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Guidelines for inspection of continuous digesters and impregnation vessels

1. Scope

This Technical Information Paper (TIP) provides guidelines for inspecting digester vessels in alkaline pulping service. *Digester vessel* refers to a continuous digester or an impregnation vessel in one- and two-vessel systems. These guidelines and procedures also apply to level tanks.

This TIP covers inspection of the code-defined pressure-containing ‘envelope’ and of internal parts, including screens and their support structure, the center-pipe and its supports and the bottom outlet device/scrapper. The TIP discusses preparing for inspection, inspecting the shell and nozzles for cracking and corrosion, inspecting internal components, and how to record the inspection findings and data. The TIP does not cover inspection of M&D and batch digesters – inspection of the latter is covered in a separate TIP.

These guidelines supplement jurisdictional regulations for pressure vessel inspection. This TIP contains no guidance for inspecting associated external piping, auxiliary systems such as liquor heaters, flash tanks, steaming vessel, the sand separator and pressure limiting devices. This TIP does not help the reader interpret inspection data or assess the continuing “fitness for service” of a digester vessel, which can be done as described in API 579-1/ASME FFS-1, *Fitness for service (1)* post-construction code, which is accepted by the National Board Inspection Code (NBIC).

2. Safety precautions

Acceptable safety practice requires full compliance with mill safety requirements for personal protection, energy source lockouts and confined space entry procedures. This TIP recommends non-destructive testing methods that require use of chemicals which may present a health hazard to humans. Procedures for handling potentially hazardous chemicals are described in Material Safety Data Sheets (MSDS) available from the chemicals’ manufacturer/importer and archived by all distributors of potentially hazardous chemicals. Users of a chemical shall read and follow the instructions in the MSDS and meet all mill, local, state, provincial, and federal regulations for safe use and disposal of the chemical.

3. Background

Most digester vessels in North America are constructed primarily from welded carbon steel. Some vessels are constructed partially or entirely from composite plate, e.g., 304L stainless-clad, or solid stainless steel. Stainless steel is widely used for nozzles, internal screens and blank plates and the central pipe. Carbon steel surfaces in digester vessels may be protected against corrosion with corrosion-resistant weld overlay, thermal spray coating or a stainless steel sheet lining. Anodic protection (AP) systems mitigate cracking and corrosion in zones where the electrochemistry conditions make this feasible.

Digester vessels are inspected to detect damage that could compromise the vessel’s fitness for service, especially caustic stress corrosion cracking (SCC) of structural welds and shell corrosion (2). Poor predictability of alkaline “spreading pit” corrosion, caustic SCC and corrosion fatigue make regular inspection of a digester vessel an important safety practice. Reliable vessel operation also requires periodically inspecting internal components and appurtenances, including the internal cone; center-pipe and supports; screens, blank plates and backing bars; internal headers and nozzles, and the bottom scrapper, on a frequency influenced by their present corrosion/cracking rates.

In 1980 a single-vessel, hydraulic continuous digester failed catastrophically in Pine Hill, Alabama, as a result of caustic stress-corrosion cracking (CSCC) of carbon steel structural welds in the top transition. This led to creation of industry consensus inspection and NDT methods and procedures to find welds with CSCC. When wash zone corrosion showed up in the 1990s, these procedures and test methods were expanded to cover corrosion that could affect the fitness for service of a digester vessel, namely general corrosion of the shell where the active alkalinity levels are too low to ensure passivity in the wash zone, and localized erosion corrosion in internal headers. This document describes the latest version of those standard procedures and practices.

4. Preparation for inspection

The vessel should be cleaned and prepared for inspection, with safe internal access and good ventilation. The rest of this section has guidelines on inspection methods, planning the inspection scope, laying out the digester for the inspection report, cleaning and frequency of inspection.

4.1 Inspection methods

A comprehensive inspection of a digester vessel involves both visual inspection and nondestructive testing (NDT). *Visual inspection alone is not good practice* and must be supplemented with the following NDT methods:

Magnetic particle testing (MT). MT is recommended for testing carbon steel welds and heat affected zones for cracks when the welds are internally accessible. MT also is used to test for cracks in other carbon steel components, including nozzles.

Penetrant testing (PT). PT is recommended for crack testing in stainless steel and other non-magnetic components, including nozzles, clad plate, overlays, top separator, central pipe, and the bottom scraper. PT is also required for crack testing in carbon steel at the edge of a stainless steel or nickel alloy weld.

Ultrasonic testing (UT). Straight-beam ultrasonic thickness testing (UTT) measures the thickness of the digester shell, blank plates, central pipe, bottom scraper arms, internal cone, etc. Shear-wave flaw detection UT, especially with phased array technology, can test welds for cracks from the external surface of the vessel – high temperature techniques make this feasible with the digester in operation. (See Section 5.4)

Special NDT methods such as radiographic testing (RT), eddy current testing (ECT) and acoustic emission testing (AET) are used under rare circumstances. Validity of every NDT procedure must be confirmed, especially with more complex methods like "hot" UT measurements (see Sections 5.4 and 6.1).

4.2 Inspection planning

Review existing information. Review the vessel documentation, drawings, and previous inspection reports. Drawings in the vessel file should be updated after each inspection with modifications, repairs, inspection data, etc. Guidelines for setting up a file for a digester vessel are in **Appendix A**. Inspection of a vessel with poor inspection documentation typically is more comprehensive than for a vessel with reliable records of inspections and repairs.

Mill responsibilities. The mill project manager/representative for the inspection typically shall:

1. Ensure the inspection scope is designed to monitor known damage symptoms in the locations where they are most likely to occur. (If required, advise the jurisdictional authority of the inspection plan.)
2. Ensure inspections and NDT are done by people qualified by training and experience to do an acceptable inspection.
3. Qualify the NDT procedures and employ only qualified NDT technicians (see **Appendix B**).
4. Ensure inspection findings and code repairs and alterations are properly documented.
5. Ensure inspection reports are technically reviewed and incorporated into future inspection plans.

4.3 Layout for data recording

A consistent numbering system is required for the shell courses, welds and nozzles. Some shell welds and nozzles are concealed behind screens, blank plates, headers, and corrosion resistant linings. A detailed roll-out drawing has a fixed zero-reference point (a common “zero” point is a vertical line through the bottom manway) and a system for identifying screens, blank plates, headers and their associated backing rings and bars.

Effective trending of the condition of digester parts requires regularly updating the layout drawings. Thickness readings are more comparable if they’re taken in a consistent grid pattern. It is common practice to use primary structural welds and weld intersections for inspection reference points. Accurate drawings of the central pipe assembly, the bottom scraper, and the internal cone for the top separator facilitate their inspections.

4.4 Cleaning for inspection

Proper cleaning of the shell surface is required for visual inspection and NDT. Internal cleaning typically starts with acid cleaning to remove scale, before the inspection is done from either a cable-suspended platform or from a pole-scaffold of safe design. *Access by floating on a raft is not acceptable.* Access is required for other purposes, including hydroblasting the screens to open the slots and unplug the space behind the screens.

Interior

Typical scale on internal surfaces must be removed to inspect surfaces and welds that are susceptible to corrosion and SCC. The acid-cleaning procedure must not damage the vessel: cleaning with hydrochloric (muriatic) acid without carefully controlling the acid temperature and inhibitor concentration can corrode the digester. Inhibitor does not inhibit chloride stress corrosion cracking of stainless steel welds by muriatic acid. Inhibited sulfamic acid and formic acid do not corrode steel or cause stress cracking of stainless steel welds. *Anodic protection must be off for acid cleaning.*

High-pressure water blasting can supplement or replace acid cleaning (it also is used to clean screens). Surfaces are locally prepared for NDT with power wire brushing, sanding, grit blasting or grinding, as appropriate - NDT technicians should identify surfaces that require additional surface preparation for NDT in accordance with the written NDT procedures.

Exterior

External NDT of welds for cracks or of the shell for corrosion requires removing insulation and preparing the external surface as required in the NDT procedure. Shear-wave UT of welds (see Section 5.4) may require the welds to be ground smooth.

4.5 Intervals between inspections

Because corrosion of steel and stress cracking of welds in digester vessels is not fully predictable, internal inspection for corrosion typically is done annually for the digester’s first few years to establish the digester’s corrosion behavior. Inspection intervals longer than one year are acceptable when based on evidence and trending of damage mechanisms, engineering assessment of the vessel’s condition and use of ‘*management of change*’ principles to account for process changes in determining the interval until the next inspection.

Digesters with no carbon steel exposed to liquor or with effective anodic protection *can have intervals between inspections longer than 2 years.* Many digesters with exposed carbon steel have two-year, ‘integrity inspection’ intervals even if screen inspections and screen and header cleaning may be required more often. Factors to consider in setting the next inspection interval for a particular digester vessel are repairs, recent process changes affecting the temperature and/or alkalinity profiles in the digester; changes in furnish and wood species, recent inspection results, and new jurisdictional inspection requirements.

5. Cracks

This section addresses testing for cracks in pressure-retaining welds. Inspection and testing of other components such as the top separator cone, central pipe, and bottom scraper are addressed in Section 7.