Enhancing
Infrastructure

FCCU Regenerator Vessel Structural Repair Utilizing Automated Weld Metal Overlay

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Topics

Background of Structural Weld Overlay Repairs with Automated Welding

- Engineered Repair History
- Automated Welding Enablers
- The Temperbead Process
- Early Use examples in Refinery Applications

FCCU Regenerator Vessel Repair

- Problem Introduction and Refinery Decision Points
- Description of Vessel Condition
- Analytical Support for Structural Overlay Repair Option
- Field Implementation of Repair

Summary of Results

Industry experience

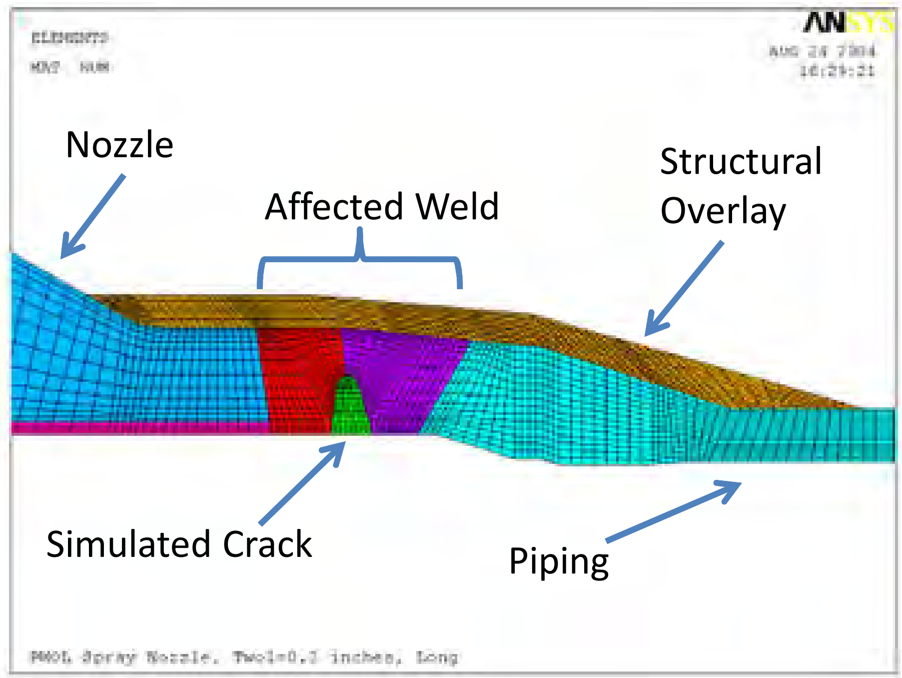
Initial uses of "Engineered Structural Overlay" weld repairs were in the nuclear industry in the 1990's.

- Primary Piping to Vessel Connections
- Highly stressed weld joints
- Corrosive environment created SCC conditions
- Common in BWR and PWR designs

Industry experience

- Structural WOL process patented
- Residual stresses from welding were used to generate compressive stresses at the joint area
- Added strength of deposit provided a redundant repair
- Over 1,000 nuclear applications performed throughout the world

Welded Structural Overlay Being Applied



Cross Section – Stress Analysis Model of Nozzle

Early Application in Refinery

Pressure Vessel Example

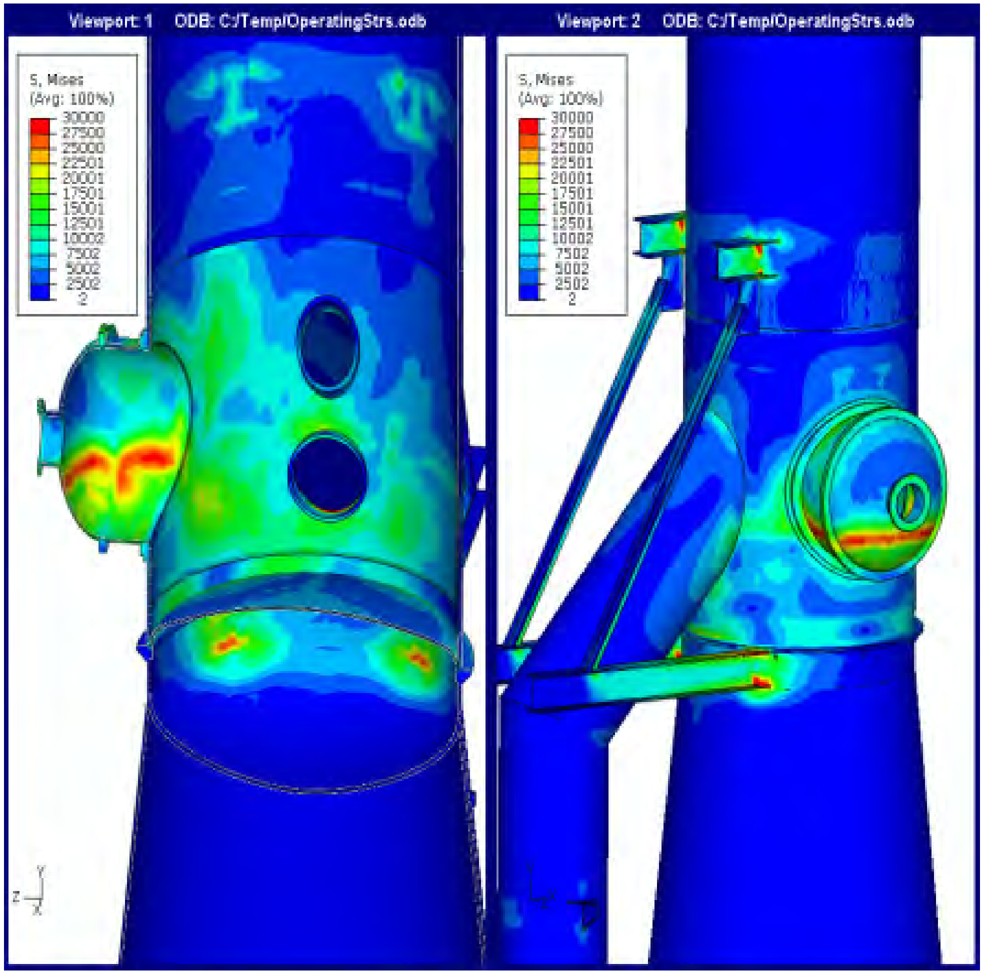
- FCCU stripper/reactor
- High temperature creep failure
- 5 Year life extension required

Anticipated Design Repair

- Model existing failure condition
- Develop "Engineered Design Repair" to manage stress levels below creep failure limits
- Perform level 3 FFS analysis

Engineered Design Repair

- Reduced scope of work
- Reduced cost for repair
- Provided Validation of repair lifetime

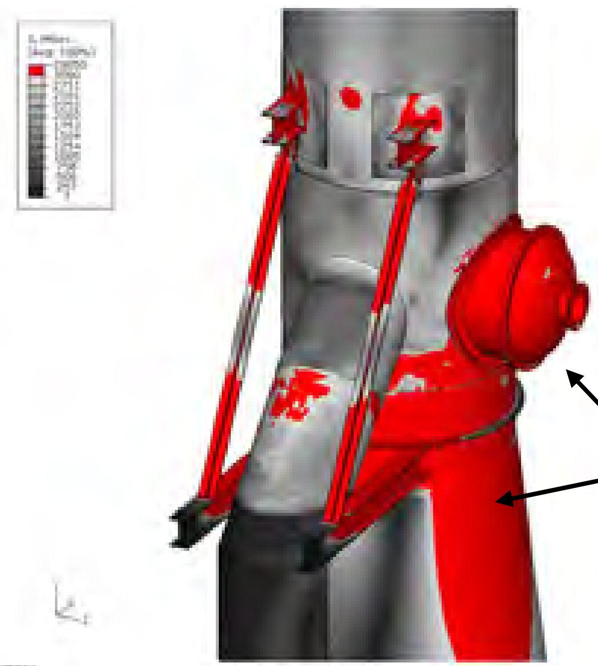


FCCU Stripper/Reactor failure area

Engineered Repair Design

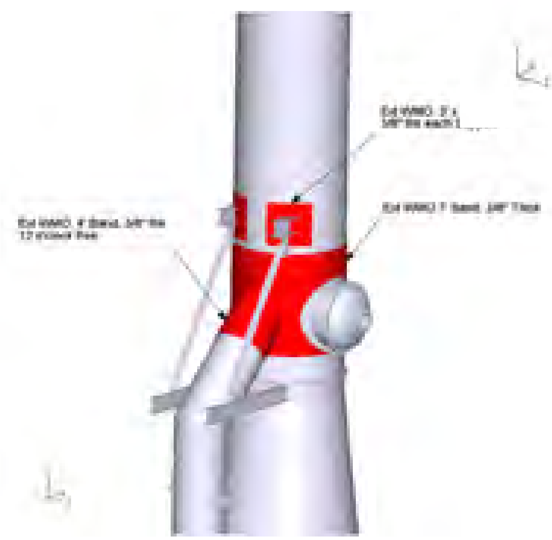
Areas Exceeding Creep Stress Limit

Estimated Life of Repair
Well in Excess of 5 Years



Regions below temperature threshold for creep

Post Overlay Stress Gradients



Engineered Structural Overlay

Automated Welding Enablers

Automated Control of Welding Parameters

- All welding parameters are controlled through automation
- Resulting heat input is predictable and homogeneous throughout the deposit
- Resulting mechanical properties and residual stresses are predictable

Capabilities Enabled by Predictable Properties

- Accurate and homogeneous mechanical properties available for analysis
- Predictable quality of deposited weld metal
- Parameter control allows the use of the temperbead process
- Minimization of distortion caused by welding
- Minimization of dilution of deposited metal

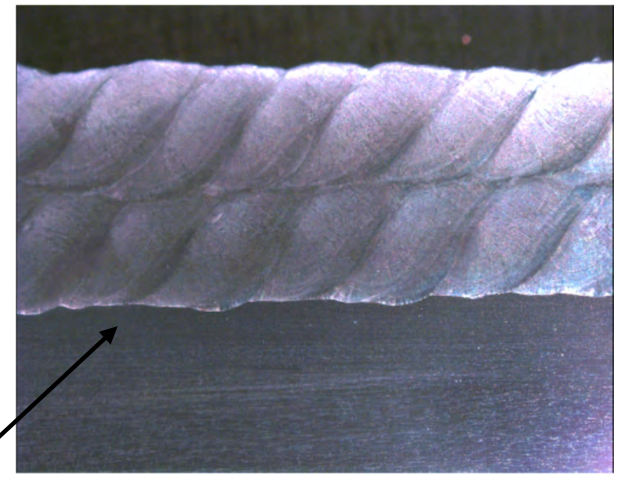
Automated Welding System
Applying Inconel 625 in Pressure Vessel

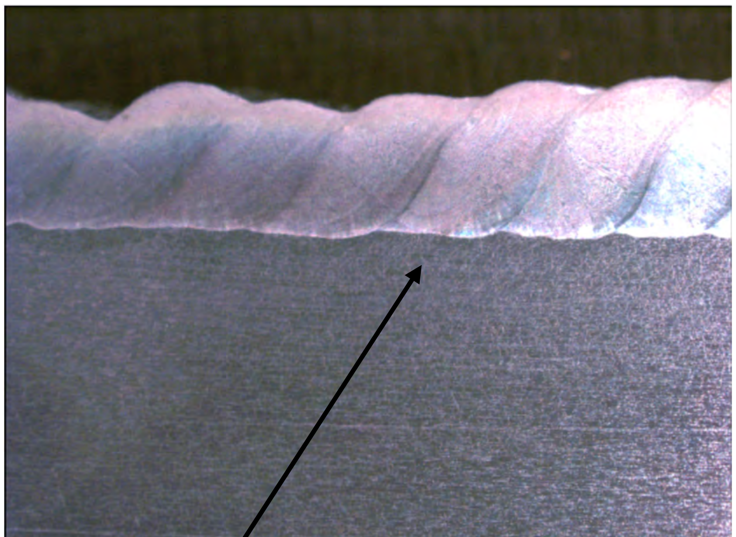
Industry experience

The Temperbead Process

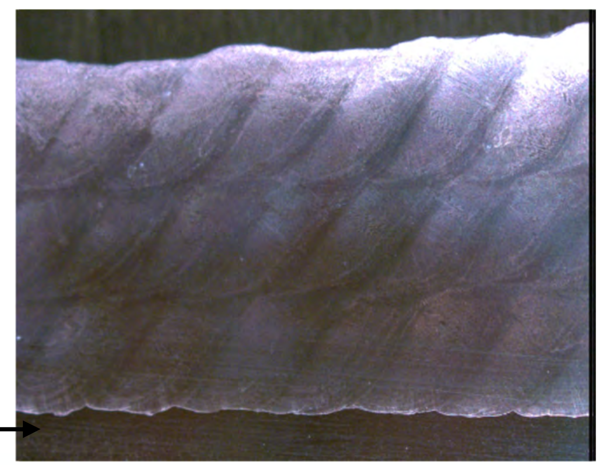
Can be used as an alternative to post weld heat treating

Ideal for large overlays on pressure vessels





HAZ created by 1st weld layer



HAZ is tempered by deposition of successive layers

Structural Overlay Repair of FCCU Regenerator Vessel

Structural Overlay Repair of FCCU Regenerator Vessel

- Refinery Located in Barrancabermeja, Colombia
- Two small leaks detected in April 2013
- Leak Areas repaired using external window patches
- May of 2013 UT mapping indicated significant loss of wall thickness in the cone to cylinder transition of the vessel
- Several repair options were evaluated:

Option	Implementation Schedule	Repair Complexity	Repair Integrity
Window Replacement	Long	High (internals)	High
Window Patches	Medium	Low	Medium-Low
Structural Overlay	Short	Low	High

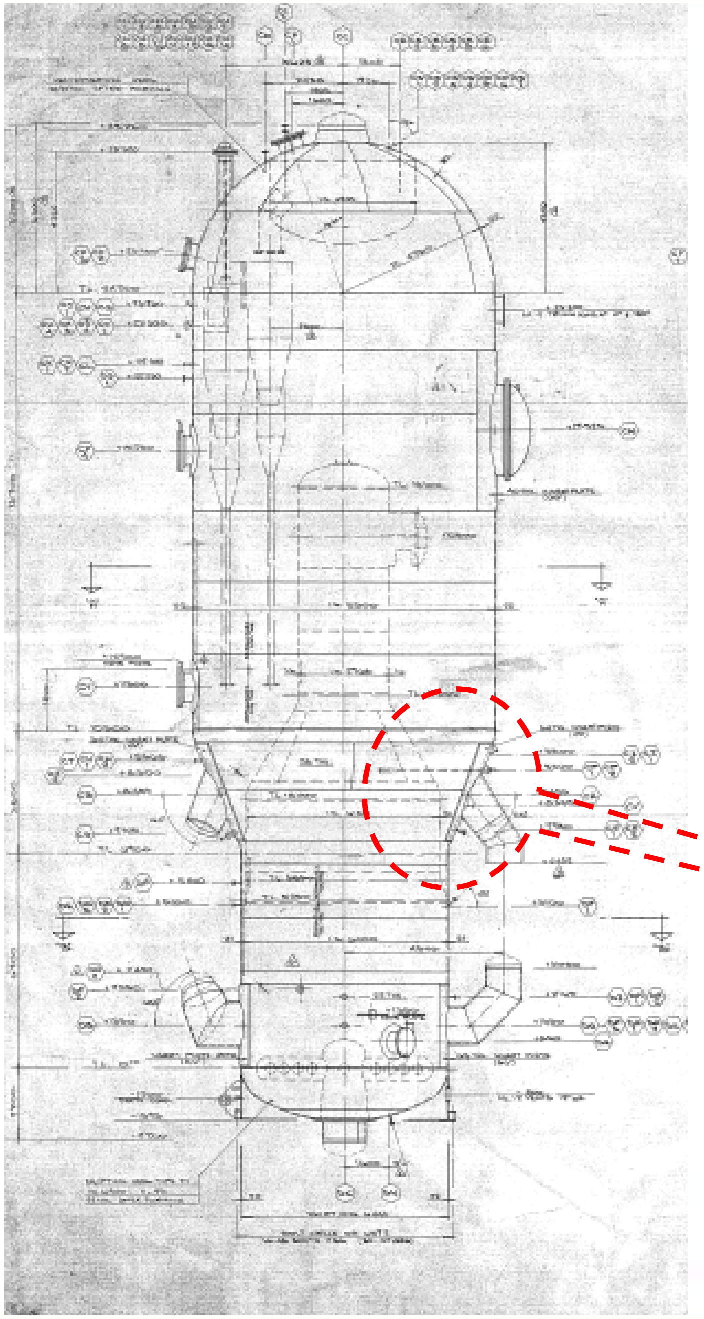
Structural Overlay Repair of FCCU Regenerator Vessel

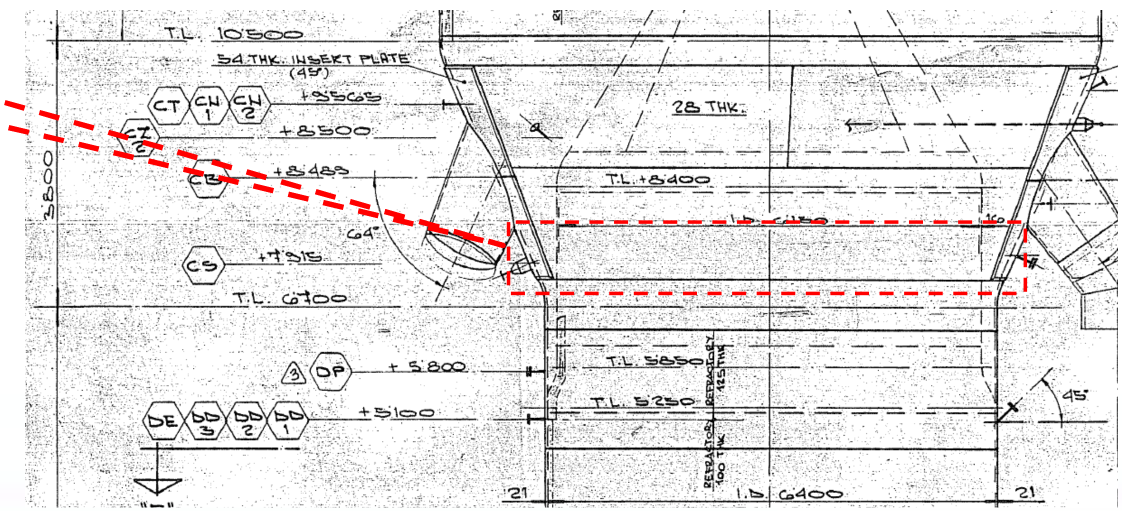
- The FCCU is critical to the overall refinery capacity
- This refinery provides the majority of fuels for Colombia
- Structural overlay was selected because of short implementation schedule and same or better repair life when compared to other options

Technical Concerns

- Given the thin remaining wall, can overlay be applied without causing excessive vessel distortion?
- Will the applied overlay meet the structural stability requirements per API 579-1 FFS Assessment?

Structural Overlay Repair of FCCU Regenerator Vessel





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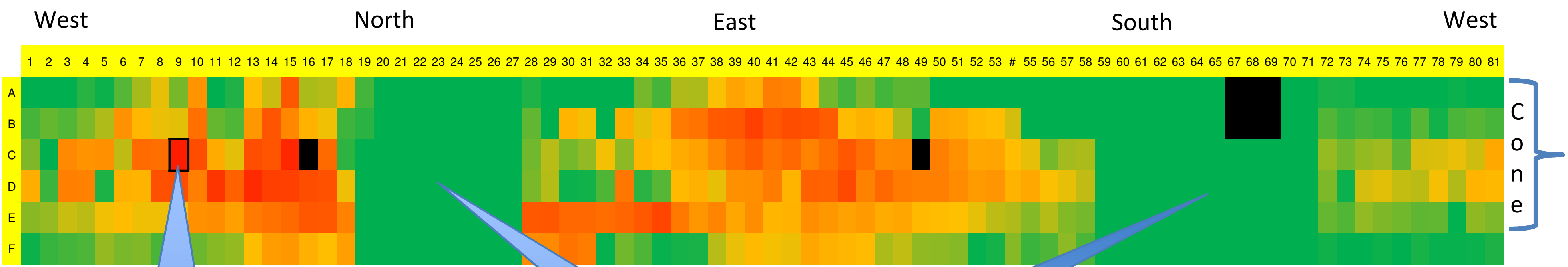
Radial Location



Lowest thickness location .192” (4.9mm)

Nozzle Reinforcement Areas

Original Thickness

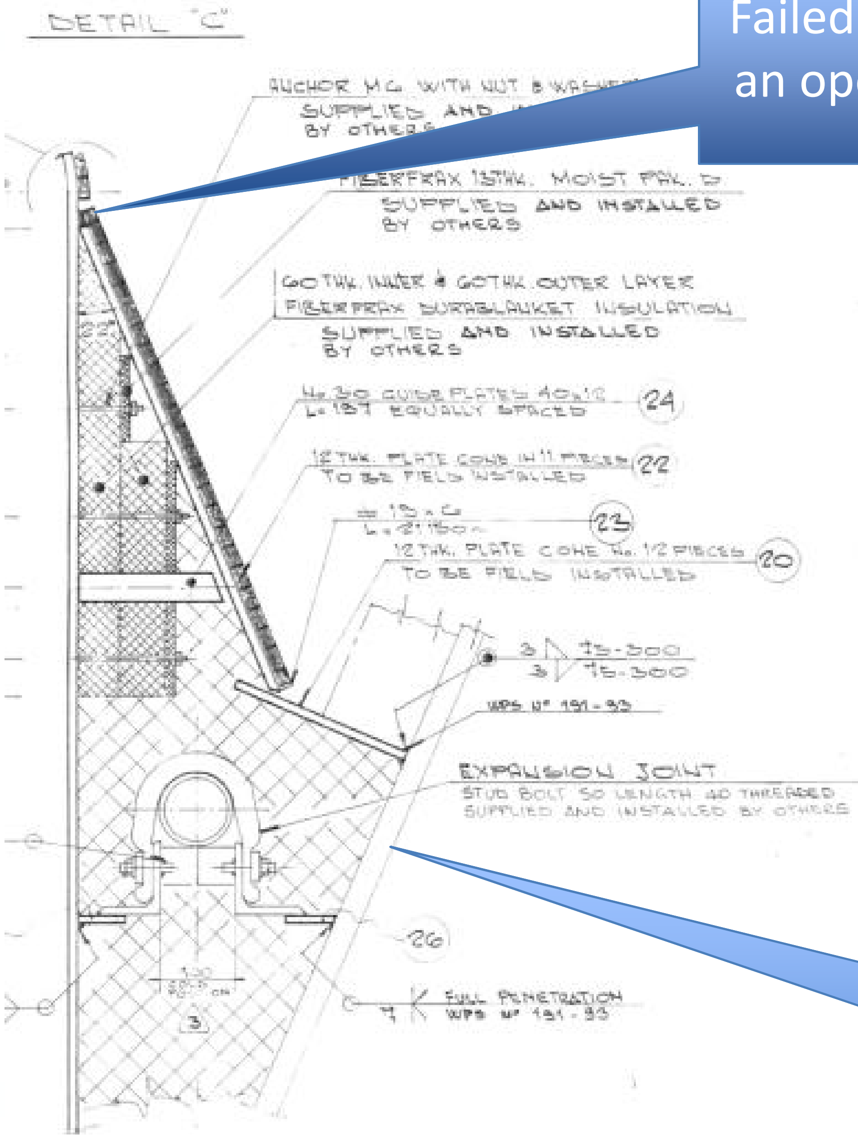
Cone = Approx 1.1” (28mm)

Shell = Approx 0.8” (21mm)

Marginal Thickness

Less than 0.7” (17.8mm)

Structural Overlay Repair of FCCU Regenerator Vessel



Failed weld allowed an opening to form

Significant ID wall thickness loss experienced

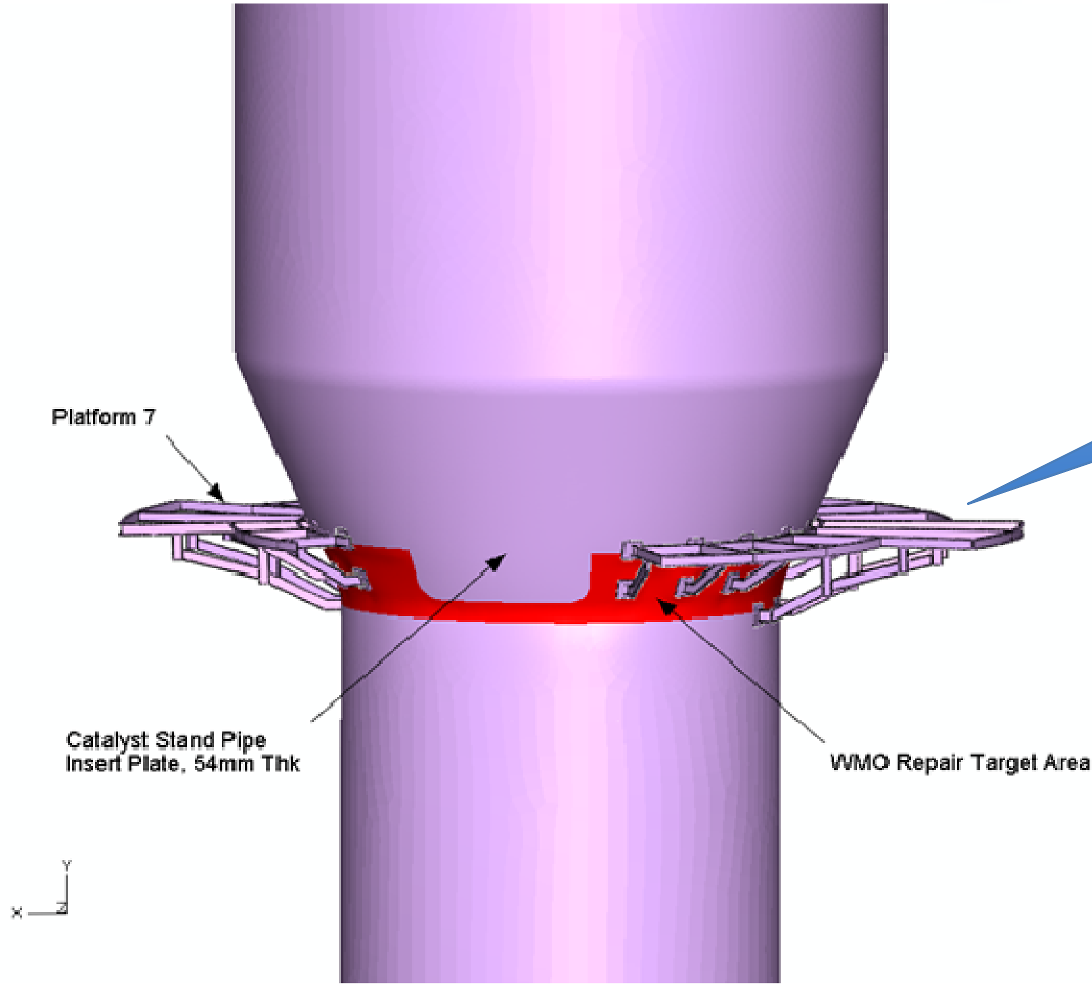
Thermal Image and Photo of leak location

Overlay Design

Two engineering efforts were performed to design and qualify the structural overlay:

1. **Predictive Numerical Distortion Analysis**
   - Large areas of the as-found vessel are critically thin
   - Since all weld overlays cause some distortion an analysis was performed to ensure that distortion experienced would not affect the vessel internals and that the vessel would meet the code required Out-of-Roundness UG-80 criteria.
2. **Assessment of Structural Stability**
   - This analysis determined that structural integrity of the vessel would be achieved by the application of a structural overlay to restore the loss of thickness.
   - A FFS evaluation was performed in accordance with API579-1 / ASME FSS-1
   - All dead weight, product weight, environmental loadings and seismic loads were taken into account.
   - Vessel was analyzed including the predicted distortions caused by the overlay developed in the No. 1 analysis above.

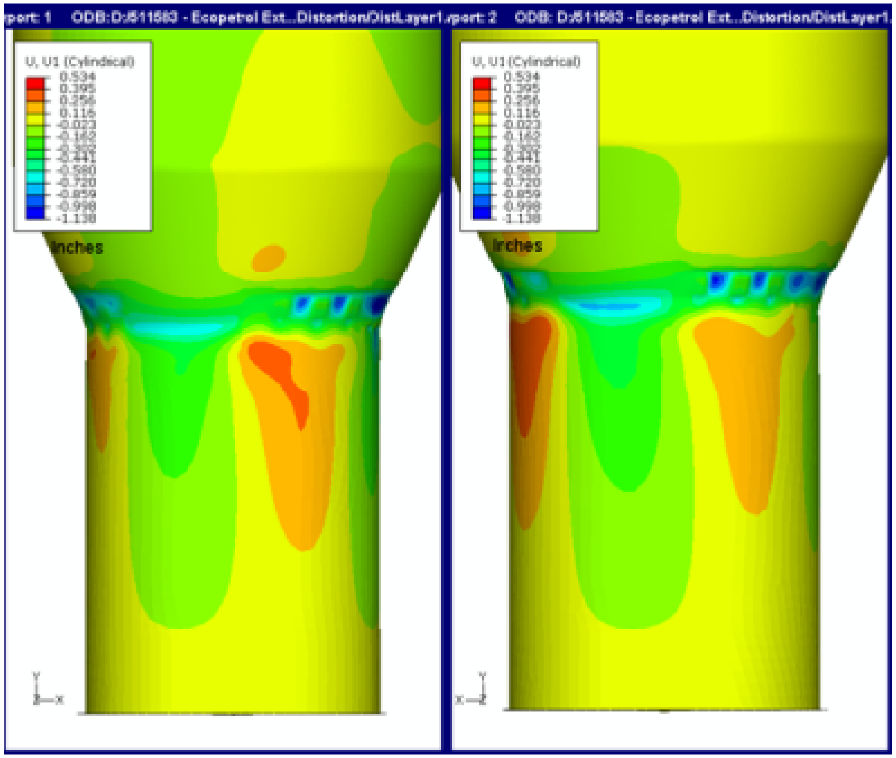
Overlay Design



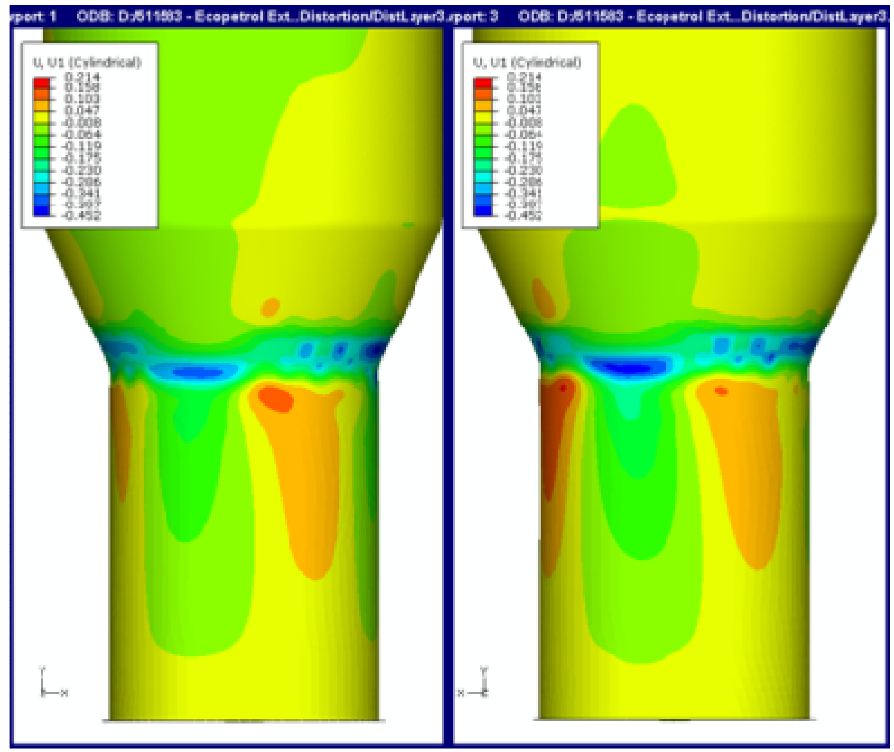
Platform was removed for overlay installation

Weld Overlay Design

Overlay Design

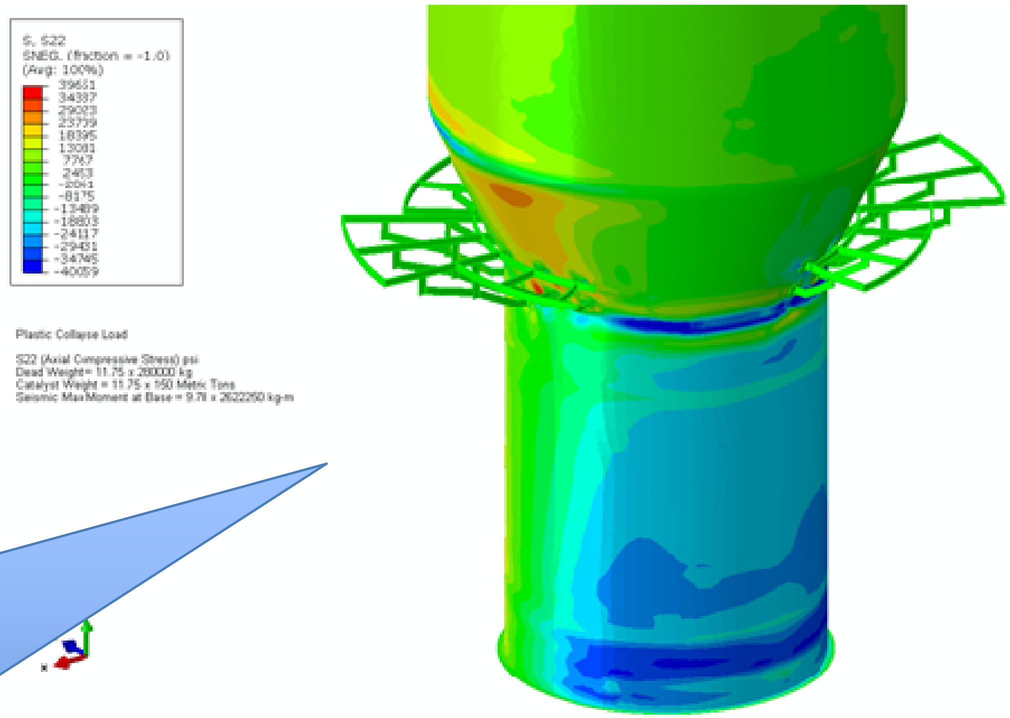


Predicted Layer 1 Distortion



Predicted Layer 3 Distortion

Overlay Design



No Plastic collapse of the vessel occurs from the identified load case.
Meets API 579 FFS Criteria

Shaded Plot of Vessel Predicted Plastic Collapse Load - Operation after Repair

Three Layer Structural Overlay

Finished Structural Overlay
(three layers)

Results

- Structural Overlay was utilized to repair significant pressure vessel wall thinning.
- A proprietary predictive numerical distortion analysis was used to determine viability of repair prior to implementation.
- A Fitness for Service analysis was performed per API 579 to qualify the repair.

- Project was performed ahead of estimated schedule with zero safety incidents.
- Project was completed below initial estimated cost.

Contact

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