BATCH DIGESTERS AND RELATED PROCESS VESSELS

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1.0 SCOPE

Recommendations are provided for the construction, protection, operation and maintenance of batch digester system vessels and piping, primarily as used in the wood pulping industry.

1.1 Changes

April 2025. Interim revision. Made editorial changes were made.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Equipment and Processes

2.1.1 Construct vessels and piping to a recognized Code, such as ASME Boiler and Pressure Vessel Code, Section VIII. Include provision for wind, seismic and precipitation loads that can be anticipated in the geographic area. Also address flood, surface water and freeze protection potentials.

2.1.2 Provide a corrosion allowance or use corrosion resistant materials to ensure vessel thickness will not be reduced below the minimum permitted by the construction code during the expected operating life of the vessel.

2.1.3 Use materials and construction processes that are less susceptible to stress corrosion cracking.

2.1.4 Post weld heat treat (PWHT) all welds of carbon steel, regardless of material thickness, in new vessels. Stress relieve welds in clad carbon steel and other materials as required by the selected construction code.

2.1.5 Construct vessels with a maximum allowable working pressure (MAWP) that is at least 115% of the maximum expected operating pressure. Construct new digester system vessels that may be subject to vacuum (such as blow tanks) for full vacuum.

2.1.6 Provide digester system vessel overpressure protection set at or below the vessel MAWP and locate to avoid plugging of the relief device by vessel contents. This protection should comply with any code or jurisdictional requirements. Provide vacuum protection for vessels not designed for full vacuum and potentially subject to vacuum. Select pressure and vacuum relief devices constructed of materials suitable for the acid or caustic digester process.

2.1.7 In addition to the above vessel over pressure protection, provide an overpressure protection scheme to begin shutoff of vessel inputs at 90% of vessel MAWP, and to open vents at 95% of vessel MAWP. The intent of this arrangement is to permit operation at the necessary process pressure and avoid operation of safety relief valves or rupture disks.

2.1.8 Provide a steam supply that can meet maximum demand (usually start-up) of the digester system without causing upset in other mill areas. This may require a backpressure regulating device to ensure steam system pressure is not reduced below some minimum value.

2.1.9 Provide overpressure protection on the steam supply with capacity to match the maximum available steam supply flow if the steam supply pressure can exceed the MAWP of vessels downstream of pressure reducing stations.

2.1.10 Protect the steam supply to the digester system against reverse flow. If steam supply pressure is lost, it is undesirable to have digester system contents flow back into the steam supply system.

2.1.11 Monitor the purity of digester system condensate for contamination, such as from indirect liquor heaters. Provide for immediate isolation or diversion of contaminated condensate.

2.2 Operation and Maintenance

Train operators on standard and emergency operating procedures. See Data Sheet 10-8, *Operators* for guidance on developing operator programs.

Operating condition changes (physical and/or process) are evaluated using Management of Change. See Data Sheet 7-43, *Process Safety*.

2.2.1 Start-up Procedure

Develop a start-up procedure, particularly for vessels constructed prior to 1940, to ensure the vessel is not pressurized until the shell temperature is well above the transition temperature.

2.2.2 Inspection, Testing, and Maintenance Program

Establish and implement a digester system (all vessels and piping) inspection, testing, and maintenance program. See Data Sheet 9-0, *Asset Integrity*, for guidance on developing an asset integrity program.

2.2.3 External Inspection

Examine external surfaces of digester system vessels and piping in the vicinity of joints for indication of leakage. If insulated, examine the covering for wet spots and discoloration. If suspicious areas are noted, remove the insulation to permit examination of the shell or pipe. Carefully examine the vicinity of all openings, nozzles, thermometer wells, etc. to determine if any defects exist in the attachments proper or in the weld metal. Examine all piping connecting the digester system vessels.

External corrosion under insulation can become a significant thinning problem. If there are any indications of corrosion under insulation on digester system vessels or piping, utilize an appropriate testing method, such as UT thickness testing applied either internally or externally, to determine if repair is necessary. Vessels or piping in damp or humid environments or environments tending to be alkaline, acidic or containing chlorides are susceptible to external corrosion. Operating temperatures of 160° to 220°F (71° to 104°C) are known to rapidly accelerate corrosion. Some warning signs that corrosion may be present under insulation:

- Weathered, damaged or missing caulking
- Dislocated jackets, exposing insulation
- Punctured, torn, loose, dislodged, bulged or missing jacketing
- Reddish brown or white stains, deposits on jackets or holes in jacketing from insulation-side corrosion
- Dented jackets resulting in opened seams and connections
- Unsealed piping insulation terminations
- Unsealed inspection ports
- Gaps in jacketing around pipe hangers and other protrusions
- Insulation system designs and jackets that do not shed water
- Exposed insulation support rings.

2.2.3.1 Provide access to the external surface of clad (weld overlay, plate lining, brick lining, composite plate, etc.) batch digester vessels that are not internally inspected on an annual basis for visual observation of through-shell leaks. This may be accomplished by removal of circumferential bands of insulation immediately above each external stiffening ring or insulation attachment ring. Immediately cease digester operation and internally inspect if through-shell leakage is visually identified.

2.2.4 Digester System Controls Testing

Functionality test and calibrate the digester system controls and safety devices on initial start-up and after no more than 12 months operation. A shorter test interval is advised for any controls or safety devices that do not function properly during testing. Test interval may be extended once devices are proven reliable, but should not exceed 12 months.

2.2.5 Digester System Internal Inspection

Inspect the complete digester system (vessels, piping, mechanical devices, etc.) prior to placing in service (see Table 1). Internally inspect vessels by visual testing (VT), after thorough cleaning. Further evaluate any indications by an appropriate nondestructive examination (NDE) method.

For digester vessels, determine the remaining thickness of carbon steel construction by ultrasonic testing (UT) or other NDE method that provides similar results, on a set grid that is duplicated on subsequent inspections. Measure remaining thickness of localized areas of more rapid corrosion/erosion, as identified by visual inspection or determined by operating history.

In addition to VT, examine digesters that have corrosion-resistant surfaces with a copper sulfate solution to determine the extent of any exposure of the base carbon steel. If the corrosion-resistant lining is weld overlay, examine with PT to locate any porosity, pinholes, or pores in the overlay. Pinholes in overlay are frequently revealed by “bleed back” following the cleaning of the digester in preparation for inspection. Repair of any pinholes requires removal of the overlay to expose base carbon steel to the full extent of the pinhole or void that may have formed under the overlay. Thickness testing of the base metal is needed only if areas of the carbon steel are exposed. It is assumed that thickness of corrosion resistant materials will generally not be significantly reduced by corrosion.

If visual inspection of corrosion resistant materials reveals indication of erosion or other thinning mechanism, thickness testing of the corrosion resistant material may be necessary in the development of a corrective action plan. Similar inspection/testing is advisable for other corrosion resistant metal clad, weld overlayed or thermal spray coated vessels and piping in the digester system.

When following a preventive (time-based) maintenance program, externally reinspect vessels and piping after no more than 12 months of operation. Internal vessel inspection frequency should not exceed 24 months. If the process is modified (chips, liquor, pressure, temperature, etc.), or if any of the following conditions is identified, reinspect internally and externally preferably within 12 months:

a) Thinning, general or local, greater than 10% of the corrosion allowance (or remaining corrosion allowance for used vessels);

b) Discovery of indications in pressure-containing welds that require grinding or weld repair.

If no indications requiring repair are found in pressure-containing welds and the corrosion allowance is sufficient, continue complete internal visual inspection and complete thickness testing at maximum 24 month interval.

2.2.6 Additional Examination Recommendations

If an adverse condition develops between the set inspection interval or is discovered during planned inspection, reduce the interval for test/inspection of that area or weld to 6 months or less.

WFMT is the preferred examination for welds in carbon steel digester vessels (not having a corrosion resistant barrier). Dry color contrast magnetic particle is an acceptable alternate method. Digesters that are not fully stress relieved are more susceptible to weld cracking.

Computer-controlled shear wave UT and phased-array UT are alternate NDE methods that may be externally applied to vessels. Base metal integrity, weld integrity and base metal thickness can be determined for vessels that are not insulated or have insulation that can be readily removed. UI, external method, may be applied while a vessel is in use, providing surface temperature does not exceed limits of the UI instrumentation. Extent of examination is as described for internal NDE methods. Similar inspection/test is advisable for all carbon steel vessels and piping in the digester system. Use of UI is not an acceptable substitute for 12-month internal visual inspections.

Annually, VT examine brick-lined digesters. If any indication of lining failure is discovered, remove the lining in the affected area and inspect the digester shell as described above for the particular material of shell construction. Take similar action if leakage is discovered on external inspection.

Inspect (VT) joints of riveted vessels and perform WFMT, as described above for carbon steel welded construction.

2.2.7 Repair Recommendations

If examinations reveal indications exceeding limits permitted by the original construction code or the jurisdictional inspection code, implement the following repair recommendations. [**Note:** for North America, the permitted indication limits are described in ASME Section VIII, Division 1, Mandatory Appendix 4 (RT), Mandatory Appendix 6 (MT), Mandatory Appendix 8 (PT) and Mandatory Appendix 12 (UT).]

2.2.7.1 Cracks may be repaired by grinding or arc-air gouging providing the remaining wall thickness exceeds the minimum required by the Code for the vessel MAWP plus twice the corrosion-erosion allowance necessary for operation until the next planned examination. Examine the repair weld by WFMT after grinding (carbon steel) or PT (corrosion resistant metals).

2.2.7.2 Reduced thickness areas, including welds, may be restored by welding. Thickness restoration with a similar filler material or with a compatible corrosion-resistant filler material is acceptable. The procedure for restoration of thickness by welding should address stress relief and weld shrinkage.

Welded repairs should meet all requirements of the original construction code and any jurisdictional requirements. For North America this is generally Section VIII and Section IX of the ASME Code and requirements of the National Board Inspection Code (NBIC). Provide stress relief of repair welds as recommended above for new construction. Examine the completed weld repair by an appropriate NDE method. This procedure is applicable to all digester system vessels and piping.

2.2.7.3 Angle beam (shear wave) UT examine at least 20% of any butt weld repair, including overlay welding, that is not stress relieved. Heat input from the welding process (or arc-air gouging), particularly at butt welds, may lead to weld cracking if stress relief is not completed.

2.2.8 Contingency Planning

2.2.8.1 Equipment Contingency Planning

The majority of mills using batch digesters typically have multiple batch digesters and there is usually at least one redundant digester to minimize any loss of production. When a batch digester breakdown would result in an unplanned outage to site processes and systems considered key to the continuity of operations, develop and maintain a documented, viable batch digester equipment contingency plan per Data Sheet 9-0, *Asset Integrity*. See Appendix C of that data sheet for guidance on the process of developing and maintaining a viable equipment contingency plan. Also refer to sparing, rental, and redundant equipment mitigation strategy guidance in that data sheet.

In addition, include the following elements in the contingency planning process specific to batch digesters:

A. If an integrated pulp mill, consider alternative sources of pulp to minimize paper machine production losses. Even if outside sources of pulp are available, careful consideration should be given to the impact on the balance of the mill if the batch digester is out of service for an extended period of time. Other potential impacts to consider include the following:

- Is operating the mill on 100% purchased pulp feasible from a stock preparation perspective (i.e., the logistics of receiving and storing significant quantities of baled pulp, the availability of ample hydro-pulpers for making down pulp bales)?
- If the digester is idled, there will be limited/no black liquor fuel for the recovery boiler? Does the shut down of the recovery boiler result in limited steam production for the mill and associated paper mill curtailments? Does the recovery boiler have load burners that can supplement steam supply when there is no supply of black liquor? Would there be any seasonal impacts (i.e., natural gas curtailments) that could impact the ability to generate sufficient steam for the paper-making process?
- What is the impact on electrical power availability if the recovery boiler is idle and it is paired with a corresponding turbine generator?

2.2.9 Visual Inspection

At 6 months but not more than 12 months after any change in the pulping process (pressure, temperature, liquor composition, feedstock composition, liquor circulation, etc.), perform a full visual inspection of at least the digester and preferably the entire system.

2.2.10 Riveted or Forge-Welded Digesters

Replace digesters of either riveted or forge-welded construction with modern, fusion-welded vessels. Riveting and forge welding are obsolete fabrication methods. The fabrication method, age, and materials of these vessels present exceptional challenges to inspection and repair efforts necessary to ensure integrity of the pressure vessel at a useful operating pressure.

Table 1 summarizes inspection recommendations.

Table 1. Batch Digester System — Vessel Inspection Matrix

Kind of Inspection	*Internal Surface*	*Thickness*		*External Surface*
Shell Material	*Interval*	*Interval*		*Interval*
Carbon steel not stress relieved	Full visual 6 to 24 months	6 to 24 months UT random/local	Do not exceed 24 months	Annual
		6 to 24 months UT grid		
Carbon steel stress relieved	Full visual 6 to 24 months	6 to 24 months UT random/local	Do not exceed 24 months	Annual
		6 to 24 months UT grid		
Clad carbon steel	Full visual 6 to 24 months	Required when thinning evident or carbon steel is exposed		Annual
Weld overlay carbon steel	Full visual 6 to 24 months	Required when thinning evident or carbon steel is exposed		Annual

2.2.11 Deficiency Management

2.2.11.1 Develop and implement a deficiency management process as part of the asset integrity program to ensure deficiencies are evaluated and tracked to closure. This process can include the following.

A. Fitness for Service - Perform a fitness for service evaluation when the inspection, testing and maintenance program (ITM) identifies one or more deficiencies and repair, alteration or replacement is not to be performed prior to restarting the digester.

B. Remaining Useful Life - Perform remaining useful life analysis when digester deterioration based on ITM results has exceeded predetermined acceptable limits but is still considered fit for service. This analysis may be performed when suitability of the equipment to operate for the intended duration is in question.

See Data Sheet 9-0, *Asset Integrity* for guidance on fitness for service and remaining useful life.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Equipment and Processes

Constructing vessels and piping to a recognized code better ensures the equipment will function as intended over the planned equipment life, and will facilitate future repairs. Specific requirements for structural loads beyond pressure containment are generally not provided in pressure vessel construction codes. These loads need to be considered to minimize damage from environmental factors.

Construction codes generally address minimum material thickness required for containing pressure, and do not provide specific guidance on material allowance for corrosion and erosion for specific service applications. As an example for vessels, see UG-25, Section VIII, ASME Boiler and Pressure Vessel Code. For piping example, see 102.4.1, Corrosion or Erosion, ASME B31.1, *Power Piping*. Digester liquors may be either highly caustic or highly acidic, leading to rapid corrosion. Digester feedstock may contain erosive material (dirt, sand) that may accelerate thinning of vessel walls and piping.

Carbon steel vessels and piping may require substantial additional material thickness due to corrosion and erosion over the planned equipment life. Stainless steel-clad carbon steel plate, stainless steel plate and stainless steel piping have proven to have greater resistance to corrosion and erosion in digester service. Corrosion and erosion resistance of existing carbon steel vessels can be improved by protecting with high nickel-content weld metal overlay or metal spray coating.

Stainless steel plate and stainless steel-clad carbon steel plate is less susceptible to stress corrosion cracking in digester service. Stress corrosion cracking, in the form of caustic embrittlement, has occurred in carbon steel vessel welds that were not stress relieved.

Carbon steel digester vessels that have been fully stress relieved have been much less prone to stress corrosion cracking.

Overpressure protection devices typically begin to open at less than the set pressure so full opening is achieved at no more than 110% of the set pressure. Therefore, vessel design MAWP must exceed the intended operating pressure by an amount to prevent operation of the selected overpressure protection scheme (safety relief valve, rupture disk, process limit controls). For safety relief valves, this amount is generally at least 110% of the planned operating pressure. It is not possible to operate vessels at the design MAWP. Constructing vessels for full vacuum avoids the cost of installing a vacuum protection scheme and the ongoing expense of maintaining such a system.

Process upsets and external exposures can result in vessel pressure exceeding intended pressure. Provision of fixed overpressure protection ensures the vessels do not experience pressure significantly above the MAWP, which could reduce the vessel life. Data Sheet 7-49, *Emergency Venting of Vessels*, provides guidelines for the evaluation of overpressure protection systems. It indicates that the overpressure protection scheme should be based on the evaluation of the worst credible case. The actual overpressure protection system design should be left to specialists.

Designing process controls to reduce inputs and to open vessel outlets at a pressure below overpressure protection device set pressure reduces the probability that the overpressure protection device will operate. Digester contents are in suspension and will generally flow toward any opening in the vessel, including overpressure protection devices connected to the vessel vapor space. The vessel contents may plug the relief piping as the flow dissipates, and can be expected to cause sticking of a pressure relief valve. Such plugging would require taking the vessel out of service until the overpressure protection system is restored. Also, safety relief valves or rupture disks are the final overpressure protection safety element. Unnecessary operation is to be avoided.

Rapid pressurization of direct steam heated digesters can seriously reduce steam supply pressure throughout a facility. This can induce unnecessary fatigue stresses on steam system equipment and may upset steam-dependent operations in other areas of the facility. A backpressure regulating device can ensure some minimum pressure is maintained on the steam supply system when initially steaming a digester.

Steam distribution pressure is frequently much higher than process demand pressure. Pressure regulating valves are generally installed to limit steam supply pressure to vessels. If the regulating valve fails in the full open position or if the typically provided manual bypass is left open, supply pressure to vessels may exceed the MAWP. To avoid operation of the vessel overpressure protection scheme, relief devices are installed on the steam supply downstream from the regulating valve. The relief capacity is determined by the maximum (single source) flow that can be supplied at the lowest, connected-vessel MAWP.

Sudden loss of steam supply can result in digester contents flowing back into the steam supply lines. Such backward flow may require system shutdown to flush liquor and pulp out of the system, and neutralize any remaining acid or caustic residue. In extreme cases, flow back may contaminate other products in process at the facility and result in degradation or loss of the other products.

Condensate contamination indicates a pressure boundary, such as a heat exchanger tube, has been compromised and prompt repair is needed. Contaminated condensate should be immediately isolated and not returned to the condensate collection system. Failure to isolate can result in damage to downstream piping, vessels and boilers.

A 1916 vintage, brick-lined sulfite batch digester failed at a riveted seam in 1971 when pressurized at ambient temperature. The shell material was determined to have low fracture toughness at ambient temperature. Adequate fracture toughness did not develop until the material was at 125°F (50°C).

3.2 Operation and Maintenance

Planned maintenance of operating controls can prevent unintentional over pressuring of digester system components. Proper function of overpressure protection devices, should an overpressure condition occur, can be ensured by regular maintenance and testing. Digester system components have been damaged due to failure of operating controls and protective devices to vent pressure and to relieve vacuum.

A thorough inspection program can locate indications of thinning or cracking to permit timely corrective action. Catastrophic failure of a digester vessel can result from wall thinning or cracking of vessel welds.

Construction and inspection codes generally provide for some thinning and some crack-like indications. When the allowable limits are exceeded, repairs compatible with the original vessel design and materials become necessary. Provision of stress relief for all welded repairs, including weld metal overlay, is essential to avoid cracking and distortion.

Many factors can improve the material performance of digester system vessels and piping. As these factors or methods are implemented at individual mills, the effect of the implementation needs to be monitored to ensure the desired result is achieved. Depending on original process and materials, changing of some factors may have no impact and others may have undesirable impact.

Digester system materials that have performed well under a particular process regimen may exhibit rapid thinning or weld cracking upon change of the process.

3.3 Loss History

The catastrophic failure of a batch digester in 1994 demonstrated the value of vigilance in the inspection for corrosion and care in repair practices. The late 1940s vintage carbon steel digester had stainless steel weld overlay installed in the early 1980s. Following the incident it was determined the original shell material in a 20 in. by 9 in. (500 mm by 230 mm) area had an average remaining thickness of 0.18 in. (4.5 mm), with one area being 0.11 in. (2.8 mm) prior to application of the overlay welding. The stainless steel overlay was fused to the carbon steel and did contribute to the overall strength of the vessel. Following the incident, the overlay was found to have preexisting cracks extending to the carbon steel, with some extending into the carbon steel. These cracks compromised the reinforcement provided by the overlay, leading to the rupture of the thinned carbon steel.

The failure started in the longitudinal direction at the thin area in the lower section of the digester, then ripped out a 6 ft (1.8 m) tall section completely around the digester. The top two-thirds of the digester was propelled out of the digester building and came through the roof of a paper machine building 300 ft (91 m) away. The digester building was extensively damaged, along with damage to six adjacent digesters.

3.4 Illustrative Losses

3.4.1 Flow Reversal Upon Loss of Steam Supply Results in Contamination of Steam Piping to Production Equipment

Loss of the mill power boiler led to mill blackout. Check valves and emergency manual isolation procedures were provided to prevent backflow from the nine batch digesters. Although the check valves are serviced annually, the swing-gate assembly of one valve was found in the bottom of the valve housing. Manual valves to all but this one digester were closed as planned. Failure of the check valve and failure to manually isolate this digester as planned permitted the digester contents to flow back into the mill steam supply system. The resulting contamination required flushing of most of the mill steam supply system and replacement of some equipment. Restoration of partial mill production took two and a half days, with an additional four and a half days to restore full production.

3.4.2 Failure to Maintain Blow Tank Results in Rupture

The three batch digesters at a wood pulp mill discharge into three 40-year-old stainless steel sheet-lined blow tanks constructed of wood staves and steel bands. During the second re-steam blow of one digester, one of the blow tanks failed at the bottom circumference. The wood staves and steel retaining bands appeared to have deteriorated over the years of service.

In addition to loss of the blow tank, electrical wiring, sprinkler piping and the building roof were damaged. Torch cutting was done in the area with impaired sprinkler protection. Some digester pulp was discharged into a water canal that was a source for process and fire protection water. Cleanup of the canal required impairment of the fire protection water supply.

As a result of this incident, the mill installed additional bands on the remaining blow tanks and replaced the damaged tank.

3.4.3 Improper Vacuum Protection Results in Blow Tank Implosion

A single blow tank serves the eight batch digesters at this 500 ADMT/day pulp mill. Vacuum protection is installed only on the hot water accumulator tank, which is connected to the blow tank by a 36 in. (914 mm) diameter vent line. The elevation of the connection to the accumulator tank is lower than the connection to the blow tank. Water level in the accumulator can rise above the vent connection level, isolating the blow tank from the vacuum protection on the accumulator.

Digester blows are generally done at 30-minute intervals. Prior to the incident, three blows were completed in less than 30 minutes. About 20 minutes after the third digester blow, the blow tank imploded.

As a result of this incident, the mill agreed to install vacuum relief directly on the blow tank. It is also important to note that loss of the single blow tank at this mill interrupted all digester operation.

3.4.4 Failure to Maintain Relief Valve Results in Blow Tank Implosion

One of two blow tanks serving five batch digesters had been in service for forty years. It was designed for 15 psi (100 kPa) pressure and estimated for 27 in. (686 mm) water vacuum. Overpressure protection was provided by a combination pressure-vacuum weighted lever relief valve. Following implosion of the tank, the relief valve was inoperable due to corrosion. The tank was damaged beyond repair. Partial production was maintained with the remaining blow tank.

3.4.5 Inadequate Relief Capacity and Valve Failure Result in Storage Tank Rupture

This 240,000 gal (910,000 l) liquor accumulation tank has a 10 in. (250 mm) vent and 12 in. (300 mm) fill line. The tank normally receives batch digester presteaming liquor at 160°F (71°C). A normally closed valve was left open (linkage to actuator broken) and liquor at 350°F (178°C) was admitted to the tank. Flashing of the liquor exceeded the 10 in. vent capacity and the top of the tank ruptured.

The mill plans to install a 36 in. (910 mm) vent, provide continuous temperature monitoring and install a high temperature shutoff valve on this tank.

3.4.6 Lack of Inspection Program for Digester Liquor Heat Exchanger Results in Mill Shutdown

This 30 year old, 30 in. (760 mm) diameter by 20 ft (6.1 m) tall shell and tube liquor heater was being returned to service after tube cleaning. Steam leakage at the heater made the local steam valve inaccessible. The steam supply header valve could not be fully closed. Ultimately, all boilers supplying steam to the digester area were shut down to stop the steam flow.

Investigation revealed a 52 in. (1.3 m) long circumferential crack at the steam chest to heater shell weld transition. The crack was determined to be due to either stress corrosion cracking or corrosion fatigue. Ultrasonic testing of three other heaters revealed crack-like indications. A decision was made to replace the steam chest portion of all liquor heaters at the mill.

Prior to this incident, there was no program to periodically examine the welds in the liquor heater vessels.

3.4.7 Stone Container Corporation Press Release “Digester Incident Update — Panama City Mill, July 8, 1994”

“On April 13, 1994, one (1) of 22 batch digesters ruptured while under normal operating pressure of 100 psig. The failure started in a longitudinal or axial direction in the lower section of the digester, then ripped out a 6-foot section all the way around the digester. The top two-thirds (⅔) of the digester was propelled up through the roof and came down through the roof of the paper machine building, landing on the paper machine refiners.

The resulting blast and destruction caused by the propelled digester caused extensive damage to the digester building, brown stock washer area, screening facilities, stock chests, blow tanks, electrical and instrument control centers, electrical distribution centers and evaporators. Six (6) adjoining digesters were damaged and will require replacement. As a result, both the Linerboard and Bleached Pulp machine were idled.

Three (3) people were killed and seven (7) injured, two requiring hospitalization.

Brown & Root, Inc., is performing the engineering and construction work for clean-up and restoration of the facility. It is expected that one machine will be back in operation by mid-August and the other in mid-September.

The cause of the failure is being investigated by Packer Engineering of Chicago, Law Engineering of Charlotte (OSHA Representative), Radian Corporation (Hartford Steam Boiler) and Stone Container Corporate Metallurgist.

The digester was manufactured in 1948, is 10 ft 6 in. ID by 36 ft 6 in. (F to F) with a volume of 2,583 ft^3. Stainless steel overlay of the entire inner surface was completed in 1983.

The shell was manufactured with 1 in. thick Type A-212, grade ''b'' carbon steel plate with a tensile strength of 70,000 psi. Metallurgical examination of the steel showed no degradation or weakening of the steel properties. The digester was hydrostatically tested in June 1993 at 225 psig.

The failure occurred in a very specific area of the digester where the stainless steel overlay was made over a thin area of base metal of about 180 sq in. (9×20 inches).

Until final conclusion as to the cause of the failure can be determined, it is recommended that operators of overlayed batch digesters assure themselves that they have accurate data concerning the shell thickness under the overlayed area. Operators should also assure themselves that the number of thickness readings and the accuracy of the instrumentation used to determine the need for overlaying presents a true representation of the shell thickness.

Stone Container took advantage of this downtime to replace all 22 of the digesters in order to eliminate the high maintenance cost associated with overlayed digesters. All 22 digesters were back in place on June 23rd and reconstruction is progressing on schedule.''

Subsequent articles in trade journals indicated a 44 year old, 30 ton (27 t) batch digester ruptured, sending part of the shell through the building roof and landing 300 ft (91 m) away. Investigation indicated stainless steel weld overlay was done on the carbon steel shell without determining remaining shell thickness. The stainless steel overlay was not bonded with the shell material. The pulp mill rebuild took 150 days.[1]

4.0 REFERENCES

4.1 FM

The following data sheets provide additional guidance on batch digesters and related process vessels:

Data Sheet 7-49, *Emergency Venting of Vessels*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 10-8, *Operators*
Data Sheet 12-2, *Vessels and Piping*
Data Sheet 12-3, *Continuous Digesters and Related Process Vessels*
Data Sheet 12-43, *Pressure Relief Devices*

4.2 Other

American Society of Mechanical Engineers (ASME), *Boiler and Pressure Vessel Code,* Sections V, VIII and IX.

American Society of Mechanical Engineers (ASME), *Power Piping,* ASME B31.1.

National Board Inspection Code (NBIC).

TAPPI Technical Information Papers:

- TIP 0402-03, Guidelines for corrosion resistant weld metal overlay of digester vessels in alkaline pulping service
- TIP 0402-04, Clad-steel plate use
- TIP 0402-22, Guidelines for inspecting batch digesters
- TIP 0402-23, Welding of duplex stainless steels
- TIP 0402-35, Post-fabrication cleaning of stainless steel in the pulp and paper industry

[1] *Meadows, D., "Stone Container's Panama City mill running again after digester explosion", TAPPI Journal, December 1994, p. 33;*
"No cause found yet for digester explosion", PAPERMAKER, July 1994, p. 10;
"Safety alert for U.S. pulp mills", PULP & PAPER, July 1994, p. 17.

APPENDIX A GLOSSARY OF TERMS

AP: anodic protection

MAWP: maximum allowable working pressure

MT: magnetic particle testing

NDE: nondestructive examination

NDT: nondestructive testing

OPTS: overpressure protective/trip systems

PT: penetrant testing

PWHT: post weld heat treatment

RT: radiography testing

SCC: stress corrosion testing

UI: ultrasonic imaging

UT: ultrasonic testing

VT: visual testing

WFMT: wet fluorescent magnetic particle

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

April 2025. Interim revision. Made editorial changes were made.

October 2024. Interim revision. Made editorial changes for additional clarity.

July 2022. Interim revision. Made editorial changes for additional clarity.

January 2022. Interim revision. Minor editorial changes were made.

July 2021. Interim revision. The following significant changes were made:

A. Added NDE inspection, testing, and maintenance guidance for digesters.

B. Updated the equipment contingency plan and sparing guidance for digesters.

January 2013. The following changes were made:

A. The recommended maximum preventive (time-based) maintenance internal inspection interval was increased from 12 months to 24 months. Table 1 was revised for consistency with the new 24 month maximum internal inspection interval.

B. Recommendations 2.2.6, 2.2.6.1, 2.2.6.2, 2.2.6.3 and 2.2.6.4 were deleted. Recommendation 2.2.6.5 is now 2.2.6. The hazard of shell cracking is adequately addressed in Recommendation 2.2.5.

C. Recommendation 2.2.7 was generalized by removing “weld” from first sentence.

D. Recommendation 2.2.7.2 was clarified regarding acceptable use of filler metals.

E. Recommendation 2.2.7.3 regarding riveted vessels was deleted.

F. Recommendation 2.2.10, replacement of digesters fabricated by obsolete methods, was added.

G. Sections 3.3 Loss History and 3.4 Loss Examples was updated.

H. Section 4.0 References was updated.

I. Appendix C Forms was deleted.

J. Appendix D (now C) Bibliography was updated.

January 2010. Revised recommendation 2.1.6 to reflect the acceptability of weighted-type valves for overpressure protection on all vessels associated with batch digester systems (including NCG collection systems attached to the vessels) that are designed for operation at less than 15 psi (103 kPa).

May 2003. Existing information has been reformatted. Guidance has been added on inspection of pressure boundary welds. Recommendations and descriptions have been expanded to cover all pressure vessels and piping involved in the batch pulping process.

2002 — Expanded recommendations to include piping and vessels associated with the batch pulping process and similar vessels in other industries. Reformatted for improved electronic search capability.

1999 — Reformatted.

1998 — Revised guidance on overpressure protection of batch digesters.

1991 — Added ‘‘Field Repairs’’ section.

1967 — First publication released.

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