

TIP 0402-26

ISSUED – 1999
REAFFIRMED – 2005
©2005 TAPPI

The information and data contained in this document were prepared by a technical committee of the Association. The committee and the Association assume no liability or responsibility in connection with the use of such information or data, including but not limited to any liability under patent, copyright, or trade secret laws. The user is responsible for determining that this document is the most recent edition published.

CAUTION:

This TIP may require the use, disposal, or both, of chemicals which may present serious health hazards to humans. Procedures for the handling of such substances are set forth on Material Safety Data Sheets which must be developed by all manufacturers and importers of potentially hazardous chemicals and maintained by all distributors of potentially hazardous chemicals. Prior to the use of this technical information paper, the user should determine whether any of the chemicals to be used or disposed of are potentially hazardous and, if so, should follow strictly the procedures specified by the manufacturer, as well as local, state, provincial, and federal authorities for safe use and disposal of these chemicals.

Guidelines for welding and inspection of stainless alloy piping

Scope

This Technical Information Paper outlines considerations for fitup, welding and inspection of circumferential butt welds made during shop spooling and field installation of stainless alloy pipe and fittings; both thin wall (gauge) and thick wall (schedule). The stainless alloys included are austenitic stainless steels, duplex stainless steels, and nickel base alloys. It is assumed that:

- the weld root will not normally be accessible for direct visual inspection or repair
- all circumferential butt welds will be made using filler metal
- a solution heat treatment will not be performed after welding.

The goal is to provide guidance in obtaining welds appropriate for the intended service. The level of discussion is intended to provide background for evaluating or writing specifications. More detail about the subjects covered in this TIP is provided by the publications in the “References” section. References 1-3 provide useful general background.

Safety precautions

Adequate safety and industrial hygiene procedures must be in place for the cutting, welding, erection, cleaning, and inspection of stainless alloy pipe. The details of these procedures are beyond the scope of this TIP. In most cases jurisdictional or company policies will be in force. Anyone involved in welding or inspection of stainless alloy piping should make themselves familiar with the safety procedures in force on the job site.

Content

General considerations - codes and standards

ANSI/ASME B31.3 “Process Piping” (4) can be applied to pulp and paper industry stainless alloy piping. This code sets minimum requirements for materials, design, fabrication, and inspection of process pressure piping in a range of alloys and non metals. Other codes and standards (5, 6) may be useful in supplementing ANSI/ASME B31.3.

B31.3 is intended to cover process piping including steam and process chemicals, where pressure is greater than 103 kPa (15 psig) regardless of temperature. It may be mandatory in some jurisdictions or it may be referred to in specifications for stainless alloy piping. Simplistic specification statements like “fabrication and inspection shall

Alloy	“Matching “ filler metal	Overmatching filler metal
304L austenitic stainless steel	AWS E or ER308L	not generally used
316L austenitic stainless steel	AWS E or ER316L	317L is sometimes used
316L with 2.5% Mo		317L
317L austenitic stainless steel	AWS E or ER 317L	904L is sometimes used
Alloy 20	AWS E or ER320	
904L	AWS E or ER385	AWS E or ERNiCrMo-3
6% molybdenum austenitic stainless steels	matching filler not generally recommended or available	AWS E or ERNiCrMo-3
high nitrogen, high molybdenum superaustenitic stainless steels	matching filler not generally recommended or available	appropriate fillers are available from alloy suppliers
2304 duplex stainless steel	matching fillers may be available from some alloy suppliers	AWS E or ER2209
2205 duplex stainless steel	AWS E or ER2209	appropriate fillers are available - consult alloy suppliers
2505 and 2507 type duplex stainless steels	AWS E or ER2553 or matching fillers available from alloy suppliers	AWS E or ERNiCrMo-3 or as recommended by alloy suppliers
nickel base alloys	consult alloy supplier for appropriate fillers	

Heat affected zone (HAZ)

The formation of phases or structures that can reduce the corrosion resistance of the base metal heat affected zone depends on alloy chemistry and welding procedure. For austenitic stainless steels and nickel base alloys heat input should be minimized. For duplex stainless steels the heat input should be controlled within an optimum range (18, 19).

Surface oxides

The negative effects of weld-related oxide scales and heat tint are best eliminated by preventing their formation through adequate inert gas purging of the weld root. Where oxide scales and heat tint form they can be removed by pickling with pastes or fluids containing nitric and hydrofluoric acids or by other surface cleaning methods including abrasive blasting and sanding. Acid pickling usually provides the best results but is seldom practical for field welds because of access, safety, and environmental considerations.

Requirements for prevention and/or removal of oxide scale and heat tint should be based on an assessment of the costs and benefits in a given application. For example heat tint is not a concern in alkaline liquor service.

Weld quality

Welds in stainless alloy piping should in general meet the quality requirements of ANSI/ASME B31.3. Special or supplementary requirements may be warranted for some service conditions depending on:

- corrosivity
- loading conditions - e.g. vibration, hammer, stock stick-slip phenomena, etc. ANSI/ASME B31.3 provides guidance on load considerations.
- special surface finish requirements - e.g. headbox approach piping

Accordingly it is difficult to generalize about acceptable levels of weld imperfections which may include:

- cracking
 - may grow easily by fatigue, not acceptable in ASME pressure piping codes
- incomplete root penetration
 - stress raiser for crack initiation

- less than 1% oxygen is often specified for stainless alloy piping systems
- less than 0.5% oxygen is required to prevent root discoloration (heat tint) in pipe up to 50 mm (2 in.) diameter
- oxygen levels approaching zero are needed to prevent heat tint in pipe greater than 200 mm (8 in.) diameter.

Reference color charts have been developed which show the heat tint on stainless steel weld roots as a function of purging gas type and oxygen concentration at the weld root (21, 22). Where it has been established that control of heat tint is important for corrosion performance, a reference weld or color chart can be used as an acceptance standard.

Fluxes

Fluxes are available which are intended to protect the weld root from oxygen. They are typically supplied as a dry powder which is mixed with alcohol to make a paste and then applied on the inside surface of the pipe adjacent to the weld root and on the faces of the weld preparation. During welding the flux melts and flows over the molten root and adjacent parent metal.

When mixed and applied according to the manufacturer's instructions such fluxes are effective in limiting oxidation of the molten weld root and allowing full penetration welds with good profiles. They are less effective in preventing heat tint and they leave a flux residue on the root which may be undesirable in some services. Flux can dry out and fall off the inside surface of the pipe if the pipe is handled roughly during fit up.

When flux is to be used written instructions should be developed and included in the (WPS). Flux should be used in welder skill testing.

Flux cored and flux coated filler rods

Proprietary filler rods with flux coating or flux cores are also available as an alternative to inert gas purging for root pass welding. The effectiveness of these fillers depends on welder skill and adherence to the manufacturer's instructions. For example the pipe wall thickness and the weld root gap can influence performance..

If flux coated or flux cored filler rods are to be used the instructions for their use should be included in the WPS and they should be used in welder skill testing.

These products are not effective in preventing heat tint of the base metal adjacent to the weld and they leave a flux residue on the weld root.

Identification of welds

It is good practice to mark each weld with the name or number of the welder. Identification of welds is required by ANSI/ASME B31.3.

Post weld cleaning

As outlined in the "General considerations" section of this TIP, the nature and extent of post weld cleaning of weld roots should be based on consideration of the effect on service performance and the cost of cleaning. Complete removal of oxide and heat tint may require a combination of mechanical and chemical cleaning. This may be difficult for long runs of pipe where worker access to the inside is not possible.

The most effective chemical cleaning agents for stainless alloys are pastes, gels, or solutions containing nitric and hydrofluoric acids. These agents are harmful to human tissue and proper safety precautions should be followed in their use. In addition most jurisdictions will have environmental regulations governing proper disposal. Safety, application, and disposal instructions are available from the manufacturers of these products.

- underfill

underfill to a maximum of 20% of the pipe wall thickness provided both sides of the joint have been fused and the underfill has rounded contour.

- root protrusion

root protrusion less than or equal to 2.4 mm (3/32 in.) provided the root profile is smooth so as not to act as a stress raiser

ANSI/ASME B31.3 does not address weld root oxidation or heat tint. If control of weld root oxidation or heat tint has been specified then an appropriate reference weld or color chart can be used as a comparator for inspection.

Keywords

Welding, Stainless steel, Nickel, Corrosion, Inspection, Piping

Additional information

Effective date of issue: May 13, 2005.

Working Group Members:

Paul Whitcraft – Chairman, Rolled Alloys
Craig Reid, Bacon Donaldson Consulting Engineers
Dave Bennett, Consultant
John Grocki, Advantage Res. Consultants
Bob Charlton, Riverside Engineering
Steve Meiley, Mechanical and Materials Engineering
Arthur Tuthill, Consultant
Ralph Davison, Outokumpu Stainless
Max Moskal, M & M Engineering
Harry Dykstra, Bacon Donaldson Consulting Engineers
Christian B. Thompson, PAPRICAN

Literature cited

1. "Guidelines for the Welded Fabrication of Nickel-Containing Stainless Steels for Corrosion-Resistant Services," Richard E. Avery and A.H. Tuthill, Nickel Development Institute Publication 11 007. Toronto, 1992.
2. "Metals and their Weldability," Volume 4 of the *Welding Handbook*, 7th edition. Miami, American Welding Society, 1982.
3. "Welding Processes," Volume 2 of the *Welding Handbook*, 8th edition. Miami, American Welding Society, 1991.
4. ASME Code for Pressure Piping, B31.3:Process piping, ANSI/ASME B31.3, New York, The American Society of Mechanical Engineers.
5. "Recommended Practices for Root Pass Welding and Gas Purging," ANSI/AWS Standard D10.11. Miami, American Welding Society.
6. "Specification for Fusion Welding of Austenitic Stainless Steels," British Standard BS 7475. London, British Standards Institution.
7. *Corrosion*, D.F. Bowers, Chapter 10 (pp. 349-407) in *Mill Control & Control Systems: Quality & Testing, Environmental, Corrosion, Electrical*. Volume 9 of Pulp and Paper Manufacture, 3rd edition. Atlanta, TAPPI, 1992.
8. *Corrosion in the Pulp and Paper Industry*, edited by Andrew Garner. Pages 1187-1220 in *Corrosion*. Volume 13 of the Metals Handbook, 9th edition. Metals Park, Ohio, ASM International, 1987.



Figure 3. External repairs made to fatigue cracking which initiated at an incompletely penetrated root in a paper machine stock line weld. Such external repairs are temporary as fatigue cracking will persist if root imperfections and cyclic loading remain. Note that the cracking has diverged into the base metal.

