REFCOMM GALVESTON

APRIL 29 - MAY 3 2019

CITGO Lake Charles Coker 1 Skirt Replacement

Presented by:

Michael Sofferin, Reid Bitten – Fixed Equipment Reliability Engineer– CITGO

Pedro Amador – VP Business Development & Technology – AZZ

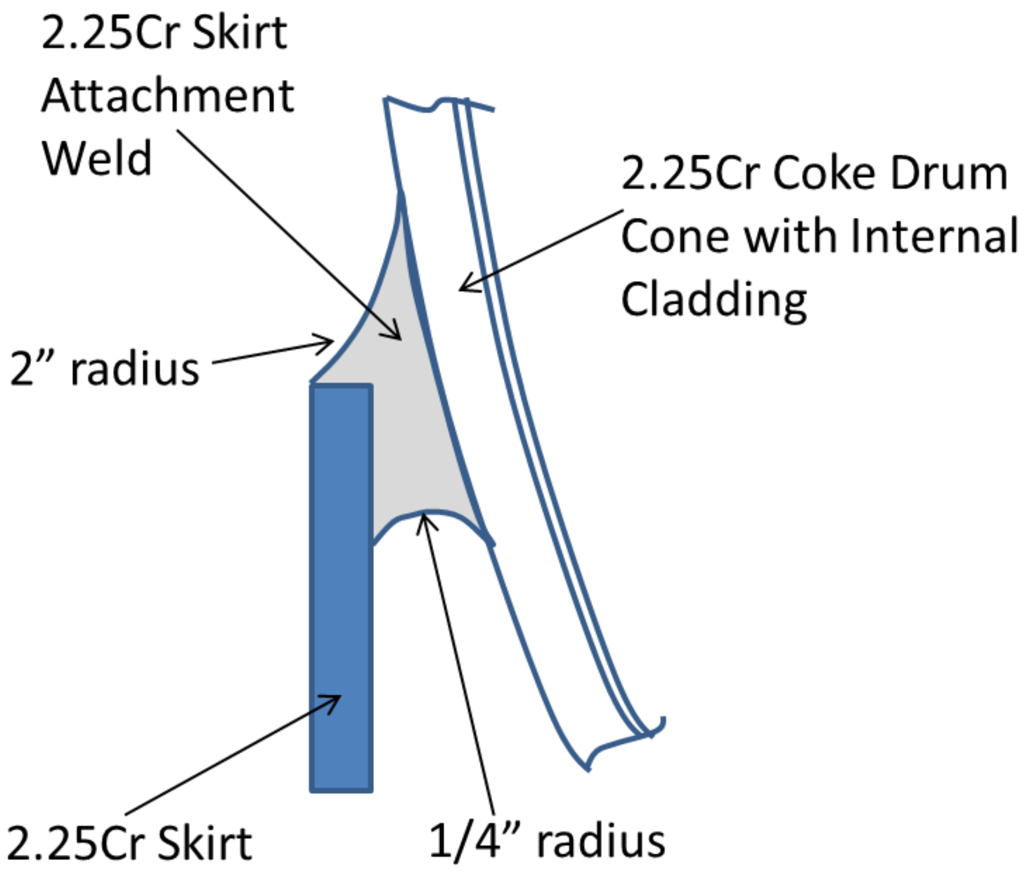
Peter Sanders – Senior Project manager - AZZ

CITGO - Lake Charles Manufacturing Complex

- Located in Lake Charles, LA
- Started Operation in 1944
- 425K BPD Capacity
- 2 DCU's
  - Both units are 4 drum Cokers
  - Coker 1 – current drums installed in 1996
  - Coker 2 – current drums installed in 2004

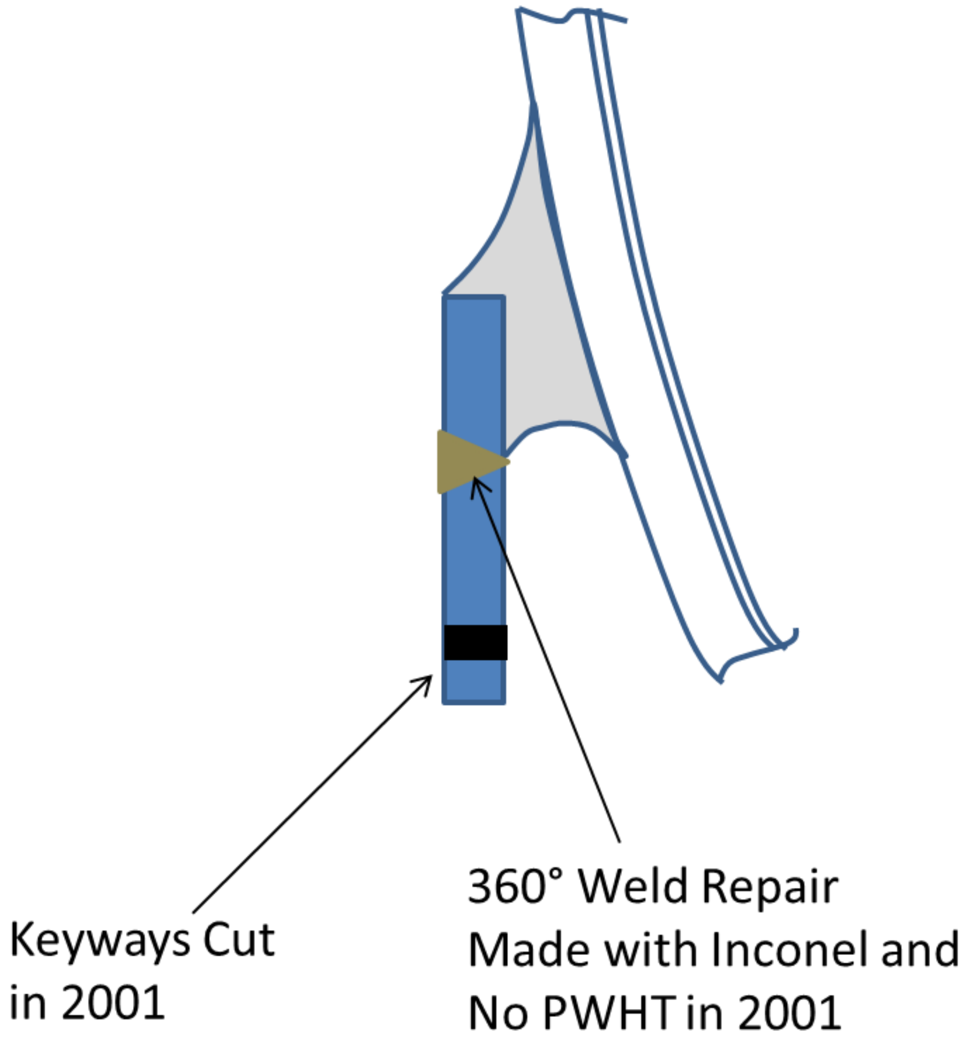
CITGO Lake Charles - Coker 1 Drum Details

- Design Info
  - Drums fabricated by Sumitomo Heavy Industries and installed in 1996
  - 2 drums constructed using 3Cr-1Mo-0.25V
  - 2 drums constructed using 2.25Cr-1Mo
  - Drums utilize a conventional skirt design
- 2018 skirt replacement focused on the 2.25Cr drums



Coker 1 Skirt Damage History

- 2001 First skirt inspection took place during a scheduled Turnaround
  - Cracking found 360º around skirts (through-wall in many locations)
  - Welds were entirely repaired from OD with pre-heat and Inconel filler (no PWHT)
  - Keyways added to reduce stresses

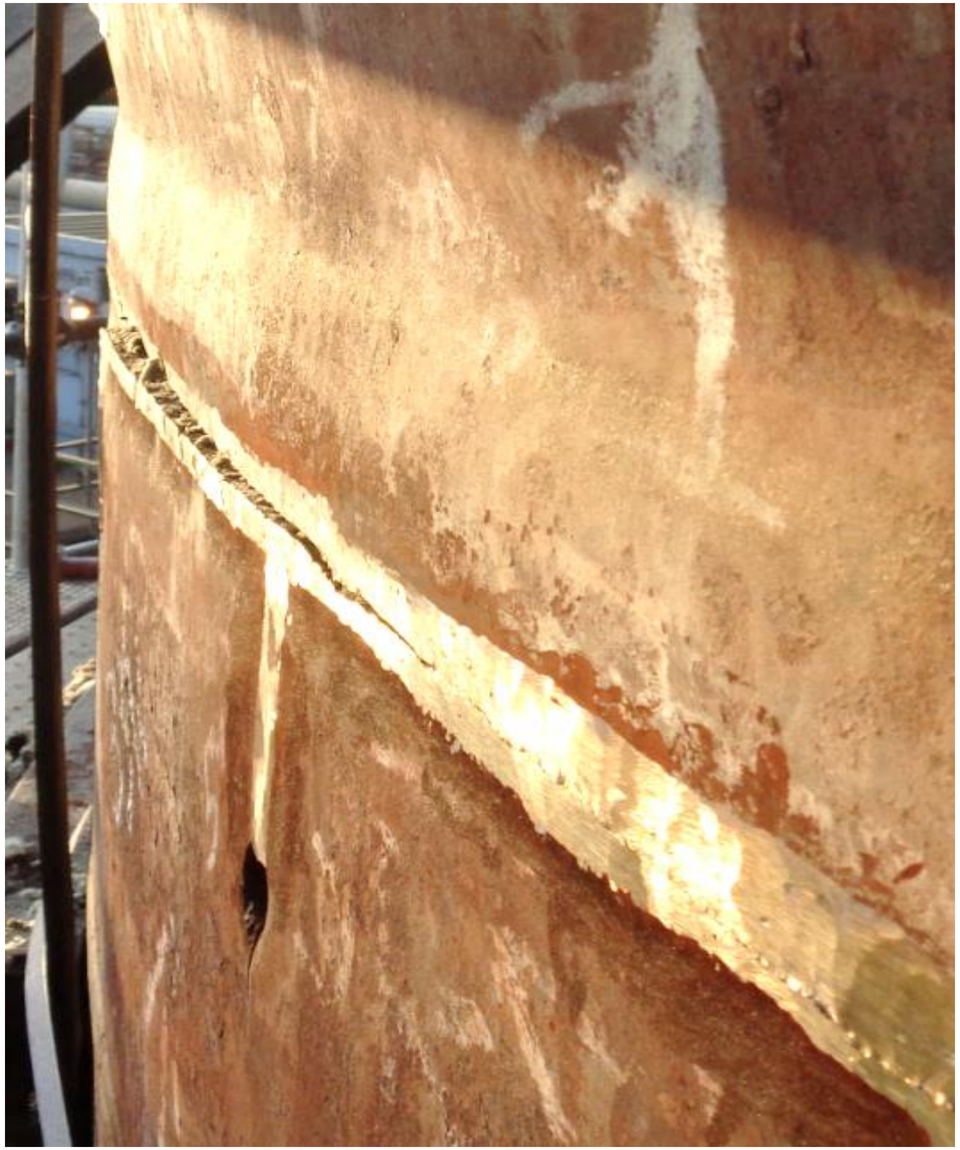


Coker 1 Skirt Damage History

- 2003 Keyway and Inconel skirt weld cracks first found
- Monitored and repaired as necessary every 9-12 months
  - Weld repairs performed with Inconel and no PWHT
- 2010 Crack propagation rates began increasing
- 2014 a stair-step increase in severity observed during inspections

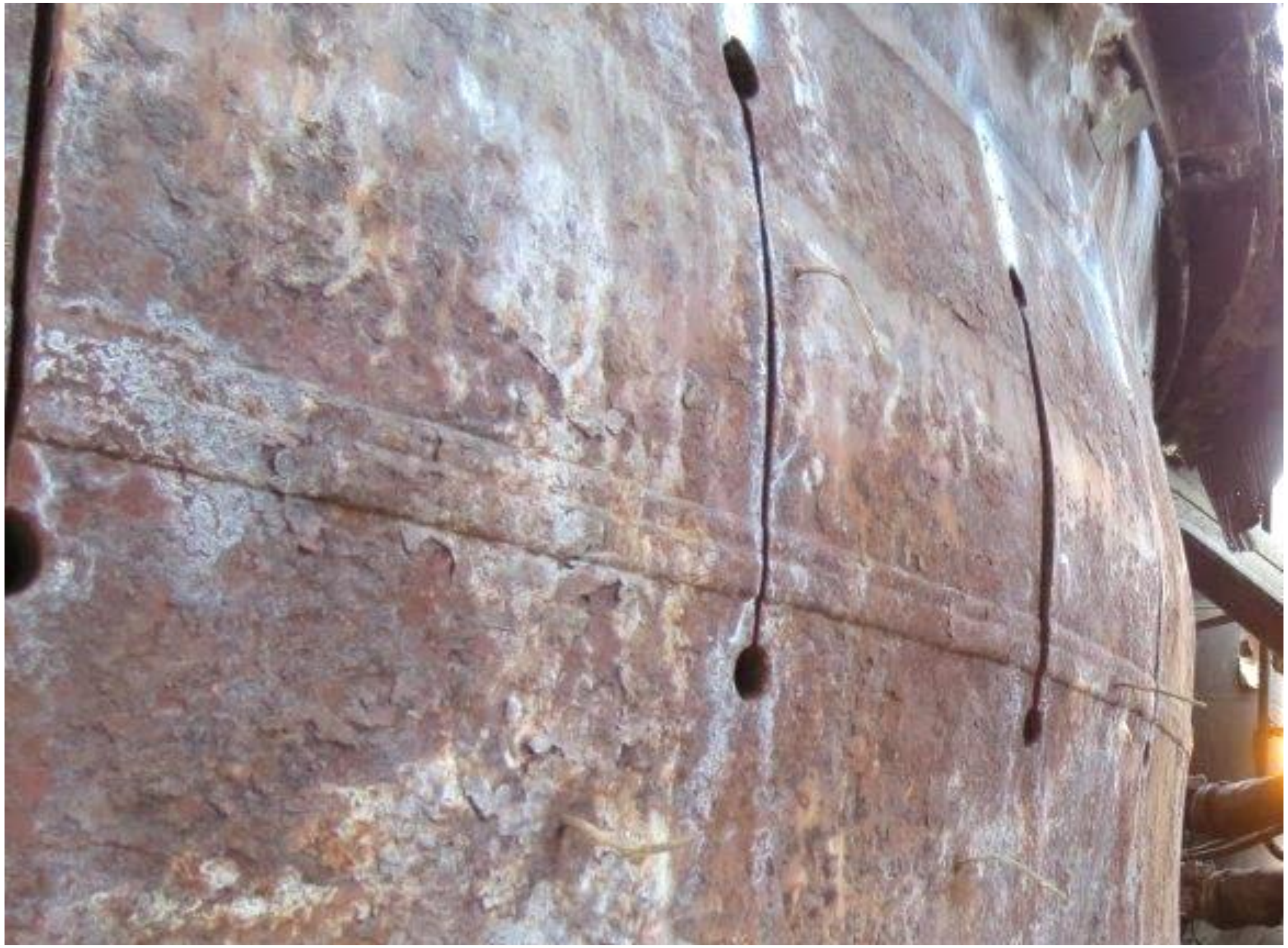
Coker 1 Skirt Damage History

- 2010 Crack propagation rates began increasing, with a stair-step increase in severity observed during the 2014 inspections
- Cracks continued to worsen, making the skirt separate into panels
- Skirt panels were worked back in and welded with Inconel
- Inspection frequency further reduced to every 6 weeks



Coker 1 Skirt Damage History

- In the areas adjacent to the cracking, the skirt began to bulge



2018 Repair Concerns

- 2018 Decision made to replace portion of the existing skirt as well as the skirt-to-vessel attachment weld deposit
- A significant amount of pre-repair planning and engineering required to address vessel stability concerns during the implementation
- The compact design of the units also requires innovative methods for material handling of the skirt sections during repair
- CITGO Engineering executed a pre-project study to evaluate available options to execute the repair scope
- AZZ Specialty Welding was contracted to provide engineering and implementation of 2 skirt upgrades in parallel and 2 local skirt repairs during the CITGO 2018 turnaround

CITGO Lake Charles Coker Skirt Replacement

Repair Design & Analysis

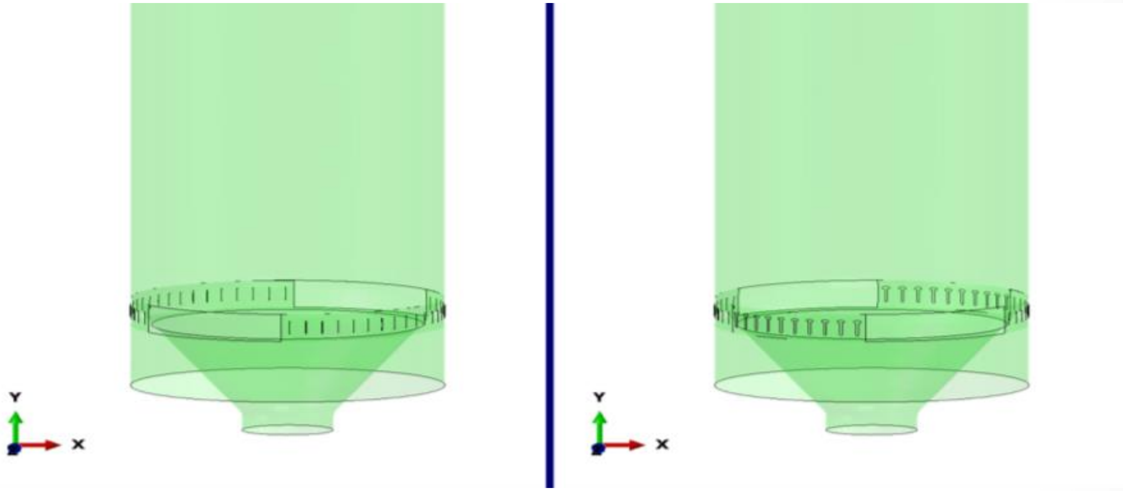
Design & Preparations

Pre-Project Design & Preparation

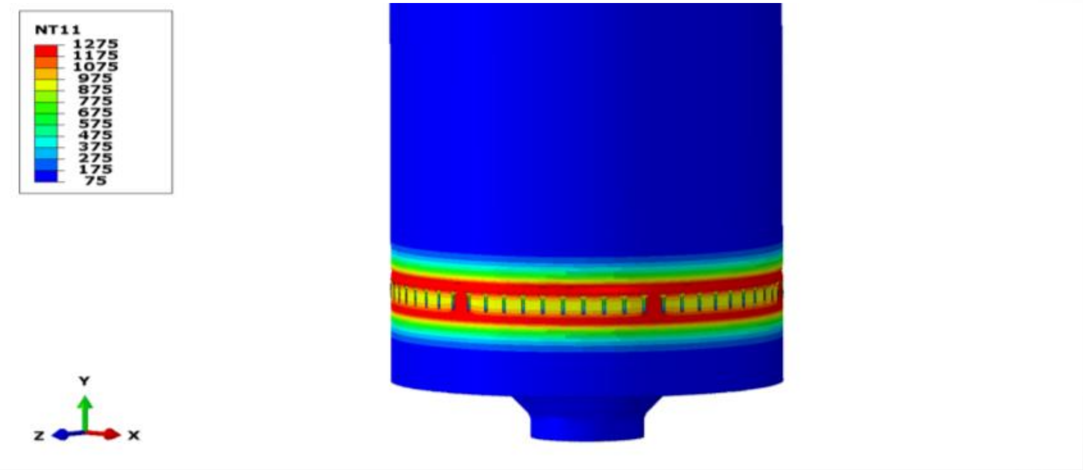
- Drum Construction Details & Unit Operating Data
- Window Replacement Stability Analysis
- Preliminary Repair Geometry Design
- Fatigue Life Comparative Analysis
  - Geometry Optimization
  - Fatigue Life
  - Buckling Analysis
  - Keyhole Edge Chamfer Sensitivity
- Site Logistics Specialty Equipment Design
- Weld Automation Equipment Modifications for Clearance
- Skirt Replacement Section Procurement & Fabrication

Stability Analysis

- A combination of external laser mapping and manual measurements were used to model the worst case existing skirt geometry
- Models were built and the quantity of replacement windows was determined
- A total of three pairs of windows in parallel was selected for each drum
- A subsequent model was also used to evaluate drum stability during the required PWHT process



Window Replacement Models



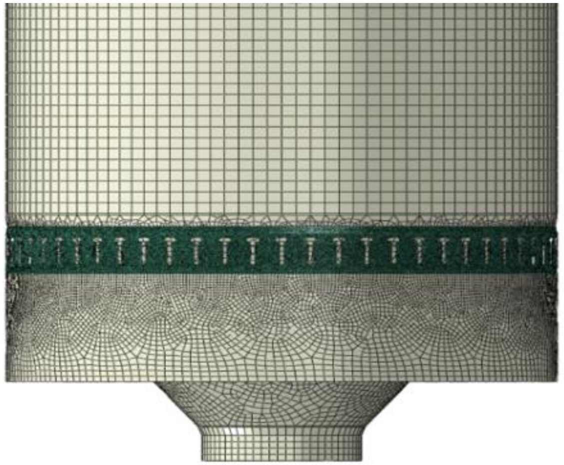
PWHT Model

Preliminary Geometry Design

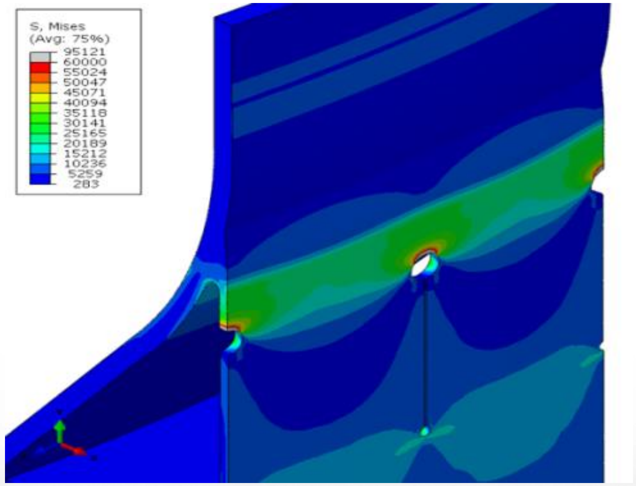
- 24” high panels selected to allow removal of bulged skirt sections
- Original 2-1/4 Cr material was substituted with 1-1/4 Cr

Fatigue Life Comparative Analysis

- Multiple Knuckle radii and slot geometries were evaluated to optimize the final window design
- API 579-1/ASME FFS-1 2016 Fitness-For-Service, Part 14 Assessment of Fatigue Damage was performed on each configuration
- Crotch and key way slot estimated fatigue life results were used to make a final window geometry selection
- 2-1/4 vs. 1-1/4 alloy choices were compared and 1-1/4 material was chosen



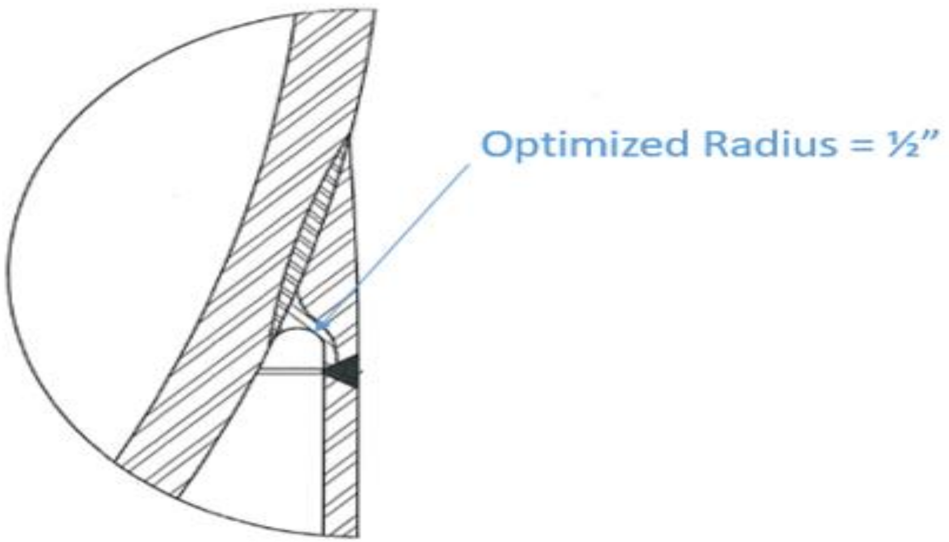
Window Replacement Models



Selected Design

Fatigue Life Comparative Analysis

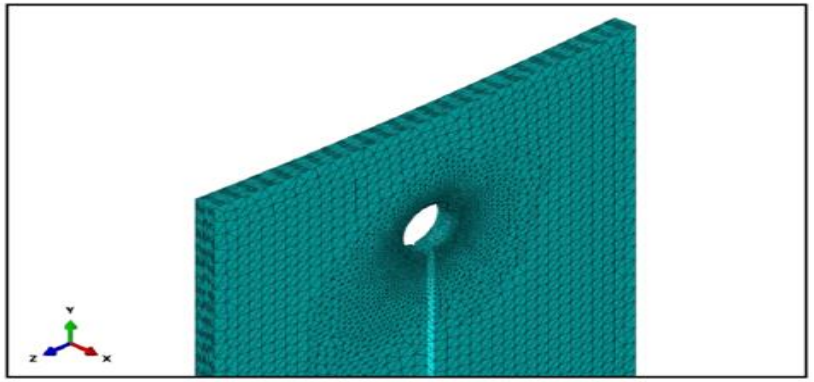
- Crotch Radius was optimized at ½”
- Deposit Transition geometry to the drum was also optimized



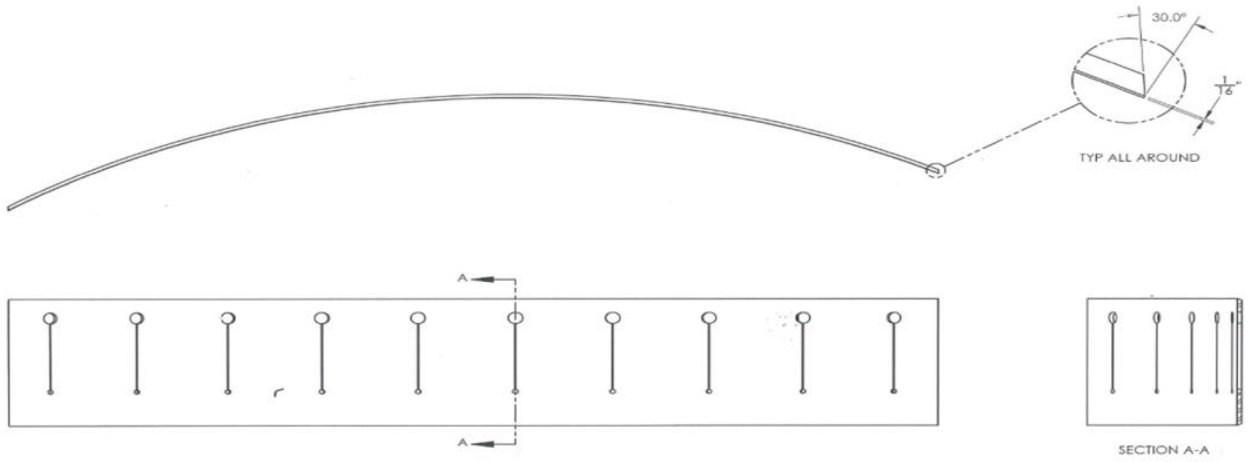
Optimized Attachment Weld
Deposit Geometry

Fatigue Life Comparative Analysis

Slots were designed with an upper radius of 1” and a lower radius of 3/8”



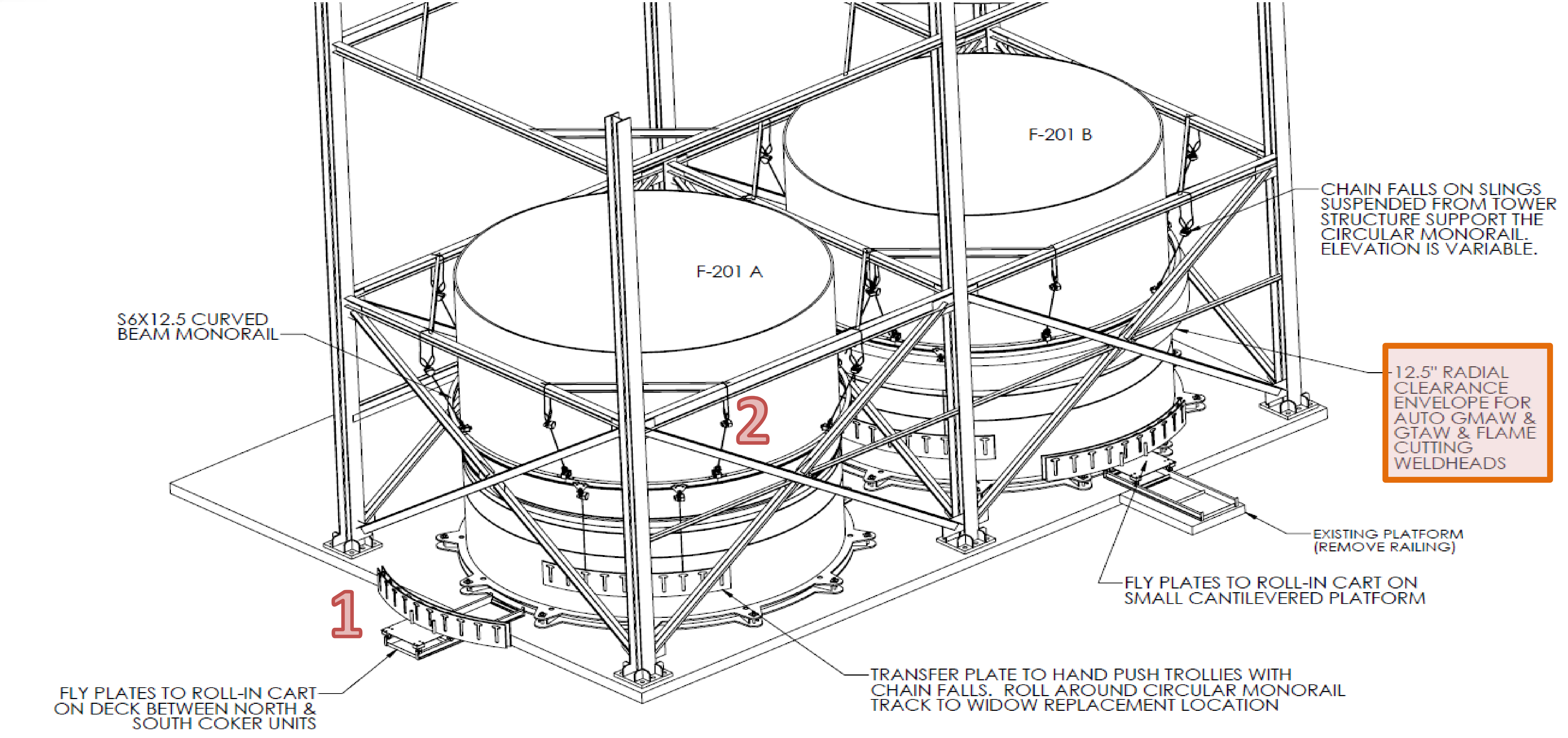
Softened Edge Slot Model



Final Selected Window Design

Analysis showed no positive or negative effect from radiusing sharp edges of the slots

Site Logistics & Special Equipment Modifications



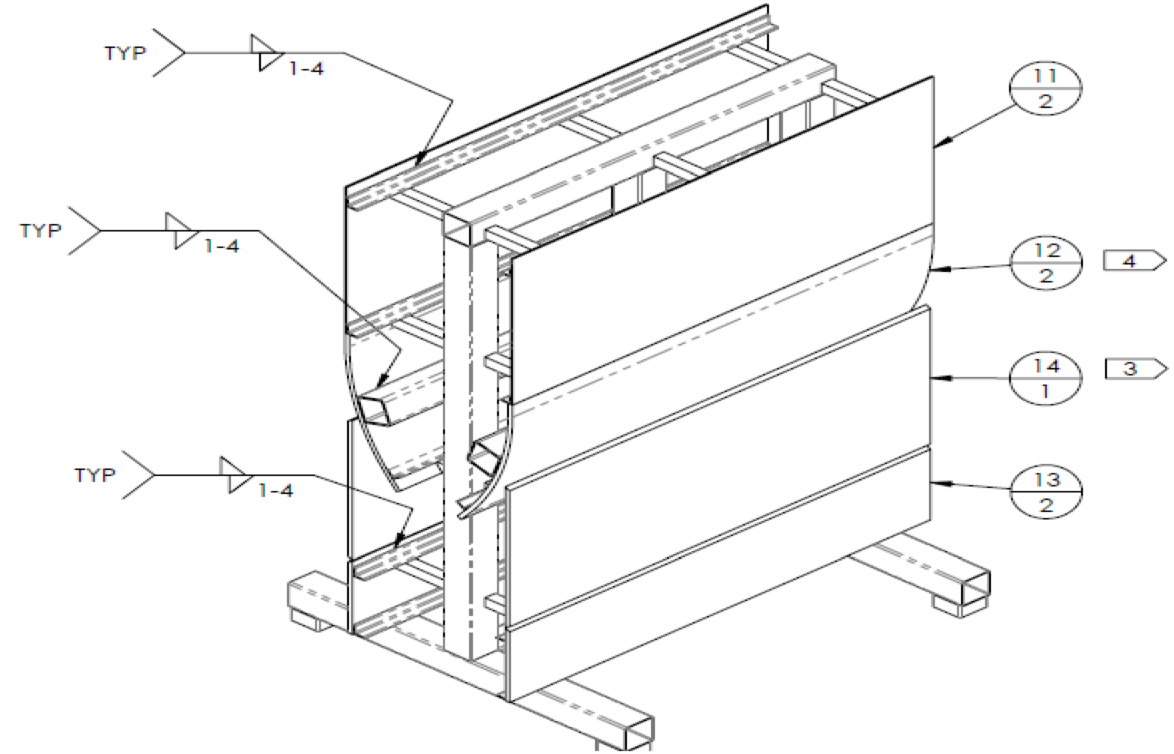
Monorail System for Replacement Window Delivery

Tooling Modifications for Low Clearance Issue

- A nested dual track was designed to reduce weld head cross section.
- Track was also designed to expedite the transition between GMAW Automated weld head and the Hot-Pulse weld head used to perform the GTAW final welding of the skirt to knuckle connections.
- This dual process approach created a final installation with GTAW mechanical properties in critical areas at excellent production rates not typically achievable with this process

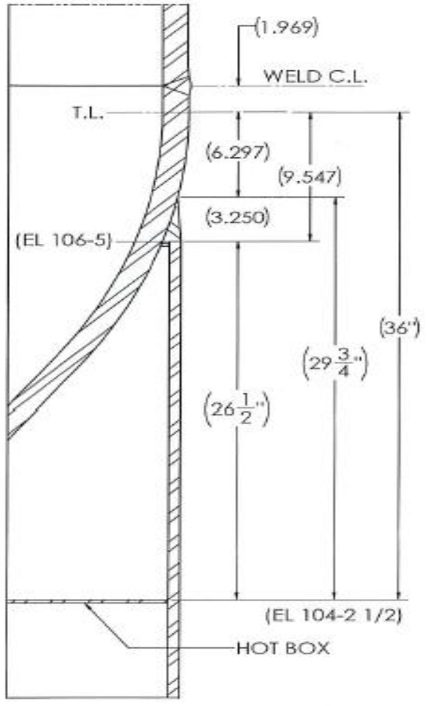
Low Profile Weld Head and Track Assembly

Mockup & Demonstration

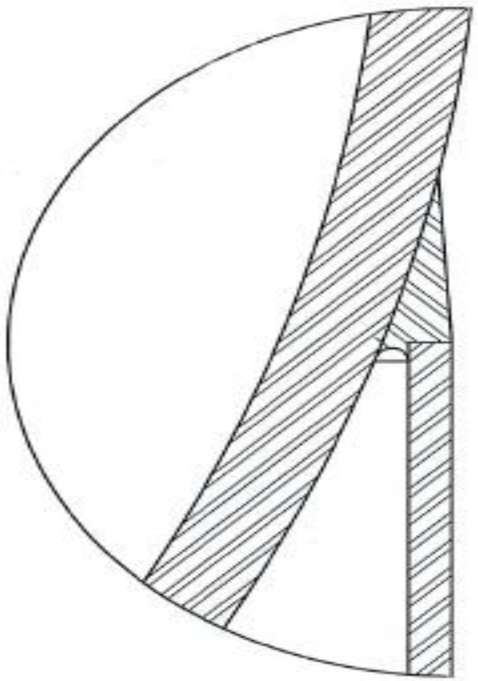


Mockups were fabricated for crew training prior to site mobilization

Field Repair Step 0 –
As Found Condition



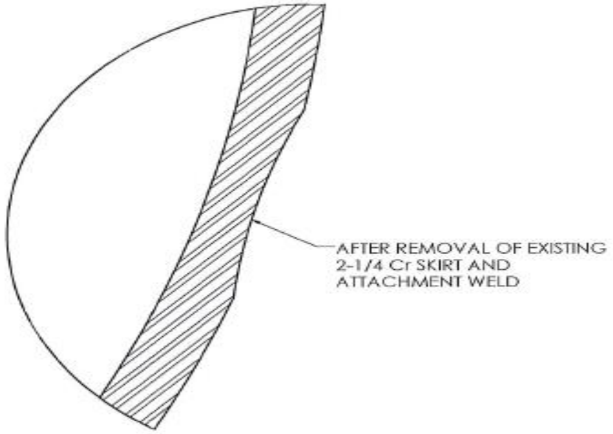
STEP 0. AS FOUND


STEP 0. AS FOUND

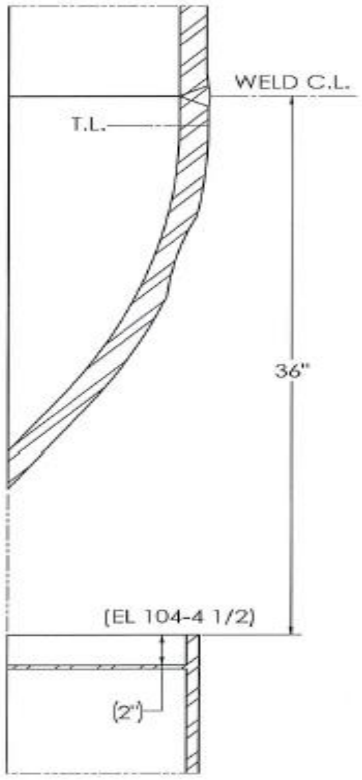
- **Original configuration (1996 vintage) with ¼" crotch radius**
- **All 2-1/4Cr material**

Field Repair Step 1 – Remove Skirt Panel

- Remove two diametrically opposed skirt sections (11’ length) on each drum
- Four total work locations in parallel
- After cutting out the old skirt section by flame cutting, the existing attachment weld is removed by gouging



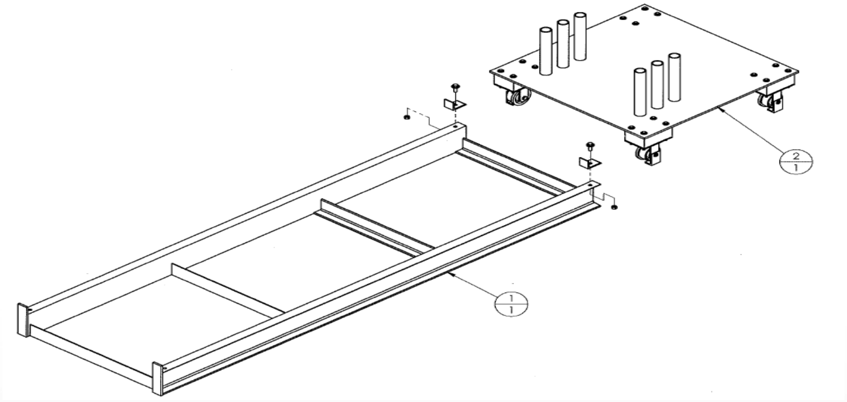
STEP 1. REMOVE SKIRT PANEL WINDOW AND ATTACHMENT WELD

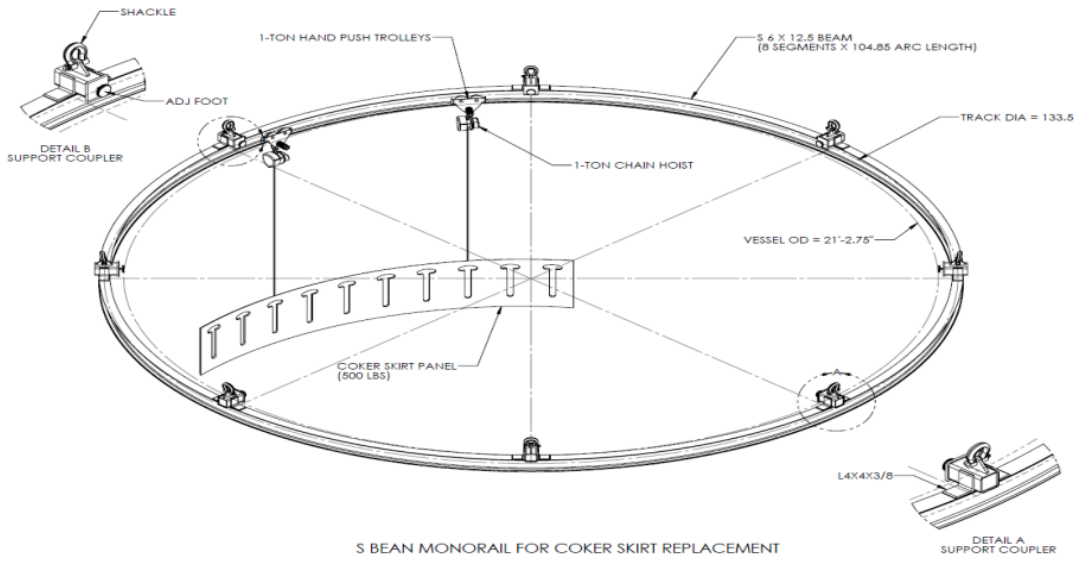


STEP 1. CUT SKIRT WINDOW & REMOVE ATTACHMENT WELD

Field Repair Step 1 – Remove Skirt Panel

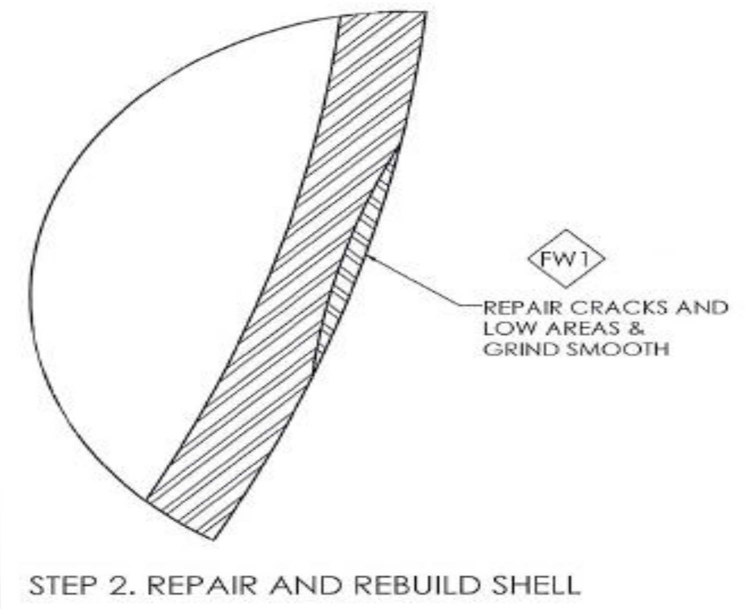
- Skirt panel is rigged out using a monorail trolley system
- Panel is transferred to a cart on rails to roll it out to the fly-out area where it is picked up by the crane





Field Repair Step 2 –
Inspect and Repair Base Metal

- MT and PAUT inspection of base material performed after skirt and attachment weld has been removed
- Any rejectable indications are excavated and repair welding is performed and ground smooth using 2-1/4Cr (ER90S-B3) weld metal



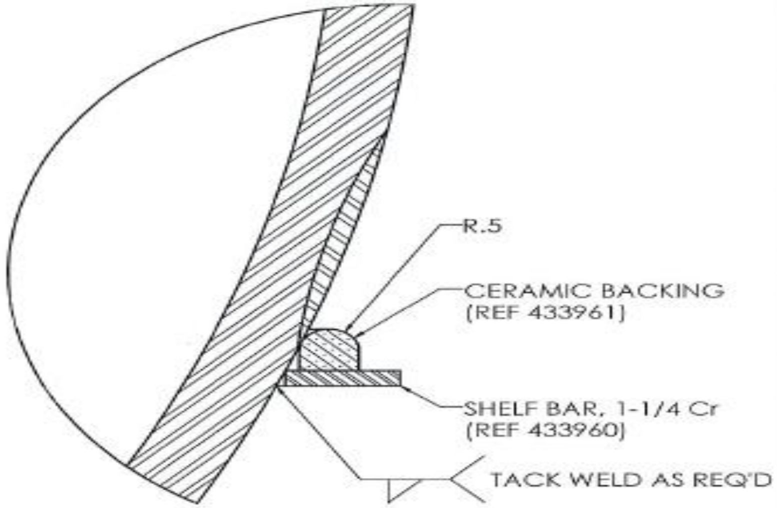
Field Repair Step 2 – Inspect and Repair Base Metal

Typical Local Flaw Removal

Typical Local Flaw Removal

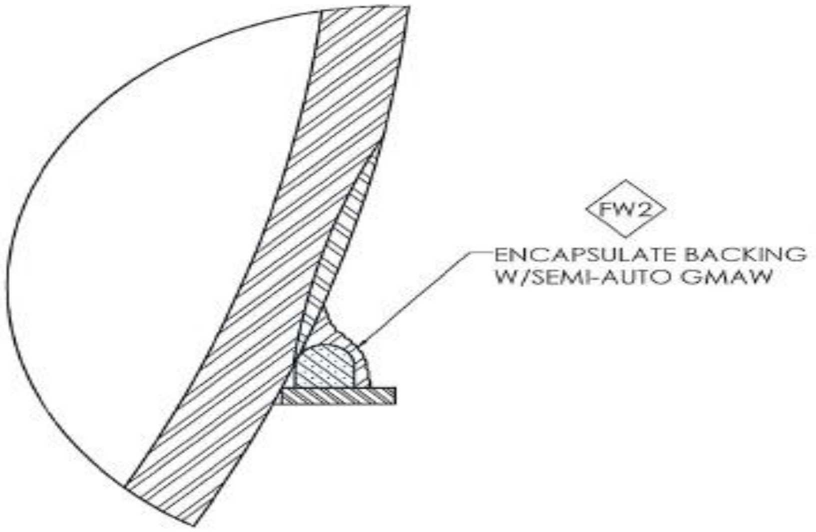
Field Repair Step 3 –
Attach Ceramic Weld Backing

- After the base metal repairs are complete, a ceramic weld backing and shelf bar were installed
- Ceramic backing is a “gumdrop” shape with ½” radius and elongated height to move weld joint down and away from the point of highest stress concentration
- Shelf bar is 1-1/4Cr material serving as a base to build up the weld over the ceramic



STEP 3. INSTALL WELD BACKING

Field Repair Step 4 – Weld Encapsulate Backing

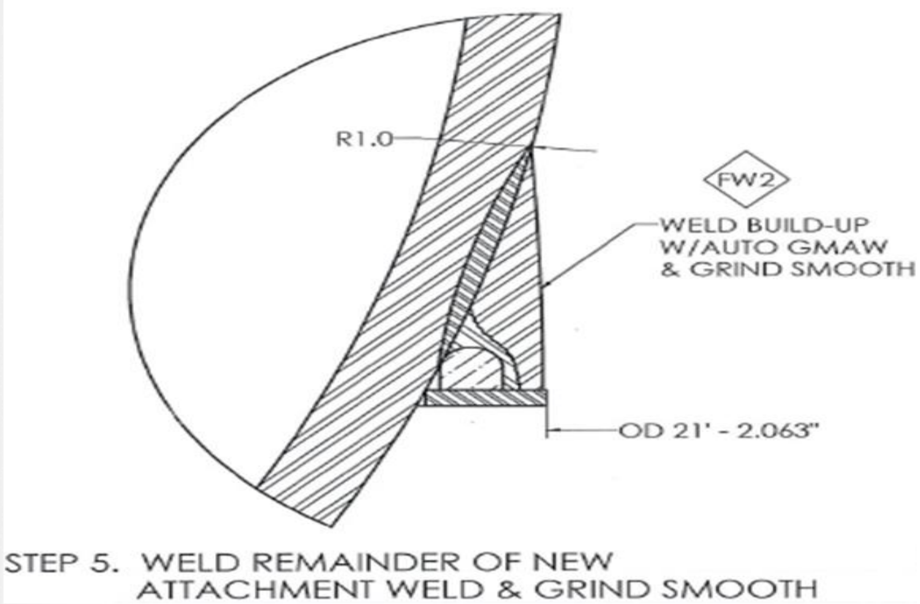


STEP 4. WELD ENCAPSULATE BACKING

- Semi-automatic GMAW welding builds from the support shelf up and over the ceramic, tying into the base material of the cone
- Filler material is 1-1/4Cr wire (ER80S-B2)

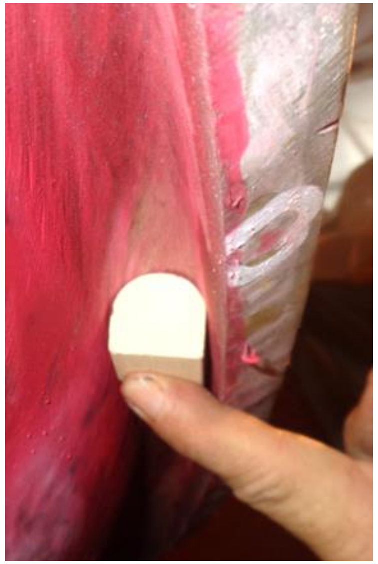
Field Repair Step 4 - Weld Encapsulate Backing

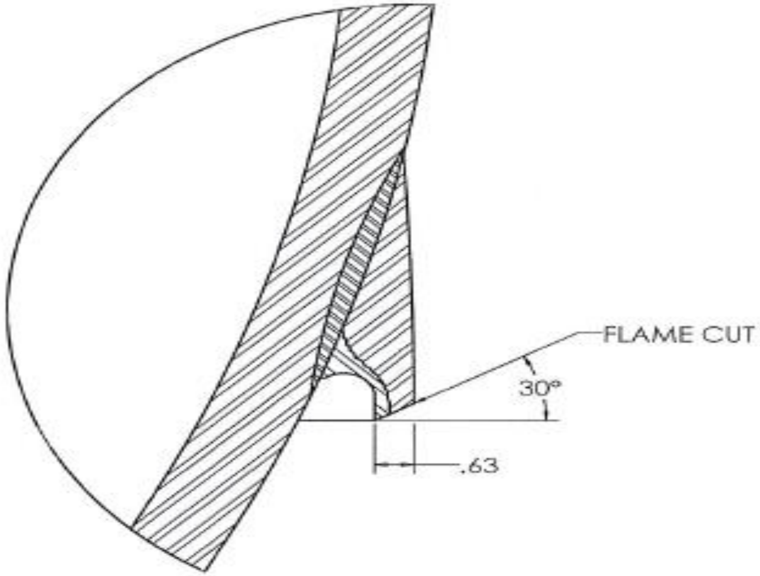
Field Repair Step 5 – Attachment Weld Fill



- Automatic GMAW welding builds up the remainder of the attachment weld from the semi-auto layer of Step 4 up to the cone
- Filler material is 1-1/4Cr wire (ER80S-B2)

Field Repair Step 6 –
Flame Cut Bevel



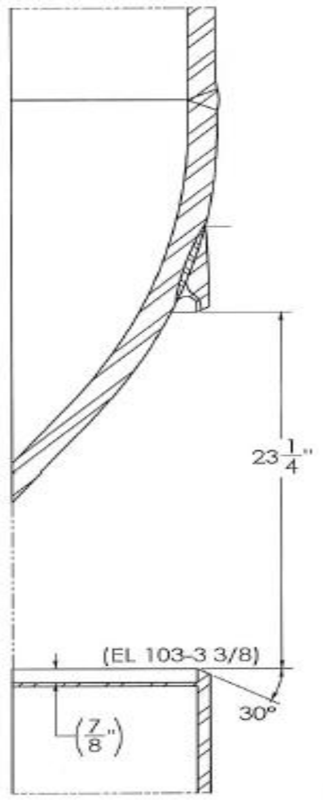


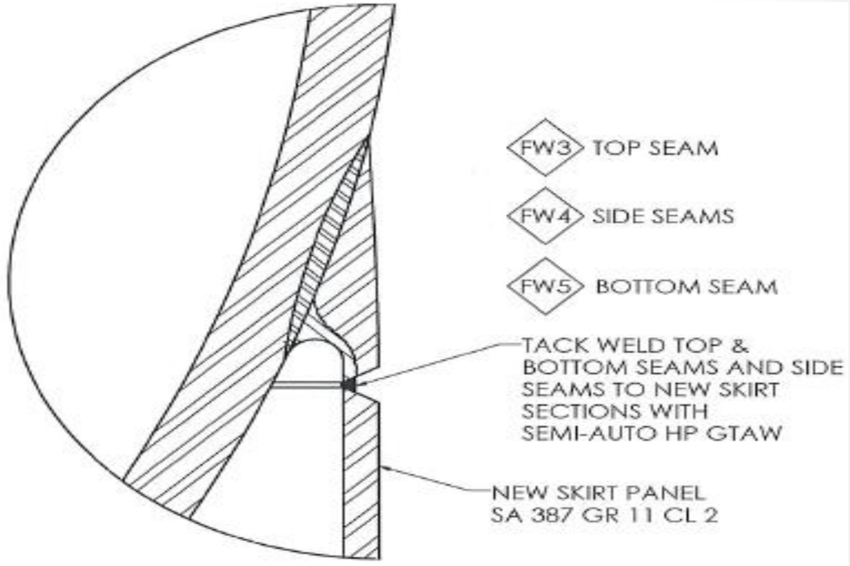
- A track mounted flame cutting machine is used to cut the 30 degree bevel for the plate attachment weld
- This cut removes the temporary shelf bar and allows for removal of the ceramic backing as well
- Inside of radius is ground smooth at this time to complete the shaping of the weld deposit

Field Repair Step 6 – Flame Cut Bevel

Field Repair Step 7 –
Fit New Skirt Panel

- Skirt opening is measured and the bottom of the window is trimmed as needed to closely match the height of the new skirt panel
- The new panel is rigged into place using the rail cart and monorail trolley system
- AZZ then fits the plate and tacks it into place
- New plate material is SA387 Grade 11 Class 2 (1-1/4Cr)





Field Repair Step 8 –
Fit New Skirt Panel

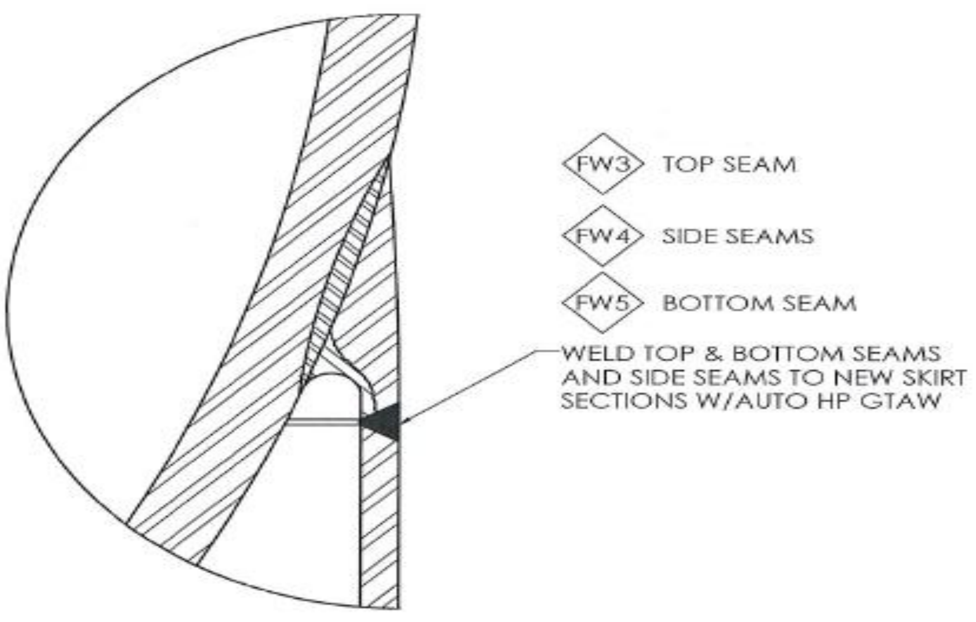
Dogs and wedges are used as needed to fit the panel into place with optimal gaps on all sides

Section Alignment Fixturing

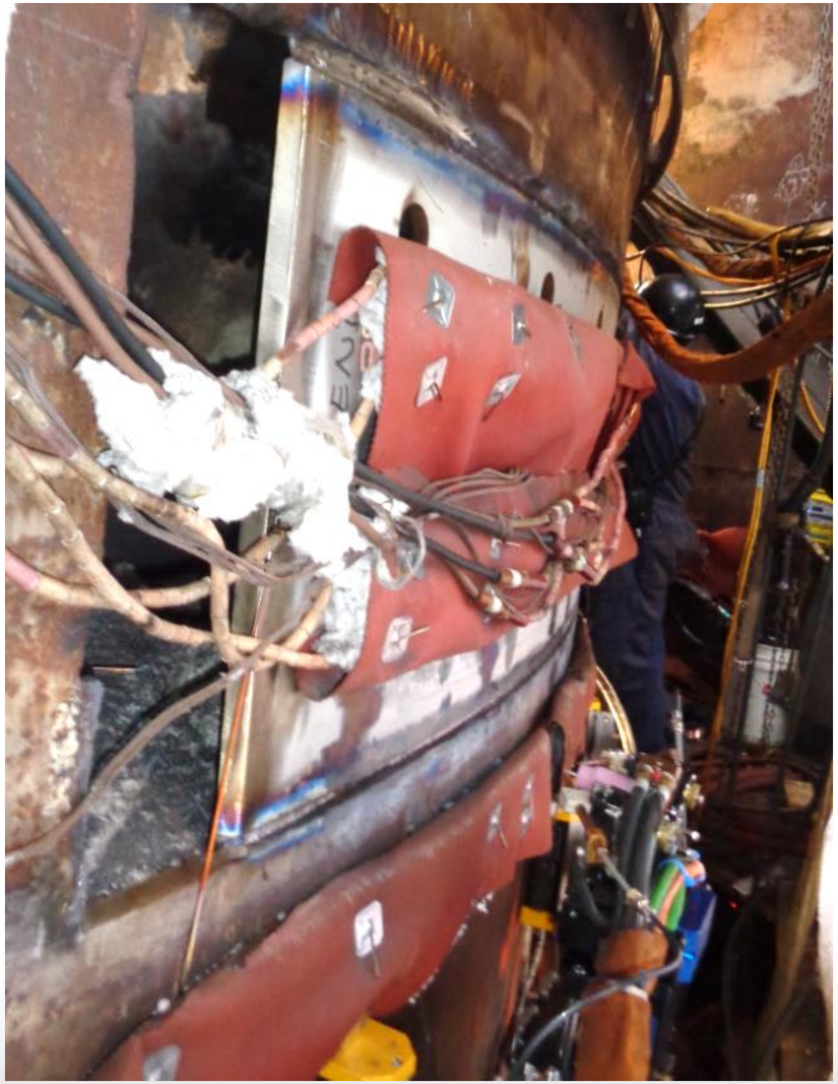
Proper Root Opening for Welding

Field Repair Step 9 –
Hot Pulse GTAW Groove Welds

- Weld out top, bottom, and vertical seams
- Root weld is completed with semi-automatic Hot Pulse GTAW
- Fill and cap are completed with automatic Hot Pulse GTAW
- Verticals are completed with either semi-auto or automatic Hot Pulse GTAW. Vertical welds will all be completed after all panels are installed
- Weld caps to be ground flush to remove stress concentrations
- Final NDE is PAUT



Field Repair Step 9 –
Hot Pulse GTAW Groove Welds



Field Repair Step 10 – Contour & Polish

- Weld caps ground flush to remove stress concentrations
- Final NDE is PAUT

Project Performance Summary

- **Zero safety incidents**
- **Successful fit & welding of six panels on each drum**
- **Adapted attachment weld design *in situ* to account for unexpected geometrical differences in vessel contour found after the skirt panels were removed**
- **Final PAUT after PWHT successful – Zero defects**
- **During skirt replacement implementation, separate inspections on the seams found additional repairs in the cones of all four drums. Additional AZZ personnel & equipment were mobilized to complete excavation and Hot Pulse GTAW repairs from ID and OD.**