Field Modification of DCU Support Skirt-to-Vessel Attachment Weld Geometry

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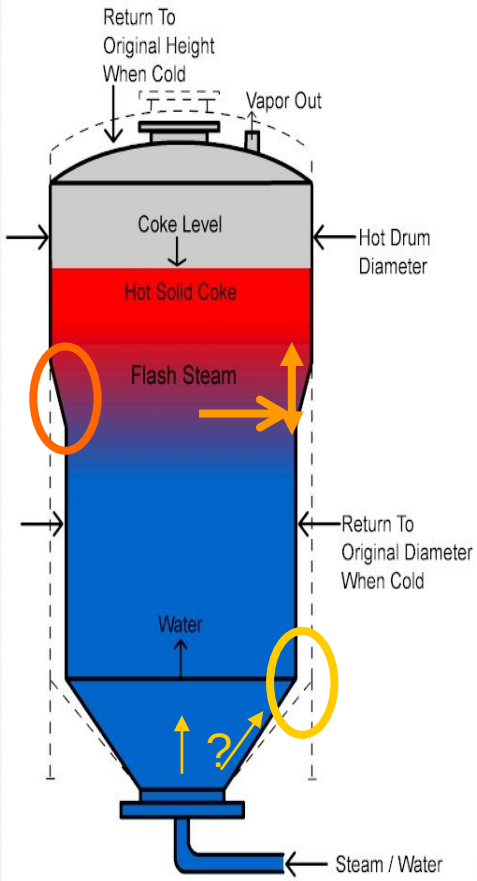
Typical DCU Vessel Failure Modes



- Coker Vessels are known to be susceptible to low cycle fatigue damage
- Delayed Coking requires cyclic operation and the cyclic changes in temperature cause significant stress intensities
- Over time, as operating cycles accumulate, vessels start to experience a variety of failure modes

Typical DCU Vessel Failure Modes

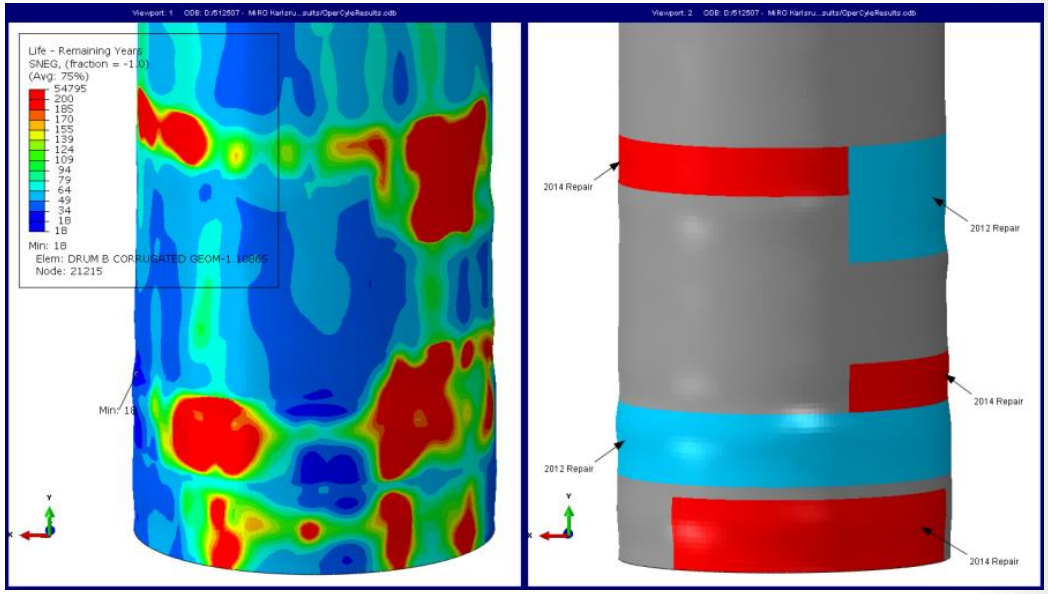
Bulging

Skirt Attachment Cracking

Pressure Boundary Cracking

Established Practice For Shell Bulging/Cracking

- Map vessel to collect deformation data
- Evaluate stress/strain intensities with analytical tools
- Characterize highly affected areas
- Design “Structural Overlays” to address critical regions



Engineered Structural Overlays

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Established Practice For Shell Bulging/Cracking

- Install structural overlay(s) in accordance with design criteria
- Utilize automated welding processes to provide homogeneous mechanical properties and minimize volumetric and surface imperfections

Engineered Structural Overlays

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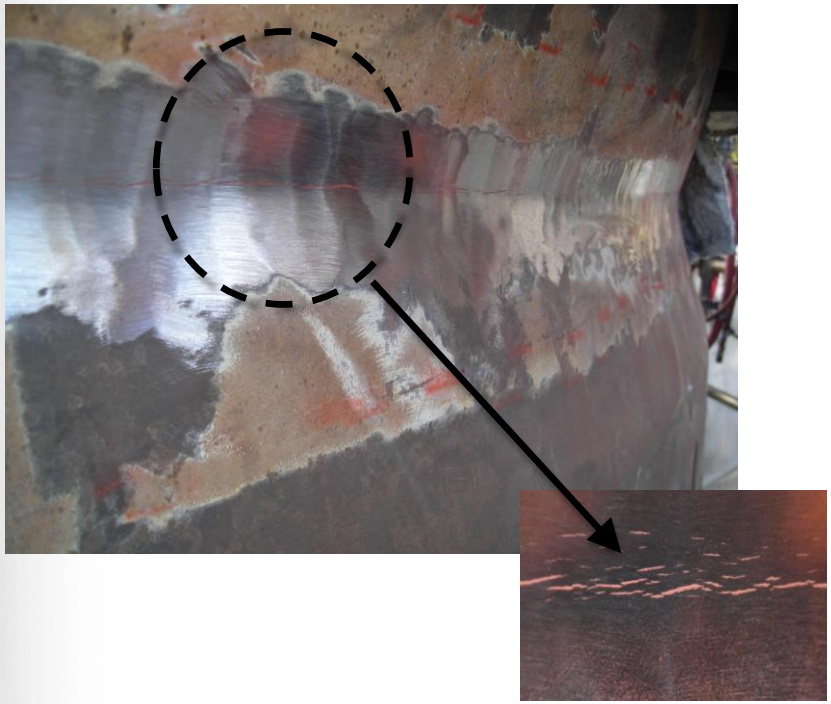
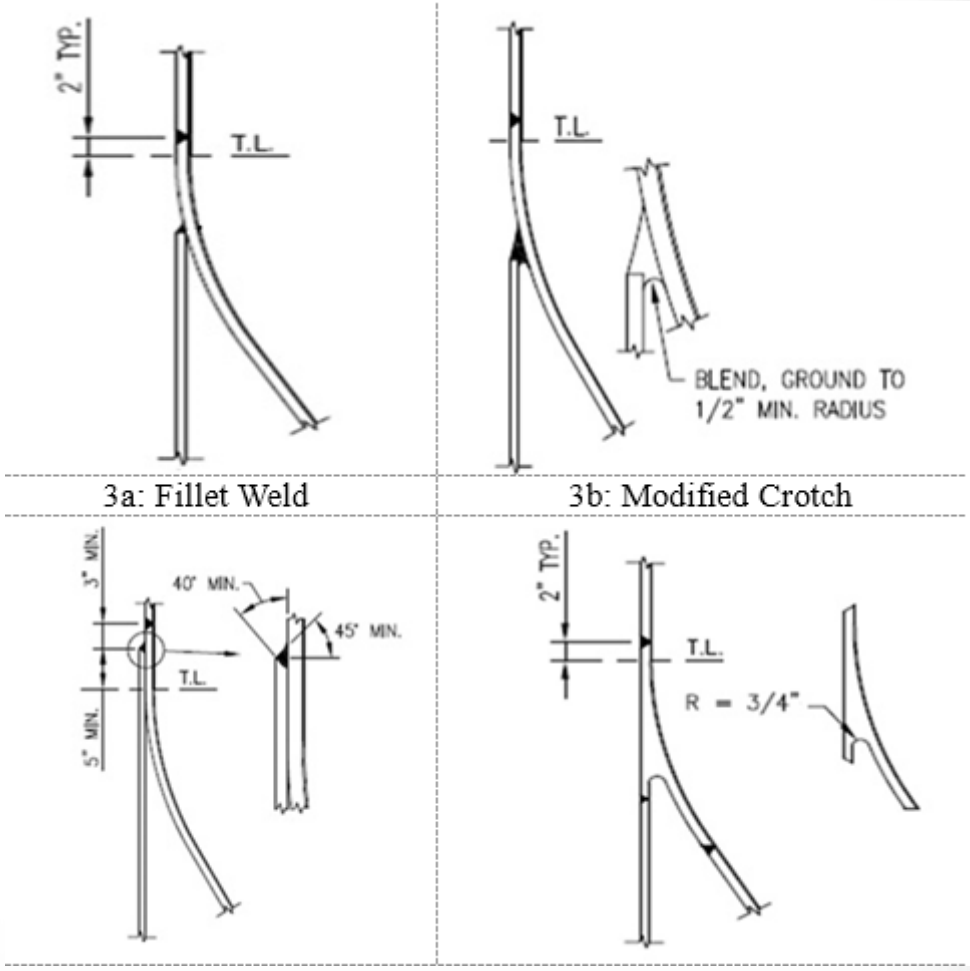
Issues at the Skirt to Vessel Interface



Cracking At Top of Skirt Attachment Weld



Typical Skirt Attachment Geometries[1]

1 - "Analyses of Alternate Skirt Attachments to Coke Drums" PVP Vol. 315, Leslie Antalffy et. al., ASME 1995

Field Attachment Weld Geometry Modification

Unique Implementation Case Study

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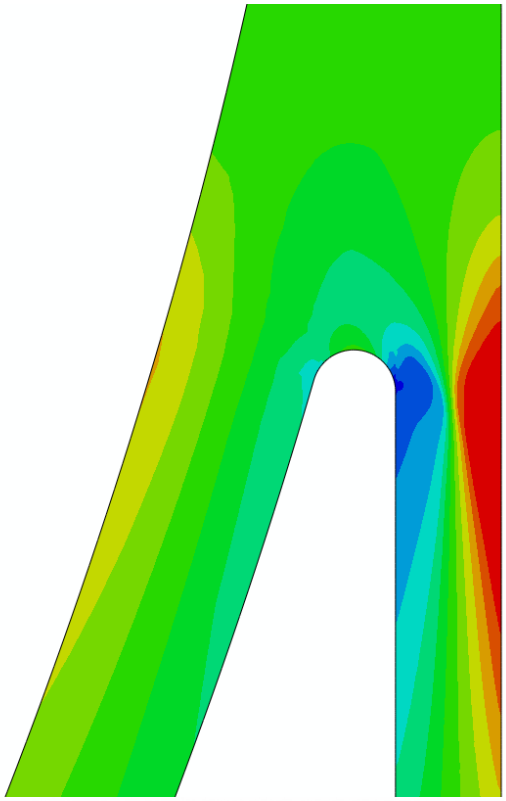
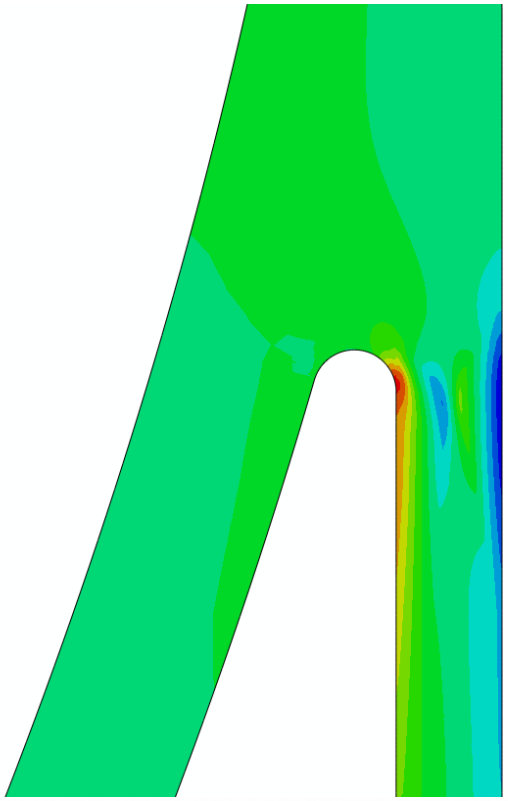
Skirt Attachment Weld Stress Model

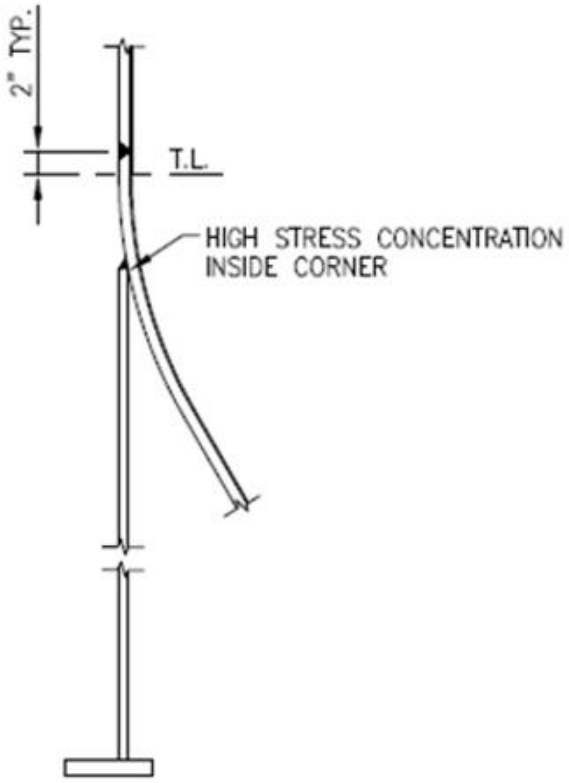


Fill

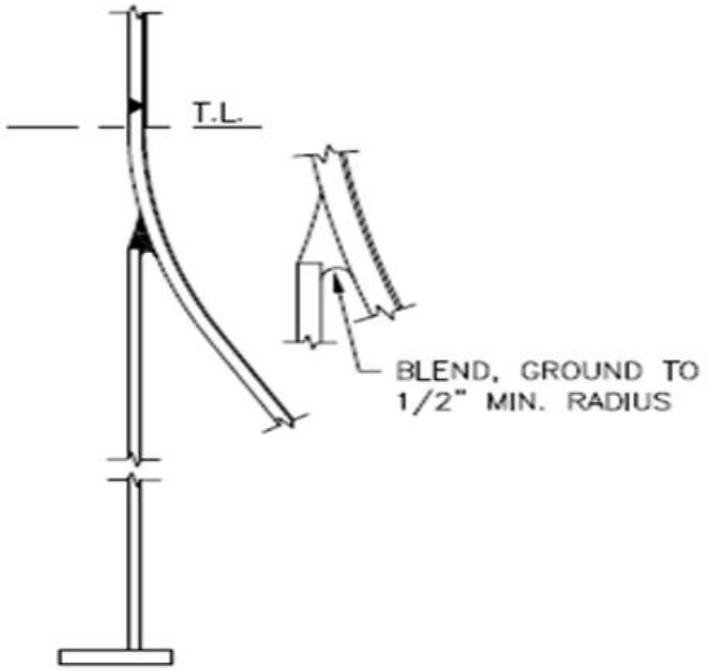


Quench

Customer Issues at the Skirt to Vessel Interface



Original Geometry[1]

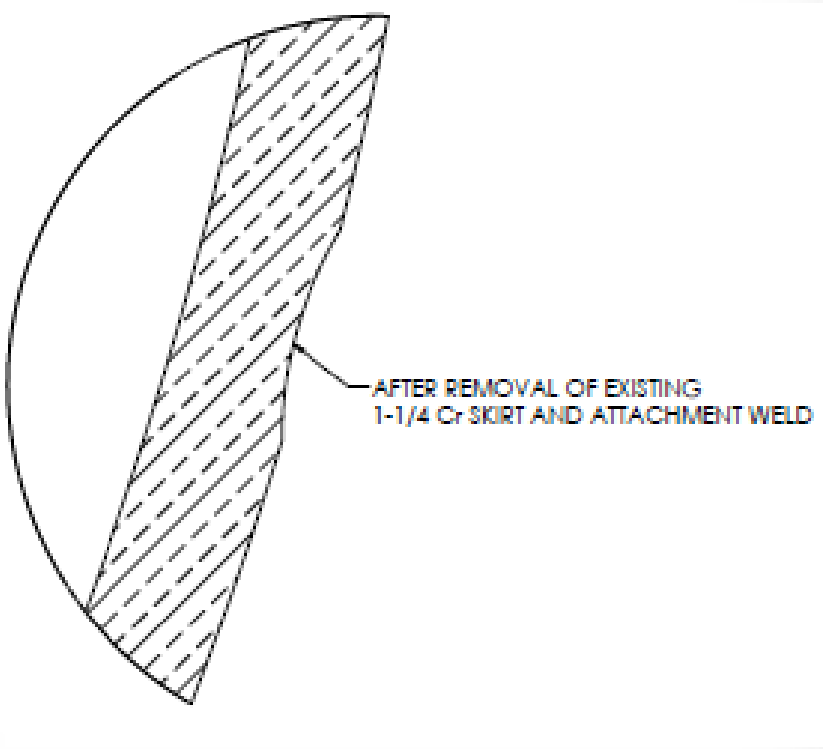


Improved Geometry[1]

1 - "American Petroleum Institute, Technical Report 934G" API, Washington D.C. 2014

Step 1 – Original Skirt Removal

- Remove portions of the existing skirt using track mounted torch cutting system
- Remove remaining skirt to vessel connection weld metal and grind flush
- Repair performed in segments around the vessel to avoid need for crane support



Step 2 – Base Metal Inspection

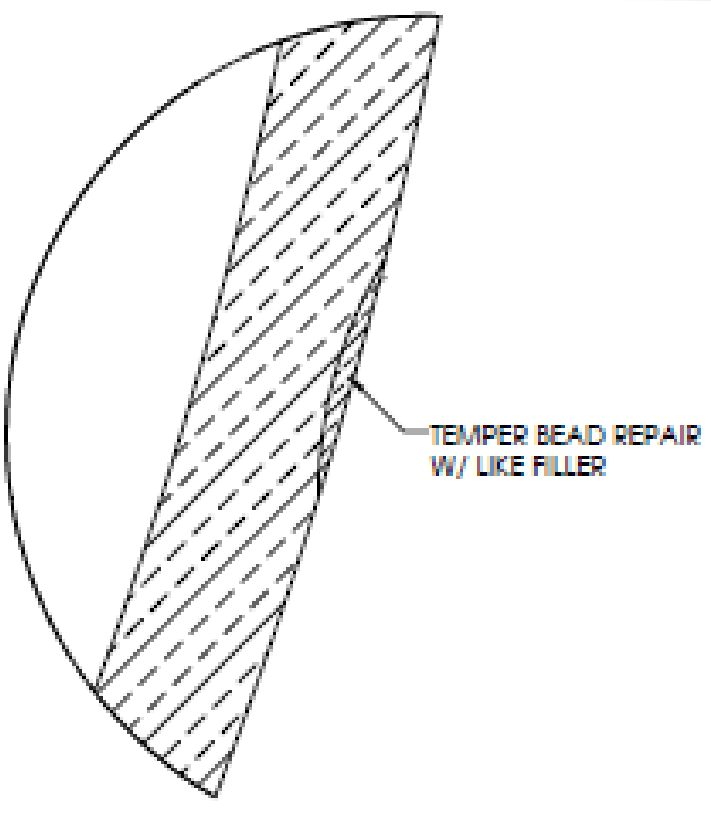
Magnetic Particle Inspection of Coker Vessel Base Material (Showing Vertically Aligned Crack)

Step 3 – Removal of Damaged Areas

Removal of Flaws Detected with Magnetic Particle and LPAUT

Step 4 – Base Material Repair Welding

- The 2-1/4 Cr Cone Base material repaired/restored to nominal using NBIC Alternative Welding Method 2 repair (Temper Bead)
- 2-1/4 Cr filler material ER80S-B3L
- After welding, the surface of the cone was ground flush



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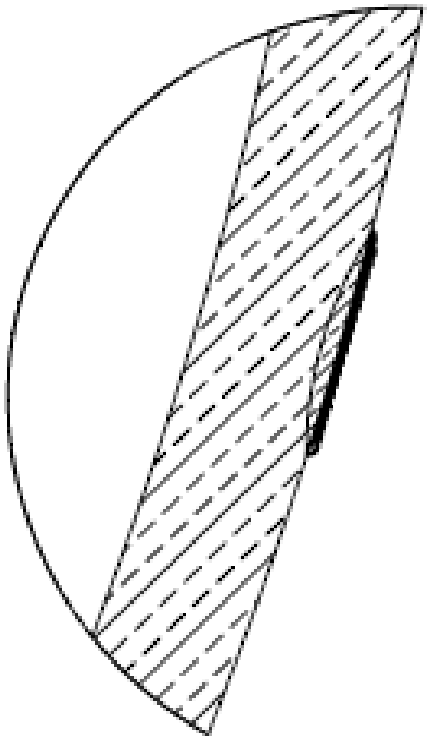
Step 4 – Base Material Repair Welding

Repair Welding of Cone Base Material

(2 Layers Required to Achieve Tempering)

Step 5 – Initial Knuckle Build-Up

- A build-up/structural overlay was deposited on the restored and unrestored surface of the cone using NBIC Alternative Welding Method 2
- Machine GMAW process and a 1-1/4 Cr filler material ER70S-B2L was used
- Two layers were applied to ensure proper bead placement and overlap



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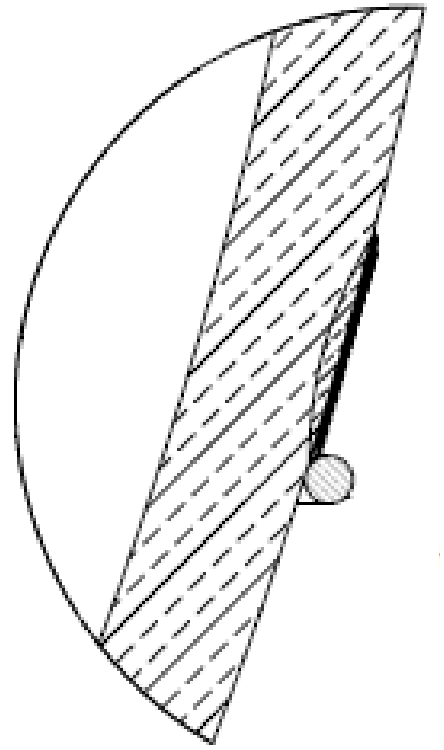
Step 5 – Initial Knuckle Build-Up

Appearance of ER70S-B2L Deposit

(Two Layers)

Step 6 – Installation of Proprietary Insert

- A Casting Insert was installed to create the desired knuckle radius
- A temporary welding shelf was installed to support the Casting Insert and provide a bottom surface for weld tie-in



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Step 6 – Installation of Proprietary Insert

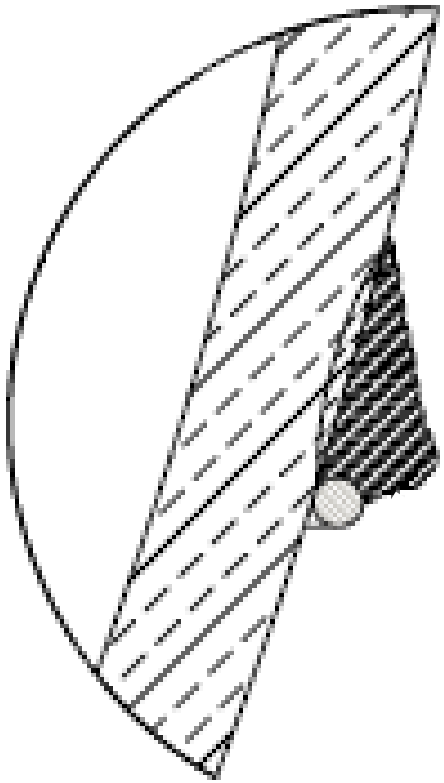
Casting Insert (White) and Welding Shelf

Step 6 – Installation of Proprietary Insert

Casting Insert (White) and Welding Shelf

Step 7 – Weld Build Up of Knuckle

- With the Casting Insert the weld build-up was completed with ER70S-B2L
- NBIC Alternative Method 2 was used for this portion of the weld
- The final deposited weld metal was considered a 1-1/4Cr, P4, base metal for the remainder of the repair



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Step 7 – Weld Build Up of Knuckle

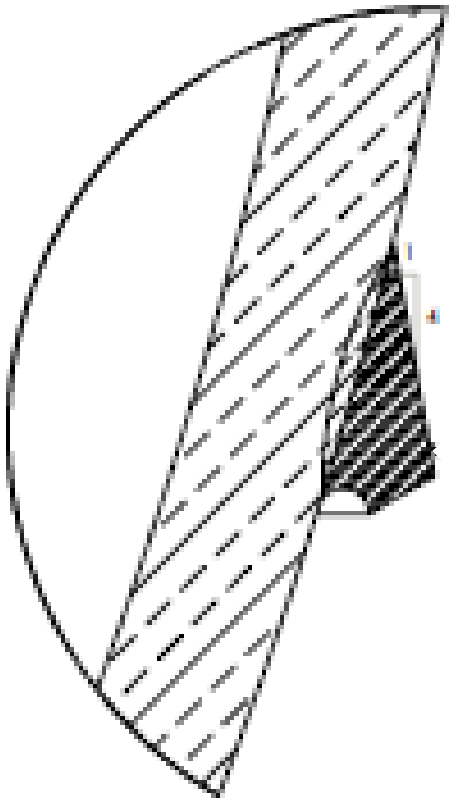
Machine Applied Knuckle Weld Deposit
Completely Covering Casting Insert

Step 7 – Weld Build Up of Knuckle

Surface Shaping of Deposited Knuckle Weld

Step 7 – Weld Build Up of Knuckle

- After sufficient build-up was deposited:
  - The Welding Shelf Was Removed
  - The Casting Insert was removed
  - The bottom radius was polished by grinding
  - The front of the build-up was blended to the cone and a bevel prep was cut for the skirt attachment weld



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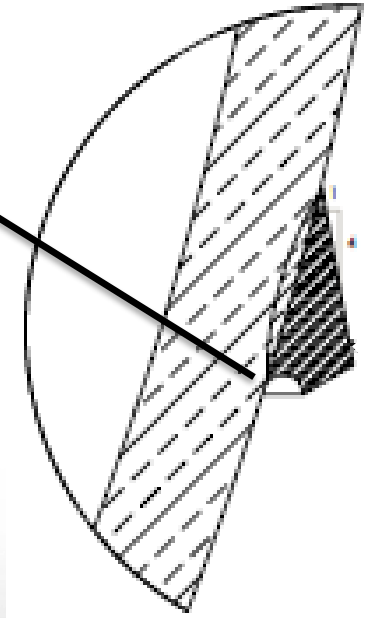
Step 7 – Weld Build Up of Knuckle

Machine Torch Cutting of the Weld Bevel

Step 7 – Weld Build Up of Knuckle



Knuckle Radius Bottom of Weld Deposit

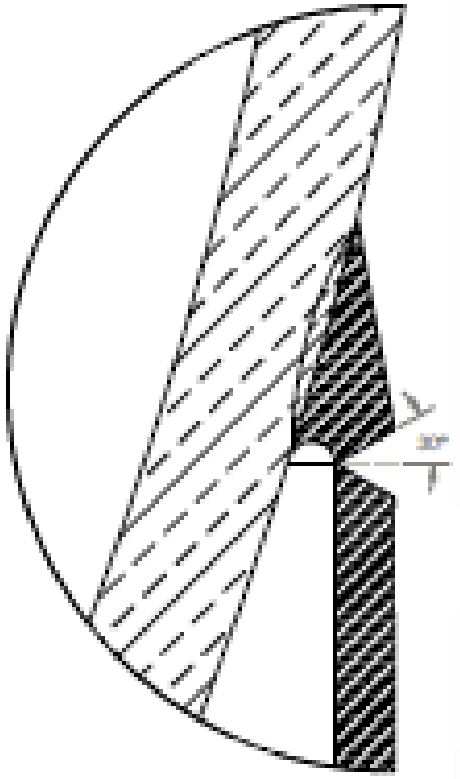
Step 7 – Weld Build Up of Knuckle

Front Surface of Knuckle Weld Deposit

(After Blending and Surface Profiling)

Step 8 – Fit-Up of Replacement Skirt Windows

- Replacement skirt windows were installed and fit to achieve proper weld geometry
- The joint to be welded 1-1/4 Cr, P4 to P4



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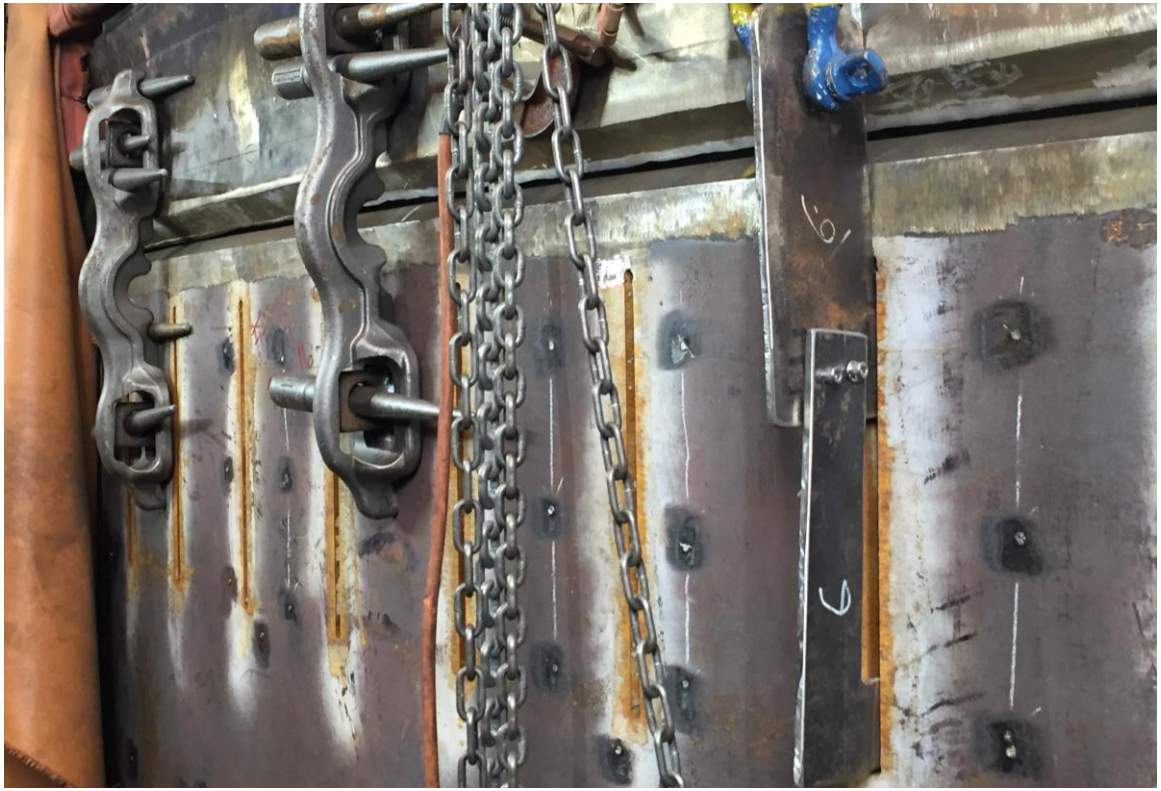
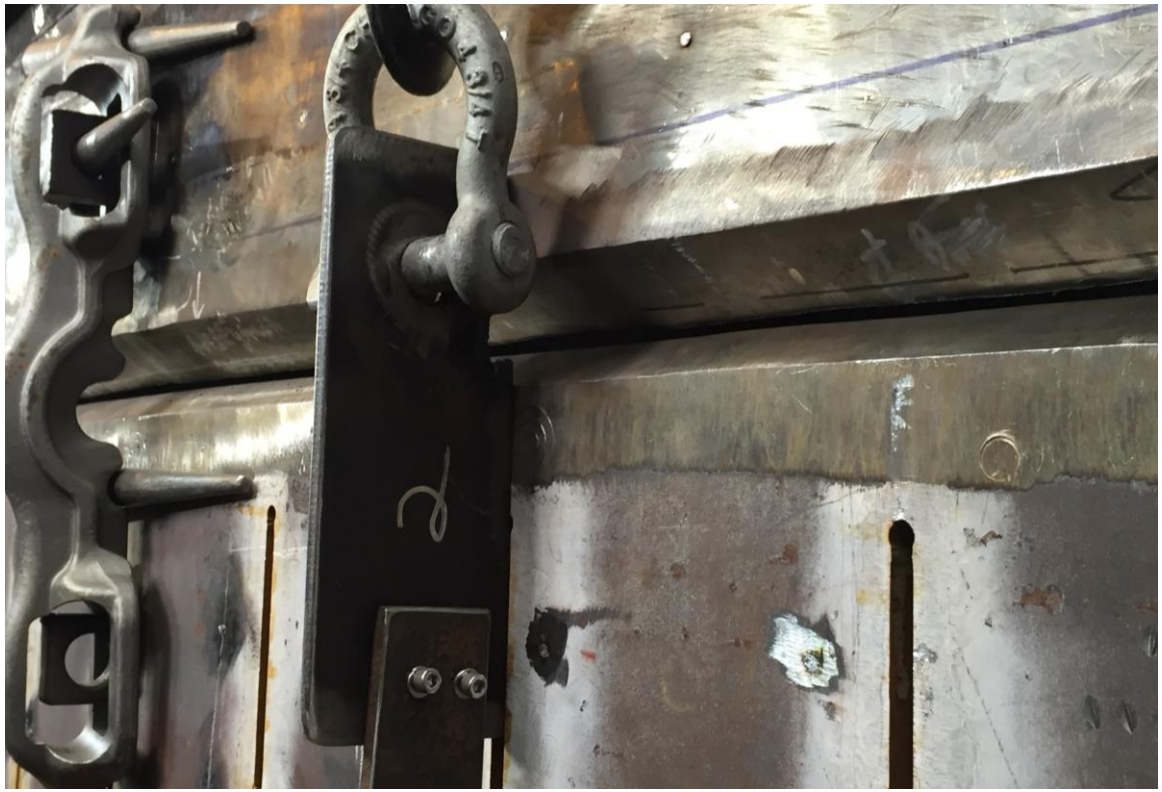
Step 8 – Fit-Up of Replacement Skirt Windows



Section Alignment Fixturing

Step 8 – Fit-Up of Replacement Skirt Windows



Proper Root Opening for Welding

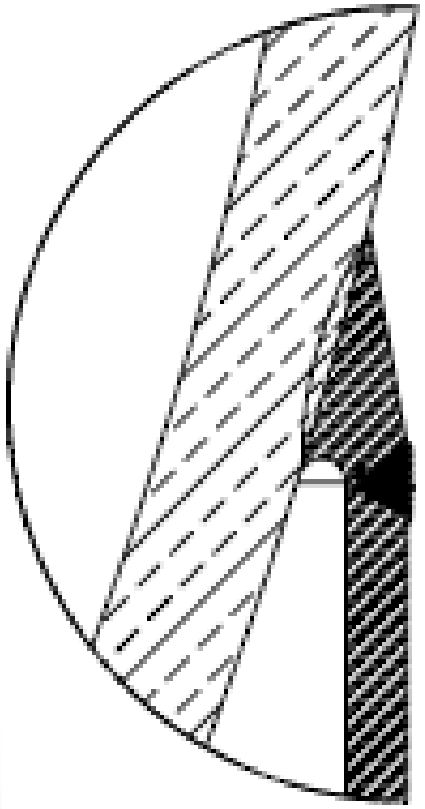
Step 8 – Fit-Up of Replacement Skirt Windows

Final Fit-Up after Tacking

Step 9 – Final Window Tie-In Weld

- Weld out completed using “Controlled Deposition” which is similar to temper bead but per API-510, not NBIC

- A proprietary GTAW HotPulse process was used for this weld



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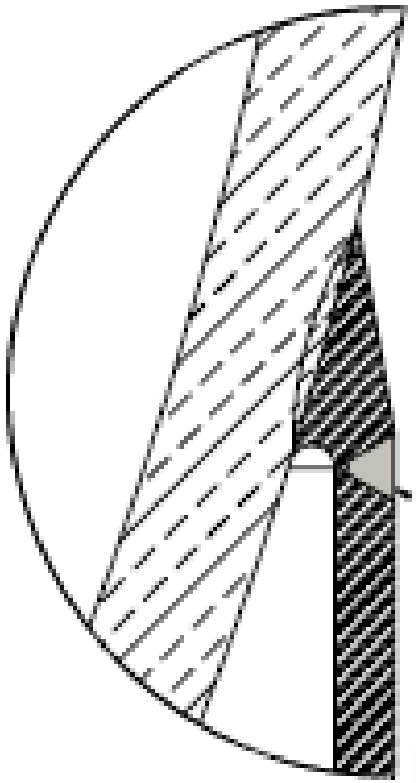
Step 9 – Final Window Tie-In Weld

- After completing the weld out of the build-up to skirt weld:
  - The backside of the joint will be cleaned up and blended with a pencil grinder
  - Contour grinding will be performed on the cap to blend with taper of build-up.



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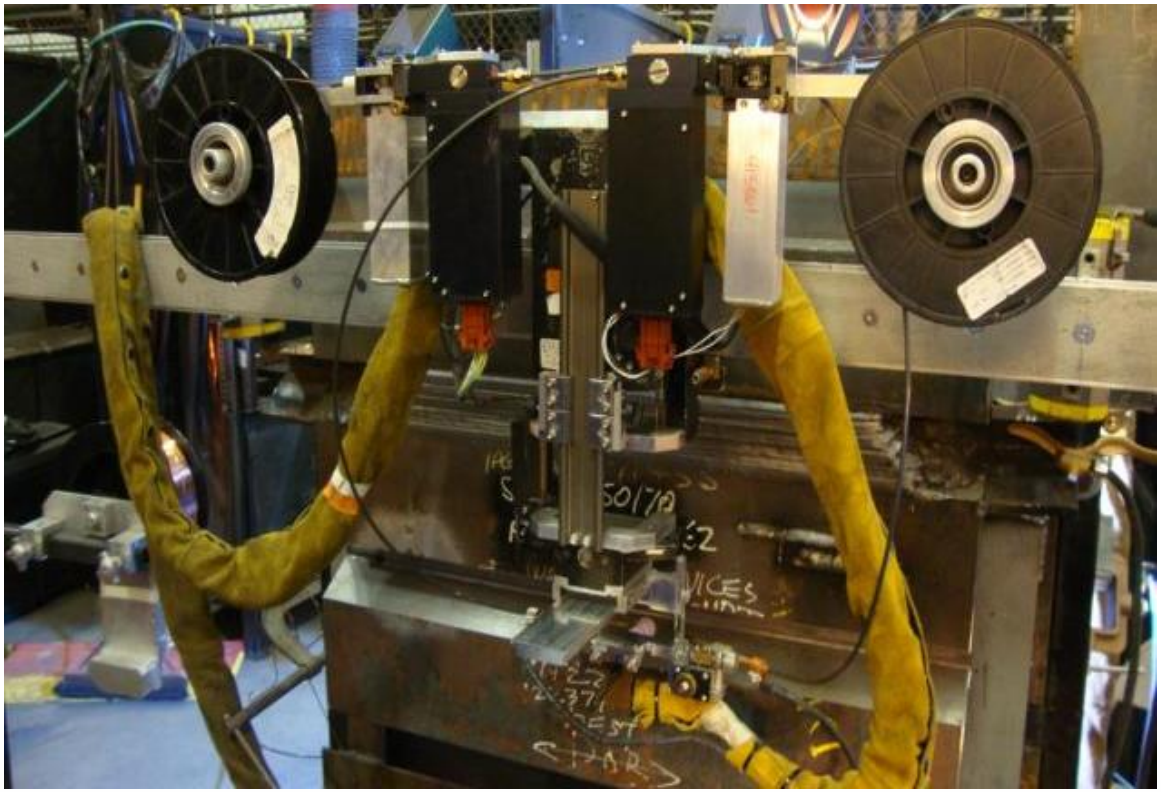
Step 9 – Final Window Tie-In Weld

GTAW Hot Pulse Welding System Installed

Step 9 – Final Window Tie-In Weld



Better Photo of GTAW Hot Pulse on Mockup

Step 9 – GTAW HotPulse Welding In Process

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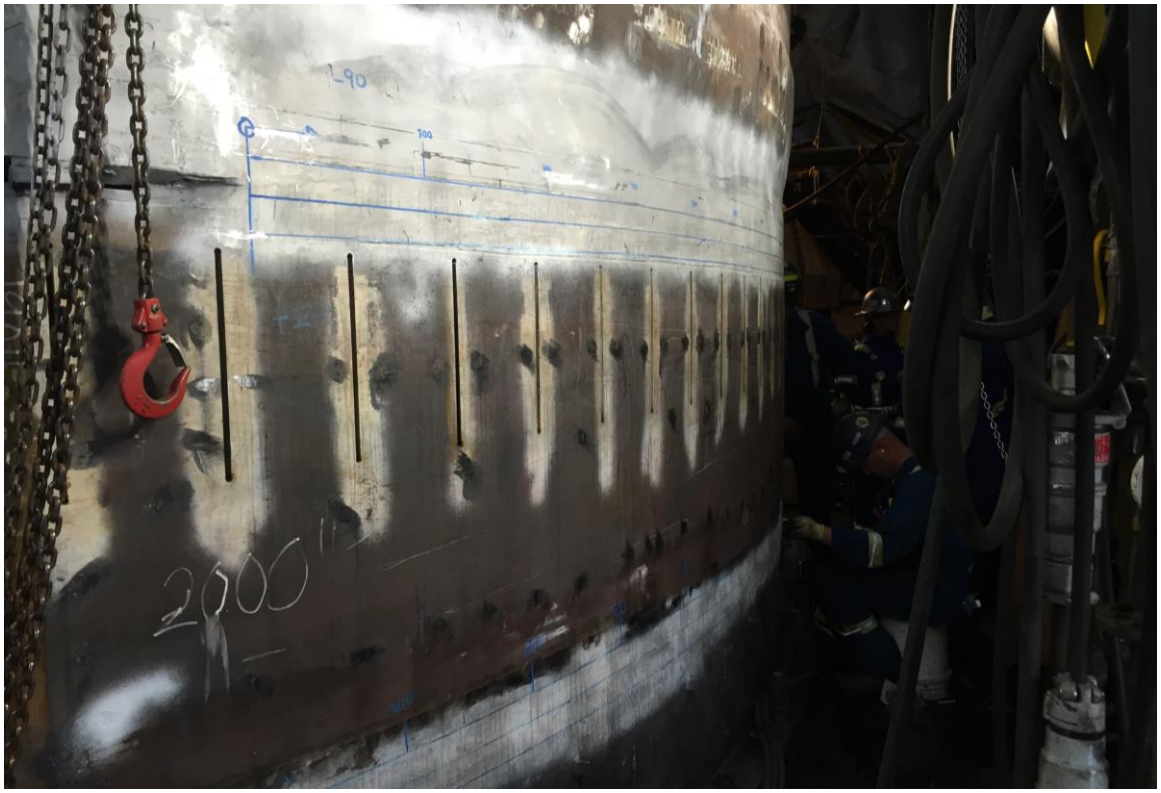
Step 10 – Final Assembly after Inspection



Final Appearance after Installation

(Inspection: Liquid Penetrant Inspection and Linear Phased Array)

Thank You!

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