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Product Safety

Digester inspections for safety and integrity

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Digesters represent equipment essential to the operation of every pulp and paper mill. The utilization of digesters is as old as the earliest integrated paper mills established in the 19th Century.

The earliest types of equipment were so-called batch digesters. However, in the 1950s several types of continuous digesters were developed. Currently both continuous and batch digesters are used.

The early digesters were generally constructed by riveting together steel plate sections. In the 1920s digesters were increasingly fabricated by welding. After the development and establishment of the Boiler and Pressure Vessel Code by the American Society of Mechanical Engineers (ASME), digesters became subject to the design, fabrication and inspection requirements of pressure vessels under Section VIII Unfired Pressure Vessels of the ASME Boiler and Pressure Vessel Code.

Since digesters essentially perform a cooking function, they are operated at elevated temperatures and pressures. Moreover, the cooking generally is done in a corrosive environment. Thus, digesters, including the earliest types, are subject to corrosion, wear, fatigue, and other types of deterioration. In addition, upset operating conditions such as pressure or temperature excursions, can and do occur in some instances.

During their 100-year history, catastrophic failures have occurred in nearly every type of digester including the most recent incident with a batch digester in a pulp and paper mill in Florida or that of a Kamyr continuous digester in Alabama, which was evaluated by Thielsch Engineering.

Increasing concern

Because of catastrophic failures in both batch and continuous digesters, the pulp and paper industry as well as the various insurance underwriters have become increasingly concerned about the inspection and condition assessment of digesters.

Thielsch Engineering has been involved in digester inspections since the early 1950s. The earlier inspections involved primarily riveted and welded batch-type digesters. Most of the riveted digesters still being operated also contained a significant number of welds either in the original design or as a result of repairs made to replace shell locations where rivet failures had occurred or significant leaks had developed at rivet locations or in the overlapping shell sections.

Since the late 1950s, the inspections also included the various types of continuous digesters that had been produced including horizontal or inclined designs where the chips are moved through the digester by means of screw conveyor flights. Subsequently, the larger continuous Kamyr digesters have also been increasingly inspected.

In the past, most digester inspections were cursory rather than thorough. Moreover, most inspections were primarily visual, supplemented on occasion by wall thickness measurements.

The more thorough and meaningful inspections combined with engineering evaluations, generally have not been done because the personnel doing the inspections were mainly NDE technicians rather than engineering personnel who are fully familiar with the design, construction, fabrication, welding and operation of digesters. Engineers are also familiar with the various carbon steel, stainless steel and high nickel alloys used in the shell sections, connected piping, and the welds.

The batch digesters evaluated by Helmut Thielsch since 1960, and by other Thielsch Engineering personnel, have involved the following types of constructions of digester vessels:

(1) Carbon steel (riveted and welded).

(2) Stainless clad steel (roll bonded with nickel layer or iron layer bond).

(3) Shells constructed with stainless steel liner plates applied to the shell by spot welding.

(4) Stainless steel weld overlays over carbon steel shells by various welding techniques: shielded metal-arc; gas metal-arc (including short-arc and pulse-arc welding); submerged-arc; flux-cored.

(5) Weld overlay repairs with carbon steel and/or stainless steel filler metals by one of the following processes or combinations of processes involving: shielded metal-arc welding; gas metal-arc welding (including short-arc and pulse-arc welding); submerged-arc welding; flux-cored welding; combinations of the four processes performed at one time or at different times and including combinations of different welding filler metals.

(6) Repairs by the application of stainless steel liner strips or shingling.
(7) Digesters constructed using other materials, fabrication and welding methods.
(8) Metallized surface layers using stainless steels and nickel alloys.
(9) Shell welds (seam and girth) made entirely with stainless steel and carbon steel and stainless steel welding filler metals. Recognized also must be the effects and quality of welds made by different welding processes and procedures. Stainless clad steels have also been used in the several types of continuous digesters installed in pulp and paper mills. Thus, the shell materials and welding methods described above for batch digesters also apply to continuous digesters.

Shells that have been welded may or may not have been subject to post-weld stress relief heat treatments. Weld areas treated thus generally exhibit greater resistance to many corrosive environments.

Many shortcomings

Our prior inspections and evaluations have revealed many shortcomings and deficiencies in the original manufacturing, fabrication, welding, and heat treating processes and with the various in-service repair procedures followed.

Some of the deficiencies detected in engineering inspections since the early 1950s included those with the potential for major catastrophic failures. These included cracking in dissimilar metal shell welds, caustic stress corrosion cracking in carbon steel digester sections, chloride stress corrosion cracking in stainless steel roll bond cladding and weld cladding, and in stainless steel welds.

Other deficiencies included accelerated shell corrosion from increasing concentrations of corrosives between the stainless surface layers and the carbon steel shells, disbonding of stainless steel plate cladding along the carbon steel bond, disbonding within stainless steel weld overlays, severe lack of fusion between layers of stainless steel overlays and between overlays involving carbon steel welding, severe corrosion, and stress corrosion cracking underneath metallized layers, cracking in dissimilar girth and seam welds, and so on.

Deterioration of and cracking at nozzle and other branch locations and attachment welds have also been evaluated. This includes ruptures and leak-type failures of nozzles as a result of erosion, and it also includes the catastrophic rupture of nozzles and external piping connections as a result of stress corrosion cracking or severe corrosion.

Severe damage from improper or excessive acid cleaning has also been diagnosed and evaluated. This includes pitting in the carbon steel shell base material, and chloride stress corrosion cracking in the stainless steel cladding.

Because of an increasing concern about digester failures, many pulp and paper mills have stepped up their frequency of inspections. Where inspection companies with inexperienced engineering personnel and/or inadequate equipment have been used, major defect conditions with potential deficiencies for catastrophic failures have been missed during the inspections.

On the other hand, there have been a significant number of instances where recent inspections concluded that specific digesters examined contained serious defects and were unsafe to operate. However, when experienced Thielsch Engineering personnel performed a subsequent inspection and evaluation, it was confirmed that the respective digester was entirely safe to operate. The prior improper inspection results "found" inconsequential conditions such as shell laminations, dissimilar weld deposits that were actually sound, inconsequential weld defects, and so on, that neither would have caused nor contributed to failures.

Recognition of the various types of digester construction and repair histories referenced above and the potential for the various types of deterioration should be applied when determining the scope of work to perform an accurate assessment of each and every type of digester. Modifications can readily be made once the failure mechanism or root cause of the deterioration has been established.

For each type of digester and digester inspection, reference file reports from the Thielsch Engineering files must be reviewed by the engineer assigned to a specific inspection project to insure that the inspections will be complete and meaningful.

Various types of non-destructive testing and inspection equipment should also be used to detect any one of the many conditions that have resulted or can result in severe deterioration or damage to digesters, or in unsafe operating conditions.

Special metallurgical equipment may also be necessary to detect potential damage that can result from improper materials, fabrication (shell forming), construction, welding, and heat treatment conditions and/or from service-related repairs.

Deaerator inspections

Responsibility and expertise applicable to digester inspections exceed the complexity of the engineering inspections applicable to deaerators. In 1983 two deaerators ruptured catastrophically, resulting in loss of life and injuries to plant personnel. Both deaerator failures, the first in Pine Hill, AL, and the second in Jackson, MI, were examined and evaluated by Thielsch Engineering personnel. Since then, we have performed extensive continued engineering inspections and evaluations of deaerators. In a number of instances, potentially catastrophic failures were detected as a result. **PI**

This article is based on background information for Thielsch engineering personnel.