New Jersey, 07007-2900, USA. Tel +1.973.882.1167 FAX +1.973.882.5155 Web site: www.asme.org

2. Latest Edition with Addenda, TEMA - Code for Heat Exchangers. Available from Tubular Exchanger Manufacturers Association, Inc., 25 North Broadway, Tarrytown, New York 10591 USA Tel +1.914.332.0040 FAX +1. 914.332.1541 Web site: www.tema.org

3. Latest Edition with Addenda, American National Standards Institute (ANSI) B31. Available from The American Society of Mechanical Engineers.

4. Latest Edition CAN3-Z299.3, Quality Assurance Program. Available from Standards Sales Department, Canadian Standards Association, 178 Rexdale Boulevard, Rexdale (suburb of Toronto), Ontario M9W 1R3 Canada. Telephone +1.416.747.4044 FAX +1-416.747.2473 Web site: www.csa.ca

5. Latest edition PD 5500, Specification for Unfired Fusion Welded Pressure Vessels. Also, Latest Edition Dutch Rules for Pressure Vessels (RtoD). Both are available from British Standards Institute, Linford, Milton Keynes MK14 6LE England. Website www.bsi-global.com e-mail: info@bsi-global.com

III. HOT WORKING

A. **Heat uniformly to a starting temperature of 1150—1232°C. Finish forging before the stock drops below 980°C.**

B. **In order to stabilize the material after hot working operations, reheat 940—1010°C for a minimum of ½ hour per 25 mm of thickness and water quench.**

IV. COLD WORKING

A. **20Cb-3 stainless has good cold formability. Bending, drawing and pressing, and other forming operations that occur in the production of fabricated items are readily performed.**

B. **20Cb-3 stainless plate can normally be press brake bent over a radius equal to the plate thickness. With sheared plate it is good practice to remove the shear burr, to avoid cracking. As with other austenitic stainless and nickel alloys, bending over a sharp male die may cause the material to crack.**

C. **Heat treatment after cold working operations is usually not required.**

V. HEAT TREATMENT

A. **20Cb-3 is a fully austenitic alloy and cannot be hardened by heat treatment. Annealing is performed either to soften the material after heavy cold work, when necessary, or to restore the stabilized condition after hot working operations. Annealing is done at 940-1010°C, followed by water quenching.**

20Cb-3 stainless welded fabrications are normally placed in service without annealing.

B. **About 35-40% stress relief may be obtained, when necessary in complex welded fabrications, by heating 480 to 540°C. No loss in corrosion resistance may be expected for stress relief temperatures below 540°C.**

VI. MACHINING

20Cb-3 stainless 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 do the plain carbon steels. 20Cb-3 stainless machines with a tough chip but not quite as stringy as the 300 series stainlesses. A somewhat better machined finish may be expected with 20Cb-3.

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. Approximate speeds for turning with high speed steel tools are 0.33 - 0.38 surface meter/second and for drilling 0.23 - 0.28 m/s. 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.

For band sawing we suggest a Lenox® Matrix 2 blade, variable pitch 12.7-8.5mm (2-3 teeth per 25mm) for large billet, 8.5-6.35mm pitch (3-4 teeth per 25mm) for smaller bar. The coolant mix should be rich, about 5:1 water to solvent. Blade set up should be rigid, with no gap. Speeds about 0.38-0.41 meter/second.

All traces of cutting fluid must be removed prior to welding or annealing.

The manufacturer has worked with Rolled Alloys to develop blade designs and cutting procedures specific to our alloys. For detailed information applicable to your own shop we suggest you contact:

American Saw International
European Customer Support Center
Grasbeemd 6 5705 DG Netherlands
Tel +31.(0)492.509.509
The North American Web Site is: www@lenoxsaw.com
US Technical Service E-mail: info@lenoxsaw.com

Lenox® is a registered trademark of American Saw & Mfg Company.

All traces of cutting fluid must be removed prior to welding, annealing, or use in corrosive service.

Suggested Machining Parameters: From Carpenter Technology Corporation
Turning: Single Point and Box Tools

Depth of cut, mm	High Speed Tools			Cast Alloy Tools		Carbide Tools			
	Speed m/min	Feed mm/rev	Tool Mtl.	Speed m/min	mm/rev	Speed, meter/minute		Feed mm.rev	ISO Grade
						Brazed	Throwaway		

3.8	20	0.38	1.3247	23	0.38	70	85	0.38	K20
0.64	23	0.18	1.3247	26	0.18	85	100	0.18	K10

Turning: Cutoff and Form Tools

Speed m/min	Feed, mm per revolution							Tool Material
	Cutoff Tool Width, mm			Form Tool Width, millimeters				
	1.6	3	6.4	13	25	40	50	
14-21	0.025	0.038	.002	0.025	0.025	0.025	0.025	1.3247
46-61	0.10	0.14	.007	0.13	0.10	0.09	0.09	K20

Drilling, High Speed Steel Drills:

Speed m/min	Feed, mm per revolution								Steel Grade
	Nominal Hole Diameter, mm								
	1.6	3.2	6.4	13	20	25	40	50	1.3247
13-16	0.025	0.077	0.15	0.25	0.36	0.43	0.53	0.64	

Reaming:

Speed m/min	High Speed Steel Tool							Carbide Tool	
	Feed, mm per revolution						Tool Mtl.	Speed m/min	Tool Mtl.
	Reamer Diameter, millimeters								
	1.6	6.4	13	25	40	50	1.3348	58	K20
18	0.076	0.13	0.2	0.28	0.36	0.43			

Tapping:

Speed mmin	Tool Material
9	1.3346; 1.3348; (M10, US standard)

Threading: Die

Speed,m/min				Tool Mat
7 or less	8 to 15	16 to 24	25 and up T.P. I	1.3247
1.2-2.4	1.8-3	2.4-3.7	3-4.6	

Broaching:

Speed, m/min	Chip Load mm Per Tooth	Tool Material
4.6	0.076	1.3343, 1.3348

Sawing: Power Hack Saw

Pitch, Teeth Per 25mm				Speed strokes per minute	Feed mm/stroke
Material Thickness, mm					
Under 6.4	6.4 to 20	20 to 50	Over 50		
10	10	6	4	70	0.13

VII. PLATE CUTTING

20Cb-3 stainless plate may be dry abrasive sawed, sheared or plasma arc cut. Shears rated for 10mm mild steel are used up to 6mm thick 20Cb-3 plate.

As with other Ni-Cr-Fe alloys, 20Cb-3 cannot be cut by oxyfuel procedures. Plasma arc cutting, however, is used at Rolled Alloys to cut shapes in heavy 20Cb-3 plate. Under 50mm nitrogen suffices for the plasma/shielding gas. At around 50mm or heavier a mixture of 65% argon 35% hydrogen gives a cleaner cut.

CAUTION: WHEN USING GASES CONTAINING HYDROGEN, TAKE CARE THAT THEY DO NOT ACCUMULATE SOMEWHERE AND CAUSE AN EXPLOSION. FOR EXAMPLE, WHEN CUTTING OVER A WATER TABLE, DROP THE WATER LEVEL BELOW THE PLATE TO PREVENT HYDROGEN GAS POCKETS FROM DEVELOPING UNDER THE PLATE.

Typical Plasma Cutting Parameters, Stainless & Nickel Alloys

Plate Thickness, mm	Nozzle & Swirling-Ring Size, mm	Torch to Work Distance, mm	Arc Current, amperes	Travel Speed, m/minute
6			350	3.8
10	4.2	6.4	380	3.2
12			400	2.5
16			400	1.9
20		9.5	500	1.9
25	4.8	9.5	550	1.5
32		9.5	580	1.1
38		12	600	0.8
45		12	700	0.6
50	5.6	12	700	0.6
64	6.4	20	900	0.45
75		25	900	0.4

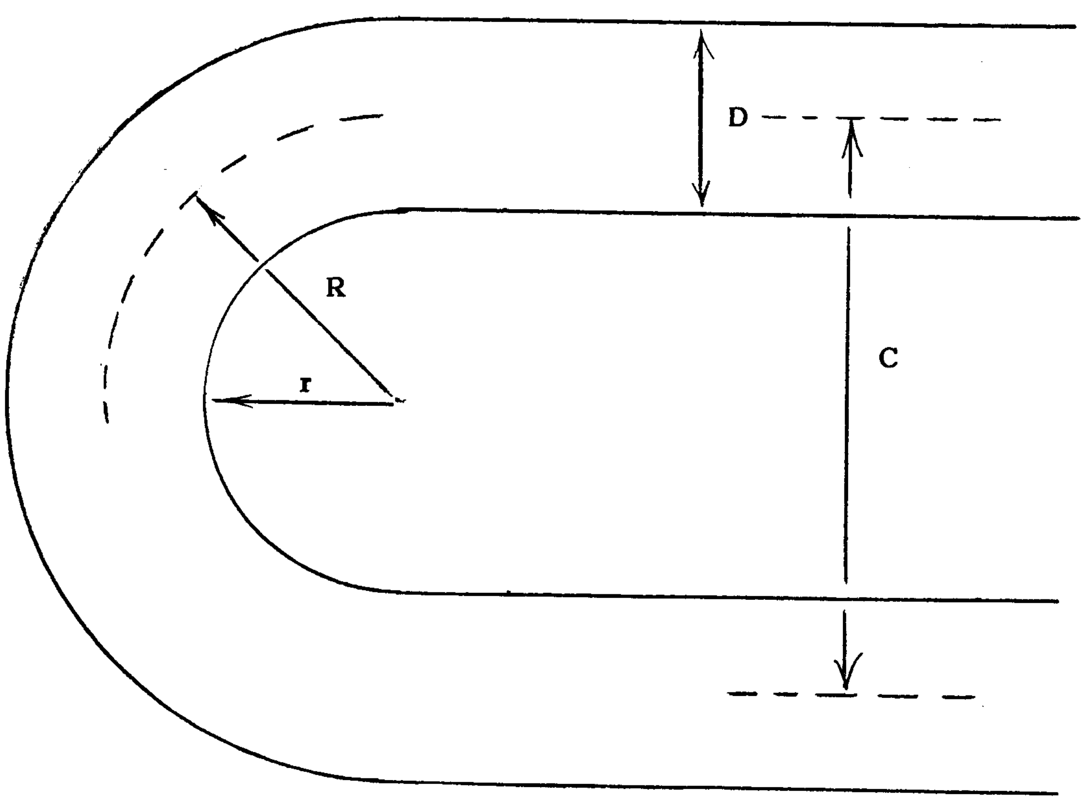
VIII. TUBING

A. Tube Bending

20Cb-3 alloy tubes can be bent to a minimum bend radius of slightly less than 1-1/2 times the tube outside diameter (O.D.). This is an inside radius of 1 times O.D., and a centerline-to centerline leg spacing of 3 times O.D.

For this tight a bend it is necessary to use a ball mandrel inside the tube. A plastic mandrel is suitable for bend radii down to 2 times O.D. More information on, and equipment for, tube bending is available from: Tools for Bending, 194 West Dakota Avenue, Denver, Colorado 80223-2195 Tel +1-303-777-7170 FAX +1-303-777-4749 e-mail tfb@toolsforbending.com

Heat treatment after tube bending is not suggested. If required, it should be limited to partial stress relief for short times at or below 538°C, or to anneal at 940-1010°C, fast cool, purge tube interior with argon. Anneal should be by induction to precisely heat only the bend; furnace heating is unacceptable.



R -- Mean radius, 1-1/2 D D -- Outside diameter
r -- Inside radius 1 D C -- Center-to-center distance

VIII. <u>TUBING</u> (continued)

B. Tube Rolling

1. Roller Expansion

Unlike copper alloy or titanium tubes, 20Cb-3 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.

Suggested tube expansion for 25mm tubes is 0.06 to 0.09mm after metal-to-metal contact. Further expansion may distort the tube sheet ligaments. Once a torque setting has been established to give optimum results, it is suggested that rolling should be checked by measuring every 50th hole with a tube I.D. gauge. Check this measurement with the initial dimension of that same tube.

2. Rolling Tools and Equipment

20Cb-3 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. The 5-roller expander compensates for some misalignment of the expander with respect to the tubesheet bore. It will not shape the end of the tube into a triangle or square if the expander is jammed into the end of the tube before the tool starts turning.

It is essential that the tool have no space between the collar and the cage where the tube can be pinched. Expanders of this description may be ordered from:

In the USA:

**Elliott Tool Technologies
1760 Tuttle Ave.
Dayton, Ohio 45403
Tel +1-937-6133 FAX +1-937-253-9189 www.elliotttool.com**

In Europe:

**Bencere Limited
Brewery Lane
Hook Norton, Oxfordshire OX15 5NX
Tel +44 (0)1608 737350 FAX +44 (0) 1608 730471
web site: www.bencere.co.uk e.mail: bencere@aol.com**

Specify tubesheet thickness, tube O.D. and wall.

VIII. TUBING (continued)

Suitable expanders may also be ordered from:

**Thomas C. Wilson, Inc.
21-11 44th Avenue
Long Island City
New York 11101-5088 USA
Tel +1-718-729-3360
FAX +1-718-361-2872
web site: www.tcwilson.com e.mail: tcwilson@tcwilson.com**

Their European distributor is:

**Tubeck AB
Brantgatan 4
426 76 V
Frölunda, Sweden
Tel +46 (0)31 299630 FAX +46 (0)31 297002
e.mail the General Manager at: ake.hofstrom@tubeck.se**

We suggest you ask for their 5-roll expander for stainless steel, and specify tubesheet thickness, tube O.D. and tube wall thickness.

Note: This entire section on tube rolling is abstracted from three more detailed articles:

**Some Considerations Concerning Tubing and Retubing Condensers
Gilbert D. Boyd**

**Some Considerations for Tubing Condensers in the Field
Gilbert D. Boyd, Second Joint ASME/ANS Nuclear Engineering Conference, July 25-28, 1982, Portland, Oregon**

Tube-to-Tubesheet Roller Expanded Joints with High Yield Alloys

IX. WELDING

A. Background

The fundamental problem to be overcome in welding austenitic nickel bearing alloys is the tendency of the weld to hot tear upon solidification.

This matter is readily handled in alloys under about 15% or so nickel. In these stainless grades the weld metal composition is adjusted, usually by slightly higher chromium and reduced nickel, to form a small amount of ferrite upon solidification.

The amount of ferrite in the weld may be measured magnetically, and is reported as a Ferrite Number, FN. This ferrite acts to nullify the effects of the elements responsible for hot cracking in the Ni-Cr-Fe austenitics. These elements include phosphorus, sulphur, silicon and boron.

In the higher nickel grades, about 20% nickel and over, it is simply not metallurgically possible to form any measurable amount of ferrite. For this reason other means of minimizing hot cracking must be used. Foremost among these is to use high purity raw materials in the manufacture of weld fillers. Reducing the amounts of harmful phosphorus, in particular, as well as sulfur and silicon in the weld metal significantly improves weldability. While the 2 to 3% niobium used in 2.4806 (SG-NiCr20Nb, AWS ERNiCr-3) is beneficial, the lower amount of Nb used in 20Cb-3 stainless may be detrimental.

AWS ER320LR bare welding wire is melted to lower phosphorus, sulphur, silicon and niobium than is common AWS E320 weld metal. Stabilization is maintained with the lower niobium by also refining to a lower carbon content. The same approach is used with the DC basic covered electrodes, E320LR. The higher purity of ER320LR permits welding 20Cb-3 stainless without the hot cracking problems that were formerly associated with common E320 weld fillers.

B. Heat Input, Interpass Temperature

1. Heat Input

Welding heat input should be as low as feasible for the joint involved.

Heat input in kJ/mm is calculated:

$$\frac{\text{Voltage x Amperage}}{\text{Travel Speed (mm/second) x 1000}}$$

The nickel alloy weld filler used with 20Cb-3 gives a more viscous weld pool than is the case with conventional stainless fillers. There is a temptation to raise welding current to improve fluidity, but this is ineffective.

2. Interpass Temperature

Interpass temperatures should be kept below 100°C. Low interpass temperature minimizes the chances of nickel alloy weld bead solidification cracking.

C. Weld Joint Design and Procedures

1. Root Passes

a. The gas tungsten or gas metal arc welding (GTAW or GMAW) processes with 100% welding grade argon torch shielding gas shall be used for all root pass welding of 20Cb-3 stainless where the back or reverse side of the weldment is inaccessible.

b. Argon backing gas shall be required on the back side of the joint of all gas shielded arc root passes. The backing gas flow rate shall be approximately 16.5-21 liter/minute.

c. The Shielded Metal Arc (SMAW) process may be used to make the root pass only when the back or reverse side of the weld is accessible.

2. Joint Details

a. It is suggested that the ASME Boiler and Pressure Code rules for such operations as joint design of head attachment to shell, butt welding of plates of unequal thickness, attachment of pressure parts to plate to form a corner joint, and welding of nozzles and other connections into shells and heads be followed in all fabrications regardless of whether the equipment is to be code stamped or not.

IX. WELDING (continued)

C. Weld Joint Design and Procedures (continued)

2. Joint Details (continued)

b. Square butt weld joints used in joining thin material (Joint Design 1) should be welded by the Gas Tungsten Arc (GTAW) or Gas Metal Arc (GMAW) process using an argon backing gas. Shielded Metal Arc welds in thin material should be with 2.4mm dia electrodes.

c. When the root pass associated with Joint Designs 2 through 9 is accomplished by the use of the Gas Tungsten Arc (GTA) or Gas Metal Arc (GMA) process, the remainder of the joint may be filled by use of any of the five welding processes listed in Section IX, Paragraph H.

d. Thicknesses of 20Cb-3 stainless over 3mm through 12mm should be beveled to form a "V", and should be welded using a purged backing bar (see Section IX, Paragraph K Fixtures) unless welded both sides, or welded by SMAW. Material 3mm thick may be either square butt welded or V-beveled.

e. Thicknesses of 20Cb-3 stainless over 12mm should be beveled to form a double "V" (Joint Design 3). Material 12mm thickness and under may be either single or double beveled.

f. Thickness of 20Cb-3 stainless, 20mm and over may also be beveled to form a double "U" (Joint Design 5) if so desired.

g. The intent of beveling one or both sides of the plate is to ensure a full penetration weld. This end may also be achieved in some cases by welding a square butt joint from one side, then grinding or plasma back gouging the other side to sound metal and welding up the resultant ground or gouged groove.

h. Joint designs 6 through 10 may be used as the need arises.

i. Each weld pass should be deposited as a straight stringer bead. Weaving of the bead creates excess heat and results in poor welds.

j. Welding should be done in the flat or downhand position whenever possible.

IX. WELDING (continued)

C. Weld Joint Design and Procedures (continued)

2. Joint Details (continued)

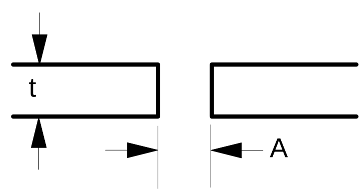
k. Joint design and welding sequence should be selected carefully to minimize the stresses that occur during welding (see pages 40-43).

l. All joint designs should be sufficiently open and accessible to permit the torch, electrode, or filler metal to extend to the bottom of the joint.

m. Incomplete penetration leaves undesirable crevices and voids in the underside of the joint, which may cause accelerated corrosion in these areas. Also, incomplete penetration creates stress raisers which act as focal points for mechanical failure.

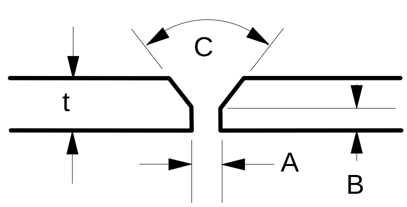
3. Joint Designs

JOINT DESIGN 1. Square Butt Joint



Maximum t = 3mm
Gap A = 1.5mm Minimum, 2.5mm Maximum

JOINT DESIGN 2. Single "V" Joint

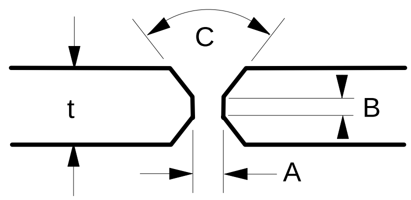


Maximum t = 12mm
Gap A = 1.5mm Minimum, 3mm Maximum
Land B = 1.5 to 2.5mm
Angle C = 60 - 75°

IX. WELDING (continued)

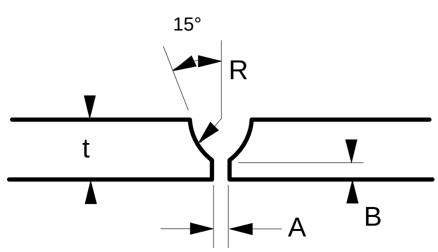
C. Weld Joint Design and Procedures (continued)

JOINT DESIGN 3. Double "V" Joint



Gap A = 1.5mm Minimum, 3mm Maximum
Land B = 1.5 to 2.5mm
t = 12mm or greater
Angle C = 60-75°

JOINT DESIGN 4. Single "U" Joint



Gap A = 1.5mm Minimum, 3mm Maximum
Land B – 1.5 to 2.5mm
Radius R – 9mm Minimum

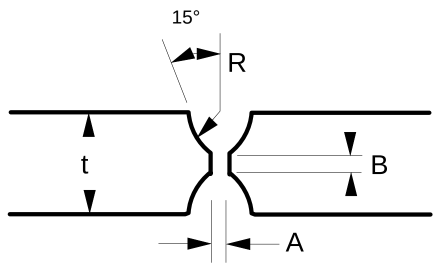
For single groove welds on heavy plate thicker than 20mm. Reduces the amount of time and filler metal required to complete the weld.

IX. WELDING (continued)

C. Weld Joint Design and Procedures (continued)

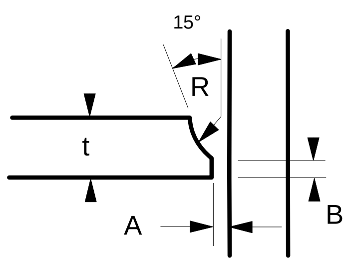
TYPICAL WELD JOINT DESIGN

JOINT DESIGN 5. Double "U" Joint



Gap A = 1.5 to 3mm
Land B = 1.5 to 2.5mm
Radius R = 9mm Minimum
Minimum t = 20mm

JOINT DESIGN 6. "J" Groove Joint



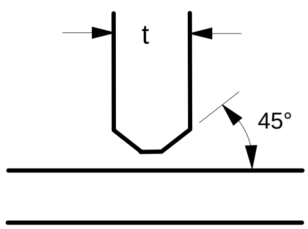
Gap A = 1.5 to 3mm
Land B – 1.5 to 2.5
Radius R – 9mm Minimum

For single groove welds on plates thicker than 20mm. Reduces the amount of time and filler metal required to complete the weld.

IX. <u>WELDING</u> (continued)

C. Weld Joint Design and Procedures (continued)

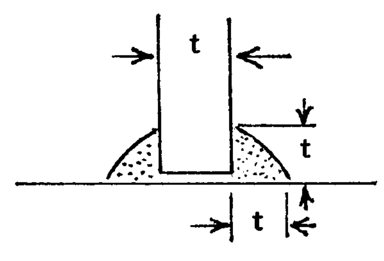
JOINT DESIGN 7. "T" Joint



t = greater than 6mm

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

JOINT DESIGN 8. "T" Joint

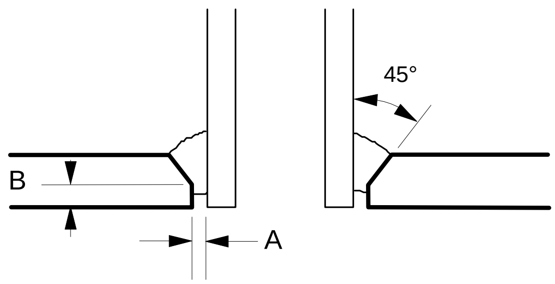


Conventional fillet weld. Fillet size should equal the thickness of the thinner member. This joint design is not suited to withstand mechanical fatigue loading. The built-in crevice in this joint must be completely sealed to prevent corrosion. Joint design 7 is preferred.

IX. WELDING (continued)

C. Weld Joint Design and Procedures (continued)

JOINT DESIGN 9. For Openings such as Manways, Viewports, and Nozzles



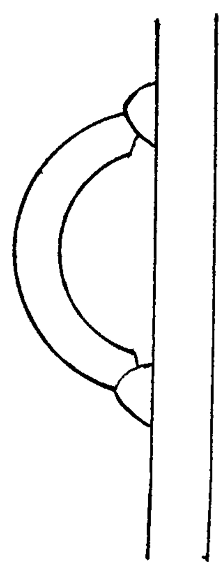
Gap A = 1.5 to 3mm
Land B = 1.5 to 2.5mm

JOINT DESIGN 10. For Installing Half-Pipe Coils to Vessel Sidewalls And Tank Bottoms

Internal bevel allows for Full Penetration Weld and eliminates the crevice which is a potential corrosion site.

Half-Pipe Coil

Welded to Vessel Sidewall or Tank Bottom



IX. WELDING (continued)

D. Surface Preparation

1. Cleanliness is a very important requirement in the joining of 20Cb-3 stainless.

2. Shop dirt, oil, grease, crayon markings, cutting fluids, sulfur compounds, marking ink, etc. should be removed from the welding surface and an area two inches wide on each side of the joint by vapor degreasing or by scrubbing with a suitable solvent.

3. Paint and other materials may require the use of alkaline cleaners or proprietary compounds. If alkaline cleaners containing sodium sesquisilicate or sodium carbonate are used, the cleaners shall be completely removed by scrubbing with hot water.

E. Edge Preparation and Fitting

1. Beveling is best done by machine, usually a plate planer or other machine tool is used. Hand grinding properly administered can produce satisfactory results. The land should be a true land and not a dull knife, or feather, edge.

2. The edges of sheet or plate shall be squared, aligned properly and tack welded prior to welding.

3. Square butt joints may be used for joining 20Cb-3 stainless sheet having a thickness of 3mm or less. A gap of 1.5 to 2.5mm is required.

4. SQUARE BUTT JOINTS SHALL NOT BE USED FOR JOINING 20Cb-3 STAINLESS OVER 3mm IN THICKNESS (unless back-gouged, see p. 17).

5. Details of joint designs are covered in Paragraph C.3 of this section.

IX. WELDING (continued)

F. Preheating

1. Preheating of 20Cb-3 stainless is not recommended, except that cold material to be joined should be heated to room temperature (10°C minimum) prior to welding to avoid condensation of moisture in the weld area.

2. If oxyacetylene preheating to room temperature is used, the heat should be applied evenly on the base metal rather than on the prepared joint surface so as to avoid carbon pickup. Hot spots should also be avoided.

G. Welding Processes

The acceptable arc welding processes for the welding of corrosion resistant piping and equipment fabricated of 20Cb-3® stainless are:

1. Gas Tungsten Arc Welding, (GTAW), Manual or Machine

a. General

It is more difficult to achieve penetration in 20Cb-3 than in lower nickel grades, 1.4404 (316L) stainless, for example. Different, more open, joint configurations may be helpful.

b. Shielding gas

Shielding and backing gases are normally 100% welding grade argon, nominal purity 99.996%, dew point -60°C. Helium may be added to the shielding gas to increase heat input and travel speed in automatic gas tungsten arc welding.

Gas cup size should be as large as practical, 12mm minimum (No. 8), if possible. Flow rates with argon should be 7-12 liter/minute for manual welding. Shielding gas turbulence (which may entrain air) should be

reduced by using a gas diffuser screen (gas lens) on the GTA torch. If the shielding gas is taken from a manifold, take care to purge the lines in the morning. Air may have been drawn back into the manifold overnight.

G. Welding Processes (continued)

1. Gas Tungsten Arc Welding, (GTAW), Manual or Machine (continued)

IX. WELDING (continued)

c. Tungsten Electrode

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.

d. Deposit Techniques

Use straight stringer beads, with minimum dilution of RA320LR alloy weld filler by 20Cb-3 base metal. Ignition of the electrode should always take place at a point within the joint itself. On thin material, the use of weld tabs is suggested for starting the arc at the weld joint.

Install tack welds of proper length and spacing for the type of joint design and metal thickness using argon shielding and backing gas.

e. Typical Parameters, Manual Welding

2% Thoriated Tungsten Electrode dia., mm	Direct Current Straight Polarity (electrode negative), amperes	Voltage
1	25-80	10-14
1.6	50-145	12-16
2.4	135-235	12-16

f. Approximate Parameters, Manual Welding Sheet

Sheet Thickness, mm	Current, DCSP (EN) amperes	Remarks
0.6	30	Weld in clamping fixture only
0.9	40	Weld in clamping fixture only
1.2	50	Prefer clamping fixture
1.5	60	May be assembled by tack
1.9	75	welding, and welded
3.0	120	without a fixture

IX. WELDING (continued)

G. Welding Processes (continued)

2. Gas Metal Arc Welding (GMAW)

a. General

Use straight stringer beads. Interpass temperatures preferred 100°C max to avoid weld bead cracking. 150°C max may be acceptable with unrestrained joints.

b. Shielding Gas

Shielding gases for GMAW (MIG) may be 100% argon, argon-helium mixes or argon-helium, with no more than a fraction of a percent of CO_2 added. 100% argon may be difficult to weld with. Some welders have been quite successful, in the spray arc transfer mode, using 90% argon 10% helium, as well as 80% argon 20% helium. The helium addition improves bead contour, helping to burn through the passive oxide film by making the arc hotter. Do NOT use oxygen additions.

Some of the newer cylinder gases may be advantageous. Linde has a number of proprietary gases specifically developed for welding stainless and nickel alloys.

Gases for pulsed-arc transfer include 100%Ar and 75%Ar 25%He.

Spray-arc transfer requires (at reasonable voltages) 80% or more argon in the shielding gas. Preferred gases are 90%Ar 10%He, or 80%Ar 20%He.

For short-circuiting arc transfer 75% argon 25% helium is suggested. We do not suggest the use of the common 90%He 7½%Ar 2 ½ %CO_2 mix for short arc welding. At this level of carbon dioxide some carbon pickup may be expected, decreasing intergranular corrosion resistance.

DO NOT USE 95%Ar 5%O_2, OR 75%Ar 25%CO_2 SHIELDING !!!!

IX. <u>WELDING</u> (continued)

G. Welding Processes (continued)

2. Gas Metal Arc Welding (GMAW)

c. Short-Circuiting Arc Transfer

Short-arc welding is a low heat input process that gives good results with thin sections (about 3mm or lighter) that could be distorted by excessive heat. Also useful for out-of-position welding on plate.

Disadvantage--weld beads deposited by the short-circuiting arc process may have cold laps or lack of fusion defects at starts and stops. It may be necessary to grind all stops before starting again, to prevent such defects.

Typical welding parameters for short-circuiting arc transfer:

Wire diameter, mm	Amperes	Volts
0.9	90-120	19-21
1.14	110-140	20-22

d. Pulsed-Arc Transfer

Pulsed-arc welding offers the benefits of spray-arc at a lower average heat input. This permits pulsed-arc welding to be used in all positions, and on sheet gages. Pulsed-arc transfer can be an excellent method of welding 20Cb-3 stainless.

Typical welding parameters for pulsed-arc transfer, 75% argon 25% helium shielding gas, 120 pulse/second.

Wire diameter mm	Amperes	Volts
1.14	150-165	20-21

e. Spray-Arc Transfer

The spray transfer mode is accompanied by relatively high heat input, a stable arc and high deposition rates. Spray-arc welding is generally limited to the flat position.

IX. <u>WELDING</u> (continued)

G. Welding Processes (continued)

2. Gas Metal Arc Welding (GMAW)

Typical welding parameters for spray-arc transfer, 99.996% argon shielding gas, 16.5-26 liter/minute

Wire diameter mm	Amperes	Volts
0.9	180-220	28-34
1.14	200-260	28-34
1.6	250-320	30-34

Use the high end of this range for plate 20mm and over. This is necessary as heavy plate acts as a considerable heat sink.

Because the welding wire must be pushed through a cable, ranging from 3 to 4½ meter long, there may be feeding problems. The result can be a tangle of wire known, in North America, as a “bird’s nest”. This shuts down the operation until the welder clears it. The care with which the filler metal is wound on the spool affects how smoothly the wire feeds. While the manufacturer is often blamed for feeding problems, more often than not proper attention to machine set up will ensure freedom from “bird’s nests”.

Smooth feeding depends on the cast and helix of the spooled wire. Both AWS A5.9 for stainless, and A5.14 for nickel alloy wire require cast and helix of wire on 300mm spools to be “such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(1) Form a circle not less than 380mm in diameter and not more than 1.3m in diameter (2) Rise above the flat surface no more than 25mm at any location” Our RA 253 MA® wire, for example, typically has 915 to 1070mm cast and 12.7mm helix.

Many nickel alloy weld wires are much higher in strength than stainless wire (for example, ER308 or ER316L), and therefor require more care to feed smoothly. When tangling, or bird’s nest, occurs the first thing we suggest is to examine machine set-up. Does this problem occur on more than one machine? How long is

IX. WELDING (continued)

G. Welding Processes (continued)

2. Gas Metal Arc Welding (GMAW)

the cable—the longer the cable, the more tension in the feed rolls. Are the feed rolls, inlet guide and outlet guide all clean? Incidentally, V groove rolls are used with solid stainless/nickel alloy wire, U groove for copper or aluminum and serrated rolls for flux cored wire.
Use minimal pressure on the feed rolls—more is not better. A rule of thumb is to hold the wire between the fingers as it enters the feed rolls. If you can hold it back, there is not enough pressure. Adjust the pressure until you just can not hold the wire, then give it another half turn beyond that.

For 1.14mm wire, consider using a 1.6mm conduit, instead of a 1.14mm conduit. The oversize conduit won't hurt, and will give more room for the wire to flex.

A heavy duty contact tip is preferred instead of a standard contact tip. When spray-arc welding the tip runs hot, and the wire may swell into the tip and jam it. The heavy duty tip simply has more copper, and can handle more heat.

3. Shielded Metal Arc Welding (SMAW) Manual

a. General

Use stringer beads 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.

Heat inputs should be maintained below 1.5 kJ/mm range for the flat position. As high as 2 kJ/mm may be required in the vertical.

Maintain low interpass temperature, preferred 100°C max, to avoid weld bead hot cracking. 150°C max may be acceptable with unrestrained joints.

b. Slag Removal

Remove all slag from each filler pass by use of chipping tools, fine grinding or stainless wire brushes. DO NOT USE CARBON STEEL WIRE BRUSHES. Steel particles will contaminate the weldment and likely initiate pits in chloride environments.

IX. WELDING (continued)

G. Welding Processes (continued)

3. Shielded Metal Arc Welding (SMAW) Manual

c. Electrode Care and Storage

E320LR covered electrodes are supplied in sealed containers to prevent absorption of moisture. Once the container has been opened, store these electrodes at 107°C in an electric oven. Electrodes which have absorbed excess moisture may be reclaimed by first heating two hours at 107°C, followed by one hour at 316°C.

Moisture in these electrodes may cause weld porosity and undesirable arc characteristics.

d. Typical Parameters

Electrode Diameter mm	Welding Current Amperes	Volts, max.
2.4	40-70	24
3.2	60-95	25
4.0	90-135	26

4. Underwater Welding

To date we are aware of no production experience wet welding 20Cb-3. This would require the use of waterproofed E320LR electrodes.

Suggested reading:

a. **ANSI/AWS D3.6-93, Specification for Underwater Welding. Available from American Welding Society, 550 N.W. LeJeune Rd, Miami, Florida 33126, customer service telephone +1-305-443-9353, extension 280. FAX +1-305-461-5112. Website: http://www.aws.org**

b. **Professional Diver's Manual on Wet-Welding, by D.J. Keats, 1990. ISBN 1 85573 006 5. Published by Woodhead Publishing Ltd, Abington Hall, Abington, Cambridge CB1 6AH, England Tel +44 (0)1223 891 358 FAX +44 (0)1223 893 694 Website: www.woodhead-publishing.com**

IX. WELDING (continued)

G. Welding Processes (continued)

5. Flux Cored Arc Welding (FCAW)

To date we have received no customer feed-back concerning production experience or the acceptability of flux cored arc welds in a specific 20Cb-3 fabrication. To our knowledge the 320LR chemistry is not currently available as a flux cored wire. A reasonable available alternate might be a flux cored wire based on alloy 625 (UNS N06625, 2.4856, NiCr22Mo9Nb). Availability may be limited, as nickel alloy flux cored wires are a fairly recent development.

Fabricators generally prefer flux cored over solid wire because of the productivity/cost advantage. Nevertheless, some end users are still reluctant to permit flux cored welding in general, while others have had many vessels fabricated successfully using FCAW. It is suggested that the fabricator clarify this point with his customer before quoting.

The use of gas-shielded, rather than open-arc, wire is preferred, shielded with 75% argon-25% CO_2 gas. Wire feed rolls should be knurled with U or V shaped grooves. Smooth rolls may cause feeding problems. Four-roll sets are generally preferred over two-roll sets.

Suggested welding parameters

Wire Dia., mm	Wire Feed m/min	Amperes, DCRP	Volts Flat	Shielding Gas, liter/min	Wire Stick-out, mm
1.14	7-9	150-210	26-31	14-24	9.5—13 ideal (13-25mm acceptable)

6. Submerged Arc Welding (SAW)

The choice of flux is very important to avoid hot cracking in the ER320LR weld bead, and possible pickup of carbon and silicon. Absolutely do not use acid or chromium compensating fluxes meant for 8-12% nickel stainless steel (i.e., 1.4307/304L, 1.4404/316L, etc.)

The flux for SAW of 20Cb-3 should be highly basic, and neutral with respect to chromium. Suggested fluxes include Avesta® Flux 805, Böhler Thyssen's RECORD NiCrW, or Lincoln® Electric's Blue Max® 2000 . Average flux consumption is about one kilogram of flux per kilogram of weld wire.

It is suggested that the root bead be made first using some other process, such as SMAW. Joint geometry is important. The width of the weld should be 2 to 3 times greater than the depth.

6. Submerged Arc Welding (SAW) (continued)

Typical welding parameters, flat position, ER320LR filler wire:

Wire Size mm	DCRP Current amperes	Voltage	Wire Stickout, mm	Travel Speed mm/minute
1.14	150-225	25-28	13	200-300
1.6	225-300	25-28	20	200-300
2.4	275-350	25-28	25	200-300
3.2	325-400	25-28	25	300-400

To minimize hot cracking, maintain low heat input, preferably below 42.5 kJ/inch. Keep interpass temperature below 100°C.

Flux must be dry. Moisture absorption by flux during storage is the most likely cause of porosity in SAW. RECORD NiCrW which has absorbed moisture may be restored by heating one hour or more at 400°C. Avesta flux 805 may be redried by heating two hours minimum at 350°C. Either flux should be mixed once during the heating period to ensure uniform drying.

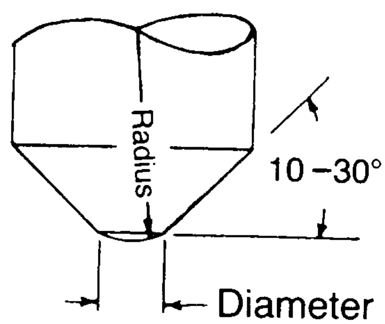
IX. <u>WELDING</u> (continued)

G. Welding Processes (continued)

7. Resistance Welding

Spot and seam welding parameters for 20Cb-3 will differ from those used with stainless such as 1.4404 (316L). 20Cb-3 typically has higher yield strength and about 20% higher electrical resistivity. Electrode force, welding current and time, and electrode tip contours may all need to be modified accordingly.

A restricted-dome electrode is suggested for spot welding. Average dome radius may be 75mm for sheet up to 3mm thick. For a larger nugget size in material 1.5 to 3mm a 125 to 200mm radius dome is sometimes preferred.



In seam welding heat time should be adjusted to ensure that the wheel maintains pressure until the weld nugget has solidified, to avoid porosity and cracking. Likewise cool time should be sufficient that welded areas are not remelted.

Suggested reference:

<u>Resistance Welding Manual</u>
4th Edition, available from:
Resistance Welder Manufacturers' Association
1900 Arch Street
Philadelphia, Pennsylvania 19103-1498 U.S.A.
Web site: www.rwma.org e-mail: rwma@fernley.com
Phone +1.215.564.3484 (Association Headquarters, Fernlee & Fernlee--ask for RWMA) FAX +1.215.564.2175

IX. WELDING (continued)

G. Welding Processes (continued)

8. Welding Processes NOT TO BE USED

The following welding processes shall NOT be used for the welded joints of 20Cb-3 stainless:

a. Fuel Gas (e.g., Oxyacetylene) Welding
20Cb-3 stainless is susceptible to carbon pick-up from the flame. Carbon lowers the corrosion resistance.

b. Carbon-arc air gouging
There is considerable risk of carbon pickup on the surfaces of cut edges when using this technique. This carbon can lower the corrosion resistance of 20Cb-3. In general, carbon-arc gouging should not be used on corrosion resistant alloys.

H. Pipe Welding

Achieving an oxide-free weld bead when making the root pass in piping welds is considered difficult. Some suggestions are:

Clean the entire inside of the pipe thoroughly, as well as at least 50mm on either side of the joint on the outside of the pipe.

Purge 7 to 10 times the volume, for a minimum time of 2 minutes. The entire length of the pipe need not be purged, by the use of closure dams local purging is generally preferred. Purge to below 5000 ppm oxygen. Purge gas flow rate should be greater than torch gas flow.

Have the exit hole on the top of the opposite side. When pipe welding is done in the vertical position the gas should enter below the weld and exit through a hole in the top dam.

Grind tack welds to a feather edge. This will help the closure weld bead tie into the tack welds and minimize chances of X-ray defects.

Before welding, plug the escape hole and, of course, remove that section of tape where you are welding.

After each weld pass, first close the tape area at the joint, then re-open the access hole.

If grinding is required to remove tacks or otherwise re-open the root gap, tape up all openings and re-purge for a minimum of 2 minutes before again welding.

IX. WELDING (continued)

I. Sheet Lining

The application of corrosion resistant alloy sheet to a carbon steel substrate is commonly called sheet lining or wallpapering. Carbon steel provides structural support while the alloy sheet provides corrosion resistance for use in flue gas desulfurization or chemical process equipment.

1. Fabrication

a. **Sheet thicknesses ranging from 1.5 to 3mm are most common.**

b. **Cut the sheet by shearing, abrasive cutting or plasma arc cutting. Do not use air carbon arc or oxy-fuel cutting, as carbon pickup will damage corrosion resistance. Plasma cuts should be ground as necessary to remove dross. Sheared edges should be clean—no oil !!**

c. **All forming shall be done cold. Warm forming may cause the metal to tear and damage the corrosion resistance.**

d. **So far as possible all shearing, forming and hole punching should be done ahead of time in the shop, rather than at the job site.**

e. **Clean the carbon steel substrate thoroughly to remove all rust, mill scale, oil and grease in areas where 20Cb-3 stainless to steel welding will be performed. This cleaning may be accomplished by sand blasting, followed by clear water rinse.**

2. Installation & Welding

a. **20Cb-3 stainless lining sheets should be in close contact with the carbon steel substrate, particularly along the edges.**

b. **Joints between 20Cb-3 stainless lining sheets should be lap joints with a nominal 25mm overlap. Less than 6mm overlap is unacceptable. The two sheets should be in close contact, with no separation greater than 1.5mm**

c. **Four types of welds are involved—tack welds, attachment welds, plug or arc spot welds, and seal welds.**

   Tack welds are used to hold the sheets in position before making the attachment welds, and later to maintain contact of 20Cb-3 stainless sheet edges before seal welding. Tack welds should be as small as possible, consistent with a sound weld.

2. Installation & Welding (continued)

c. (continued)

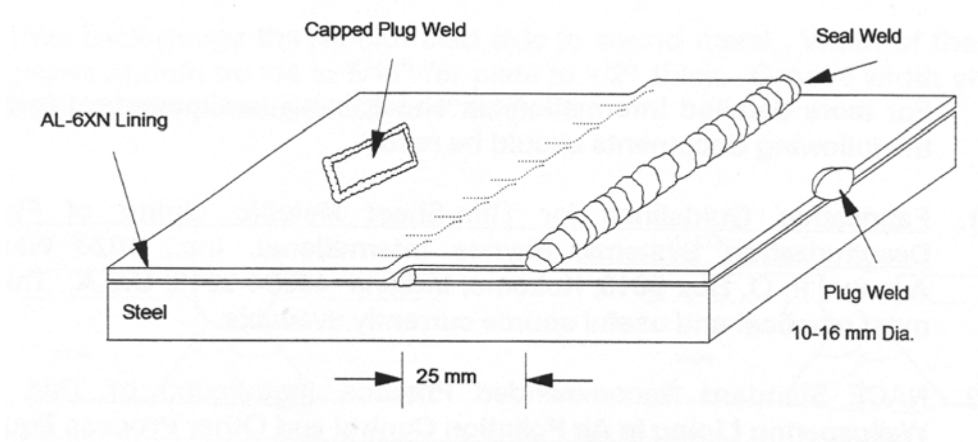
Attachment welds join the 20Cb-3 stainless sheet edges to the carbon steel substrate. These welds provide the entire structural strength of the lining system. Typically these are intermittent fillet welds 25mm long, spaced on 150mm centers. They should be flush with the sheet lining surface to permit close contact by the overlying sheet.

Plug welds may be used for additional structural strength. Pre-punched or drilled holes 10 to 15mm diameter, typically on 600mm centers have been used. The effects of weld dilution by carbon steel may be minimized by using a higher alloy weld filler, such as alloy C-22 (2.4635 SG-NiCr21Mo14W, AWS ERNiCrMo-10). Or, the welds may be capped with a small piece of 20Cb-3 stainless sheet, seal welded around the edges.

Seal welding, the last operation, provides a leak tight system and adds to the structural strength. Small tack welds are needed to keep the two overlapping sheets in close contact. The tacks are small, typically 6mm long on 75mm centers.

It is very important that these tack welds be ground to a feather edge prior to seal welding.

Seal weld starts and stops also should be ground and feathered.



IX. <u>WELDING</u> (continued)

d. Gas Metal Arc Welding (GMAW) in either the short circuiting arc or pulse arc mode is the most common welding process. Gas Tungsten Arc Welding (GTAW) is used primarily for repair.

Shielding gases for GMAW in the short circuiting arc mode include 75%Ar 25%He. For pulse arc welding argon-helium mixtures are often used.

Welding defects will almost invariably be associated with starts, stops or tack welds. Grinding the tack welds, also the seal weld starts and stops can minimize these defects and the associated repair welding.

e. ER320LR (20Cb-3LR) filler wire is normally used to weld 20Cb-3 stainless.

3. Inspection & Repair

a. Visual inspection should be performed first, and is capable of locating the majority of possible defects.

b. The most accurate and effective test method is currently vacuum-box testing, per ASME Section V, Article 10.

c. Dye penetrant inspection is used for small areas or confined spaces where the vacuum box is not practical.

d. GTAW is the most appropriate repair method. GMAW or SMAW may also be used.

A further reference on sheet lining (wallpapering) techniques is:

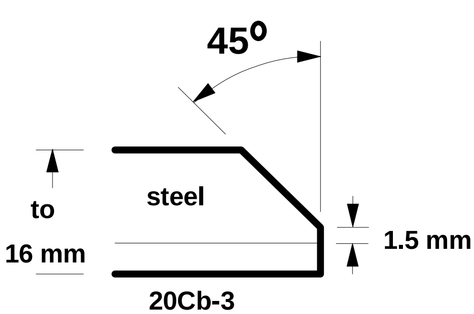
NACE Standard Recommended Practice, *Installation of Thin Metallic Wallpapering Lining in Air Pollution Control and Other Process Equipment,* NACE, P.O. Box 218340, Houston, Texas USA 77218-8340 telephone +1.713.492.0535 FAX +1.713.492.8254 web site www.nace.org

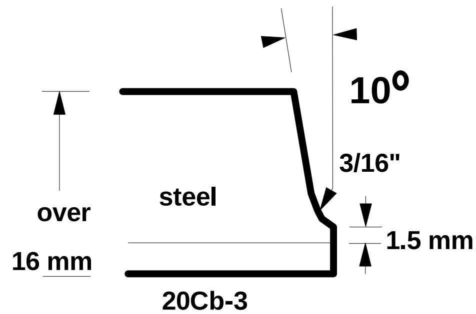
IX. WELDING (continued)

J. Clad Plate Welding

20Cb-3 may be clad to carbon and alloy steels such as ASTM A 282, A 514, A 516 and others. The steel side of the joint is welded with the filler metal and procedure appropriate to that steel. The 20Cb-3 side should be welded with at least two layers of ER320LR wire or E320LR-15 DC lime type electrodes.

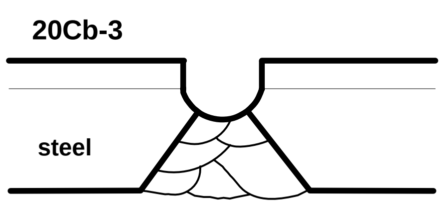
Prepare the joint with a minimum 1.5mm land on the backing steel to minimize dilution from steel into the 20Cb-3 cladding.

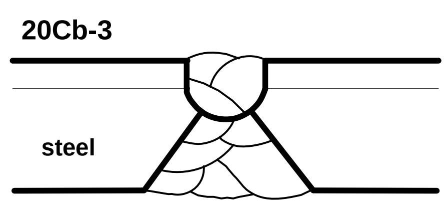




Tack the joint on the steel side using the same electrode as intended for the steel root bead. Finish welding the steel side.

Then back-gouge the 20Cb-3 clad side to sound metal. Width of the gouged groove should be 6 to 8mm for plate to 12mm thick. Groove width should be 9 to 12mm for plate over 12mm to 25mm thick.





Weld the clad side with two or more layers of ER320LR weld wire or E320LR electrodes. Minimize dilution by using pulsed-arc GMAW (preferred), second choice FCAW or SMAW. A root pass with ERNiCrMo-10 wire or ENiCrMo-10 electrodes (alloy C-22) may be used, if desired, to counter-act dilution by the steel.

IX. WELDING (continued)

K. Dissimilar Metal Welds

Considerations in selecting a filler metal for dissimilar metal weld joints include the expected corrosive conditions at the joint and freedom from weld cracking.

This suggested list of weld filler metals is based primarily on welding knowledge rather than laboratory work. Final selection should be approved by the end user and weld procedures qualified by the fabricator.

For joining 20Cb-3 to:	Suggested Filler Metals
carbon steel *, 1.4307 (304L), 1.4541 (321), 1.4550 (347)	2.4806 (alloy 82 wire) or 2.4620 (alloy 182 covered electrodes)
1.4404 (316L), 1.4438 (317L), 2.4856 (625)	2.4831 (alloy 625 wire) or,
duplex stainless 1.4462, 1.4410 nickel alloys 2.4819, 2.4602, 2.4605, 2.4068	2.4886 or 2.4635 (alloys C-276 or C-22 wire) 2.4607 (alloy 59 wire)
2.4360 (alloy 400)	While a mechanical joint could be made using a high nickel filler metal, the weldment would lack the chloride corrosion resistance of either base metal. Some success has been reported with 2.4621 covered electrodes.

* Carbon steel must be ground to bright metal. A "mill finish" is not acceptable. All rust, hot rolling scale oil and paint must be removed before using nickel alloy weld fillers on carbon steel.

IX. <u>WELDING</u> (continued)

L. Controlling Distortion

1. **20Cb-3 stainless has about 20% higher coefficient of thermal expansion than does carbon steel, but only about one fourth the thermal conductivity of steel. This combination naturally increases welding stresses and results in distortion in welded structures.**

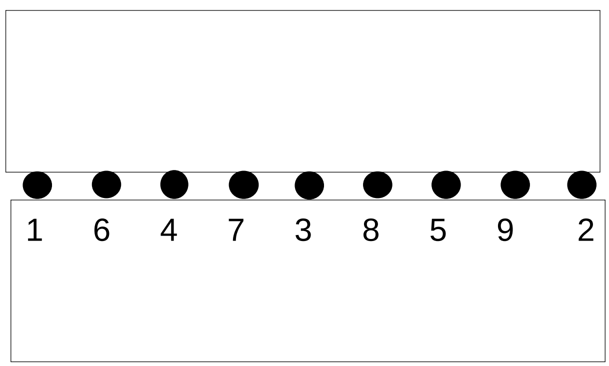
   Heat treatment to relieve welding stresses in stainless or nickel alloys is usually ineffectual, impractical or downright harmful.

   Proper fixturing, joint design, staggered weld bead placement or weld sequence and controlling heat input can all serve to minimize distortion.

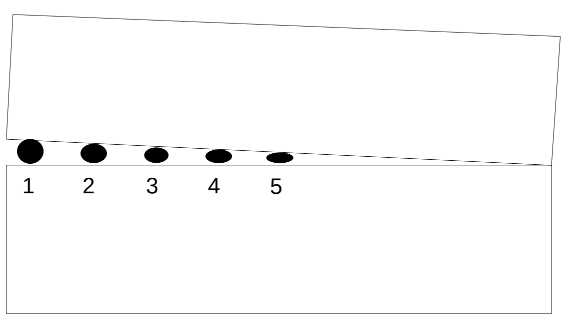
The following are general suggestions:

2. **Sequence[A]**

   a. **Tacks should be sequenced**



If the tacks are simply done in order from one end, the plate edges close up.

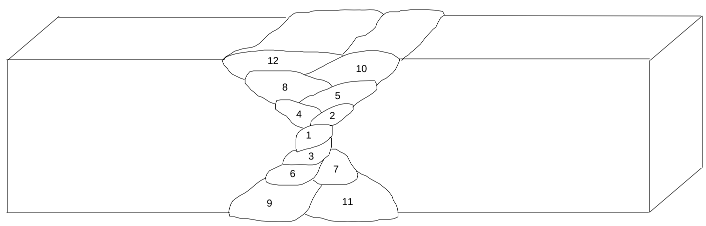


IX. WELDING (continued)

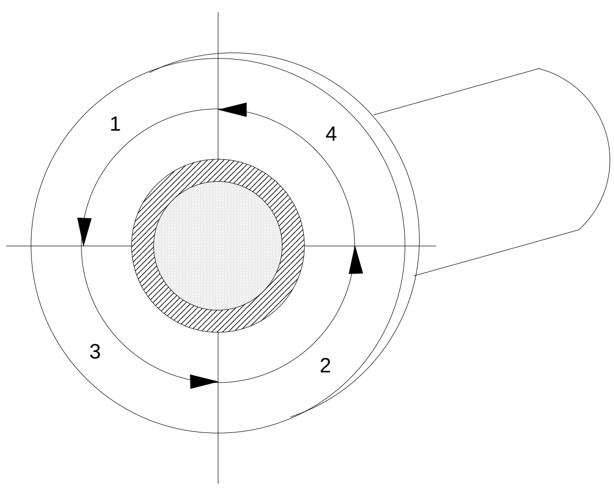
L. Controlling Distortion (continued)

2. Sequence

b. Weld runs should be done symmetrically about the joint's center of gravity to balance stresses [B]



double V - preparation



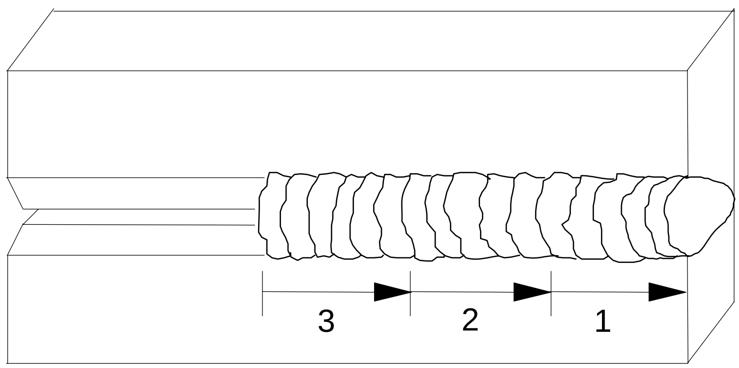
flange to cylinder

IX. WELDING (continued)

L. Controlling Distortion (continued)

3. Heat Balance[B]

Back step welding is helpful



[A] from Avesta Handbook for the Welding of Stainless Steel, Inf. 8901, Avesta Welding AB, S-774 27 Avesta Sweden FAX +46 (0)226.81575
Website: www.avestawelding.com

[B] from Sandvik Welding Handbook, by Berthold Lundqvist, AB Sandvik Steel, SE-811 81 Sandviken Sweden FAX +46 (0)26.27.4720
Website: www.steel.sandvik.com

IX. WELDING (continued)

L. Controlling Distortion (continued)

4. Heat Input

Heat into the workpiece is controlled by welding current, arc voltage, travel speed and the specific welding process used. For the same amps, volts and speed submerged arc welding (SAW) transfers the most heat, manual arc (SMAW) and gas metal arc (GMAW) with argon next and roughly equivalent, while gas tungsten arc welding (GTAW) can put the least heat into the work.

Reducing heat input reduces the stresses and distortions from the welding operation.

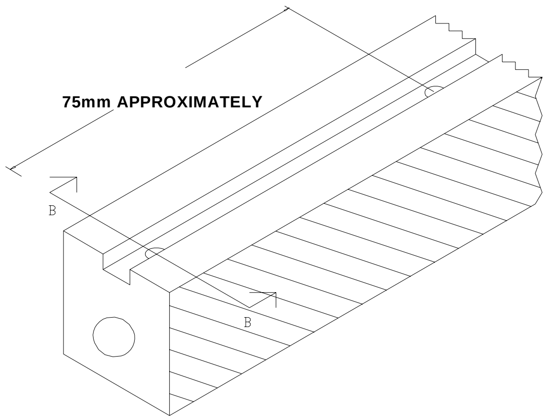
There is some tendency for welders to want to increase heat input with 20Cb-3, for two reasons. First, the high nickel weld filler tends to be sluggish and not flow well, as compared with a typical stainless filler. Second, weld penetration tends to be less in 20Cb-3 than in common stainless such as 316L (1.4404). It is generally preferable to deal with flow and penetration by technique and weld joint design, rather than increasing arc energy.

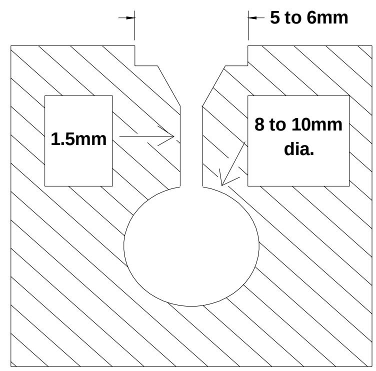
M. Fixtures

1. While making GTAW or GMAW root passes, fabricators may use a square corner grooved backing bar to provide inert gas (argon) coverage while making root pass of the welded joint.

IX. WELDING (continued)

2. The backing bar shall be fabricated from copper and be of the purging type, having small diameter holes throughout its length so that the root side of the joint only sees argon gas. The inlet area of the purge bar shall be a minimum of three times the sum of the individual purge holes to provide uniform distribution of the argon purge gas. The backing bar or purge bar also serves as a chill to the base metal and a support to prevent excessive penetration of the weld bead. A typical chill bar cross-section is shown below which features square corner grooves and drilled for gas purging. Groove depth depends on gas flow required and length of bar.





Section B-B

Groove design for backing bars

Square-corner groove employed with backing gas (groove depth depends on gas flow require and length of bar).

Note: It may be advisable to nickel or chromium plate the copper backing bar to prevent HAZ cracking from copper contamination. This is particularly the case in seam welding operations where restraint from hold-down pressure enhances cracking.

Copper contamination at levels not visually apparent can result in HAZ cracking in austenitics, which cracks will be obvious by dye penetrant inspection. One simple means of detecting copper is by the use of Cuprotesmo® copper test paper.
This is available USA as Product No. 90601 from Gallard-Schlesinger Industries,
Website: www.gallard.com e-mail info@gallard.com

In Europe, contact Macherey—Nagel GmBH & Co, P.O. Box 101352, D—52313 Düren, Germany Tel +49 2421 9690 FAX +49 2421 969199 Cuprotesmo copper test paper is not yet listed on their web site, www.mn—net.com

IX. WELDING continued

N. Weld Filler Consumption

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.

		APPROXIMATE WEIGHT, IN KILOGRAMS, OF		
JOINT DESIGN	PLATE THICKNESS, mm	WELD METAL DEPOSITED PER LINEAL METRE WITH REINFORCEMENT	COVERED ELECTRODES REQUIRED (A)	GMAW, GTAW WIRE REQUIRED (B)
SINGLE FILLET	3 4 6 10 12	0.060 0.098 0.22 0.64 0.92	0.12 0.20 0.45 1.28 1.85	0.07 0.12 0.26 0.75 1.08
"V" GROOVE	6 10 12	0.52 0.97 1.22	1.04 1.93 2.44	0.61 1.14 1.44
DOUBLE "V" GROOVE	12 16 20 25	1.13 1.44 2.11 2.71	2.26 2.89 4.23 5.42	1.33 1.70 2.49 3.19

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

X. DESCALING AND PICKLING

A. Oxide, tarnish or discoloration can be removed from 20Cb-3 by mechanical and/or chemical means.

1. Annealing or hot working scale may be removed by abrasive blasting followed by pickling in the following nitric-hydrofluoric acid solution:

Nitric Acid, nominal 42°Be, 10 to 20% by volume plus 2% hydrofluoric acid, at 50- 60°C for 30 minutes. When possible, use water containing less than 50 ppm of chlorides.

2. Oxides and heat tint caused by welding may be removed by:

a. Stainless power wire brushing . Brushes should be clean, new austenitic stainless not previously used on carbon steel. This is the most common, but far from the best, method. Wire brushing tends to smear the oxide, and embed residual scale into the surface. It may also expose the thin alloy-depleted layer beneath the surface. Nevertheless, weldments treated in this manner have performed satisfactorily.

b. Fine grinding (120-180 grit finish). Grinding wheels or belts must be clean and new, not previously used on carbon steel.

c. Abrasive blasting with fine soda-lime glass beads. Somewhat more expensive than wire brushing but leaves the weldment in a much more corrosion resistant condition. This is one of the better methods of cleaning 20Cb-3 stainless weldments.

d. Abrasive blasting followed by pickling. This is the highest cost method due to handling and waste disposal procedures required with nitric-hydrofluoric solutions or pastes. Acid cleaning of weldments may be considered when 20Cb-3 is to be used near its limits of performance in agressive environments.

X. DESCALING AND PICKLING (continued)

For maximum effect acid cleaning should be done in the solution listed in X A. 1, above. Commercial pickling pastes are good, but not so effective as an acid dip. Pickling pastes are appropriate when only small areas need to be cleaned. Two possible sources for such nitric-hydrofluoric pastes include:

Avesta Pickling Paste, available from Avesta Welding AB, S-774 27 Avesta Sweden. FAX +46 (0)226 81575 Website: www.avestawelding.com
Detailed information regarding pickling stainless and the use of these pickling pastes may be found on this website.

Sandvik AB, SE-811 11 Sandviken Sweden
FAX +46 (0)2627 4720 Website: www.steel.sandvik.com

Pickling paste should be neutralized and removed in accordance with the manufacturer's recommendations. Precautions should be taken in handling pickling solutions and cleaners. Positive ventilation is required to remove the fumes. Protective clothing, face shields and rubber gloves are required. Environmental considerations will affect the procedures to be followed for disposal of wash liquors from the pickle and cleaning operations.

B. Detection and Removal of Embedded Iron

1. During rolling to shape, machining, or other mechanical operations, small particles of iron become firmly embedded in the surface of any corrosion resistant alloy that they cannot be removed by normal cleaning methods. This iron will cause a light surface rust to appear when the parts have been exposed to the weather.

   For many applications of 20Cb-3 stainless, the process environment will itself dissolve and remove surface iron in service. There are some applications where iron is known to contaminate the product, so that it is desirable to test for and to remove any iron.

2. Detection is accomplished by chemically treating the iron to develop a colored reaction product, as a visual sign of contamination. The simplest means involves corroding the iron by water, which may be distilled or mildly saline, to produce red rust. More sensitive tests result in blue, brown or purple colors.

   a. Wet the surface with distilled water and cover with a clean cloth for fifteen minutes. Remove the cloth and allow the surface to dry for fifteen minutes. Iron contamination will show as red rust. The cycle may be repeated. Probably after 4 cycles (1 hour total wet, 1 hour total drying time) any iron that is going to be found, will be found.

X. DESCALING AND PICKLING (continued)

b. Spray or immerse the 20Cb-3 fabrication in a solution of 0.3 milligram per liter of hydrogen peroxide (H_2O_2) in water. After 12 to 24 hours, iron particles are easily detected bye the presence of red rust spots. Take care not to use too concentrated a solution, for example, 3 milligram per liter H_2O_2 is too oxidizing and will simply passivate the iron.

3. Removal of embedded iron—

a. Treat with a 50-60°C 10 to 20% nitric, 2% hydrofluoric acid solution. Nitric acid alone will remove superficial iron contamination but have little effect on larger, deeply embedded particles. More concentrated nitric will passivate the iron particles and prevent their removal.

b. Locally apply pickling compounds as in Section X para A.2.d., or similar commercial stainless cleaner containing nitric and hydrofluoric acids.

XI. QUALITY

Fabrication quality is key to the successful applications of advanced nickel alloys. Users are strongly urged to have the potential fabricator develop weld procedures and to qualify them to ASME Standards. Qualifications should include the lightest gage sheet involved in the fabrication, as well as the heaviest plate gage. It is suggested that the end user specify the choice of weld filler metals.

Weld procedures should also be qualified for any dissimilar alloy weldments, such as to carbon steel, stainless or other nickel alloys.

Sub-contractors should be required to develop their own weld procedures to be approved by the end user.

XII. WORKMANSHIP-INSPECTION-REPAIR

A. Workmanship

1. Weld bead contour and shape should be controlled. Straight stringer beads deposited with a distinct crown (convex surface) are preferred.

2. No pits, porosity, cracks, pinholes, slag inclusions, undercutting, overheating, or other weld defects should present in the fabricated equipment. Complete penetration is important on the entire length of the welded joint.

3. Remove all slag from the weld prior to the start of the next pass and/or the final weld pass. Grind all welds smooth on the process side, but preferably not flush. Remove all weld spatter by fine grinding.

B. Weld Inspection

1. Non-Destructive Testing

a. For ASME code fabrications, certain mandatory non-destructive test inspections are required. Applicable paragraphs of the ASME Boiler and Pressure Vessel Code give the requirements for a given fabrication.

b. Various non-destructive test methods such as radiographic, dye-penetrant, ultrasonic and hydrostatic should be used as specified in the purchase order to insure weld quality. These methods should also be used for intermediate inspections during equipment fabrication as well as for the final acceptance test.

c. Fillet and butt welded joints should be given non-destructive test inspections even though the fabrication may not be governed by Code requirements. Inspections required are specified in the user's purchase order.

C. Repair of Weld Defects

1. Removal of Weld Defects

a. All rejectable weld defects shall be completely removed by grinding. The ground crater shall be dye-penetrant inspected to insure that all objectionable defects have been removed.

The area of the repair shall be thoroughly cleaned prior to the weld repair. See Section IX, Paragraph E for details.

b. All rewelding shall be accomplished using acceptable methods described in Section IX, Paragraphs G-1, 2, 3, 5 and 6.

c. Attempts to "heal cracks" and the "washing out" of defects by remelting weld beads or by depositing additional weld beads over the defect are unacceptable, and could locally reduce corrosion resistance of the alloy. The defects shall be removed and repaired per paragraphs (a) and (b) above.

Suggested Fabrication Procedures
for 20Cb-3® stainless UNS N08020

COMPARISON—American and European Standards

CORROSION RESISTANT ALLOYS, BASE METAL

Grade	UNS No.	ASTM*	Werkstoff Nr.	DIN Designation
2205	S31803	A 240	1.4462	X2CrNiMoN22-5-3
304L	S30403	A 240	1.4307	X2CrNi18-9
316L	S31603	A 240	1.4404	X2CrNiMo17-12-2
321	S32100	A 240	1.4541	X6CrNiTi18-10
347	S34700	A 240	1.4550	X6CrNiNb18-10
904L	N08904	B 625	1.4539	X1NiCrMoCu 25 20 5
AL-6XN®	N08367	B 688	--	--
20Cb-3®	N08020	B 463	--	--
3620Nb	N08020	B 463	2.4660	NiCr20CuMo
625	N06625	B 443	2.4856	NiCr22Mo9Nb
C-276	N10276	B 575	2.4819	NiMo16Cr15W
C-22	N06022	B 575	2.4602	NiCr21Mo14W
59	N06059	B 575	2.4605	NiCr23Mo16Al
400	N04400	B 127	2.4360	NiCu30Fe

*Sheet and Plate

WELD FILLERS. The prefix "SG" denotes bare wire, "EL" means covered electrodes.

Grade	UNS	AWS	W. Nr.	Designation
320LR	N08022	ER320LR	--	--
320LR-15	W88022	E320LR-15	--	--
625	N06625	ERNiCrMo-3	2.4831	SG-NiCr21Mo9Nb
112	W86112	ENiCrMo-3	2.4621	EL-NiCr20Mo9Nb
82	N06082	ERNiCr-3	2.4806	SG-NiCr20Nb
182	W86182	ENiCrFe-3	2.4620	EL-NiCr16FeMn
C-276	N10276	ERNiCrMo-4	2.4886	SG-NiMo16Cr16W
C-276	W80276	ENiCrMo-4	2.4887	EL-NiMo15Cr15W
C-22	N06022	ERNiCrMo-10	2.4635	SG-NiCr21Mo14W
C-22	W86022	ENiCrMo-10	2.4638	EL-NiCr20Mo14W
59	N06059	ERNiCrMo-13	2.4607	SG-NiCr23Mo16

SUGGESTED READING

20Cb-3® stainless data and other fabrication information available from Rolled Alloys include:

Bulletin No	Title	Pages
151	Corrosion Resistant Alloy Specifications & Operating Data Includes nine pages of corrosion tables	25
1006	20Cb-3® Stainless	4

320LR welding material is discussed in: R.S. Brown and J.B. Koch, Development of a Solidification Crack Resistant Weld Filler Metal for a Stabilized Fully Austenitic Alloy, pages 38-s to 42-s, *Welding Journal,* Volume 57 Number 2 February 1978

General austenitic alloy welding information is available in:

"Welding Dissimilar Metals" ed. N. Bailey, The Welding Institute, 1986.

T. G. Gooch "Solidification Cracking of Austenitic Stainless Steel" pp 31-40, Weldability of Materials, ed. R. A. Patterson & K. W. Mahin, ISBN: 0-87170-401-3 ASM International 1990.

"Arc Welding of Nickel Alloys" ASM Handbook Series Volume 6, Welding, Brazing and Soldering, ASM International, Ohio, USA.

E. F. Nippes & D. J. Ball "Copper-Contamination Cracking: Cracking Mechanism & Crack Inhibitors" pp 75-s to 81-s, Welding Research Supplement March 1982.

William G. Ashbaugh "Liquid Metal Embrittlement--Part II" pp 88-89, Materials Performance, February 1993.

INDEX

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