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Guidelines for inspection of continuous digesters and impregnation vessels

Scope

This Technical Information Paper (TIP) provides guidelines for inspecting digester vessels in alkaline pulping service. (The term ‘*digester vessels*’ refers to continuous digesters or impregnation vessels in one- and two-vessel systems.) This TIP addresses inspection of the code-defined pressure-containing ‘envelope’ and internal static and mechanical components, including screens, pipe supports and the bottom scraper. The TIP discusses preparing for inspection, inspecting for cracking and corrosion, inspecting internal components, and how to record the inspection findings. The TIP does not cover batch and M&D digesters.

These guidelines do not supersede jurisdictional and regulatory requirements. Regular inspections of associated external piping, auxiliary systems (such as liquor heaters, flash tanks, steaming vessel, sand separators, and level tanks), and pressure limiting or protective devices are also part of a condition monitoring program but are outside the scope of this TIP. This TIP does not discuss interpreting inspection data or assessing the continuing “fitness for service” of a ‘digester vessel’ – modern practice involves using API 579-1/ASME FFS-1, *Fitness for service*¹ for this purpose.

Most digester vessels operated in North America are of welded steel construction. Some digester vessels, especially impregnation vessels, are constructed entirely of composite plate (e.g., 304L stainless-clad) or of duplex 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 and thermal spray coatings. Anodic protection systems mitigate cracking and corrosion mechanisms.

2. Introduction

The main purpose of a digester vessel inspection is to detect damage mechanisms that affect the vessel’s fitness for service, including cracking of structural welds and corrosion of the shell². Poor predictability of alkaline corrosion, caustic SCC and corrosion fatigue make regular inspection of digester vessel an important safety practice. Reliable vessel operation also requires inspecting internal components and appurtenances, including the internal cone, central pipe and supports, bottom scraper assembly, screens and blank plates.

In 1980 a single-vessel, hydraulic continuous digester failed catastrophically in Pine Hill, Alabama, as a result of caustic stress-corrosion cracking (SCC) of carbon steel structural welds in the upper courses of the digester. As a result inspection methods and procedures were developed to find cracks and to carefully monitor other damage

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mechanisms that could affect the fitness for service of digester vessels: these include unexpected corrosion of the carbon steel shell, particularly in the wash zone but also between the extraction and cooking screens. Nevertheless, no assurance is given or implied that this TIP describes all possible damage mechanisms or preventive measures that may occur in digester vessels.

3. Safety precautions

Personnel safety requires total compliance with mill lockout and confined space entry procedures and all mill safety requirements.

4. Preparation for inspection

The mill must prepare the vessel for inspection (Section 4.4), provide safe vessel access (Section 4.5), proper ventilation, and lighting for inspection personnel. The following sections provide guidelines on inspection methods, planning, layout, cleaning, access, 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.

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.

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 welds – high temperature techniques make this feasible with the digester in operation

Validity of every NDT procedure must be confirmed, especially with more complex methods like "hot" UT measurements (see Sections 5.4 and 6.1).

Special NDT methods such as radiographic testing (RT), eddy current testing (ECT) and acoustic emission testing (AET) are used under rare circumstances.

4.2 Inspection planning

Review existing information. Begin by reviewing the vessel's documentation, drawings, and previous inspection and NDT 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**.

If vessel documentation is incomplete, the 'baseline' condition of the vessel must be established. This typically requires more extensive inspection and analysis than a regular inspection.

Mill responsibilities. The mill should assign management of the digester inspection to a representative who by virtue of appropriate authority, training, and experience, can:

1. Ensure the inspection scope is purposely designed to find the 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 the inspection work is done by experienced people with adequate training and skill to conduct a satisfactory inspection.
3. Verify the effectiveness of NDT procedures and ensure qualified NDT technicians (Appendix B) are used.

4. Ensure inspection findings and all repairs and alterations are properly documented.
5. Ensure inspection reports are appropriately 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 structural welds and nozzles are concealed behind screens, blank plates, headers, and liners. A detailed roll-out drawing shall have a fixed zero-reference point (a common “zero” point is a vertical line through the bottom manway) and a consistent system for identifying screens, blank plates, headers and their associated backing rings and bars.

Effective inspection and trending analysis of the condition of these elements and the digester vessel itself requires regular updating of the detailed layout drawings. Thickness readings have more value if taken on a fairly consistent grid pattern. A common practice is to use the primary structural welds and weld intersection points as 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 prior to inspection

Proper cleaning is a prerequisite for both visual inspection and NDT of digester vessels.

Interior. Digester vessels typically build up scale on the internal surfaces during operation and this scale must be removed to inspect the internal surfaces and welds. In North America it is common practice to remove the scale by acid-cleaning, which must be done in such a way to avoid damaging the vessel. Acid cleaning with hydrochloric (muriatic) acid without adequate control of the temperature and inhibitor concentrations can harm the digester vessel: risk of excessive corrosion increases if acid temperature exceeds 60°C (140°F). Sulfamic and other acids are less damaging, especially to stainless steel, but may increase the time required to clean the vessel.

Supplementary high-pressure water blasting is used when acid cleaning does not fully remove surface deposits or instead of acid cleaning (it also is used to clean screens). Effective interior cleaning produces surfaces free of scale, debris and liquor. Additional local cleaning for NDT is done with power wire brushing, sanding, grit blasting or grinding, as appropriate - NDT technicians should identify surfaces that require further surface preparation for NDT in accordance with the written NDT procedures.

Exterior. External testing of welds for cracks or the shell for corrosion requires removing the insulation and power brushing or sanding the surface to meet the requirements of the NDT procedure. Shear-wave UT of welds (see Section 4.1) may require the welds to be ground smooth.

4.5 Access for inspection

Most internal inspections are done from either a cable-suspended platform or from a pole-scaffold - safe design of both is essential. Good scaffolding provides safe access to the weld seams and permits access behind designated screens. Pole scaffold structures provide simultaneous multi-level access. *Access by floating on a raft is not acceptable.*

4.6 Frequency of inspection

Since the onset of corrosion and SCC of carbon steel in continuous digesters and impregnation vessels, is difficult to predict, internal inspection for corrosion typically is done annually until the digester behavior is established after several inspections. Intervals exceeding 1 year should be based on thorough engineering assessment of the vessel's current condition, trending of inspection results, and demonstration of a method for integration of process changes into the inspection frequency determination.

Repairs, production rate changes, process changes that may have changed the kappa number, temperature, and/or alkalinity profiles within the digester vessel, changes in the kind(s) of wood species being pulped, recent