Batch Digester Corrosion

- Chips plus a mixture of white and black liquor are fed into the top of the vessel which can be up to 60 ft high.
- The vessel is sealed and the chips are cooked with heat supplied by direct steam injection or indirect steam heating for about 2 hours.
- The pulp is then blown from the bottom of the vessel into a blow tank.
- Corrosion occurs during filling when liquor splashes on the wall.
Hot Plate Boiling

- Dominant batch digester corrosion mechanism
- Liquor splashes onto the wall or off the chip pile onto the shell that is still hot from the last cook.
- The boiling effect concentrates liquor chemicals on the wall and destroys the protective passive layer
- Corrosion rates are high as 100 mils/yr
- Stainless steel also corrodes in the splash zone

Corrosion of 316L cladding after 4 years

Nominal clad thickness 0.125"
Other Corrosion Locations

- Corrosion may occur in the top head or bottom dome
- Preferential corrosion of carbon steel welds
- Erosion corrosion
  - bottom dome
  - outlet nozzle
- Stress Corrosion Cracking is unusual in batch digesters

Carbon Steel Corrosion

[Photo courtesy of Angela Wansley]
Carbon Steel Corrosion

Photo courtesy of Angela Wensley

Carbon Steel Corrosion

Photo courtesy of Angela Wensley
Stainless Steel Corrosion

Corrosion Protection – Thermal Spray

- A variety of processes characterized by per cent porosity and oxides
- Alloy 625 composition
- Used for large areas
- May have to build up before spraying
- Surface preparation is important
- Requires ongoing maintenance
Thermal Spray Damage

Corrosion Protection – Overlay

- Corrosion resistance depends on chromium content
- Materials
  - Alloy 625 ~18% not recommended
  - 309L 18% – 20% Cr is insufficient
  - 312L 22% - 27% Cr is the best choice
- Overlay cracking
  - Ferrite too low for 309L
  - Ferrite or hardness too high for 312

Photo courtesy of Angela Wensley
Corrosion Protection – Overlay

• May have to build up with carbon steel or qualify the overlay
• Surface preparation
• Pinholes in the overlay are serious a serious defect
• Requires ongoing maintenance
• There is a limited number of times a digester can be re-overlaid


Overlay over 316L Cladding
309L Overlay Damage

Bleed Through – Possible Pin Holing
Corrosion Behind Pinholes

Superficial 312 Damage
312 Bottom Tee Erosion

Batch Digester Corrosion Summary

- 'Hot Plate' boiling corrodes the surface
- 25% Chromium for corrosion resistance
- 312 overlay preferred for repairs
- Thermal spray is an alternate repair method
- Duplex stainless steel for new construction
  - 2205 is typically used though lean grades are also applicable
Continuous Digester Corrosion

- The vessel is nominally 200 feet high and 20 feet in diameter at the bottom.
- Conventional Cooking: Chips and white liquor are fed into the top. As the chip mass moves downward, it is heated, cooked and washed. The outlet device at the bottom removes pulp from the digester.
- Modified Cooking: White liquor is added at multiple locations. The temperature profile differs and lignin content is lower at the end.

Conventional Cooking

- Carbon steel construction, stress relief of the top courses unlikely before the late 80’s
- Stress corrosion cracking
  - Tends to occur towards the top of the digester
  - Corrosion Control includes:
    - Anodic protection
    - Thermal spray with Alloy 625
    - Corrosion resistant overlay
- General corrosion
  - In most cases well under 10 mils/year
  - Over decades a low rate, <2 mils/year is detectable
Continuous Digester Cracking

Ditching in the HAZ – Potential Site for SCC
Corrosion Protection – Anodic Protection

- Cathodes are mounted on the central pipe or stitch welded to the wall.
- Reference electrodes measure the carbon steel potential.
- Rectifiers supply current to raise the potential on the digester shell to a zone in which SCC does not occur.
- Effective in stopping cracking.
- Does not control general corrosion in modified cooking digesters.
- Quick installation.
- Requires ongoing maintenance.

Anodic Protection Cathode
Horizontal Cathode with Cage Damage

Corrosion Protection Continued

- Overlay
  - Alloy 625 is resistant but not used anymore
  - Stainless steel would now be used
  - Edge creates a heat affected zone. Watch out for ditching and cracking

- Thermal Spray
  - Twin wire arc spray
    - Coating thickness well over 50 mils
    - High porosity and oxides but rugged
  - Denser coatings under 25 mils thick
    - More sensitive to surface profile
    - More likely to blister and spall
Weld Overlay Corrosion

Weld Overlay
Ditching
Feather Grinding

The entire dome is overlaid with alloy 625
Overlay on vertical and horizontal seams

Corrosion next to the overlay after feathering
Smooth transition at the overlay edge

Corrosion Protection – Thermal Spray
Modified Cooking

- Digesters built after 1980 were stress relieved
  - SCC has not been an issue
- General Corrosion of carbon steel up to 40 mpy
  - It occurs in MCC, EMCC, Lo-Solids and ITC digesters
  - The bottom two thirds of the digester is affected
  - Two types of corrosion
    - “Ocean-Island”
    - “Polishing”
  - The flash tank corrodes as well
- Softwood digesters corrode more than hardwood

Typical Corrosion Patterns

Average Corrosion Rates
- < 2 mpy
- 2 - 15 mpy
- >15 mpy
No corrosion at the top

The shell has receded from the stainless steel nozzle
Pitting on the shell

Preferential weld corrosion
Corroded Lettering

“Ocean-Island” Corrosion
More ocean-island corrosion

Same ring 8 years later
Side view showing steel spikes

After another 5 years
Weld washout, grooving and smoothing

Weld close-up. Note polished effect
Corrosion Protection – Weld Overlay

• 309L with 18% Chromium has enough corrosion resistance
• 312L duplex stainless steel, is not required, but its strength may be used if the shell is below minimum thickness
• Establish quality requirements to prevent hot cracking i.e. control ferrite in stainless steel
• Often requires an extended shutdown
• Vertical or horizontal overlay

Vertical Down Overlay
The shell is receding from the top edge

309L overlay in good condition after 15 years
Thermal Spray Protecting an Overlay Edge

Thermal Spray After 10 Years
Other Digester Vessel Issues

- Stitch weld cracking
- Stainless steel weld cracking
- Outlet device cone thinning
- Digester nozzles
- IV Bottom head erosion
- Header erosion
- Outlet device rake arm erosion and cracking
Stainless Steel Seam Overlay Cracking

Lining the Bottom Cone with additional SS
Lower Wash Nozzle Cracking

Upper Liquor Level Nozzle Stress Corrosion Cracking
309L Overlay Wears in the Bottom of the IV

Header Erosion
More Header Erosion. Note the Nozzle Protrusion

Carbon Steel Build up and 309L Overlay
Outlet Device Rake Arms

- Carbon steel cracks and erodes
- 304L liners and 309L overlay have been the least successful in terms of maintenance.
- 2205 Duplex stainless steel is an improvement over other stainless steels though it also cracks
- Damage mechanism: Environmentally Assisted Cracking
- Recent material selection has focused on stress relieved, carbon steel with reinforcement or alloy 600 overlay on the leading edge. Wear is still an issue.

Severe Erosion of Carbon Steel
Erosion to the Point of Perforation

Cracking of the Stainless Steel Liner
Cracking of Duplex Stainless Steel

Another Duplex SS Arm – no cracking after 16 years
Alloy 600 Overlay on Both Sides of the Arm

Digester Ancilliary Equipment

- 304L stainless steel for erosion/corrosion resistance in liquor piping
- Duplex stainless steel
  - Improved wear, fatigue, SCC and corrosion resistance over 304L
  - Liquor heater tubes
  - Sand separators
  - Steaming vessels
  - Flash tanks
Sand Separator Cracking

Inner Cone Erosion – Alloy Steel is Used
Steaming Vessel Nozzles Can Crack

Steaming Vessel Wear Plate Thinning
Steaming Vessel External SCC

Coating the Solid 304L Steaming Vessel
Level Tank Liquor Inlet Nozzle Erosion

Level Tank Stress Corrosion Cracking
Flash Tank Lower Cone Corrosion

Flash Tank Shell Corrosion
Flash Tank Upper Duct Corrosion, ¼ “ Deep

Flash Tank Thermal Spray, Note Blisters
Continuous Digester summary

- SCC of carbon steel in vessels that have not been stress relieved
- General corrosion related to modified cooking
- Corrosion control options
  - Anodic Protection for cracking
  - 309L weld overlay
  - Alloy 625 arc spray
  - Lean Duplex Sheet linings
- New Construction
  - 304L clad or solid duplex stainless steel
  - Appropriate material selection and inspection for continuous digester system equipment

Questions?

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