

Continuous Digester – A Story of Shell Corrosion Under Insulation (CUI)

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Abstract

This paper shares two case studies where external corrosion was observed in two areas of continuous digesters. In both cases, a reactive approach to the shell breaches was required, which led to the formation of a multidisciplinary team charged with generating company practices to be used to avoid future reoccurrences. This paper creates awareness of how a cross-functional team applied industry best practices [1], the potential for applying new inspection technologies, and using low chloride-containing insulation to improve asset longevity.

Introduction

Corrosion under insulation (CUI) has occurred since insulation began being utilized for personal protection and improving thermal efficiency. This white paper reviews two Corrosion Under Insulation (CUI) case studies of Continuous Digesters owned by Georgia-Pacific (GP). Both are single-vessel hydraulic pressure vessels built in the 1960s (Digester A was built in 1966, and Digester B was built in 1968). Both digesters are in the Southeastern United States. Both digesters are of carbon steel construction (Digester A was built of SA 516 Grade 70 and Digester B was built of SA 285 Grade C). Both Digesters A & B had their upper and lower heads built of SA 264 with 304L explosion cladding. Digester A utilized a typical mineral wool insulation with lagging, while Digester B had been reinsulated using spray-on ceramic insulation in 2019, which was previously mineral wool insulated with lagging. In both cases, the design of structure support attachments and the insulation system were identified as contributing factors in CUI leading to breaches of the continuous digester vessels.

Attention and research have been focused on caustic stress-corrosion cracking (CSCC) of carbon steel structural welds of continuous digester pressure vessels. This focus has primarily been because of the catastrophic failure of a single-vessel, hydraulic continuous digester upper weld in 1980 in Pine Hill, AL. Since this failure and the discovery of the CSCC mechanism in continuous digester welds, the industry has created inspection procedures, TAPPI TIPs, and best practices to find, monitor, and repair welds with CSCC.

Corrosion occurs in an environment where a reaction occurs between the material of construction and the process environment. In this case, the insulation creates an environment where moisture from the surrounding air condenses on and in the insulation or liquor spills may penetrate the insulation and pool within specific geometries on nozzles, stiffener rings, and insulation supports. The corrosion mechanism (i.e., general, localized, or SCC) depends on the construction material depending on the temperature and chemistry of the moisture. A challenge with CUI is that external corrosion of the continuous digester may go unnoticed and reduce the shell thickness to below t_{min} , resulting in shell perforation.

As companies may repeat previous years' inspections focused on SCC of internal welds and general corrosion of welds, it may not be common to look outside the digester behind insulation or structure attachments during routine inspection.

Corrosion Under Insulation (CUI)

Thermal insulation barriers are utilized across almost every industry. They are essential for personal protection and improving energy efficiency. Under the umbrella of CUI, various forms of corrosion mechanisms can occur. These include galvanic, uniform/general, localized corrosion (crevice and pitting), and SCC. CUI does not define the mechanism, but its severity is a function of the environment (temperature and pH), chemistry, composition and impurities found in the insulating/coating material, construction materials, and the insulation system's design. The rate of CUI is uncertain and can become an issue in as short as a year after installation or as long as a few decades after. In all instances of CUI, there must be a means by which a liquid is allowed to enter past the insulating barrier and be in contact with the equipment. The source of moisture may result from proximity to the bleach plant, existing leaks on the equipment, leaking of equipment above/nearby, or if the digester is outside, it may be seasonal or coastal due to rain events. [2] The failure of an insulating barrier may increase the severity of CUI. The barrier designed to keep moisture away from the asset will act as a retaining barrier, prolonging exposure to the corrosive contaminants and accelerating corrosion. In some instances, the insulating material can leach corrosive chlorides into the entrapped liquid, causing corrosive conditions. Using low chloride-containing thermal insulation as outlined in ASTM C795 Standard specification for thermal insulation for use in contact with austenitic stainless steel is strongly encouraged.[3]

Practical learnings from CUI are outlined in the conference paper [4]; however, a guiding document generated by AMPP using a multi-industry approach is also available.[1] Insights from these documents will be valuable tools for mill engineers responsible for seeking locations where indications of CUI may exist, quantifying the depth of attack, and ways to manage them.

Until 2021, the focus for continuous digester inspection was around CSCC identification, restoration of welds, and overall internal shell thinning. During the later part of 2021, two continuous digesters had thru shell breaches due to CUI, and the following section outlines detection and how it was managed.

DIGESTER A

Digester A was undergoing a routine annual outage during the Fall of 2021. After maintenance, the vessel was filled with water and brought to operating pressure for a hydro test. At this time, operations personnel began to walk down the vessel while also conducting functional testing of the overpressurization protection interlocks. To test the overpressurization protection interlocks, the pressure is increased to roughly 20 psi higher than the operating pressure to trigger the first sequence of interlocks. At this time, while the pressure was 20 psi higher than the operating pressure, a puddle of water was developed around the top separator nozzle repad of Digester A (Figure 1). The water pool subsided, and the leak stopped when the digester returned to operating pressure.

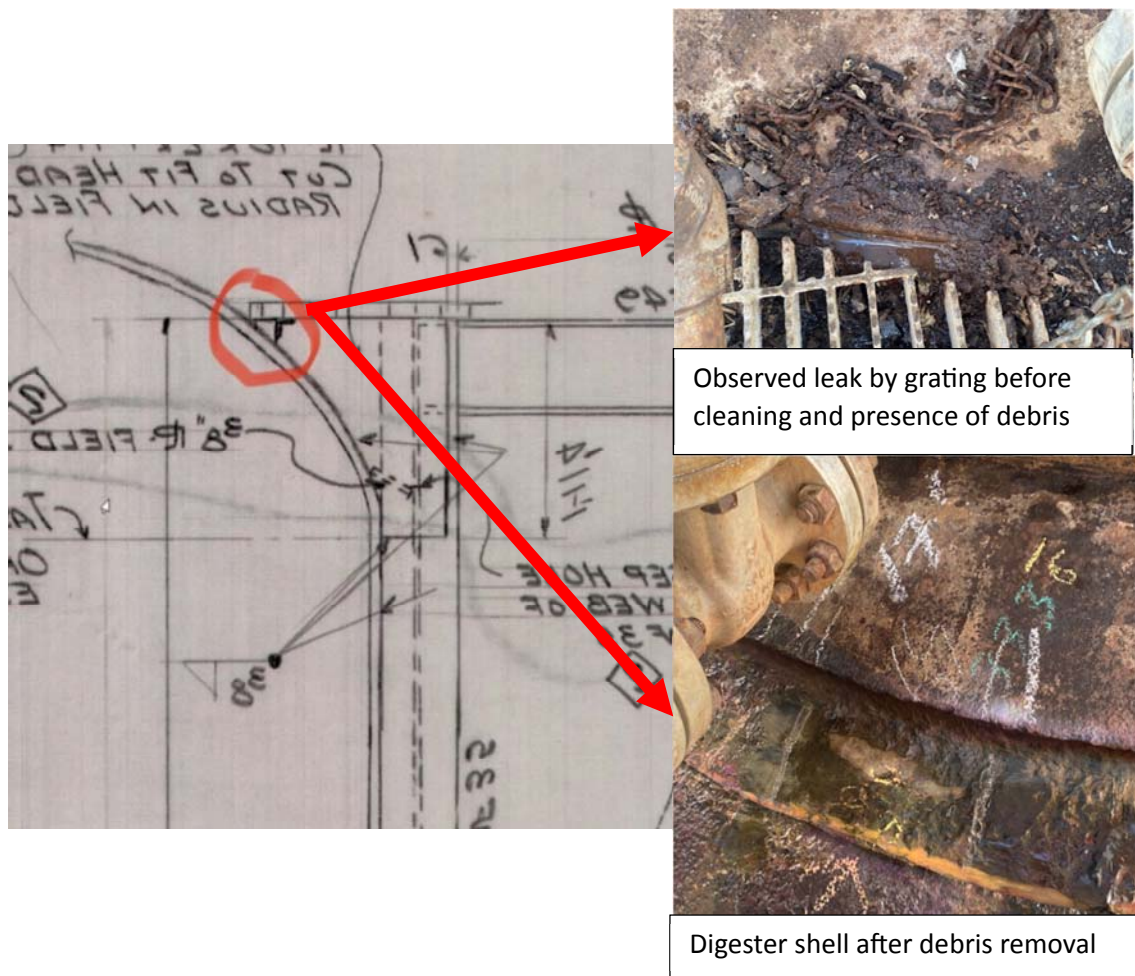


Figure 1 Formation of water by Top Separator repad during hydro testing of Digester A occurred around the top separator nozzle repad in Digester A.

After discovering the water, the digester was drained and the area around the top separator nozzle repad was excavated to investigate its source further. Once the area was clear of debris and obstruction, exterior corrosion had degraded Digester A's carbon steel dome, with spots of the stainless-steel cladding visible. A crack indication was noted in the cladding where the leak was observed, and general corrosion of the carbon steel was observed in the vicinity.

Ultrasonic Thickness Testing (UT) was performed around the entire Top Separator nozzle repad and other suspected areas to quantify the amount of general corrosion. Testing confirmed that several other areas which had been corroded past t_{min} .

Digester A's startup from its annual outage was delayed for 5 days to allow for flush plate patch repair of the digester dome.

A Root Cause Failure Analysis (RCFA) investigation was conducted, and it was concluded that a platform support attachment to Digester A's dome allowed for the collection and build-up of debris, water, and potential liquor from packing leaks causing exterior CUI. Although there was

no thermal insulation on the area surrounding the Top Separator nozzle repad, this failure can be grouped under CUI since the debris and support attachment acted to contain a corrosive liquid against the vessel shell, like how it might occur with CUI with insulation.

DIGESTER B

During a routine operator round walking down the vessel, an apparent leak containing cooking liquor was observed around a beam attachment to the top of the digester dome (Figure 2). Digester B was operating under normal operating conditions at this time. Due to vessel integrity and safety concerns the digester was blown empty and locked out for maintenance immediately after discovery of the leak. The structural support beams were removed, revealing exposed stainless-steel cladding behind them. There was a crack indication in the exposed cladding where the leak was located. This observation resulted in Digester B being down for 3 weeks to complete curved insert flush plate patch repair of the digester dome in several areas, which were tested and found below t_{min} .



Figure 2 Cooking liquor leak originates behind the digester structure support beam.

The Root Cause of Digester B's shell breach was like that of Digester A and was discovered only 3 months after Digester A. The digester super structure attachment beams and spray insulation created a void that collected debris and liquid. These areas did not drain freely and allowed continuous contact between the entrapped liquid and the carbon steel digester shell, allowing for

corrosion. During the next annual outage for Digester B, the lower portions of the structural beam attachments were inspected for suspected corrosion. These lower beam attachments created a void area further down on Digester B's shell where an insulation ring beneath them prohibited drainage. Several areas below t_{min} were weld code repaired with base metal restoration welding.



Figure 3 ASME Code repair of exterior CUI found behind a structure support beam.

Continuous Digester Inspection and Procedure Changes

These failures resulted in unexpected downtime and lost production. These events resulted in the forming a cross-functional team of resources, which included corporate quality assurance/quality control, mechanical reliability, and external metallurgy subject matter experts. This group of individuals found improvements to the inspection scope, outage practices, and critical zone of concern by damage mechanism.

After reviewing Digester A & B's findings with a cross-functional team of resources, several changes to internal inspection and procedures:

1. Developed Standard Operating Procedure for walking down vessels during hydro/testing of overpressurization protection interlocks.
 - o Leak checks to be done while vessel is held standard operating pressure.
 - Digester A's leak was not present unless pressure was brought up above operating pressure to test the first over pressurization interlock trip.
 - o Callouts specifically in walkdown procedures to check for leaks around suspected areas of concern for CUI. Areas of concern include those mentioned in SP0198 [1] best practice document (figure 6).

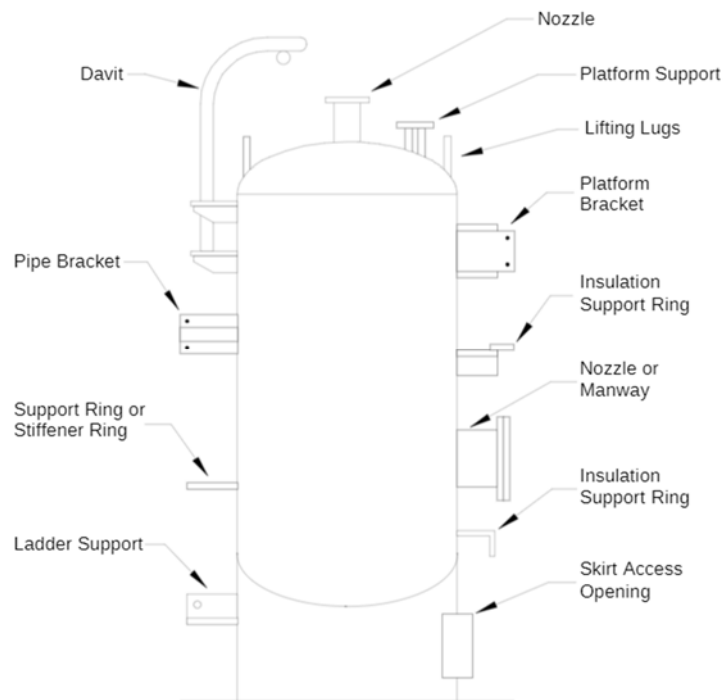


Figure 6 Vessel Attachment types where water intrusion or debris buildup may occur reproduced from SP0198 [1]

2. Design of new and existing insulation systems was scrutinized to pay attention to ensuring intended drains for attachments are not covered by insulation.
3. Performed visual inspection of areas where grating supports, insulation, lagging, etc., can cause a collection of seal water, liquor, or other liquid sources (Figure 6).
4. Developed mitigation strategy for risks associated with digester shell attachments.
 - o Grating supports modified on Digester A to allow for proper drainage and eliminate potential for long term debris buildup.
 - o Support beam attachments which create cavities for collection of debris such as what caused the penetration of Digester B's shell have been modified to where they are free draining and will not collect debris or retain moisture.
 - o If attachments cannot be engineered to prevent CUI then proper administrative controls such as routine visual inspections and thickness testing should be performed in suspected areas where CUI is observed.

5. Managed potential for accumulation of seal water at the top of digester – appropriate drains for Top Separator, etc.
 - o Proper routing of drain hoses was accomplished along with ensuring drainage pipes were unclogged and allowed to drain freely. Checking for proper drainage of Top Separator seal water was added to operator inspection rounds.

Conclusions and Recommendations

The formation of a multidisciplinary team charged with generating company practices to be used sound approach to improve asset integrity, inspection scope, and awareness of what drives credible damage mechanism

- CUI and corrosion under deposits are common issues plaguing many industries. Guiding documents exist in other industries that pulp and paper maintenance programs should be using such as NACE Standard Practice SP0198. Although overwhelming, critical locations can be identified and managed using industry best practices. Practical learnings have also been previously discussed and presented on at TAPPI PEERS by Margaret Gorog [4] and should be referenced as a guide for engineers to know what to watch out for.
- Investigate the application of technologies often not used on continuous digesters (i.e., UT robotics) for full-thickness mapping of continuous digester shells or in specific areas known to be susceptible to CUI.
- Corrosion is driven by the presence of chloride, using insulation with low chloride content is encouraged to minimize the severity of CUI.

TAPPI has an opportunity to develop an incident self-reporting forum like BLRBAC (Black Liquor Recovery Boiler Advisory Committee) for continuous digesters. This forum would create a safety-focused platform to share findings like the ones in this paper while protecting all members from anti-trust concerns to drive better industry guidance on safely operating and maintaining an aging fleet of North American continuous digesters.

Acknowledgements

- [1] SP0198-2017, "Control of Corrosion Under Thermal Insulation and Fireproofing Materials - A systems Approach," NACE International, SP, 2017.
- [2] G. Danielson and N. Risebrough, "External Stress Corrosion Cracking of Evaporator Domes," presented at the Engineering Conference, TAPPI, 1991. Accessed: Aug. 31, 2023. [Online]. Available: <https://imisrise.tappi.org/TAPPI/Products/eng/ENG91807.aspx>
- [3] ASTM C195-2018, "Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel," ASTM International. doi: 10.1520/C0795-08R18.
- [4] M. Gorog, "Corrosion Under Insulation," presented at the PEERS, TAPPI, 2011.