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This Technical Information Paper may require the use, disposal, or both of chemicals which may present serious health hazards to humans. Procedures for the handling of such substances are set forth on Material Safety Data Sheets which must be developed by all manufacturers and importers of potentially hazardous chemicals and maintained by all distributors of potentially hazardous chemicals. Prior to the use of this technical information paper the user should determine whether any of the chemicals to be used or disposed of are potentially hazardous and, if so, should follow strictly the procedures specified by the manufacturer as well as local, state, provincial, and federal authorities for safe use and disposal of these chemicals.

Guidelines for inspection of continuous digesters and impregnation vessels

1. Scope

This Technical Information Paper (TIP) provides guidelines for the inspection of digester vessels in alkaline pulping service. The term "digester vessels" in this TIP is used to refer to either continuous digesters or impregnation vessels in both single and two-vessel systems but does not refer to batch or M&D digesters. This TIP addresses inspection of the pressure-containing shell plates and welds, welded internal attachments, and critical components. This TIP discusses preparation for inspection, inspections for cracking, inspections for thinning, specialized inspections of digester components, and what do to with the inspection findings.

This TIP does not discuss the interpretation of inspection data. These guidelines are not intended to supersede jurisdictional and regulatory requirements. Regular inspections of associated external piping, auxiliary systems (such as the outlet device, liquor heaters, flash tanks, steaming vessels, sand separators, and level tanks), and pressure limiting or protective devices are also part of a comprehensive condition monitoring program but are beyond the scope of this TIP.

The majority of the digester vessels currently in operation in North America are of welded carbon steel construction. Some digester vessels have been constructed entirely of composite plate or of solid duplex stainless steel. Stainless steel (typically 304L) is widely used for internal screens, central pipes, nozzles, cladding (compound plate), and is sometimes used for blank plates. The carbon steel surfaces inside digester vessels may be protected against corrosion using stainless steel lining, corrosion-resistant weld overlay, thermal spray coatings, or by anodic protection.

2. Introduction

The two main objectives of a digester vessel inspection are to detect:

1. Cracking of the pressure-retaining welds.
2. Thinning of the vessel wall.

It is also important to inspect the top separator, the internal cone, the central pipe and supports, the bottom scraper, and internal attachments for the screens and blank plates.

Exterior. Before inspecting the welds or measuring the shell thickness from the external surface, the insulation needs to be removed and the exterior surfaces cleaned of any deposits or scale. Ultrasonic shear wave inspection of the welds may require grinding to obtain smooth weld profiles. This is typically done only in designated "windows" unless the extent of such an inspection must be enlarged.

4.5 Access for inspection

Most internal inspections are conducted either from cable suspended platforms or from pole-scaffolding structures. A safe engineered design of both is important. A good scaffold should provide access to weld seams and permit opening of screens. Pole scaffold structures provide simultaneous multi-level access. Inspection while floating on a raft is unacceptable since the internal surface is wet and personnel safety is a major concern, especially when magnetic particle testing (MT) is attempted.

4.6 Frequency of inspection

Due to the unpredictability of the onset of corrosion and SCC of carbon steel in continuous digesters and impregnation vessels, annual internal inspections are generally recommended and practiced. A decision to exceed a 1 year inspection frequency should be based on an engineering assessment of the current condition of the vessel, trending of inspection results, and demonstration of a method for integration of process changes into inspection frequency determination.

Repairs, process changes, inspection experience, insurance considerations, and jurisdictional inspection interval requirements are among the factors that should be considered in determining the inspection interval for a specific digester vessel.

5. Crack inspection of the wall

The following sections address crack inspection of the pressure-retaining welds. Crack inspection of other components such as the top separator head, central pipe, and bottom scraper are addressed in Section 7.

5.1 Cracks in carbon steel welds

SCC of carbon steel is more likely to occur in non-stress relieved welds, especially at vessel shape transitions where significant pressure-related stresses can also exist. SCC of carbon steel is also likely to occur where these stresses coincide with the highest active alkali levels in the process environment, e.g., in the impregnation zone of single-vessel systems or in the impregnation vessel in two-vessel systems.

It is common practice to prioritize weld inspections, such that the welds most susceptible to SCC receive the highest inspection priority. These include:

1. Non-stress relieved seam welds in the impregnation zone.
2. Weld seams that were found to be cracked in previous inspections, or are known to be cracked.
3. New carbon steel welds and weld buildup.
4. Circumferential seam welds in the top cylindrical-to-conical transition.

Other pressure-containing welds, including those welds below the impregnation zone, are less susceptible to SCC but should be included in a digester inspection plan that ensures all welds are inspected within a multi-year cycle (e.g., 6 years). Kinds of cracking other than SCC may exist in digester welds so it is important that all welds are inspected. Removal of screens, blank plates, headers, liner, backing rings, backing bars, and gusset plates may be required to gain access to representative locations of welds that are otherwise inaccessible.

The most effective NDT inspection method for SCC in carbon steel welds is MT. Wet fluorescent MT is the most sensitive of the MT techniques and is recommended. If crack indications are present, the extent and severity of cracking in the affected weld must be determined by expanding the scope of the inspection. In

6.3 Erosion-corrosion damage

Erosion-corrosion damage of the digester wall is normally due to impingement by high liquor velocity such as occurs inside internal headers adjacent to orifice holes in the circumferential backing rings. Erosion-corrosion gouging of the digester shell can also occur where liquor can by-pass behind backing rings and bars. For example, where welds to the shell have become corroded or broken or where gaps exist between segments of backing rings. To visually inspect for erosion-corrosion thinning behind internal headers it is necessary to remove the header plates and not just the clean-out doors. Erosion-corrosion damage of the digester wall can also occur in the top head of the digester, particularly adjacent to the liquor make-up outlet and the top circulating return lines. A pit gauge is useful for measuring the depths of erosion-corrosion pits.

7. Inspection of other components

Components that are usually included in a digester vessel inspection include the top separator head, the central pipe, and the bottom scraper. This section also addresses inspection of corrosion-resistant barriers and of anodically-protected digester vessels.

7.1 Top separator heads

Some stainless steel top separator heads can experience external SCC under immersion conditions from seal water. This also includes the lower part of the stainless steel top circulating line and the weld that attaches it to the head, where these experience immersion conditions. These cracks can be found by using sanding or light grinding to prepare the surface, followed by PT.

Carbon steel top separator heads can experience corrosion thinning under the same immersion conditions that produce SCC of stainless steel top separator heads. Where the external access to the head is prevented by the presence of a pan, it may be possible to detect thinning of the head from the inside by using UT.

7.2 Internal Cone

Internal cones (also called the false cone) are found in impregnation vessels and in single-vessel continuous digesters. The internal cone and supporting braces can be damaged by erosion-corrosion due to high velocity flows adjacent to the outlet of the liquor make-up line. The welds between the cone and the digester wall are susceptible to SCC if the cone was modified after the original construction of the digester. There can be erosion-corrosion damage to the cone at gaps that permit liquor to by-pass the top separator screen. Cracking of inverted top separators has also occurred.

7.3 Attachment welds

Attachment welds include welds for the central pipe gussets, internal cone welds, screen and blank plate welds, and welds for the backing rings and bars. Attachment welds may crack from SCC, fatigue, or from original welding (e.g., hydrogen cracking). Hot cracking of stainless steel attachment welds can also occur. Carbon steel attachment welds can also experience preferential weld corrosion. A complete digester inspection must include appropriate examination of these components and their welds to ensure that all internal attachments are robust enough to remain in place during operation.

A detailed visual inspection is essential and can be complemented with PT or MT to properly characterize the condition of the attachment welds. Screen and blank plate welds can be satisfactorily checked by visual inspection, tested with a pry bar, and sounded with hammer blows.

7.4 Central pipe

The central pipe is not a pressurized component, but the failure of the central pipe during digester operation can result in damage to the shell of the digester and loss of production. Carbon steel central pipes can experience severe corrosion thinning or pitting. There have been several reports of SCC of type 304L stainless steel central

a. Repairs by welding or other methods, including description of all corrosion-resistant barriers (where it was applied, when, by what method and procedure, and by whom). NBIC R-1 forms should be filed or a similar type of report should be used if NBIC rules do not apply.
b. Alterations, including NBIC form R-1A, if applicable, or a similar substitute report.
c. Records of UT inspection confirming that required minimum carbon steel thicknesses are present beneath any corrosion resistant weld overlay or thermal spray coating. Test results shall be on file to confirm that there were no unacceptable defects (such as cracks) present before the repairs were performed.

4. Inspection and NDT reports. Inspection and NDT reports should document findings from visual observations and nondestructive examinations, thickness readings and other relevant information. It is very useful to include photographs, drawings, etc. of areas of special interest and of repairs. Certification documents for the inspectors and technicians performing the nondestructive examinations should be attached to the NDT reports. Vessel drawings used for inspection reports should show the circumferential and elevation reference points, as well as the mill's designated minimum thickness value for each course or part of the vessel wall. A standardized digital format will aid in trending corrosion rates.

5. Inspection reports should include notes to future inspectors about items that may need particular attention and should include recommendations to schedule items of deficient integrity for maintenance during future shutdowns.

Appendix B: Qualifications of nondestructive testing (NDT) inspection personnel

1. NDT inspection personnel should be trained and certified in each NDT inspection method used to inspect the digester in accordance with either:
SNT-TC-1A (American Society for Nondestructive Testing; Address: ASNT, 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228, Phone 1-614-274-6003) or CGSB (Canadian General Standards Board; Address: CGSB, Ottawa, Ontario, Canada K1A 1G6, Phone 1-819-994-5373.

2. Personnel certification records should be made available to the mill representative for review before the inspection.

3. Written procedures for all NDT to be performed should be made available to the mill representative for review.

4. Personnel certified to Level I may perform the NDT examinations, but only under the supervision of a Level II technician. Advanced ultrasonic techniques using B-scan and C-scan should be performed by certified Level II or Level III technicians.

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