MANAGING AGING PLANTS Conference & Expo USA 2018

Maintaining Aging Titanium Clad Equipment

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Reactive Metal Clad in CPI

- Typically Ti, Zr, Ta, Nb – Ti Dominates, presentation focus' on Titanium but generally applicable to all four metals
- Clad is commonly used in stationary CPI equipment---pressure vessels, columns, heat exchangers
- For over 50 years, >95% of titanium clad has been made by Explosion Cladding

Preventive Design: a Head Start on Aging Equipment Management

- History shows 50+ years good Ti Clad experience, yet…NOT Ti-clad is still not your everyday commodity material
- When equipment production team is adequately experienced, performance issues with clad are rare-
- When properly designed, constructed and operated this equipment is highly robust, typically providing problem-free performance for 25 to 50 years

Preventive Design: a Head Start on Aging Equipment Management - continued

- Knowledgeable, experienced design, fabrication, clad manufacture are critical- few applications are Cookie Cutter (even ones that seem to look alike)
  - Alloy selection must be appropriate for the application – CP Ti vs Ti-Pd vs Ti-12 vs ???
  - Materials thicknesses – appropriate for fabrication <u>and</u> service
  - Dissimilar metal concerns & manufacturer understanding- this is not stainless steel
  - Limited breadth of supply chain-
    - Explosion Clad Producers- Over 50 globally, yet ~10 are OK for Ti clad tubesheets, ~5 for Ti clad vessel plates
    - Fabricators- many reliable for HX tube bundles- far fewer for Ti-clad vessel fabrication
  - Limited availability for 3rd Party Inspectors knowledgeable Ti Clad projects… not so critical with experienced producers, but very important for newbes and wannabes

Typical Ti-Clad Equipment

Ti Clad Equipment Reliability

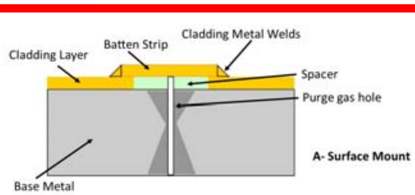
- Diligence during clad equipment selection, design and manufacture has assured very low clad equipment maintenance concerns
- When there are failures they typically result from-
  - Fabrication weld quality- primarily in batten strip welds or similar nozzle liner closure welds
  - Loss of cladding thickness due to corrosion, erosion or mechanical damage
  - Design

Ti Clad Equipment Risk

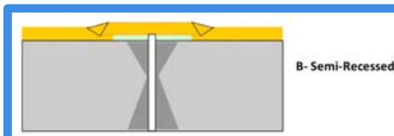
- Clad equipment relies on-
  - The cladding layer for process corrosion containment
  - The base metal layer for process pressure containment
- A through-thickness cladding metal failure can result in aggressive corrosion of the base metal layer.
- The resulting Risk is loss of the equipment and further potential damage from a high pressure release of the process media. How big is it?

When Problems Arise

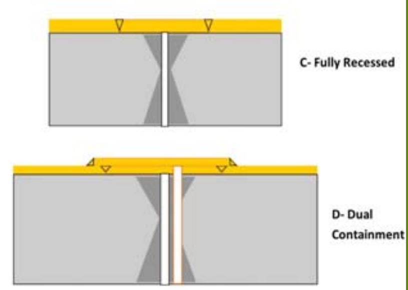
- Ti-Steel Clad fabrication requires batten strip weld designs
- Titanium batten weld cracks are the most common cladding defect
- Properly made batten welds very rarely crack



>90% of Ti Clad Equipment Fabrication



Preferred when clad is thicker, erosion or corrosion are expected



Other specialized batten designs

Surface Mount Batten Picture Here

Inspection for Batten Weld Defects

- There are currently no reliable NDE methods for detecting purely subsurface partial penetration batten strip weld defects.
- Batten strip fabrication welds should be examined by penetrant testing (PT) and helium leak testing (HLT) as part of the fabrication ITP.
- On-site re-test of by PT and HLT is recommended pre-startup and/or post startup, with ongoing frequency depending upon the reliability record of the Fabricator and the Risk Assessment.
- Periodic inspections throughout the equipment lifetime should be addressed in the Risk Based Inspection Plan.

In-Service Detection of Batten Weld Defects

- Telltale inspection access to the hidden backside of the batten strip is an important feature of the design
  - Batten strip fabrication welds necessitate backside inert gas purge
  - The purge is achieved via a hole drilled through the steel backing metal to access the titanium weld root
  - This same hole provides a non-intrusive “telltale” monitoring tool during operation.
- When **properly maintained and monitored**, the telltale’s will reliably provide early warning of a weld failure.

Telltale Detection of Batten Weld Failure

- Tubes attached to the telltale ports can be located where frequent monitoring is easy.
- Modern, automated monitoring systems can be used.

- This photo shows a poorly managed telltale monitoring bank. Regrettably the importance of telltale tube maintenance if often not understood by operators

Repair of Batten Weld Defects

- When found early, batten repairs can be made without major complications
- Repairs should be made on-site by an experienced titanium clad fabricator using best titanium welding, fabrication and inspection practice
- It is critical to fully clean the area behind the failure prior to installing a new batten strip.

Repair of Batten Weld Defects

Cladding Metal Thickness Concerns

- Titanium cladding is typically chosen for its corrosion resistance
- As with solid titanium equipment, titanium cladding is generally selected only if the corrosion rate is predicted to be <u>zero</u>. A corrosion allowance is rarely considered necessary in the titanium thickness decision.
- Titanium thickness has traditionally been established by Costand manufacturing/fabrication limitations on the rule **"less is better".**

Historical Cladding Metal Thickness

- In 1960's 2mm (0.078 in) titanium cladding thickness was established as the best "practical" thickness for clad manufacture and fabrication
  - Most titanium clad vessels produced between 1960 and 1990 used 2mm nominal cladding thickness
- In 1990's the industry began to realize that 3mm (0.118-in) cladding was actually **lower initial cost, lower damage risk and more easily repaired when needed**.
  - Since 1990 the standard has gradually transitioned toward 2.5 to 3.5 mm (0.10 to 0.14 in) thick cladding.
  - When erosion or mechanical damage is considered a possibility additional thickness is added.
  - For example, in hydrometallurgical process equipment the cladding thickness is typically increased to the 6 to 8mm range (0.25 to 0.31 in)

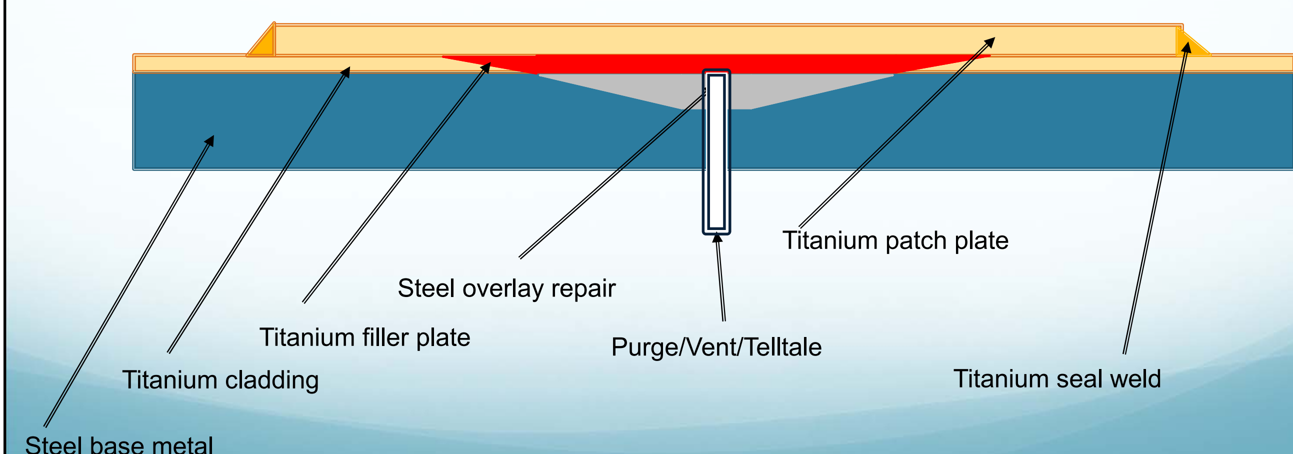
Cladding Metal Thickness Damage

- Rare but Real operational problems can cause cladding metal thickness loss
  - Corrosion- most commonly pitting/crevice
  - Erosion
  - Mechanical damage –
- In the absence of proper design and/or monitoring, full thickness cladding loss can result.

Repair of Cladding Loss

- When the thickness monitoring proves provides early warning, areas of reduced cladding thickness can be repaired by overlay welding. Typically OK when around 1.5mm (0.060 in) cladding remains
- Defects shown in the prior photo are more challenging
  - Cladding alloy patches have been used successfully. See photo on following sheet
  - In worse cases, full through-thickness vessel sections have replaced to salvage the equipment

Technique for Patching Larger Areas of Cladding Metal Loss



Heat Exchangers

- Clad metal is primarily used for
  - Tubesheets
  - Shells
  - Bonnets
- Issues with shells and bonnets is similar to the vessel discussion above

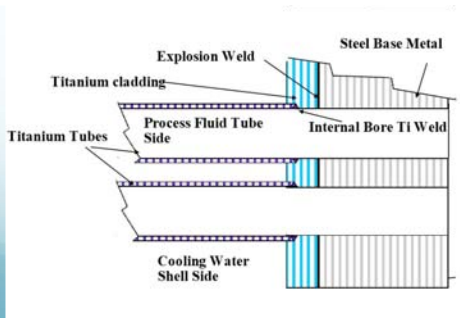
Clad Tubesheets

- Issues with clad tubesheets has typically been related to
  A. Improper tubesheet and exchanger design
  B. Inadequate tubesheet metal thickness selection
  C. Improper fabrication

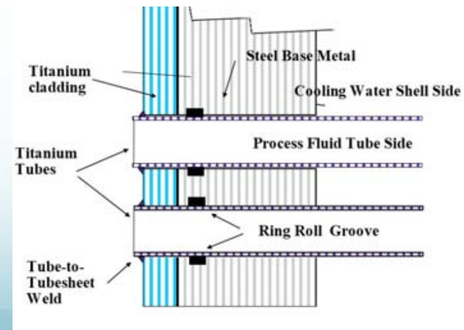
Heat Exchanger Failure #1

- Designed as shown on left with clad interface exposed to process media.
- Bimetal corrosion caused titanium hydriding and eventual bond failure.
- Preferrec design is shown on right.

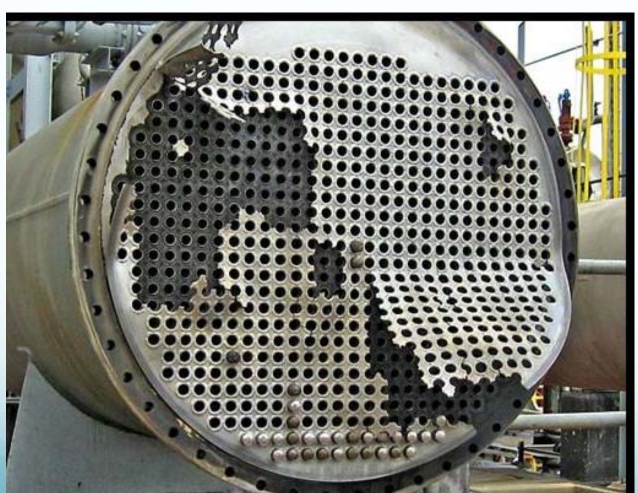
Tube-to-Tubesheet Weld on Shell-Side Face



Tube-to-Tubesheet Weld on Tubeside Face



Heat Exchanger Failure #2



- Zirconium-Stainless clad tubesheet + Zirconium Tubes
- 5mm (0.19 in) Zr as clad
- Face machining reduced Zr to 2mm thick (0.080 in)
- Tubes were fully welded to Zr face, very significant weld cracks
- Cracks masked with “seal welds”.
- Failed after 12 years service.
- RBI penetrant inspections would have sent up Concern Flags years earlier.

Conclusions

- When properly designed, manufactured and fabricated clad equipment performs highly trouble free
- Without all 3 of the above, clad can fail
- A well established Risk Based Inspection Plan will greatly reduce unanticipated problems
- If detected early, most clad equipment defects can be repaired

Thank You

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