Asset Lifecycle – Guidance Note

Stainless steel pipe welding

MECHANICAL AND ELECTRICAL

Purpose

Recent projects involving stainless steel welding have highlighted inconsistent quality control measures, welding procedures, and documenting of treatment & testing results. The purpose of this Guidance Note is to recognise key aspects of stainless-steel welding practices and its importance to **validate the integrity of fabricated pipework**, so this doesn't impact the intended asset life.

Overview

Stainless steel pipework is commonly and increasingly used for fluid conveyance at treatment plants, pump stations and other Watercare facilities. This is due to the material's inherent strength, durability, and corrosion resistance to the surrounding environment. It also possesses the ability to self-heal and reinstate the passivated (protective) film following welding, provided the **correct procedure and post-weld treatment** is followed.

For all Watercare applications, **austenitic stainless steel 316L is the minimum grade**. This material is suitable for liquids with higher chloride concentrations (when compared to 304) and generally comprise of around 18% Chromium, 11% Nickel and 2% Molybdenum.

For stainless steel pipe welding to be performed effectively, it's important that pipework is kept clean during the welding procedure and that the **same level of care is administered whether shop or site welding is carried out**.

Gas Tungsten Arc Welding **(GTAW)** or Tungsten Inert Gas **(TIG)** is generally the preferred welding procedure for stainless steel pipes at plants where it should be ensured that:

- The approved Welding Procedure Specification **(WPS)** must be followed.
- A comprehensive Inspection and Testing Plan **(ITP)** must be submitted, approved and signed-off at each hold-point for all pipe welds.
- Quality control **(QC)** documentation must be complete, reviewed and recorded during fabrication of welds.
- **Full weld penetration** must be achieved with no internal crevices.
- **Inert gas** (example: Argon / Nitrogen) must be used in the pipe bore to remove oxygen and minimise heat tint.
- Where external heat tint is present, this should be **pickled and polished**.

Deviation from these requirements and / or lack of inspection and QA planning can lead to inconsistent fabrication quality, contributing to **corrosion and eventual leakage (failure)** of the pipeline. The consequence of this can be serious, resulting in expensive repairs, environmental or health and safety incidents and potential "down-time" at plants .

References

Watercare

- **ME:** General Mechanical Construction Standard (Section M7)
- **MS:** Material Supply Standard

Other

- **Nickel Institute** (https://www.nickelinstitute.org/)
- **International Molybdenum Association (IMOA)** (https://www.imoa.info/index.php)
- **American Welding Society (AWS): D18.2-2209**
- **ASTM A380** - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
- **ASME B31.3**: Code for Pressure Piping
- **ASME IX**: Boiler and Pressure Vessel Code
- **Nickel Institute**: **IGN 4-45-02**: UK Water Industry – Applications for Stainless Steel in the Water Industry

Watercare

To mitigate the risks of weld-induced failures there are several key factors to consider before, during and after welding stainless steel pipes.

Before welding

Before any welding work starts the **contractor and welding inspector / engineer's witness shall verify and agree the following**:

- ***Design documentation*** – confirming the application (water, wastewater etc.), drawings / shop drawings, specification, pipe material and welding requirements.
- ***Welding Procedure Specification (WPS)*** – when welding stainless steel pipe, e.g., SS316L (with no change in material grade) throughout a plant, the WPS is generally pre-qualified i.e., welders are qualified against the procedure for all similar welds. However, the contractor should still submit this specification to confirm the recommended procedure. Information on this specification includes the weld process (e.g., *GTAW*), joint type (*e.g., single-V*), base material (e.g., SS316L), weld filler material, weld technique (e.g., *vertical up*) etc. This WPS should be used for any tack welding that may be required during fit-up. This document must provide enough information for a competent welder to interpret and perform.
- ***Welder qualification*** – The individual to carry out the weld should have a certified qualification document demonstrating their ability to perform the WPS. For pipework, ASME IX is the qualification standard for a welding operator.
- ***Inspection and Test Plan (ITP)*** – The contractor is responsible for submitting an ITP for review and approval before the start of any work (see *Figure 5* below for example). The welding inspector or engineers witness needs to approve the ITP before any work gets started – this is to ensure that testing and inspections are correct in method and frequency (%). This document should also include all steps, documentation requirements, hold & inspection points from pre-fabrication to final approval. Reference to the acceptance criteria and signatory approvals should be included in the ITP. This document forms an integral part of quality assurance and final sign-off.
- ***Cleanliness of pipes***

  All pipes should be cleaned and free of any potential contamination, especially around the welding area. To avoid contamination, the use of handheld tools for cleaning and weld preparation of stainless-steel welds should be exclusively used with stainless steel and not used if they have come into contact with **any** carbon steel, e.g., grinding discs, flapper/cutting discs, files etc.

  Care should be exercised in the selection of cleaning agents and pipe markers etc, for use on stainless steel surfaces. Chlorides can lead to corrosion, especially in environments where the stainless steel is exposed to moisture or harsh environmental conditions.

During Welding

Administering **Quality Control during welding is fundamental** to consistently produce high quality work. Adherence to the welding parameters in the WPS, positioning pipes correctly, correctly monitoring oxygen rates in the bore of the pipe, and minimising slag spatter on the pipes all reduce the potential amount of post-weld clean up and treatment required.

High concentrations of oxygen in the bore of the pipe whilst welding can result in depletion of the chromium layers in the pipe, formation of oxides, weld defects such as porosity and subsequent internal weld corrosion. This becomes visibly evident in the colour of the heat tint – the darker the colour, the higher the oxygen concentration present around the welding area.

To address heat tints, **oxygen levels must be controlled within the specified limits** (25-50 parts per million) by introducing an inert "backing" gas such as *Argon* or *Nitrogen*. The gas is forced through the pipe to remove residual oxygen around the internal welding area, mitigating the effects of heat tint.

The American Society of Mechanical Engineers (ASME) requires oxygen levels to be no greater than 0.04% before welding commences – this is displayed as a percentage on all welding oxygen meters.

NOTE: The use of TGX filler wire is **NOT** permitted as an alternative to gas purging

Figure 1 below shows the range of acceptable heat tint profiles recommended by the *American Welding Society* (AWS D18.2).

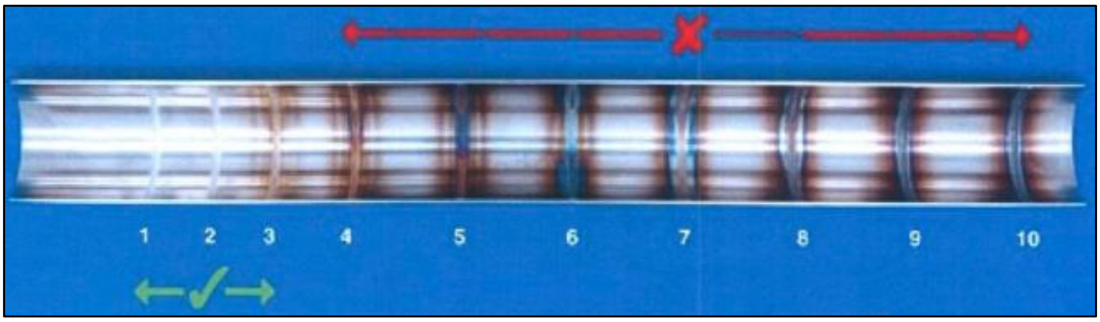

Figure 1: *Internal heat tint of pipe ranging from 1 (10ppm oxygen concentration) to 10 (25,000ppm), 2 being 25 ppm and 3 - 50 ppm (Ref. AWS D18.2-2209)*

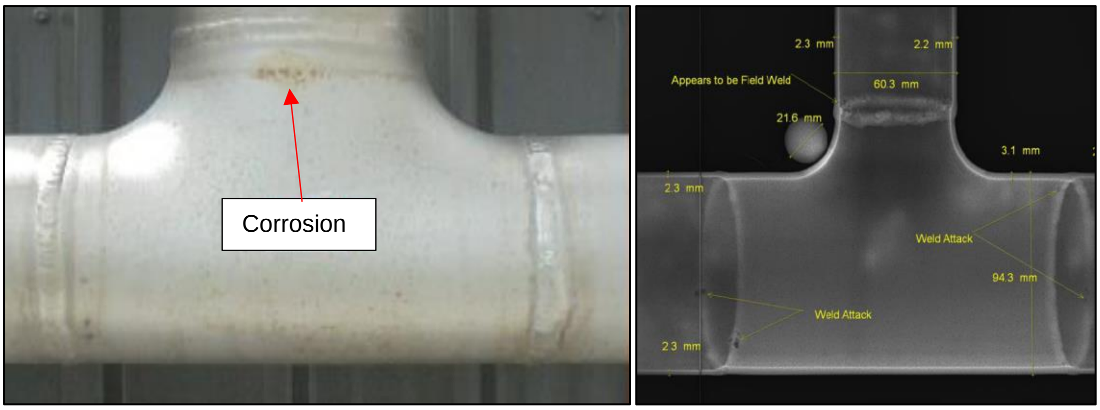

Figure 2: *Example of visible corrosion on exterior of pipe and radiographic testing to inspect welds*

Figure 3*: Pipe failure as a result of internal corrosion.*

After welding

Following the fabrication of welds, it's important that the necessary post-weld treatment and inspections be completed by those responsible for these tasks. These inspections **confirm that work carried out meets the minimum requirements** before these assets become operational.

Post-weld treatment

A variety of surface defects may be present after the welding process and can result from:

- Transporting and storing materials prior to welding
- Organic and solvent contamination during handling
- Welding conditions / incorrect welding parameters

Figure 4 below shows examples of defects and potential contaminants that may initiate corrosion if not properly cleaned or treated.

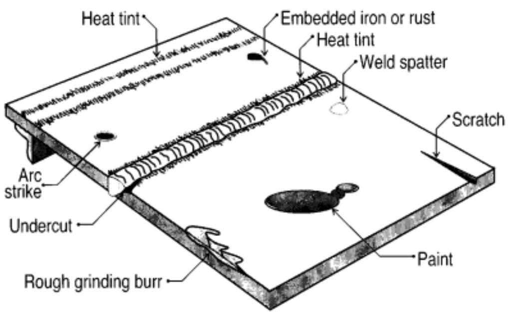

Figure 4*: Potential surface defects around stainless steel welding areas (Ref. Nickel Institute - https://nickelinstitute.org/media/opkfzaug/10080_cleaning-stainless-steel-surfaces-prior-to-sanitary-service.pdf)*

These **contaminants and defects should be removed / treated** before putting the pipework into service. The *American Society for Testing and Materials* (ASTM) specifies appropriate methods for cleaning and treating stainless steel.

Where heat tint is present, superficial discolouration can be removed on the outside of the pipe using *Scotch-Brite* or an appropriate stainless wire brush, however **chemical pickling is still required** to fully reinstate the corrosion resistance properties of the material. An appropriate ***Pickling and Passivation Procedure*** should be documented and followed by the contractor to treat heat tints.

Visual Inspection

All welds (100%) should be visually inspected by a certified welding inspector (refer to ***ASME B31.3 – section 340.4*** for suitable qualifications)**.**

Non-Destructive Testing (NDT)

Radiographic testing and dye penetrant testing are the two most popular methods used to inspect weld integrity . Watercare requires that **at least 10% of shop-fabricated welds be inspected** using radiographic testing, and that **20% of fillet welds be dye penetrant tested** (DPI).

Note: It is near impossible to carry out ultrasonic testing on austenitic materials (e.g. stainless steel) due to the formation of the grain structure which both attenuates and distorts the ultrasonic beam. Radiography testing is understood to the only acceptable volumetric examination.

Previous welding failures have shown that welding performed on-site (i.e., not in controlled fabrication conditions) should be administered more carefully, due to the variability of site conditions. **Site conditions may require more stringent quality control** measures to complete welds in accordance with the WPS parameters. Therefore, **all field welds (100%) shall be radiographically tested** to confirm the integrity of the welds. *Figure 5* below shows an example of an *Inspection and Testing Plan* listing the requirements discussed in this Guidance Note. It is recommended that a similar approach be adopted for works carried out at Watercare sites to ensure that work consistently meets the expected standards – producing quality assets.

Example Stainless Steel Welding Inspection and Testing Plan (ITP)

No.	Activity	Inspection or Test Required	Reference Document	Acceptance Criteria	Records	Contractor			Welding Inspector/Engineer's Witness		
1	Pre-Fabrication					Scope	Sign	Date	Scope	Sign	Date
1.1	**Design / Manufacturing drawing**	Review and approval	Issue for Construction drawings	Design specifications ASME B31.3	Design Drawings followed by Shop Drawings	Hold Point			Review		
1.2	**Inspection and Testing Plan Review**	Review and approval	N/A	ASME B31.3	Approval of ITP	Hold Point			Review / Approve		
1.3	**Welding Procedure Specification (WPS)**	Review and approval	Approved Welding Procedure Specification	ASME IX	WPS	Hold Point			Review		
1.4	**Welder Qualification Record (WQR)**	Review and approval	Approved Welder Certification	ASME IX	Welder Qualification Certificate	Hold Point / Review			Review		
2	Fabrication and Welding					Scope	Sign	Date	Scope	Sign	Date
2.1	**Material Inspection**	Inspect all material upon delivery	Quality Control Document			Inspect			N/A		
2.2	**Material Certificates (ILAC accredited)**	Review and approval	As per ASTM Code	Material test certificates to comply with ASTM material standard	Material Test Certificates	Review			Review		
2.3	**Check fit-up, joint clearance, internal alignment and dimensions prior to welding**	Visual and dimension checks	Drawings and WPS	ASME B31.3 Drawings and WPS	Weld Map / Visual and Dimensions control report	Inspect			Witness		
2.4	**Monitoring of welds**	Quality Control Procedure		WPS	Weld Map	Inspect			Review		
3	Testing and Evaluation					Scope	Sign	Date	Scope	Sign	Date
3.1	**Cleaning, pickling and passivation**	After welding slag, heat tint and residual surface contaminants to be treated / removed	ASTM A380	Chromium depleted layers removed and clean welds	Pickling and passivation procedure	Inspect			Review and Inspect		
3.2	**Visual weld checks**	Visual inspection of all (100%) welds post cleaning Where pipe bore cannot be visually inspected, CCTV inspection should be undertaken to confirm integrity of pipe wall and presence of heat tint.	ASME B31.3	ASME B31.3	Inspection record and CCTV footage	Hold Point			Review		
3.3	**Non-destructive testing (NDT) Radiographic Inspection**	**10% of shop fabricated welds** shall be radio-graphically tested (or other appropriate NDT test) - Watercare Requirement **All field welds shall be radiographically tested**	ASME B31.3: Section 341.4	ASME B31.3: Section 341.4	Testing Report	Hold Point			Review		
3.4	**Hydrostatic leak testing**	In-line pipe system		ASME B31.3: Section 345.4 - No leak or pressure drop	Testing Report	Hold Point			Review		
4	Handover					Scope	Sign	Date	Scope	Sign	Date
4.1	**Repairs**	Review defects remediation	Snag list and remediation methodology	Repair report		Hold Point			Review and witness repairs		
4.2	**As-built drawings**		Red-line drawing mark-ups	Within specification tolerances	As-built drawings	Hold Point			Review		
4.3	**Final Inspection / Practical Completion**				Submission of all QA documentation approved	Hold Point			Review		
5	Sign-off and Final Approval					Comments					
		Company Name	**Full Name**	**Signature**	**Date**						
	Contractor Representative										
	Welding Inspector										
	Client Representative										

***Figure** 5: Example inspection and testing plan for stainless steel welding*