Optimum Engineering Solutions, Inc.

Girth Weld Failure Analysis In Coker Blowdown Headers

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Background

Our customer recently experienced cracking issues with the blowdown header for their Coker Unit blowdown system. The blowdown header was fabricated from 36” Sch. 40/STD A-672-C70 pipe. The thickness of the pipe varied along the length of the header (3/8” or 3/4”).

At the time of the analysis, the following cracks had been observed by the customer:

- Two (2) through-wall cracks located at girth welds (The cracks were repaired using temporary pipe clamps).
- Five (5) internal surface cracks (not penetrated through the thickness). Pro-active maintenance for the cracked locations was performed by installing 6” wide C.S. bands at each of the weld locations.
- All of the cracks were located at approximately the bottom centerline of the header pipe (6 o’clock position). All of the cracks initiated from the inside surface of the header pipe.
- All of the cracks were located at thickness transition welds between 3/8” and 3/4” sections.

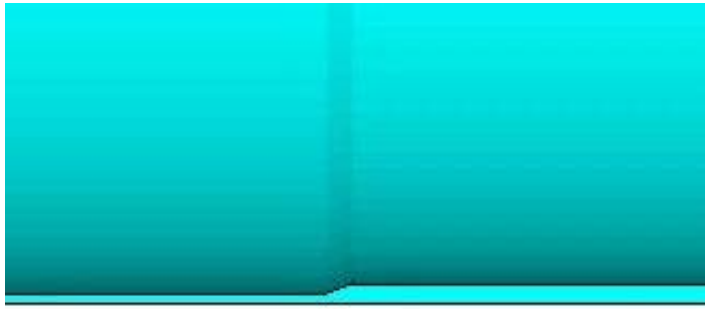
Scope of the Analysis

In order to determine the root cause of the failures observed in the blowdown header, the following analyses were performed:

- To determine if there were any issues with the original design in regards to the pipe supports or the overall piping flexibility, the blowdown system was analyzed under the intended operating conditions.
- The effect of circumferential thermal gradient similar to the gradient observed in the field was analyzed.
- The effect of continuously heating the lower portion of the blowdown header using hot oil stream was analyzed.
- The effect of insulating the blowdown header was analyzed.
- The effect of thickness transition used along the length of the blowdown header was analyzed.
- The life expectancy of the currently implemented repair bands and clamps were determined.
- Long-term repair for the blowdown header was determined.
- Temporary repair to the blowdown line was determined to prolong the life expectancy to the next turnaround.

Transition Girth Welds

- 10 years into service our client had cracking issues with the blowdown header for the coker unit blowdown system.
- The blowdown line was constructed by welding together several segments of pipes.
- At major branch connections, thicker pipe sections were used to inherently reinforce the openings. The pipe outside diameter was maintained.



Reasons for Cracking

- Formation of liquid pool at the bottom of the blowdown line due to different inside diameter of pipes exacerbates the circumferential thermal gradient.

- Poor workmanship may have contributed to some weld failures.

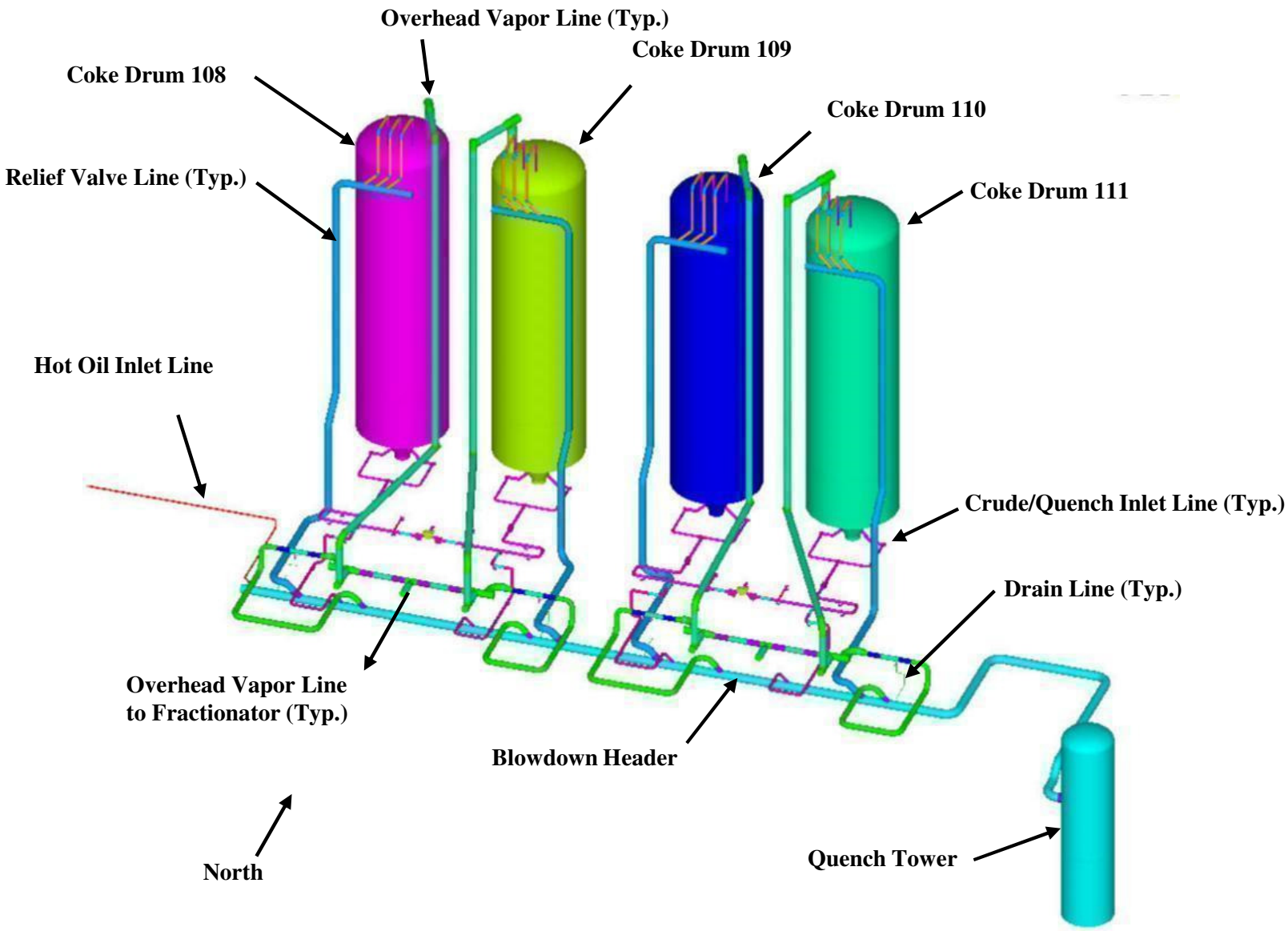
- Abrupt change in stiffness by using two different pipe thicknesses causes accumulation of induced stresses and the eccentricity between the centerlines of the pipe sections additionally intensifies the bending moment.

Reasons for Formation of Liquid Pool

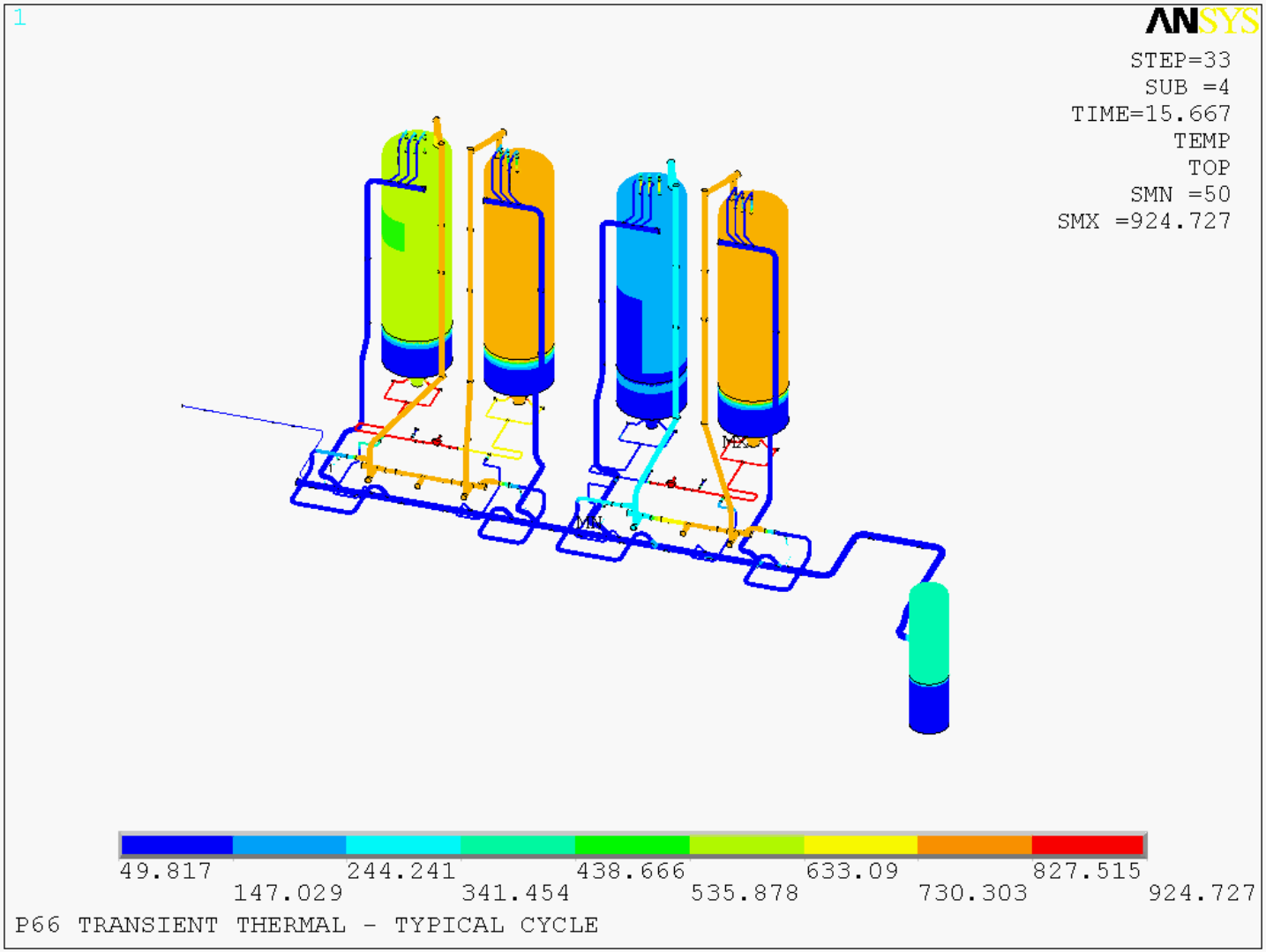
Formation of a liquid pool at the bottom of the blowdown line causes a circumferential thermal gradient

- Steam traveling through the drain lines and relief lines loses heat because the lines are uninsulated.
- A majority of the steam in the relief lines condenses to water prior to entering the header.
- Hydrocarbon vapor from the drums condenses in the header.
- The low slope of the header does not reduce the length of liquid pool in the header pipe.

Coker Unit

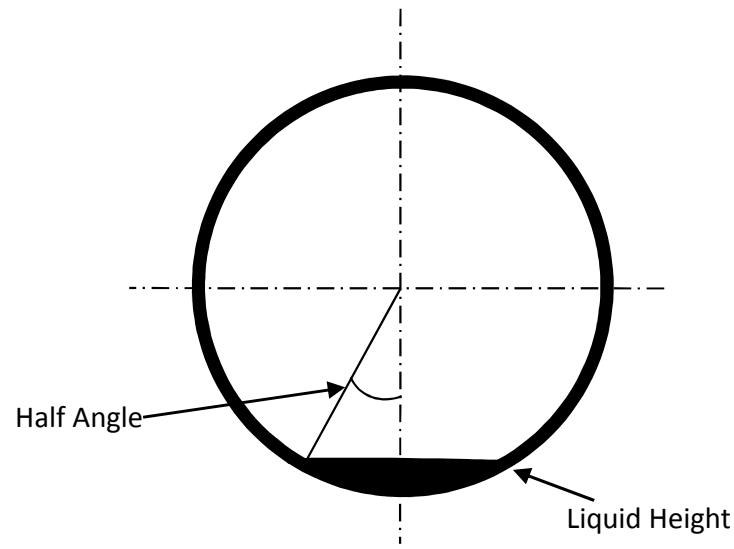

Overhead Vapor Line (Typ.)
Coke Drum 109
Coke Drum 108
Coke Drum 110
Relief Valve Line (Typ.)
Coke Drum 111
Hot Oil Inlet Line
Crude/Quench Inlet Line (Typ.)
Drain Line (Typ.)
Overhead Vapor Line
to Fractionator (Typ.)
Blowdown Header
North
Quench Tower

Operating Cycle

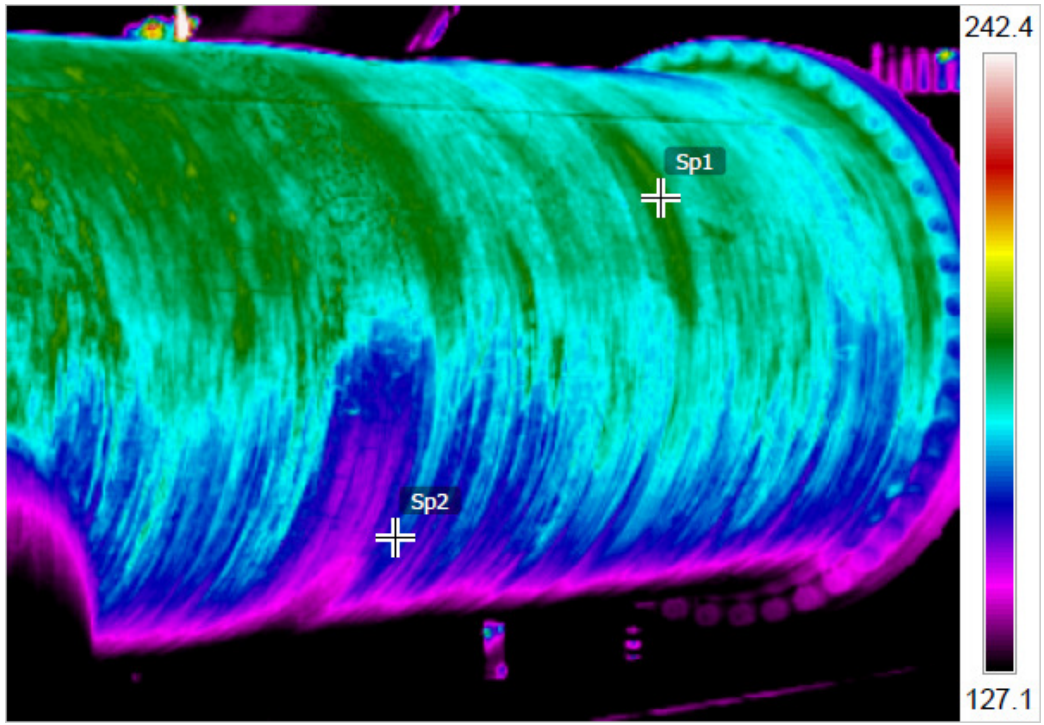


Analysis of Condensate Fill Height

- Sensitivity analysis was performed to determine the effect of circumferential temperature gradient.
- Several different "fill heights" for the liquid at bottom of the header were considered:
  - ~0 – Normal Operating Condition
  - ~11.25° half angle
  - ~17° half angle
  - ~22.5° half angle
  - ~30° half angle
  - ~45° half angle
  - ~90° half angle



Analysis of Condensate Fill Height



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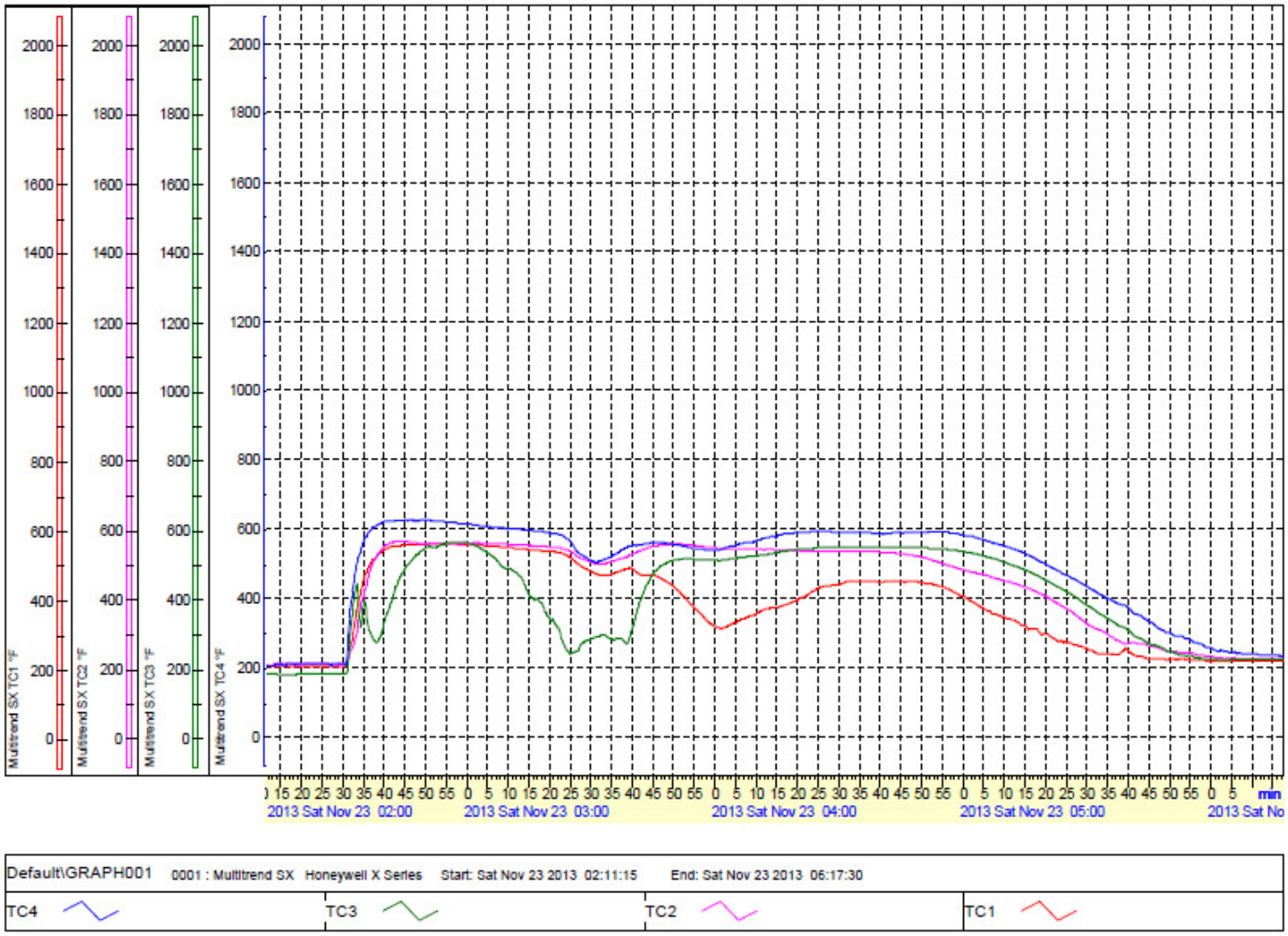
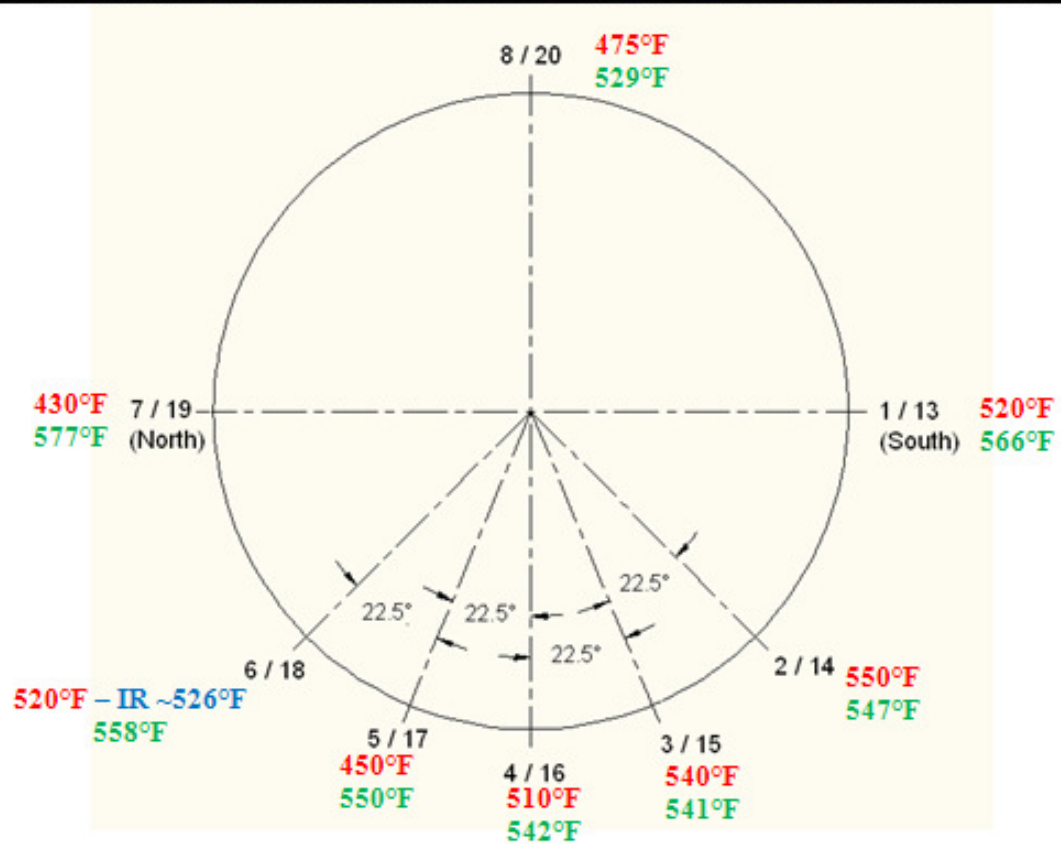


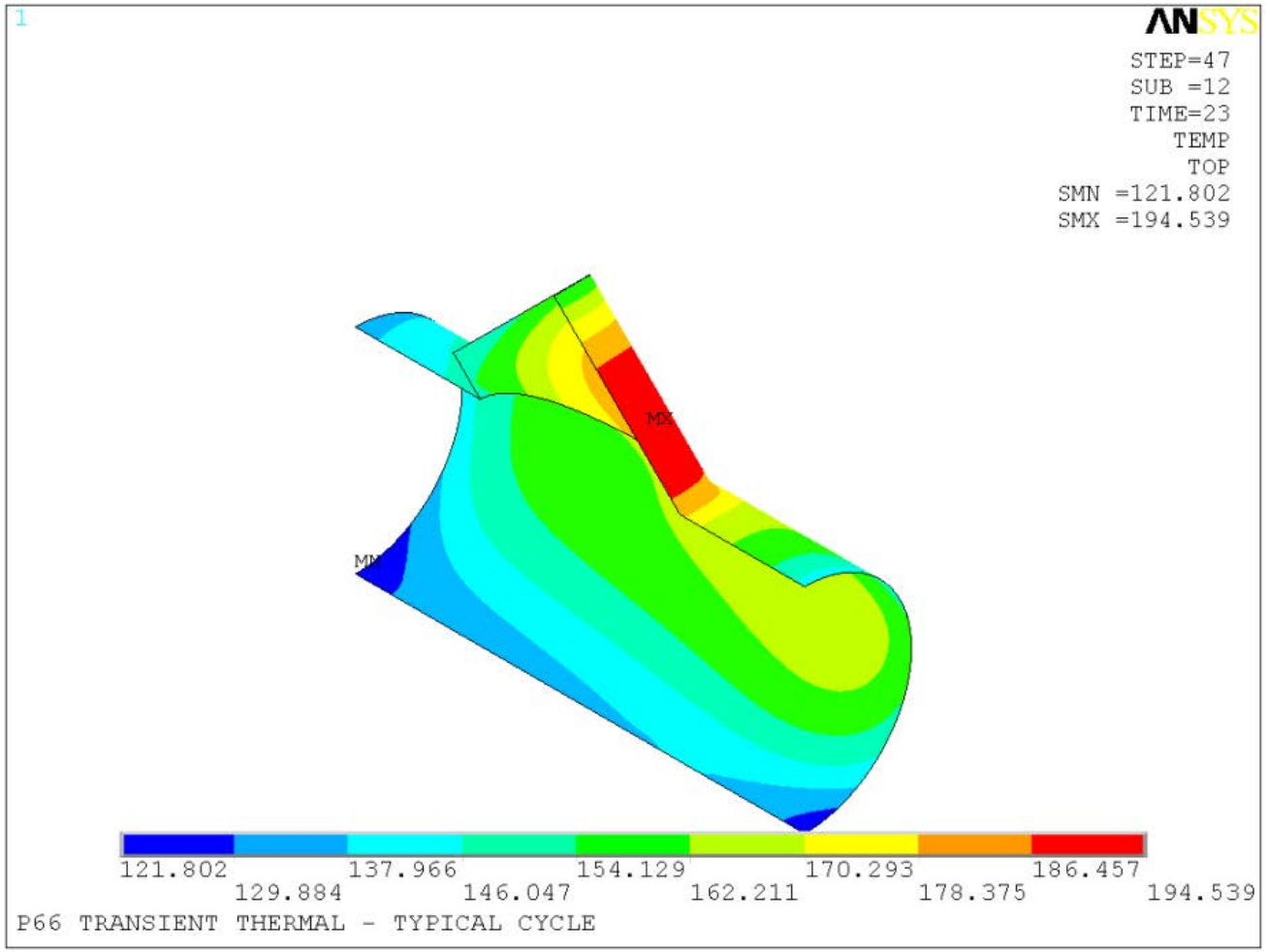
Analysis of Condensate Fill Height

Legend:
Red: Thermocouple
Blue: IR
Green: FEA Result

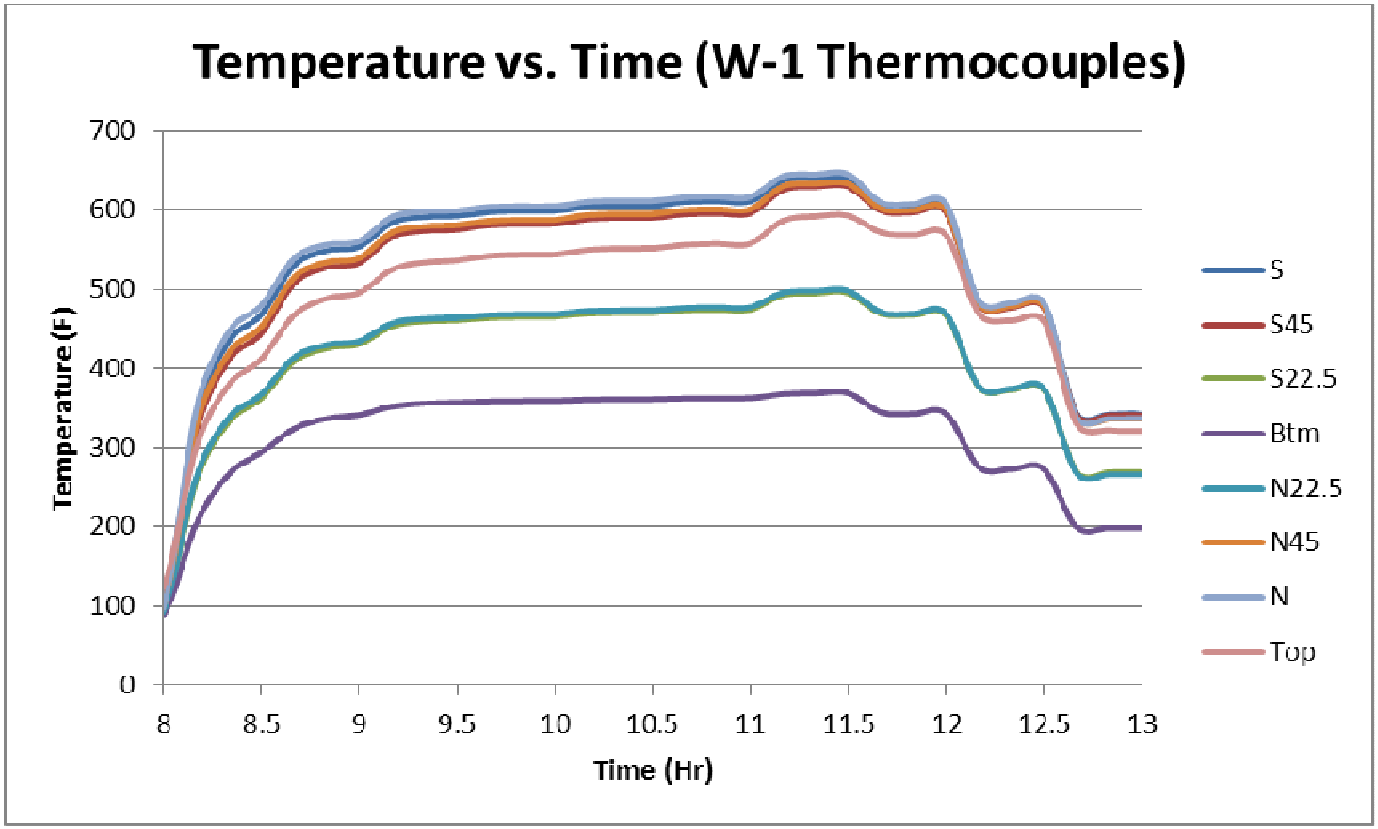
109 @ ~10:45pm on 2/6/14 (IR Time Point #1 – 109 Stm-to-BD No HGO) – Typical Cycle



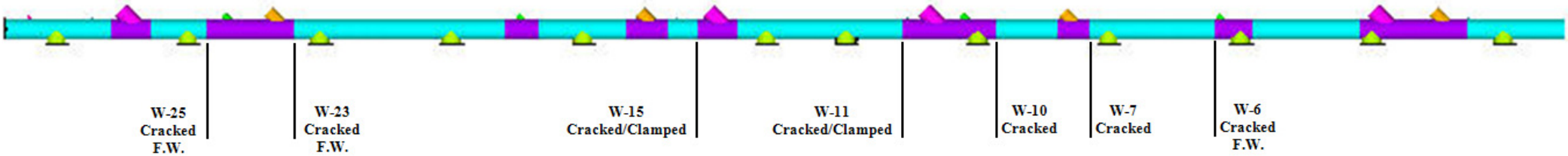
Thermal Gradient Due to Pooling



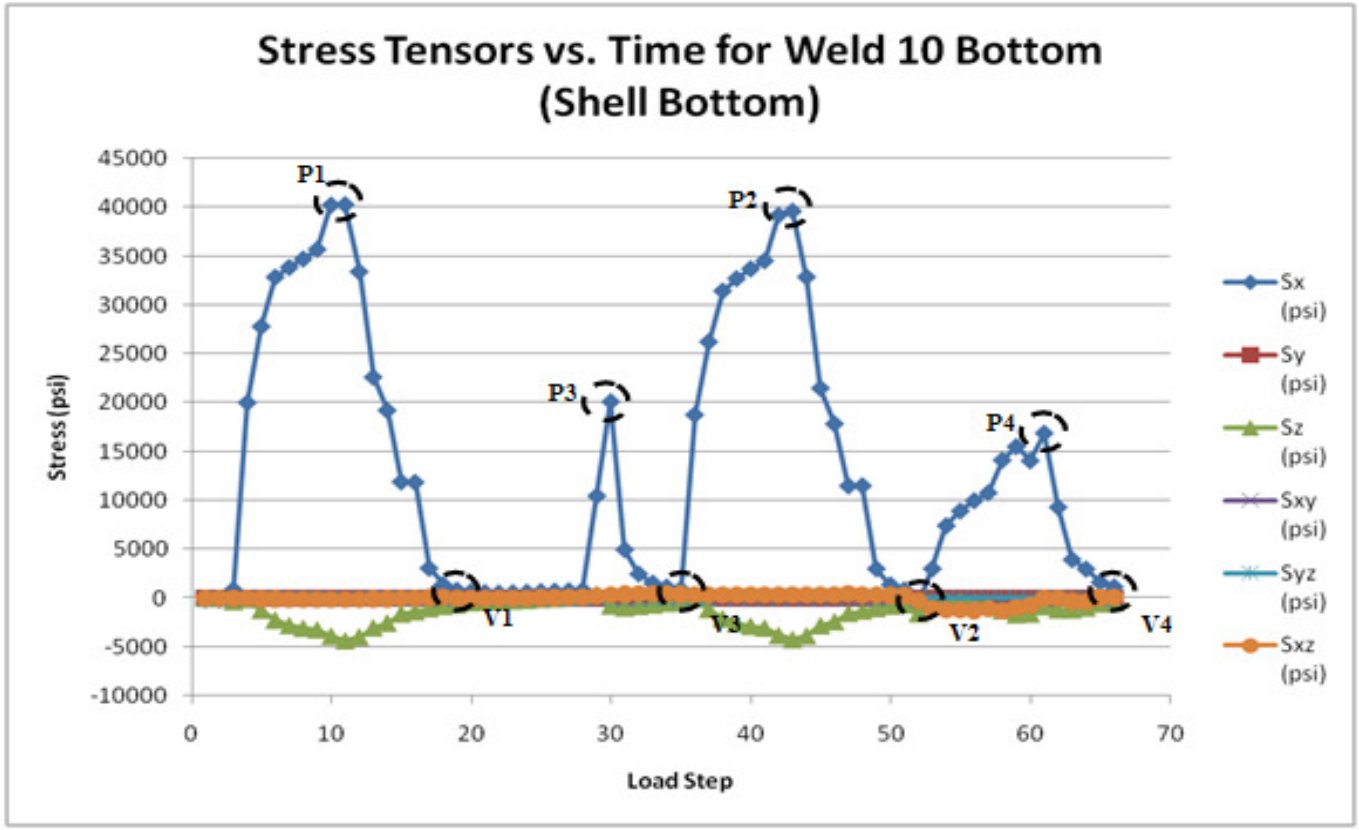
Temperature During the Operating Cycle



Summary of Header Crack Locations (Looking North)



Stresses During the Operating Cycle



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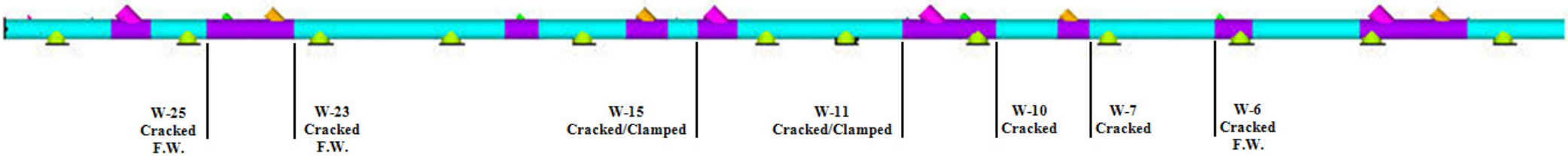
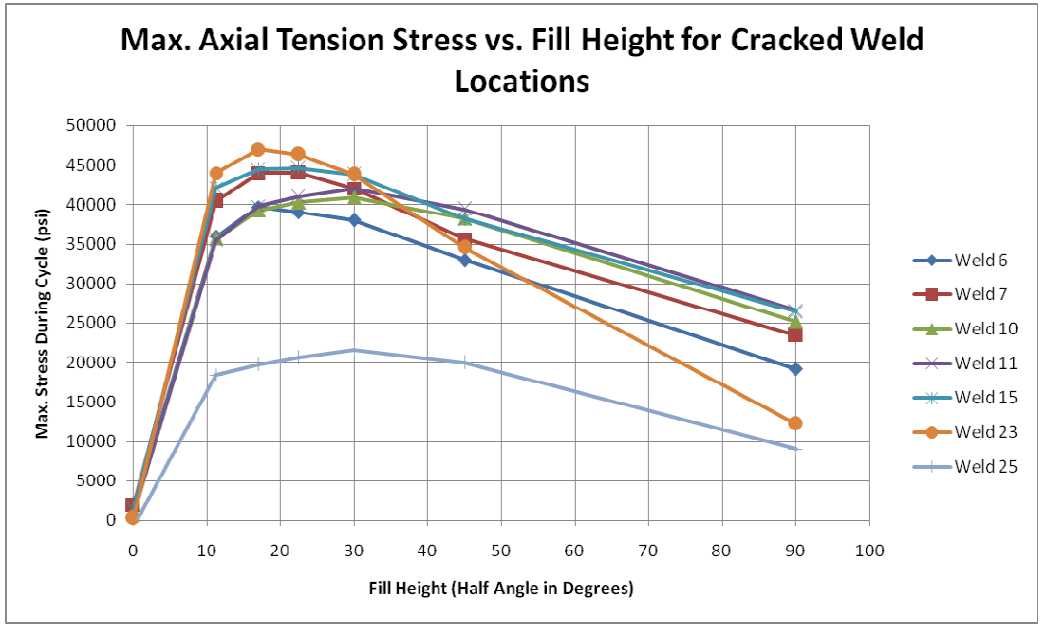
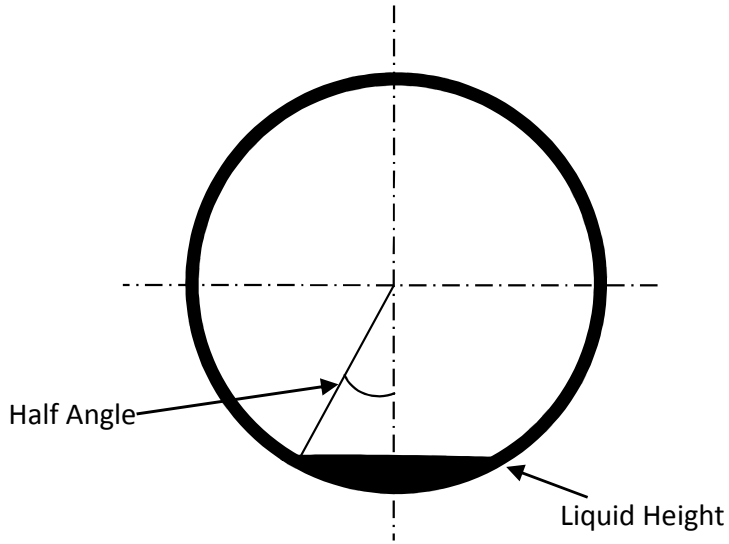
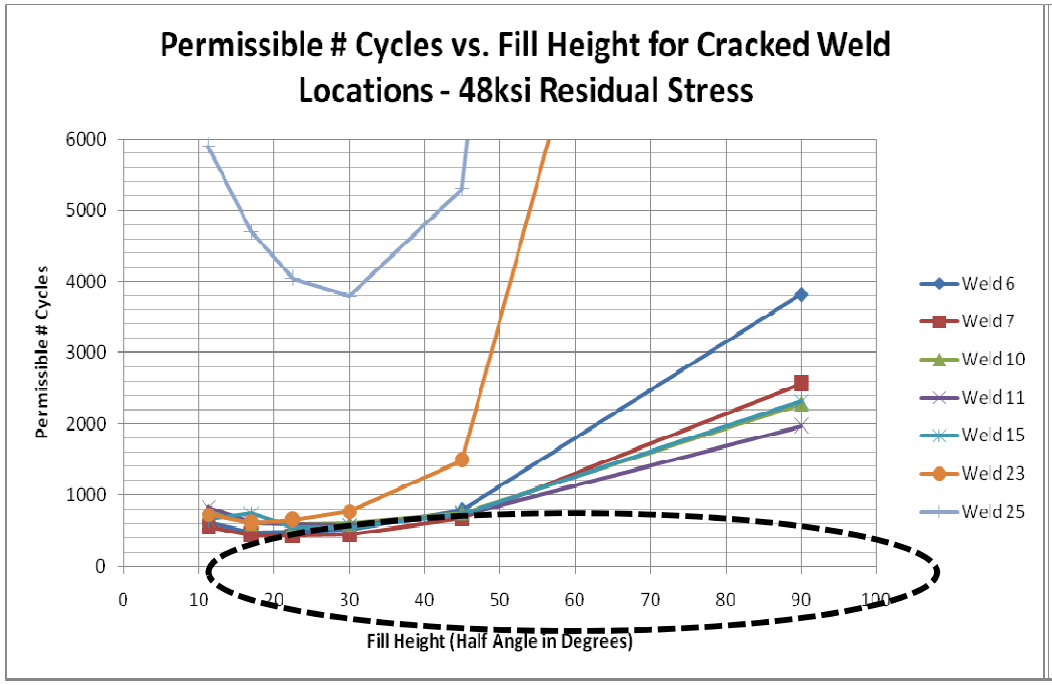


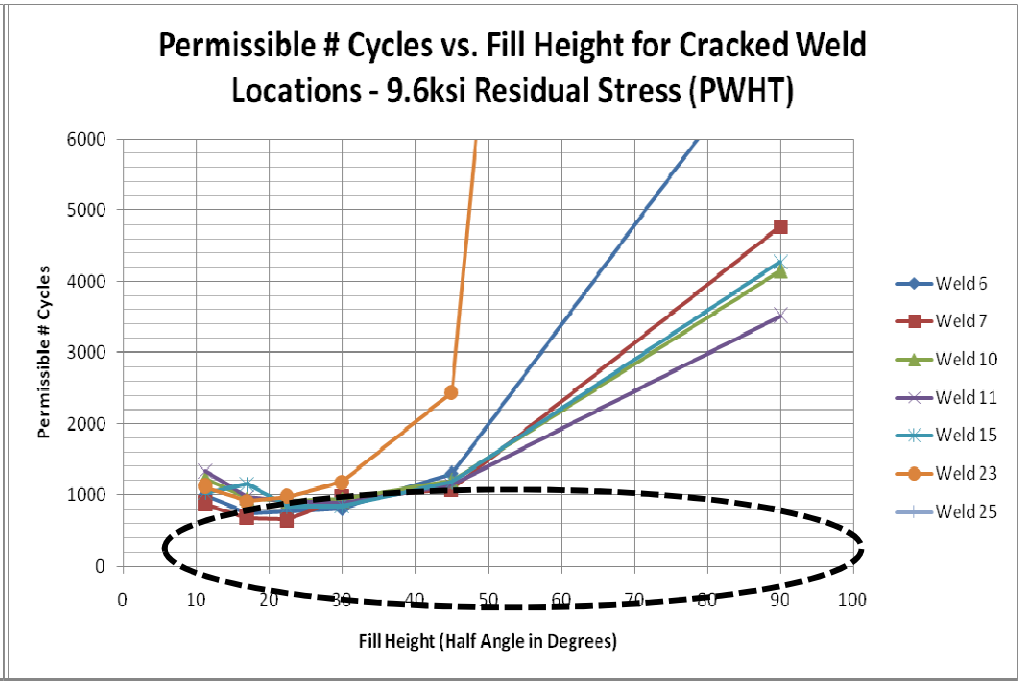
Analysis of Condensate Fill Height



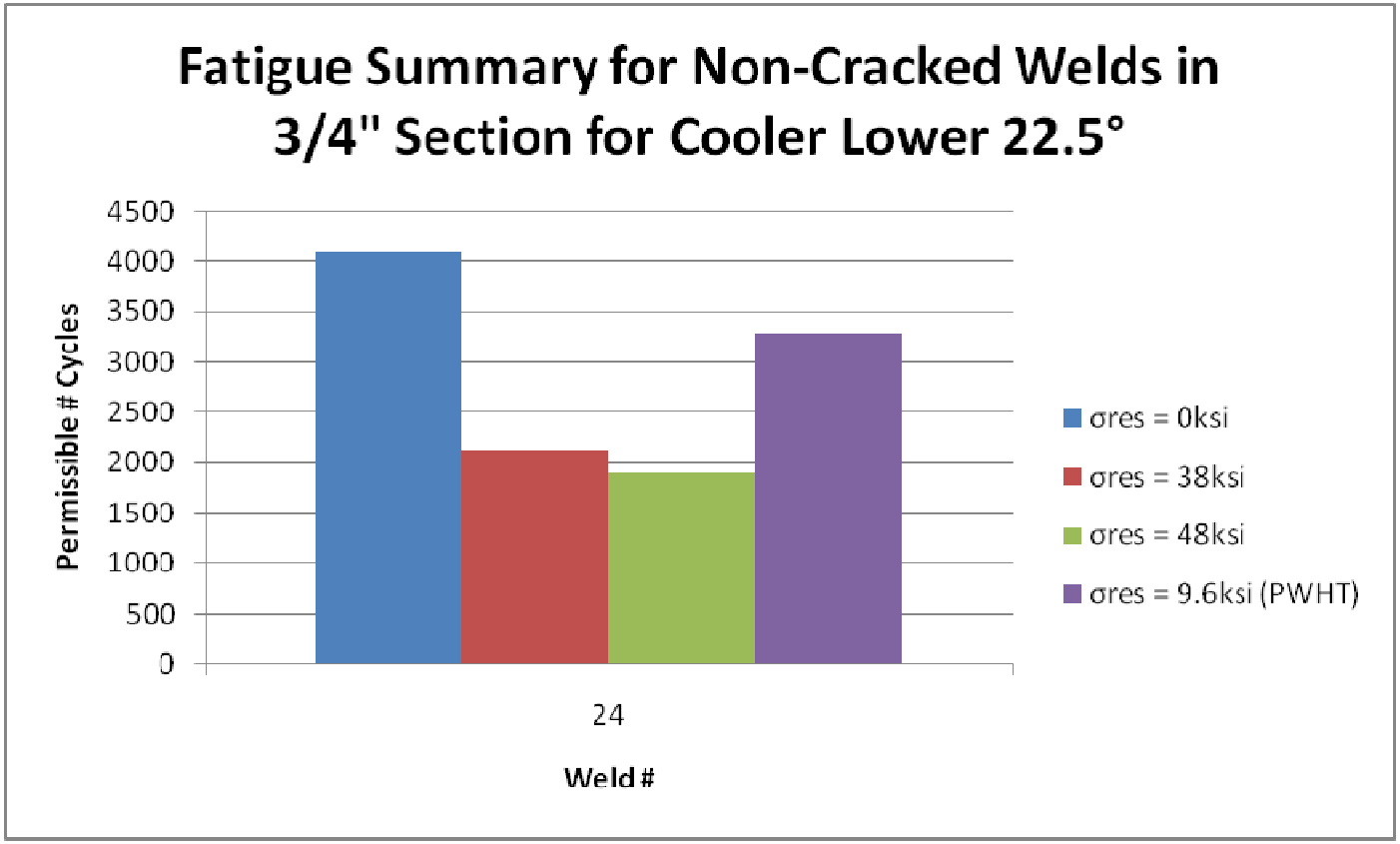


Analysis of Fill Height and Residual Stress

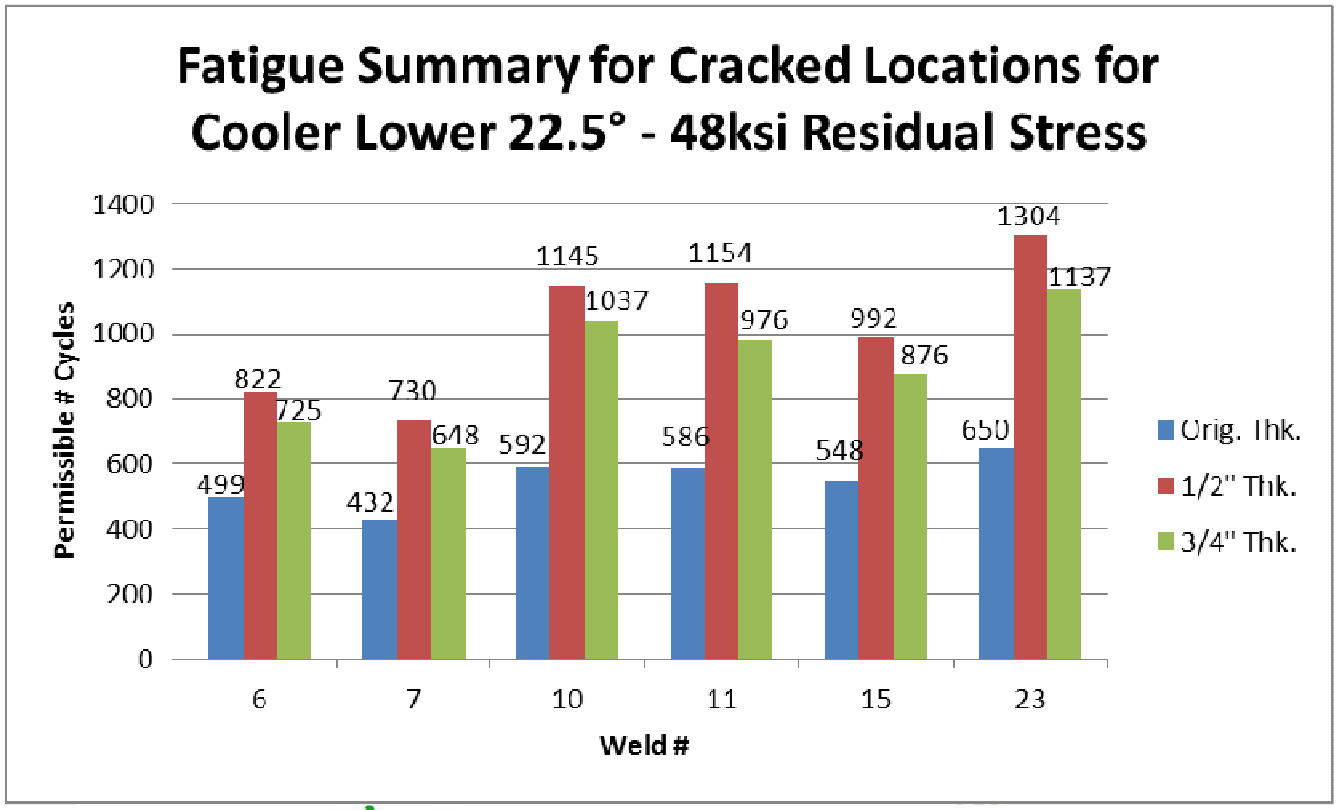


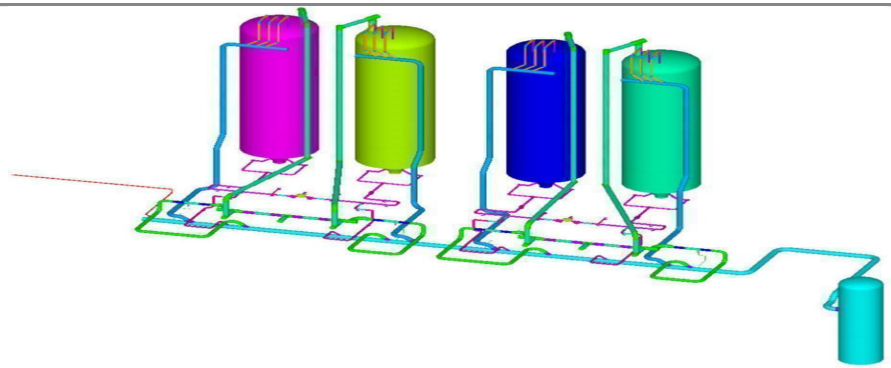


Effect of Residual Stress on Fatigue Life

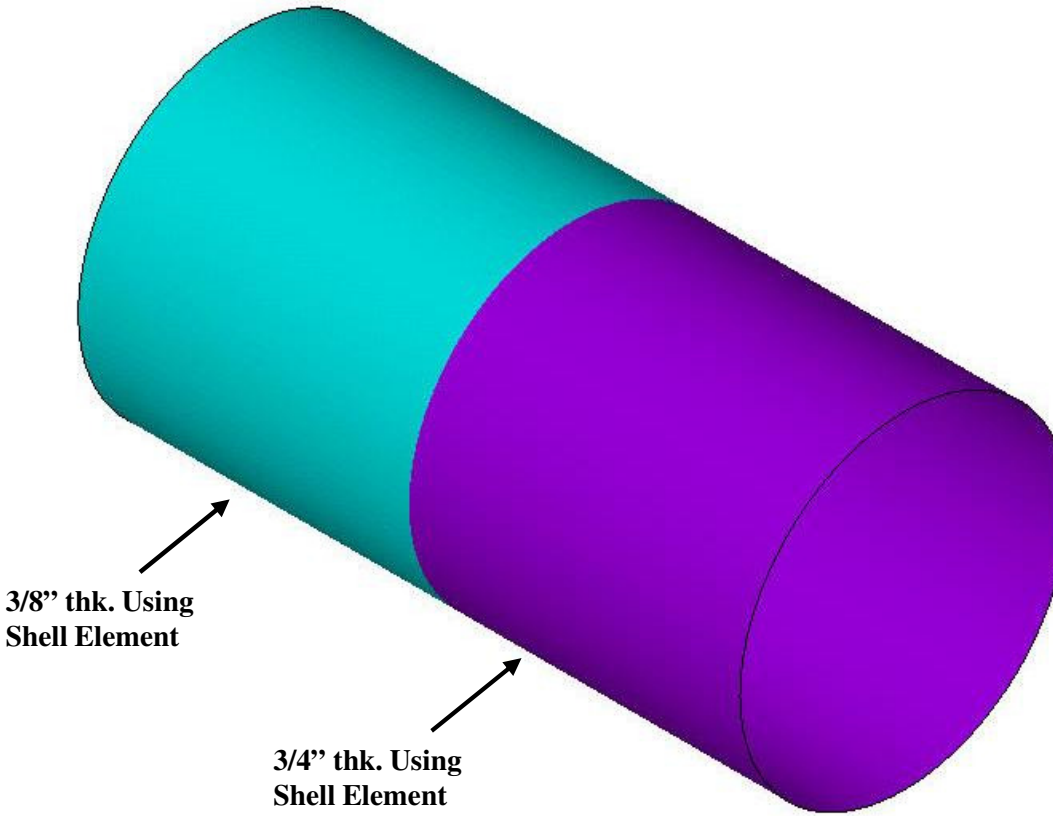


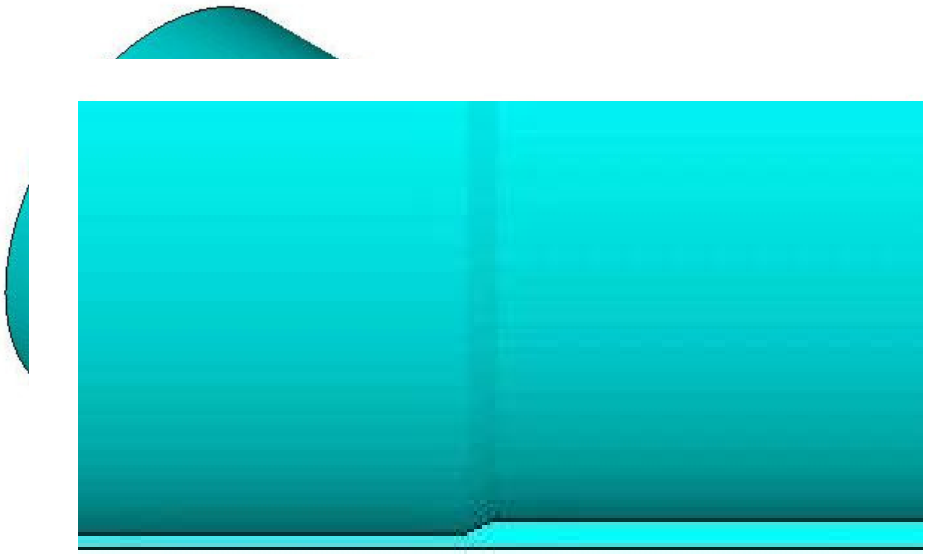
Effect of Pipe Thickness on Fatigue Life





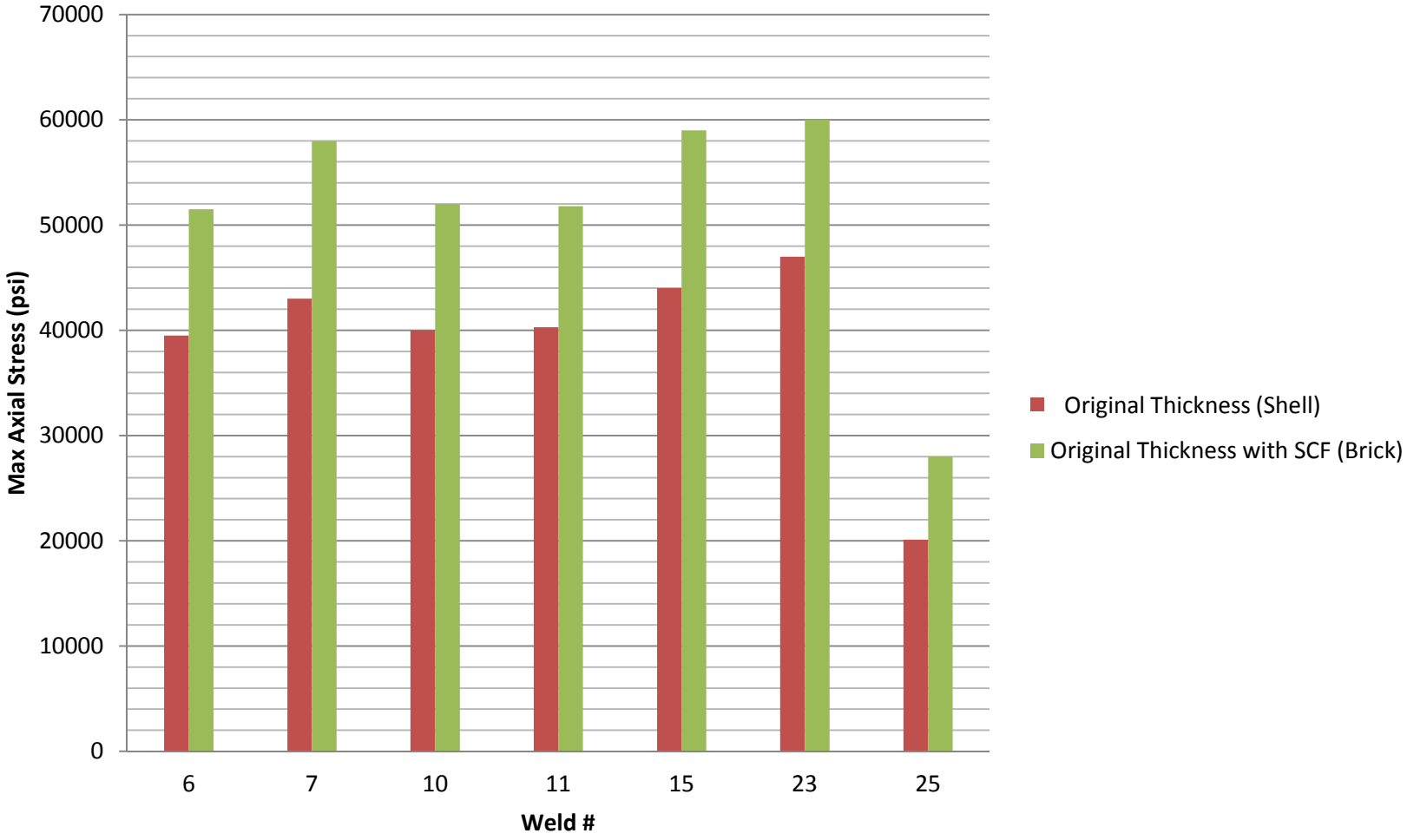
Effect of Stress Concentration



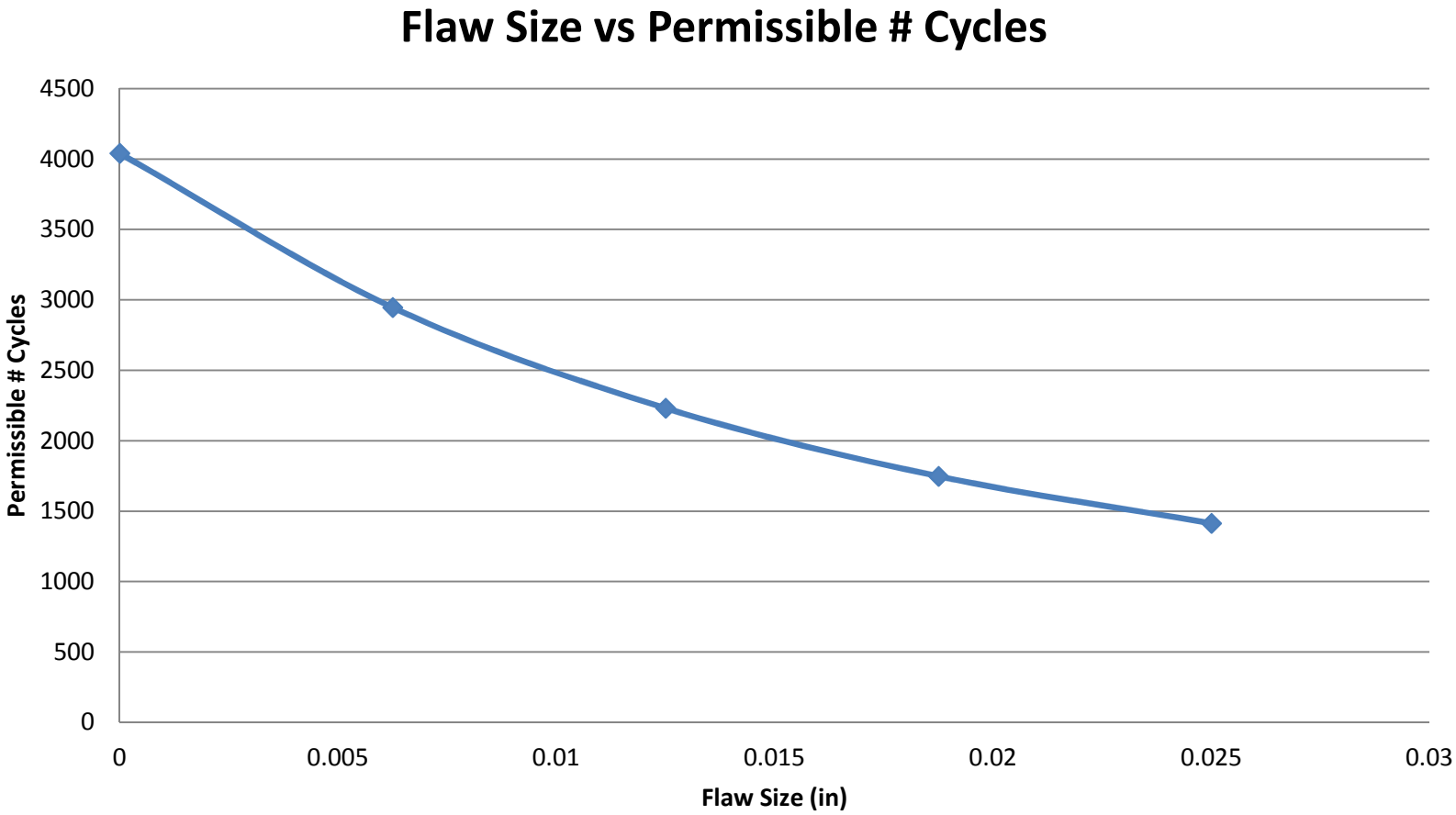


Brick Element

Pipe Thickness Versus Axial Stress



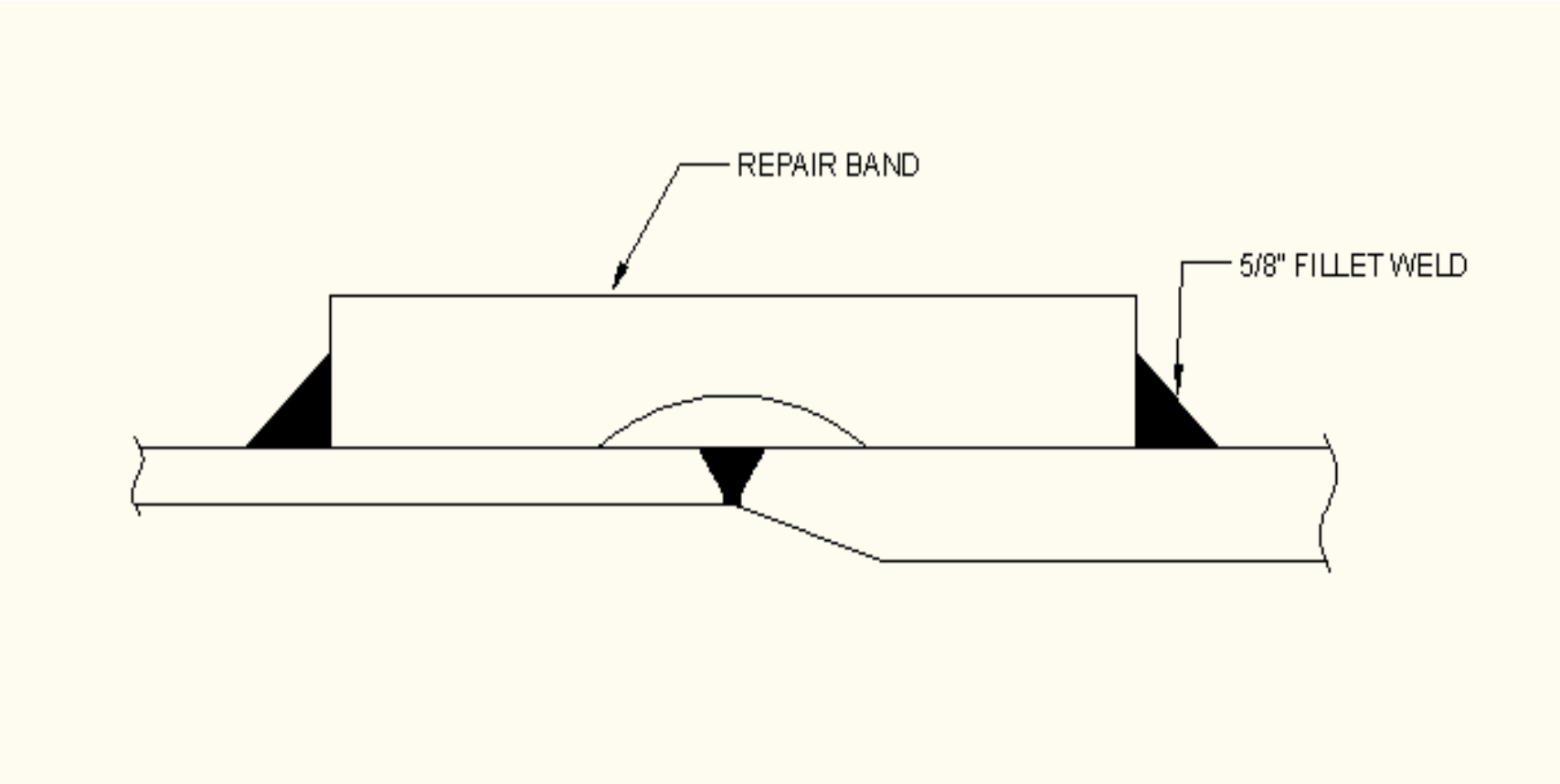
Effect of Weld Quality on Fatigue Life



Potential Solutions

- Before crack formation:
  - The addition of hot oil to the blowdown header
    - The oil had negligible effect on the metal temperature downstream at the overhead vapor inlets.
  - Insulating the Blowdown Line
    - Insulation would not appreciably reduce the amount of condensate in the header.
    - Cost would be prohibitive.
- After crack formation:
  - Installation of bands and clamps

Temporary Repair Band



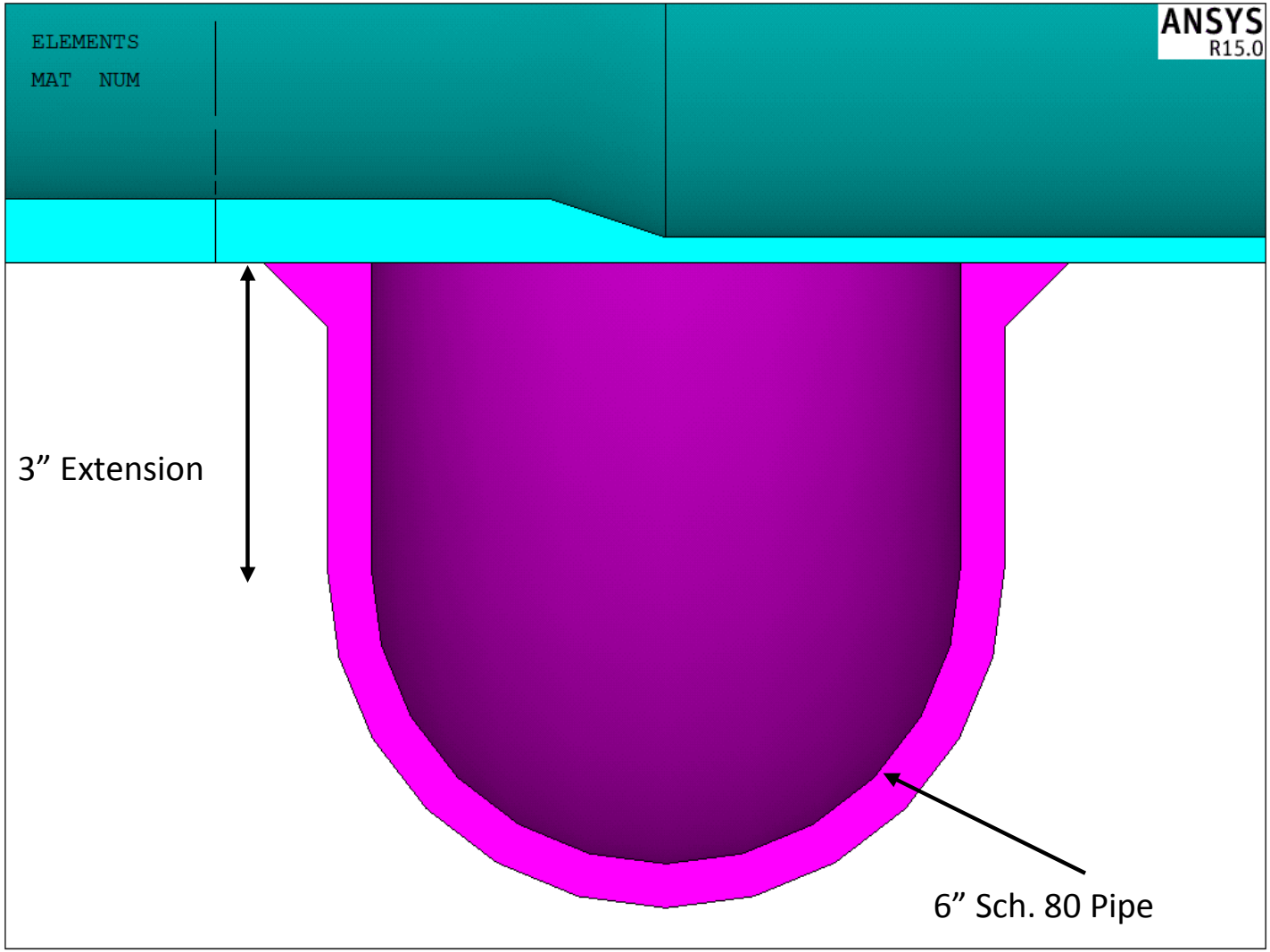
Band Design

- The band design initially used on the header (6” flat band) resists the deformation of the pipe and causes high stresses in the band-to-header fillet welds.

- An alternative band design was developed to reduce the stresses in the band and the header by remaining more flexible

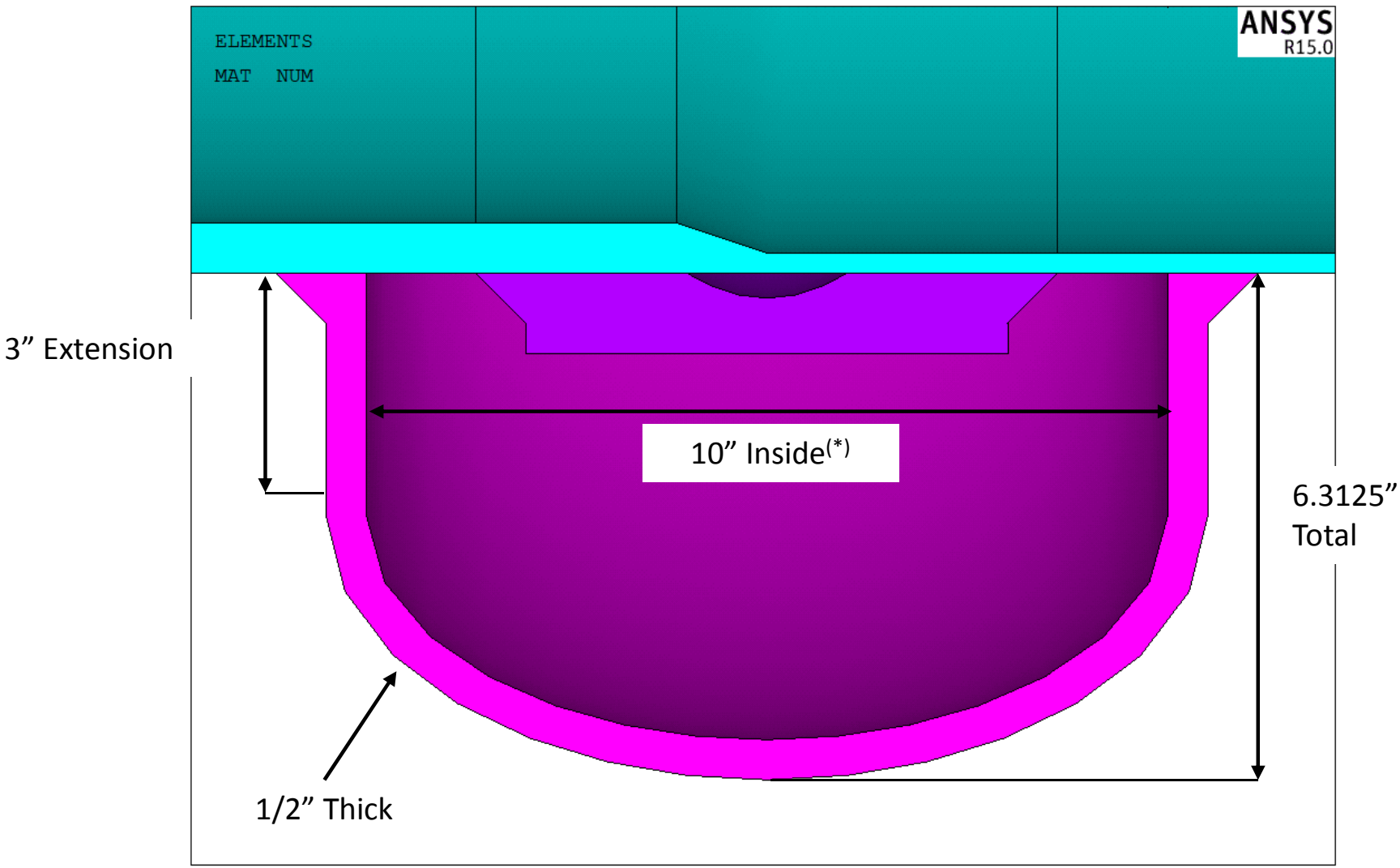
- The increased flexibility helped reduce stresses at many locations and will provide 20 year fatigue life

Geometry of the Long Term Band



*Typical band geometry utilized where interferences did not exist

Modified Elliptical Design – Long Term Repair



*Dimension chosen to keep the band welds out of the heat affected zone

Prevention of Cracking in Blowdown Headers

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- Process Improvement
  - Redirecting the condensate through a different line
  - Minimize the amount of steam
- Fabrication Quality
  - Use uniform pipe thickness throughout to avoid pipe eccentricities
  - Girth welds to be ground smooth, inside and outside surface, to minimize stress concentration.
  - Weld quality and weld inspection to be in accordance with ASME Section VIII Division 2 Tables 5-11 and 5-12.
  - Increase header slope
- Proactive Measures
  - Monitoring
    - Temperature data should be collected (using IR or thermocouples) at critical locations on the header
  - Install bands at critical welds

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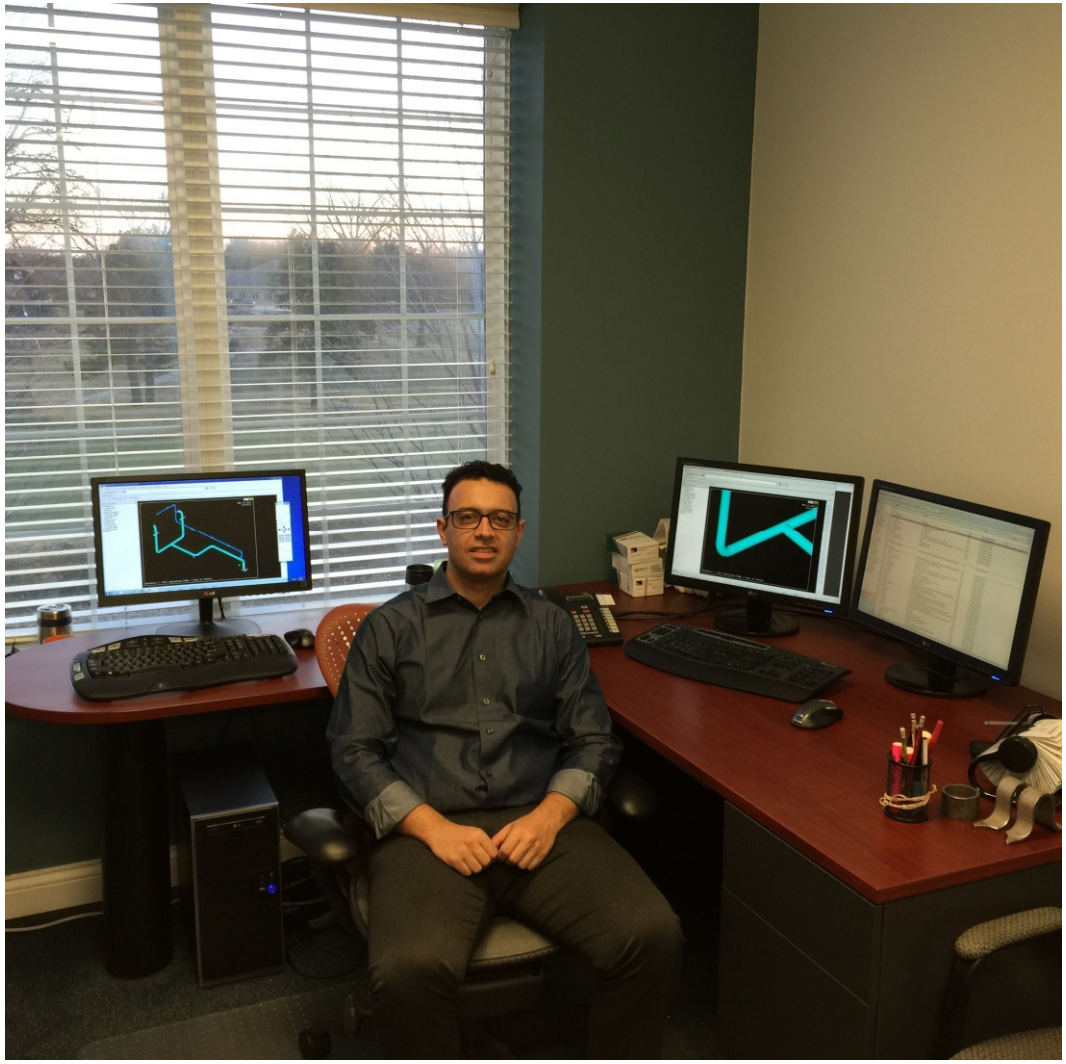

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