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Guidelines for corrosion resistant weld metal overlay of digester vessels in alkaline pulping service

1. Scope

This document provides guidelines and describes quality control and testing procedures for application of either stainless steel or nickel-base corrosion resistant weld metal overlay (hereafter referred to as CRO) on internal surfaces in continuous digesters, impregnation vessels, and batch digesters in kraft and soda service. These guidelines provide information concerning overlay properties and application procedures that affect the performance of the overlay.

The scope for CRO in digester vessels should specify the:

- Area to be overlaid.
- Welding materials to be used.
- Surface preparation required.
- Criteria for deciding where it is necessary for buildup or repair of the substrate, and detailed procedures for this.
- Jurisdictional regulations and applicable Codes to be complied with.
- Procedure documentation.
- Work-product documentation required.
- Quality control and testing plan.
- Safety and job support requirements (scaffolding, ventilation, power supply).

2. Introduction

CRO is applied in carbon steel digester vessels to prevent corrosion. CRO can be applied using manual, semi-automatic, or automatic welding processes. CRO is usually deposited directly on the carbon steel although it also can be applied over existing CRO or on clad plate.

The automatic welding processes most commonly used include submerged arc welding (SAW) and gas metal arc welding (GMAW). SAW overlay is deposited in the horizontal mode. GMAW overlay may be deposited horizontally or vertically. Manual overlay of small areas or to repair of defects in automatically-applied CRO is often done using the shielded metal arc welding (SMAW), GMAW, gas tungsten arc welding (GTAW) or flux core arc welding (FCAW) processes.

3. Safety precautions

Ensure personnel safety by complying with established confined space entry procedures and all mill safety and lockout procedures. Respiratory and personal protection equipment should adequately protect against dust, smoke, and fumes generated by surface preparation and welding. (Silica-containing blasting media should not be used.) Carbon monoxide may arise during preheating using oxy-acetylene torches. Arc flash from open-arc welding processes should be addressed.

Local jurisdictions may have exposure limits for chromium and nickel that require specific kinds of respiratory protection. In the United States OSHA's revised Permitted Exposure Limit (PEL) for hexavalent chromium (Cr^{+6}) of $1 \mu\text{g}/\text{m}^3$, with Action Level of $0.5 \mu\text{g}/\text{m}^3$, affects virtually all stainless steel welding work and may present more problems for welding in enclosed spaces, including overlay welding of digesters.

4. General requirements

4.1 Codes

Both the CRO installation and repair weld buildup in digester vessels constructed to the ASME Boiler and Pressure Vessel Code, Section VIII Division 1, must conform to the code rules (1) - welding procedures, welders and welding operators and weld quality must meet the requirements of Section IX of the ASME B&PV Code.

Part UCL of ASME Section VIII Div. 1 gives the requirements for new vessels constructed of base material with corrosion resistant integral or weld metal overlay cladding. Articles in Section IX relevant to CRO include Article II on Procedure Qualifications (Paragraph QW-214 and Tables QW-253.1, QW-254.1, QW-255.1, QW-256.1, QW-257.1); Article III on Welding Performance Qualifications (Paragraph QW-381), and Article IV on Welding Data (Table QW-453). In North America inspection, repair, and alteration of Code digesters is covered by the National Board Inspection Code (NBIC) (2) and by the ASME post-construction code API579-1/ASME FFS-1, *Fitness for service*. The NBIC deems installation of CRO in a digester vessel a "Repair."

In Europe, the Pressure Equipment Directive 97/23/EC implemented in 2002 is a unified code for the design and manufacture of pressure vessels. This TIP does not directly address requirements of other codes and standards, and CRO installation in non-ASME code vessels may be performed to non ASME standards.

4.2 Surface preparation

Proper surface preparation shall remove:

- Process contaminants.
- Surface irregularities that make overlay application problematic, such as sharp changes in contour of the surface, ditched weld seams, or excessively prominent weld seams.
- Cracks, pits and porosity
- Residues from nondestructive testing.
- Carbon contamination from arc gouging.

Arc gouging and grinding may be required prior to grit blasting to prepare excessively rough surfaces or projecting weld seams for overlaying.

Abrasive blasting removes contaminants, scales, and thermal spray coatings from the digester wall that would otherwise interfere with the application of CRO. Abrasive blasting to SSPC SP-10 "near-white" condition is adequate for CRO (3); SP-6 "commercial" cleanliness is acceptable if the wall is smooth and free of deposits prior to

blasting. The surface must be dust free. Flash rusting of the sandblasted surface generally is not a concern for CRO but some installers use aluminum-based paints to prevent flash rusting.

Liquor dripping onto grit blasted surfaces is invariably a problem with continuous digesters where it is very difficult to prevent liquor seeping out from behind headers and screens. Installation of a drip pan has been found to be very effective in minimizing contamination of the surface with liquor before and during the overlay process.

4.3 Carbon steel weld buildup

API 579-1/ASME FFS-1 assessment determines when carbon steel weld buildup is required to ensure the digester is fit for service over the next specified operating period.

Carbon steel weld buildup must be crack-free and be a smooth enough substrate for the CRO. Control of heat input and shell distortion is important, especially for weld buildup made with multiple passes. Carbon steel buildup shall not be installed on surfaces that previously had CRO or a thermal spray coating unless the substrate is confirmed free of residual alloy that might cause cracking of the carbon steel weld buildup.

4.4 Overlay onto existing CRO or cladding

The composition, soundness and thickness of existing CRO or a clad layer (roll-bonded or explosion-bonded plate) and adequate thickness of the carbon steel substrate should be confirmed before new CRO is applied. The old CRO or clad layer must be fully metallurgically bonded to the base metal: the bond can be checked by ultrasonic testing. The clad layer in roll-bonded clad plate has been reported to disbond from the steel during installation of a CRO.

Metallurgical compatibility of the new CRO with the old alloy barrier is an important consideration. For example, 309 SS overlay that acquires too much Ni from the substrate CRO, clad layer or thermal spray coating is more susceptible to hot cracking.

4.5 Nozzles

Where feasible, CRO on carbon steel nozzles should extend at least half the nozzle diameter into the nozzle, with a smooth, minimum 2:1 edge taper inside the nozzle. CRO should blend into stainless steel nozzles or into nozzles with a CRO lining. Carbon steel nozzles that experience accelerated corrosion should be replaced with stainless steel, especially with duplex grades.

4.6 Coefficient of thermal expansion

The coefficient of thermal expansion of the CRO is not an important consideration for CRO because the CRO metallurgically bonds to the carbon steel. The residual tensile stresses produced in the carbon steel heat affected zone are of similar magnitude for all CRO alloys.

4.7 Composition of the overlay

The as-deposited composition of the CRO depends on the composition of the filler metal and of the substrate and how much of the substrate, which could include overlay welds, is dissolved into the molten weld. Excessive weld penetration into a carbon steel substrate can over-dilute the alloy content of as-deposited CRO. Careful attention to the as-deposited composition of the CRO is important in batch digesters, where the corrosion mechanisms, including “hot-plate boiling” corrosion are more aggressive than in continuous digesters. The filler metal composition also influences the microstructure, as discussed in Section 4.8.

The CRO alloys most commonly used in digester vessels are Type 309L and Type 312 stainless steels. 309L is commonly applied in continuous digesters either by the SAW process or the GMAW process (4). 312 is applied by SAW and GMAW in continuous and batch digesters and is the current state-of-the-art for batch digesters.

Table 1 compares the composition ranges for bare stainless steel welding electrodes from ASME Specification SFA-5.9 with the composition ranges of boat samples of single-layer CRO taken from several digesters.