

GUIDELINES FOR FABRICATION & INSTALLATION OF STAINLESS STEEL HIGH PURITY DISTRIBUTION SYSTEMS

Prepared by
Pipe Fabrication Institute Engineering Committee



All PFI Standards are advisory only. There is no agreement to adhere to any PFI Standard and their use by anyone is entirely voluntary.

Copyright by
PIPE FABRICATION INSTITUTE
*Dedicated to Technical Advancement and Standardization in
the Pipe Fabrication Industry*
Since — 1913

P. O. Box 173 ● Springdale, PA 15144

GUIDELINES FOR FABRICATION & INSTALLATION OF STAINLESS STEEL HIGH PURITY DISTRIBUTION SYSTEMS

1.0 Scope

- 1.1 This Technical Bulletin addresses materials, fabrication, installation and final documentation required for stainless steel high purity distribution systems, for either liquid or gaseous products.

2.0 Application

- 2.1 Stainless steel high purity distribution systems are typically specified for critical clean applications in the Semiconductor, Pharmaceutical, Bio-Pharmaceutical, Chemical, Fiber Optics, Food, and Dairy Industries.
- 2.2 This information provides a contractor the ability to review customers' specifications from materials acquisition through system installation. This Technical Bulletin is not intended to take precedence over customer specifications or procedures.

3.0 References

- 3.1 ASME, Section IX Welding & Brazing Qualifications.
- 3.2 ASME Sections as applicable.
 - A. ASME B 31.1 Power Piping.
 - B. ASME B 31.3 Chemical & Petroleum Refinery Piping.
 - C. AWS Z 49.1 Safety in Welding & Cutting.
- 3.3 ASTM, Sections as applicable.
 - A. ASTM A632
 - B. ASTM A269
 - C. ASTM A270
 - D. ASTM A450
- 3.4 Current Good Manufacturing Practice (CGMP) Regulations of the Food and Drug Administration chapter 1 of CFR 21, part 210 & 211.

4.0 Materials

- 4.1 The normal alloy of choice is 316L stainless steel. To satisfy specific applications, the customer may specify stainless steel materials of other ASTM types such as 304, 304L, 316, 317, 317L or nickel alloys such as Hastelloy or Inconel. Additional specific controls on material chemistry (i.e. limits on sulfur content or other elements) may be required for best success in specific applications.
- 4.2 Tube and tube fittings are the typical product form specified in lieu of pipe except for large diameter systems. Tube and fittings are manufactured to more exact dimensional tolerances, meeting the requirements of high purity automated welding processes and weld acceptance criteria. Tubing sizes smaller than 2" OD should be specified to be seamless material. Tubing 2" OD and larger is typically specified as rolled-and-welded with a continuous long seam. The longitudinal seam is manufactured to present a smooth, uniform interior surface. All fittings should be of the long tangent tube type, with a square butt weld end preparation to facilitate automatic welding. The interior surface should have the same quality finish as the tube or component item to which it is to be welded.
- 4.3 Valves: All valves should be of the type, model, and size specified in the design. Valves should have an interior surface finish equal or better than the adjacent tube. The valve body should be of forged or wrought material in lieu of castings. Valves shall have either square butt end preparation for welding or sanitary tri-clamp type end connections when they must be removable.
- 4.4 Components: All other components such as regulators, filters, pressure transducers, etc., that are integrated into the systems should have the same quality surface finish as the tube and fittings. Components shall have sanitary tri-clamp type end connections or extended square butt ends for welding.

4.5 Surface Finish: The interior surface of high-purity tubing is normally polished (commonly 180 grit or better) to minimize surface roughness and cleaned to minimize systems contamination upon installation. The interior surface may require mechanical polishing and/or electro-polishing to meet specific Ra microinch finish. Exterior polish for aesthetic or housekeeping reasons is optional to the customer. Surface finishes as specified by the customer, are available as follows:

4.5.1 Mill Finishes: An unpolished mill finish is typically 60 to 100 Ra.

4.5.2 Mechanical Polish Finishes:

- A. 180 grit polish = an average 25 Ra or maximum 30 Ra
- B. 240 grit polish = an average 16 Ra or maximum 20 Ra.
- C. 320 grit polish = an average 10 Ra or maximum 12 Ra

4.5.3 Chem-Polished:

- A. Less than 20 Ra
- B. Less than 10 Ra

4.5.4 Combinations of mechanical polishing and a subsequent electropolish process can produce surface roughness readings as low as 5 Ra microinch.

4.6 Receipt Inspection:

4.6.1 Minimum Inspection Checklist:

- A. Damage during shipment
- B. Dimensional tolerances (in accordance with ASTM Spec.)
- C. Surface Finish (Ra)
- D. Material markings traceable to Material Test Reports (MTR's)
- E. Surface contamination
- F. Or other owner specified criteria

5.0 End Preparation

5.1 Cuts and end preparation should be performed using tubing cutters and equipment specifically designed for making a square face butt weld end prep. Abrasive wheel or saw cutting is discouraged for contamination reasons, and the difficulty in removing chips or dust from the inside of tubing.

5.1.1 End preparations should be cleaned with Isopropyl Alcohol (IPA) or other customer approved cleaning solutions, and lint free wipes.

5.2 Tools and equipment used for preparing or cutting tubing and/or fittings should be segregated from other tools and not used for other work. Tools, equipment, and machinery should be cleaned with Isopropyl Alcohol (IPA) or other customer approved cleaning solutions, and protected from contamination when not in use. (See PFI Std ES 43.)

5.3 If valves or components contain heat sensitive parts, such as plastic or rubber, these parts should be removed before welding to prevent heat damage. Components that cannot be removed, should be properly cooled during welding.

5.4 Proper levels of cleanliness should be provided for materials to be fabricated, as well as the fabrication area. (i.e. clean room, moon suits etc.)

6.0 Welding

6.1 Process: The Gas Tungsten Arc Welding (GTAW) process shall be used. Automatic orbital welding should be used whenever possible; however, manual welding may be used when it is not practical to use the automatic process. The piping system should be erected in a manner that will minimize manual welding. Inert backing gas shall be utilized for all welds.

6.2 Equipment: Automatic orbital weld equipment should include as a minimum, a constant current power supply, a control console with the capability of controlling the current and travel speed in at least four zones, and an enclosed shielded orbital welding head with high frequency arc initiation. Where line voltage fluctuates, a constant voltage transformer may be required.

6.3 Manual GTAW equipment should include a constant current power supply, high frequency arc initiation, and a foot pedal current control or equivalent. The welding torch should be equipped with a gas lens.

6.4 Electrode: The electrode may be two percent thoriated or two percent ceriated tungsten, of size and configuration suitable for autogenous welds, and in accordance with the WPS and equipment manufacturers' recommendations. Electrode should

be sharpened to a pencil point having a flat end of 0.005" - 0.010". Grinding should be performed using a fine grinding wheel.

6.4.1 Tungsten lengths for orbital heads should be prepared per equipment manufacturer schedules.

6.5 Gas Tungsten Arc welds on high purity distribution systems should be single pass, autogenous (no filler metal added). The maximum thickness of tube to be fusion welded is 0.125" in a single pass. Typically, the use of a filler metal in any weld must have approval of the customer.

6.6 Shielding and backing gases should be procured to the required purity level accompanied by actual analytical certifications. The fabricator or installer may be required to perform independent analytical certification of their gas delivery systems. Gas purifying filters as required by the specification shall be used in all gas delivery systems.

6.7 After welding has been completed, a post weld shielding gas should remain flowing long enough to minimize discoloration of the weld.

6.8 Blind welds should not be permitted except as follows: An initial, identical weld coupon must be welded using the same materials (heat number, dimensions etc.) as the blind weld and under the same welding parameters. If this weld is acceptable, the blind weld may be accomplished. After making the blind weld, a second weld coupon is made with the same materials and the same weld parameters. Only when the second weld coupon is acceptable should the blind weld be accepted.

6.9 Weld Repairs:

6.9.1 One re-weld over a weld bead rejected for incomplete penetration or excessive concavity is permissible. If the re-weld attempt fails, the weld must then be removed from the system.

6.9.2 All other rejectable weld defects shall be corrected by removing the entire weld bead and heat affected zone. The joint is to be re-prepared for welding and a replacement weld installed.

7.0 Weld Acceptance Criteria

7.1 Welds should meet the following characteristics:

- A. Oxidation: The interior surface of the weld shall be free of black, dark brown, dark blue, or grain type (sugaring) oxidation. Light straw, yellow, or light blue oxidation are acceptable. Discoloration of the interior weld and heat affected zone, should be minimized.
- B. Lack of fusion and/or incomplete penetration is not permitted.
- C. Undercut: Undercut is not permitted.
- D. Misalignment: Misalignment in welds two inch in diameter, and smaller shall not exceed 10% of wall thickness. Misalignment in welds over two inches in diameter shall not exceed 15% of wall thickness (Note: Percentages may vary per customer specifications).
- E. Heat Cracking (checking): None is permitted.
- F. Porosity: No visually detected surface porosity is permitted.
- G. External Concavity: Concavity in welds two inch in diameter and smaller shall not exceed 10% of wall thickness. Concavity in welds over two inches in diameter shall not exceed 15% of wall thickness.
- H. External Convexity and Internal Protrusions: For welds under two inches in diameter - 0.005" maximum. For welds over two inches in diameter - 0.010" maximum.
- I. Meandering (Bead Wandering): Maximum amount allowable - 25% of the width of the interior weld bead. Any amount of meandering that results in a lack of fusion is not acceptable.
- J. Inspections of the weld crater: The depth of the weld crater shall not exceed 10% of the weld thickness. When the end of the weld does not have full taper at its conclusion, the weld is subject to rejection.
- K. Weld Bead Width: The width of the weld bead on the interior surface shall be "T" - "2T" (where "T" equals the wall thickness of the base metal). The weld bead uniformity shall not exceed plus or minus 1/2T.

7.2 Sample welds (workmanship welds) shall be made using the same heat No. of the material that will be used to install the system. The sample welds should be available for all personnel involved in welding and inspection. Sample welds should depict acceptable and rejectable criteria. The customer may require additional weld samples to establish a schedule of weld acceptance criteria for specific projects.

7.3 Daily Weld Coupon: At the beginning and at the end of each shift (or as specified by the customer), each welder should produce one acceptable sample weld of the same size as the production welds which the weld machine is configured to produce. The welds should be logged on a daily welding log after they are produced.

7.4 The cause of any defective weld should be determined and appropriate steps taken to correct the problem and its re-occurrence.

8.0 Qualifications

8.1 Qualifications: Each welding procedure, welder, or welding operator should be qualified in accordance with ASME Section IX. In addition, each welding operator should qualify separately on each size and wall thickness to be welded in production, by a visual examination of exterior and interior surfaces.

9.0 Weld Documentation

9.1 A documentation program should be agreed upon before the project is started. A typical documentation file may consist of the following:

- A. Material Purchase Order (copy)
- B. Receiving Records
- C. Material Test Reports
- D. Receipt Inspection Reports
- E. Weld Procedure Specifications (WPS) and Procedure Qualification Records (PQR)
- F. Approved Weld Schedules (programs)
- G. Welder Qualification Records
- H. Daily Automatic Weld Log Sheets
- I. Weld Location Drawings
- J. Purge Gas Test Reports or Certification Documents
- K. Weld Inspection Reports
- L. System Testing, Flushing, or Passivation Reports

A current index of the latest revised ES Standards and Technical Bulletins is available from the Pipe Fabrication Institute.

PFI Standards and Technical Bulletins are published to serve proven needs of the pipe fabricating industry at the design level and in actual shop operations. Hence, such needs are continually considered and reviewed by the Engineering Committee of the Pipe Fabrication Institute to provide recommended procedures which have been demonstrated by collective experiences to fulfill requirements in a manner for Code compliance. However, as the PFI Standards are for minimum requirements the designer or fabricator always has the option of specifying supplementary conditions in the form of requirements beyond the scope of the PFI publications.