AWWA C231

American Water Works Association

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ANSI/AWWA C231-17
(First Edition)

AWWA Standard

Field Welding of Stainless-Steel Water Pipe

Effective date: Dec. 1, 2017.
First edition approved by AWWA Board of Directors June 11, 2017.
Approved by American National Standards Institute June 29, 2017.

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AWWA Standard

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ISBN-13, print: 978-1-62576-272-6 eISBN-13, electronic: 978-1-61300-456-2
DOI:http://dx.doi.org/10.12999/AWWA.C231.17

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C231.*

I. Introduction.

I.A. *Background.* The provisions of this standard describe the requirements for welding stainless-steel water pipe joints in water transmission and distribution lines. The purchaser for each project is responsible for determining if any unusual circumstances related to the project require additional provisions that are not included in the standard.

The design of field-welded joints is not discussed in this standard. Useful information on this subject may be found in AWWA Manual M11, *Steel Pipe: A Guide for Design and Installation*,† and in *Useful Information on the Design of Plate Structures.*‡

I.B. *History.* This is the first edition of this standard. This edition was approved by the AWWA Board of Directors on June 11, 2017.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF§) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the Water Research Foundation (formerly AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.¶ Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

Specific policies of the state or local agency.

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* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

† AWWA Manual M11. *Steel Pipe—A Guide for Design and Installation*. Denver, CO: AWWA.

‡ American Iron and Steel Institute. *Useful Information on the Design of Plate Structures, Steel Plate Engineering Data*, Vol. 2. Washington, D.C.: American Iron and Steel Institute (1101 17th Street, NW, Suite 1300, Washington, DC 20036).

§ NSF International, 789 North Dixboro Road, Ann Arbor, MI 48105.

¶ Persons outside the United States should contact the appropriate authority having jurisdiction.

1. Two standards developed under the direction of NSF: NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.

2. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,* and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdictions. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA C231 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.

2. Determine the status of certifications by parties offering to certify products for contact with, or treatment of, drinking water.

3. Determine current information on product certification.

II. Special Issues. This standard has no applicable information for this section.

III. Use of This Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. *Purchaser Options and Alternatives.* The following information should be provided by the purchaser:

1. Standard used—that is, ANSI/AWWA C231, Field Welding of Stainless-Steel Water Pipe, of latest revision.

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* Both publications available from National Academy of Sciences, 500 Fifth Street, NW, Washington, DC 20418.

2. Whether compliance with NSF/ANSI 61, Drinking Water System Components—Health Effects, is required.

3. Details of other federal, state or provincial, and local requirements (Sec. 4.1.1).

4. Type of joint (Sec. 4.2).

5. Option regarding backing rings (Sec. 4.2.3).

6. Weld inspection, if required (Section 5.1.3).

7. Testing methods, if required (Section 5.2).

8. Nondestructive testing of welded joints if substituted for hydrostatic tests (Sec. 5.2).

9. Affidavit of compliance (Sec. 6.2).

III.B. *Modification to Standard.* Any modification of the provisions, definitions, or terminology in this standard must be provided by the purchaser.

IV. Major Revisions. This is the first edition of the standard.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Engineering and Technical Services at 303.794.7711, FAX at 303.795.7603; write to the department at 6666 West Quincy Avenue, Denver, CO 80235-3098; or email at standards@awwa.org.

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AWWA Standard

Field Welding of Stainless-Steel Water Pipe

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes manual, semiautomatic, and automatic field welding by the metal arc-welding processes for stainless-steel potable water, wastewater, and reclaimed water pipe manufactured in accordance with ANSI/AWWA C220. This standard describes field welding of two types of circumferential pipe joints: lap joints and butt joints. This standard also applies to other welding required in field fabrication and installation of specials and appurtenances. When possible, fabrications should be performed by the manufacturer at a manufacturing facility. The design of field-welded joints is not within the scope of this standard.

This standard recognizes AWS* D1.6/D1.6M as the supporting document that provides more specific information except as noted in this standard.

Sec. 1.2 Purpose

The purpose of this standard is to provide minimum requirements for field welding and inspection of field welds on stainless-steel potable water, wastewater, and reclaimed water pipe.

* American Welding Society, 550 Northwest LeJuene Road, Miami, FL 33126.

Sec. 1.3 Application

This standard can be referenced in documents for field welding of stainless-steel potable water, wastewater, and reclaimed water pipe. The stipulations of this standard apply when this document has been referenced and then only to field welding of stainless-steel pipe.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

ANSI/AWWA C220—Stainless-Steel Pipe—½ In. (13 mm) and Larger.

ANSI/AWWA C226—Stainless-Steel Fittings for Waterworks Service, Sizes ½ In. Through 72 In. (13 mm Through 1,800 mm).

ANSI/AWWA C228—Stainless-Steel Pipe Flange Joints for Water Service—Sizes 2 In. Through 72 In. (50 mm Through 1,800 mm).

AWS A2.4—Standard Symbols for Welding Brazing and Nondestructive Examination.

AWS A3.0M/A3.0—Standard Welding Terms and Definitions; Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying.

AWS A5.30/A5.30M—Specification for Consumable Inserts.

AWS D1.6/D1.6M—Structural Welding Code—Stainless Steel.

AWS QC1—Standard for AWS Certification of Welding Inspectors.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Backing gas:* A gas used to replace air to avoid oxidation on the backside of a weld.

2. *Buttering:* The addition of material, by welding, on one or both faces of a joint, before preparation of the joint for final welding, for the purpose of providing a suitable transition weld deposit for the subsequent completion of the joint.

3. *CJP:* Complete joint penetration.

4. *Constructor:* The party that provides the work and materials for placement or installation.

5. *Crevice:* Narrow openings, gaps, pores, and so on between metal-to-metal components that may encourage localized corrosion. Seams, cracks, and porosity in welds may act as crevices.

6. *CWI—certified welding inspector:* Certified welding inspector as defined in AWS QC1.

7. *Faying surfaces:* The mating surface of a member that is in contact with, or in close proximity to, another member to which it is to be joined.

8. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

9. *Potable water:* Water that is safe and satisfactory for drinking and food preparation.

10. *PQR—procedure qualification record:* A record that contains the actual variables used to weld a test specimen. This record also documents the destructive and nondestructive test results and the certifying organization.

11. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

12. *Reclaimed water:* Wastewater that becomes suitable for beneficial use as a result of treatment.

13. *Specials and appurtenances:* May include, but are not limited to, fittings per ANSI/AWWA C226 and flanges per ANSI/AWWA C228.

14. *Wastewater:* A combination of the liquid and water-carried waste from residences, commercial buildings, industrial plants, and institutions, together with any groundwater, surface water, and stormwater that may be present.

15. *Welder or welding operator:* A person who performs a manual, semiautomatic, or automatic welding operation.

16. *Welding symbols:* Symbols used on documents to define the weld type, location, and geometry per AWS A2.4.

17. *WPQR—welder performance qualification record:* The document to describe the welder testing and results of that testing that allows certification of a welder to perform welding.

18. *WPS—welding procedure specification:* A document to describe the range of voltage, amperage, travel speed, and other parameters intended to be utilized in the welding process.

SECTION 4: REQUIREMENTS

Sec. 4.1 General Requirements

4.1.1 *Materials.* Materials shall comply with the requirements of the Safe Drinking Water Act and other federal regulations for potable water, wastewater, and reclaimed water systems as applicable.

4.1.2 *Construction drawings.* Construction drawings shall be the purchaser's drawings or approved constructor's drawings.

4.1.3 *Welding terms.* Welding terms shall be interpreted in accordance with the definitions given in AWS A3.0M/A3.0, supplemented by Annex L of AWS D1.6/D1.6M.

4.1.4 *Equipment.* The constructor's equipment for all welding shall be designed and maintained in such condition as to permit qualified welding operators to follow the welding procedure details (Sec. 4.5) and obtain the results prescribed.

4.1.5 *Welding.* Welding shall be performed by a process that will meet the welding procedure qualification required in Sec. 4.3 of this standard and provide corrosion resistance for the application.

4.1.6 *Safety and environmental considerations.* This standard does not address all hazards associated with welding operations. Welding, cutting, and grinding operations will produce smoke and fumes. In confined spaces, the constructor may be required to utilize exhaust ventilation systems, employ air-monitoring equipment, and take other actions to ensure compliance with safety regulations. Interior pipe welding shall only be performed after safe and adequate access and egress are provided for the personnel. Federal, state or provincial, and local regulations shall also be followed.

4.1.7 *Pipe condition.* Prior to welding, ends of pipe to be welded shall be in conformance with the requirements for end preparation for field joints in accordance with ANSI/AWWA C220. Any coatings or linings shall be held back from the end of the pipe in an amount that is appropriate for the type of joint.

Sec. 4.2 Joint Types

4.2.1 *General.* Joints shall be lap joints or butt joints as specified by the purchaser. Crevices resulting from a joining process shall be avoided when welding stainless steels.

4.2.2 *Lap joints.* To prevent crevices and potential corrosion, lap joints shall be joined with fillet welds on both sides of the joint. A different type of joint

should be used if the interior lap joint weld cannot be completed. Field joints shall be assembled so that seams in adjacent pipe sections are offset from each other by at least five times the thickness of the thinner of the pipes being joined.

4.2.3 *Butt joints.* Butt joints shall be complete joint penetration (CJP) welds. Field joints shall be assembled so that seams in adjacent pipe sections are offset from each other by at least five times the thickness of the thinner of the pipes being joined. An inert gas for purging shall be used if the pipe interior is inaccessible. If required, various devices including inflatable, rigid, and water-soluble dams can be used to contain backing gases. If the interior is accessible, the use of an inert gas for purging is recommended. However, if a purging gas is not used, all heat tint shall be removed.

If backing rings are used, they should be removed after welding is complete to eliminate potential crevices. Consumable inserts may also be used to ensure the joint is complete and free from crevices. Information on consumable inserts can be found in AWS A5.30/A5.30M.

Sec. 4.3 Qualification of Welding Procedures, Welders, and Welding Operators

4.3.1 *General.* Joint-welding procedures (except procedures that comply with Sec. 4.4.2) to be used for work under the provisions of this standard, welders, and welding operators shall be qualified by testing. General requirements for qualification shall be in accordance with AWS D1.6/D1.6M, Clause 4, Qualification.

4.3.2 *Welding procedure qualification record (PQR).* Certain welding procedures as outlined in AWS D1.6/D1.6M, Clause 3, Prequalification, are prequalified and are exempt from further qualification testing. Other procedures shall be qualified in accordance with AWS D1.6/D1.6M, Clause 4, Qualification. Written PQRs and WPSs (welding procedure specifications) shall be prepared by the constructor and shall be made available to the welders at the jobsite and to those authorized to examine the welds. In the case of prequalified welds, PQRs are not required.

4.3.3 *Welder, welding-operator, and tack welder qualification.* Welders and welding operators shall be qualified by tests as prescribed in AWS D1.6/D1.6M. The welder performance qualification record (WPQR) provides certification that the welder, welding operator, or tack welder is qualified to perform welding under this standard.

4.3.3.1 Period of effectiveness. The period of effectiveness shall be in accordance with AWS D1.6/D1.6M.

4.3.3.2 Records. Records of the test results shall be kept by the constructor and shall be made available to the purchaser.

Sec. 4.4 Stainless-Steel Filler Material

4.4.1 *General.* Filler material and electrodes shall have the same specifications as those used for welding procedure qualifications in Sec. 4.3.2. The constructor shall control the storage and handling of electrodes as recommended by the electrode manufacturer to limit moisture exposure.

4.4.2 *Dissimilar metals.* When welding dissimilar base metals, it is typical to use a filler metal that is available for the higher composition base metal. When dissimilar welds are made (such as 304 to carbon steel), a buttering technique may be used to reduce the potential for hot cracking. (See appendix A for dissimilar welding filler material recommendations.)

Sec. 4.5 Welding Procedure Details

4.5.1 *General.* Welds in the pipe and the attachments shall be performed in strict accordance with the procedures stated in Sec. 4.3. If the interior of the pipe to be welded will be purged with a backing gas (typically argon or nitrogen) in accordance with Sec. 4.2.3, before welding, follow a repeated flushing procedure to reduce the oxygen content to a level below 100 ppm. The successful use of gas-purging equipment for site fabrication will shield the inside of the joint from atmospheric contamination and can have a major impact on limiting stainless-steel weld zone discoloration and improving the final weld quality. Unsatisfactory purging results in oxidation of the weld zone leading to a reduction in corrosion resistance.

4.5.2 *Preparation of welding surfaces.* Surfaces to be welded shall be free from moisture, oxide scale, slag, embedded iron, heavy rust, grease, coatings, paint, primer, cement, crayon markings, or any other foreign material. Joint surfaces shall be smooth, uniform, and free from defects (such as oxide scale) that adversely affect proper welding. Surfaces that were previously torch cut or air-arc gouged shall be ground to remove slag and oxidation. All grinding materials should be clean and not previously used for grinding carbon steel.

4.5.3 *Environmental conditions.* Welding shall not be performed when surfaces are wet or during periods of high wind unless the operator and the work are properly protected.

4.5.4 *Preheating and interpass temperature.* At a minimum, preheat temperatures shall be sufficient to remove moisture from the joints to be welded. Specific preheating and interpass temperatures for the joints to be welded shall be

per qualified WPS. Preheat and all subsequent minimum interpass temperatures shall be maintained during the welding operation for a distance at least equal to the thickness of the thickest welded part but not less than 3 in. (75 mm) in all directions from the point of welding.

4.5.5 *Tack welding.* Small erection tack welds used in the assembly of joints need not be removed provided (1) they are sound and their size does not exceed the subsequently applied root pass; (2) they do not prevent the proper distribution of the annular space to control the distance between faying surfaces in lap joints; (3) the filler material used in making the tack welds shall be the same as used in the final welds; and (4) welding is performed in strict accordance with the procedures stated in Sec. 4.4.

4.5.6 *Application and weld contour.* The welds shall be applied using continuous stringer beads or a weave pattern as qualified per Sec. 4.3. AWS D1.6/D1.6M shows acceptable and unacceptable weld profiles. On second pass and each subsequent pass, all slag or foreign materials shall be completely removed. The cleaning process shall not contaminate the weld area. When wire brushes are used, the brushes shall be made of stainless-steel materials; under no circumstance shall carbon steel brushes, or iron brushes, or brushes previously used on carbon steel or iron be used. Grinding shall be done with iron-free abrasive wheels. Contaminating the stainless-steel base material with iron particles will cause premature corrosion and potential failure of the joint. Welded joints shall not be covered or coated until after welding is completed and the weld accepted. All heat tint and weld slag shall be removed on completion of the weld (see appendix B for recommendations).

4.5.6.1 Surface pass. The surface pass on groove welds shall be smooth and free from depression.

4.5.6.2 Undercutting and finished fillet weld. Undercutting that exceeds AWS D1.6/D1.6M statically loaded requirements is a defect and shall be repaired. Burning back the inside or outside corner during application of a fillet weld shall be permitted if the edge can be clearly defined. The finished fillet weld shall be free of grooves, deep valleys, or ridges and shall contain no abrupt changes in the section at the toe.

4.5.6.3 Fillet welds. Fillet welds shall have legs of equal size, except when specified otherwise. The faces of fillet welds may be slightly convex, flat, or slightly concave.

4.5.6.4 Cracks, pinholes and arc strikes. Cracks in welds and base metal, incomplete fusion, lack of complete joint penetration (including fillet welds that do

not penetrate past the point of intersection of the members being joined), and weld overlap are unacceptable. Pinholes are unacceptable and shall be repaired according to Sec. 4.6. Arc strikes outside the weld boundary are unacceptable and shall be ground flush with the base metal and shall be repaired according to Sec. 4.6 if additional weld metal is required.

4.5.7 *Butt joint alignment.* Butt joints shall be accurately aligned and retained in position during the welding operation so that in the finished joint the abutting pipe sections shall not be misaligned by more than 20 percent of the lesser pipe wall thickness or a maximum of ⅛ in. (3.2 mm), whichever is less.

Sec. 4.6 Repair of Welds

Defects in welds or defective welds shall be removed and that section of the joint shall then be repaired in accordance with Sec. 4.3, Sec. 4.4, and Sec. 4.5. The amount of material removed shall be limited to that required to correct the defect. After the repair is made, the joint shall be checked by repeating the original test procedure.

SECTION 5: VERIFICATION

Sec. 5.1 Inspection

Inspection or a lack of inspection shall not relieve the constructor of the responsibility for performing work in accordance with this standard. The constructor shall notify the purchaser before performing any work under the provisions of this standard so that the purchaser can prepare for the inspection.

5.1.1 *Access.* The purchaser shall have access to those areas of the project that are involved with the performance of any work pertaining to this standard.

5.1.2 *Facilities.* When requested by the purchaser, the constructor shall provide reasonable facilities and space for inspection, testing, and obtaining the information required to determine the character of materials used, the progress and conditions of the work, and the results obtained.

5.1.3 *Weld inspection.* When requested by the purchaser, a full-time welding inspector shall be present whenever welding is to be performed. The welding inspector shall have prior welded pipe inspection experience and shall be a certified welding inspector (CWI) in accordance with the provisions of AWS QC1.

5.1.4 *Visual inspection.* An individual who by training, or experience, or both in metals fabrication, inspection, and testing is competent to perform the

visual inspection shall visually inspect all field welds. Any of the weld defects identified by visual inspection shall be cause for rejection, and the deficient weld shall be repaired or replaced. The acceptance criteria for field welds shall meet the requirements of AWS D1.6/D1.6M, section on Quality of Welds—Statically Loaded; AWS D1.6/D1.6M, Annex A, Recommended Inspection Practice; and the weld profile acceptance requirements of AWS D1.6/D1.6M, Figure 5.2, Typical Weld Profiles.

Sec. 5.2 Testing

Testing for joint leaks shall be performed as specified by the purchaser.

5.2.1 *Hydrostatic test.* Tests for leaks in all types of welded joint pipelines shall be made by hydrostatically testing the entire pipeline. If leakage exceeds the amount allowed in the purchaser's documents, leaks shall be located and repaired in conformance with Sec. 4.6.

5.2.2 *Alternative tests.* In lieu of the hydrostatic test, the purchaser may approve other methods of nondestructive testing of welded joints.

Sec. 5.3 Rejection

Any work that is not in accordance with the requirements of this standard will be rejected. The constructor has the option of either repairing or removing and replacing the welds.

SECTION 6: DELIVERY

Sec. 6.1 Marking

Original markings shall be maintained. Any markings that must be removed for welding should be relocated unless the pipe can be identified after removal.

Sec. 6.2 Affidavit of Compliance

The purchaser may require an affidavit from the constructor stipulating that all field welds on the pipe and attachments have been made in accordance with applicable provisions of this standard.

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APPENDIX A

Stainless-Steel Filler Material

This appendix is for information only and is not a part of AWWA C231.

Filler material specific to welding processes are given in the following AWS standards:

1. AWS A5.4 SMAW electrodes
2. AWS A5.9 GMAW electrodes, GTAW welding rod, SAW electrodes
3. AWS A5.22 FCAW electrodes, cored wire for GTAW
4. AWS A5.30 Consumable inserts

Table A.1 Recommended filler materials

Base Metal/Grade—Type	AWS A5.9 (GMAW, SAW, GTAW, PAW) Bare Filler Material	AWS A 5.4 (SMAW) Welding Electrodes	AWS A5.22 (FCAW, GTAW) Flux Cored Wires (Gas Shielded/ Self-Shielded)
304—Austenitic	ER 308	E308-XX	E308TX-X/E308T0-3
304L—Austenitic	ER 308L	E308L-XX	E308LTX-X/E308LT0-3
316—Austenitic	ER 316	E316-XX	E316TX-X/E316T0-3
316L—Austenitic	ER 316L	E316L-XX	E316LTX-X/E316LT0-3
2205—Duplex	ER 2209	E2209-XX	NA/E2209T0-X
2101—Duplex	ER 2209	E2209-XX	NA/E2209T0-X
2202—Duplex	ER 2209	E2209-XX	NA/E2209T0-X
2003—Duplex	ER 2209	E2209-XX	NA/E2209T0-X
2304—Duplex	ER 2209	E2209-XX	NA/E2209T0-X

NOTE: GMAW—gas metal arc welding; SAW—submerged arc welding; GTAW—gas tungsten arc welding; PAW—plasma arc welding; SMAW—shielded metal arc welding; FCAW—fluxed cored arc welding; NA—not applicable; ER—electrode rod; E—electrode

Table A.2 Recommended filler material for joining dissimilar metals

Base Metal/ Grade— Type	AWS A5.9 (GMAW, SAW, GTAW, PAW) Bare Filler Metal	AWS A 5.4 (SMAW) Welding Electrodes	AWS A5.22 (FCAW, GTAW) Flux Cored Wires (Gas Shielded/ Self-Shielded)
304L—Austenitic to Carbon Steel	ER 309L	E309-XX	E309TX-X/E309T0-3
304L—Austenitic to Duplex SS 2205	ER 309L or ER309LMo	E309L-XX or ER309LMo	E309LMoTX-X/ E309LMoT0-3
304L—Austenitic to LDuplex SS 2304, LDuplex SS 2101, LDuplex 2202, LDuplex SS 2003	ER 309L or ER309LMo	E309L-XX or ER309LMo	E309LMoTX-X/ E309LMoT0-3
Duplex SS 2205—to Carbon Steel	ER 309L or ER309LMo	E309L-XX or ER309LMo	E309LMoTX-X/ E309LMoT0-3
Duplex SS 2205—LDuplex SS 2304, LDuplex SS 2101, LDuplex 2202, LDuplex SS 2003	ER 2209 (Alternates: ER 309L, ER 309LMo)	E2209-XX (Alternates: E309L, E309LMo)	NA/E2209T0-X
LDuplex SS 2304, LDuplex SS 2101 or LDuplex SS 2003 to Carbon Steel	ER 309L or ER309LMo (Alternate: ER 2009)	E309L-XX or ER309LMo (Alternate: E2209)	E309LMoTX-X/ E309LMoT0-3

NOTE: GMAW—gas metal arc welding; SAW—submerged arc welding; GTAW—gas tungsten arc welding; PAW—plasma arc welding; SMAW—shielded metal arc welding; FCAW—fluxed cored arc welding; NA—Not applicable; ER—Electrode rod; E—Electrode

APPENDIX B

Postfabrication Cleaning of Stainless Steels

This appendix is for information only and is not a part of AWWA C231.

Stainless steel relies on a thin invisible "chromium oxide" passive film to protect itself from environmental corrosion. Postfabrication cleaning may be the most important factor in maximizing and preserving the passive film and therefore the corrosion resistance of fabricated stainless-steel pipe. The postfabrication cleaning should remove all contamination (high temperature oxide films from welding, other nonstainless metals, grease, or oil) associated with the fabrication process. This cleaning process generally involves various chemical and mechanical methods, either individually or in combination.

The type of contamination(s) will determine the cleaning methods required.

Sec. B.1 Cleaning Methods

B.1.1 *Grease, oil, and so on.* The contamination can be removed using a nonchlorinated industrial solvent. Mechanical cleaning may be used, but it may smear the contamination on the surface and the contamination may then inhibit any chemical cleaning step to follow.

B.1.2 *Surface rust.* For surface "rust bloom" caused by iron (from carbon steel or ductile iron) particles rusting on the surface of the stainless steel either a well-controlled mechanical or a nonaggressive chemical treatment can be used for removal. For a mechanical method, both complete removal of the contamination and an appropriate surface finish must be achieved. Nonaggressive chemical solutions would be either phosphoric acid or citric acid.

B.1.3 *Embedded rust.* To remove iron particles "mechanically" embedded into the stainless surface, either a controlled mechanical or an aggressive chemical treatment will be required. With mechanical methods, care must be taken to avoid smearing clean metal over the contamination, hiding it rather than removing it. Final surface finish is also a concern. Aggressive chemical treatments are nitric-hydrofluoric acid mixtures and are commonly called "pickling solutions." These solutions will dissolve some of the stainless steel around the embedded particle, ensuring complete removal of the particle while conditioning the surface for complete reformation of the passive film in that area. If mechanical damage to the

surface is significant, a mechanical treatment may be required after pickling to smooth the surface.

B.1.4 *Heat tint.* For high temperature oxides such as weld heat tint, an aggressive chemical "pickling" treatment will provide the best results. Heat tint is a high temperature chrome-oxide layer formed using chrome from the base metal. It is not a passive layer and the darker it is the thicker it is and the more chrome has been removed from the base material. Aggressive ions can break through the heat tint, exposing the chrome-depleted layer below. The depleted layer is susceptible to corrosion. Once corrosion starts in the depleted layer, it will likely continue into the base material.

Pickling (HNO_3/HF) solution chemically attacks the oxide layer, dissolving it to leave a clean, fully alloyed base material surface, which passivates naturally when exposed to oxygen and oxygenated atmospheres. This provides optimum corrosion resistance in the treated area. Mechanical treatment (e.g., grinding) for the weld zone area is possible, but the smearing issues can result in incomplete removal of the heat tint and result in decreased corrosion performance. It is beneficial to do a chemical treatment after any mechanical treatment whether that mechanical treatment is used to develop a required weld profile, remove spatter, or even as a preliminary step to heat tint removal. The chemical treatment should always be the final treatment.

Another concern with heat tint is whether it needs to be removed at all. As the oxide layer becomes thicker, the negative effect on corrosion resistance increases. At thinner conditions the effect may not be sufficient to change the material's overall performance. Typically, the color of the heat tint is considered a gauge of its thickness: darker equals thicker. The actual effect varies not only by thickness but also by alloy. Color comparison charts are available to assist in the determination of the nature of heat tint, but these are also subjective and should be used carefully. The best results will always be achieved by pickling.

Sec. B.2 Safety

Proper safety and environmental precautions per manufacturer's recommendations and local regulations should be followed for any chemical and/or mechanical treatment selected.

Sec. B.3 Additional Information

In-depth information on cleaning method selection, procedures and techniques, health and safety issues, and so on can be found in the following documents:

TAPPI TIP 0402-35—Post-Fabrication Cleaning of Stainless Steel in the Pulp and Paper Industry. Available from TAPPI (Technical Association of the Pulp and Paper Industry @ TAPPI.org).

AWS D18.2—Guide to Weld Discoloration Levels on Inside of Austenitic Stainless Steel Tube.

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1P–2M 43231-2017 (12/17) IW

Printed on Recycled Paper

ISBN 978-1-62576-272-6