

Used Fuel Disposition Campaign

Residual Stress Measurements from the SNL Mockup Container

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Sandia National Laboratories

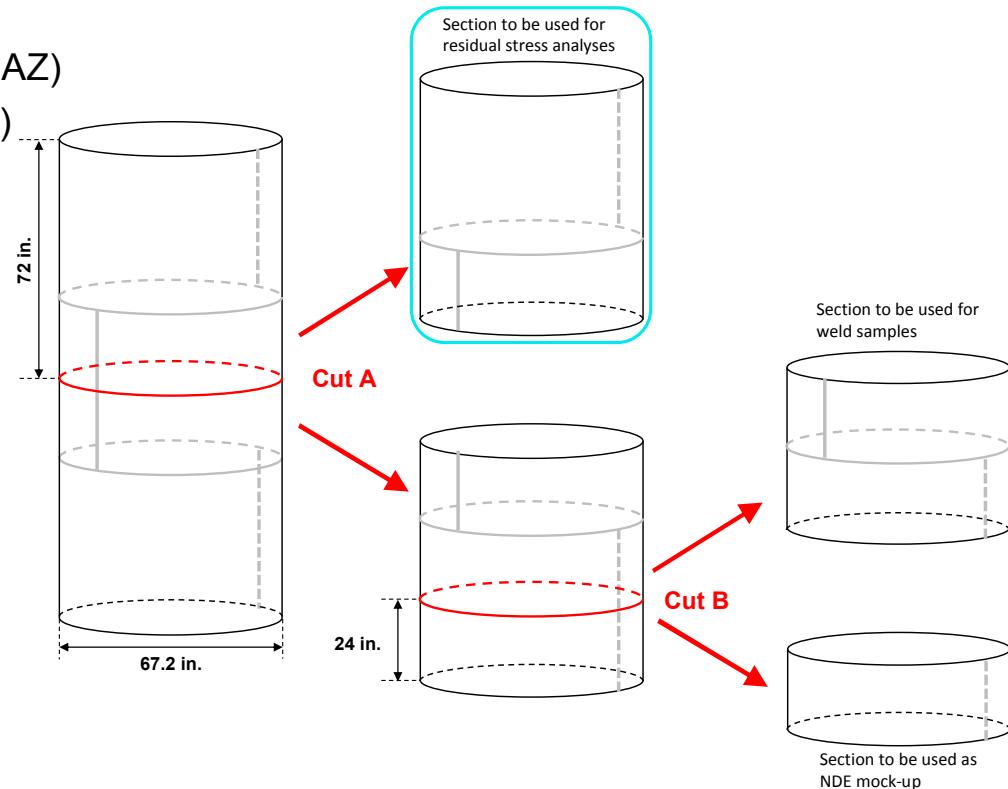
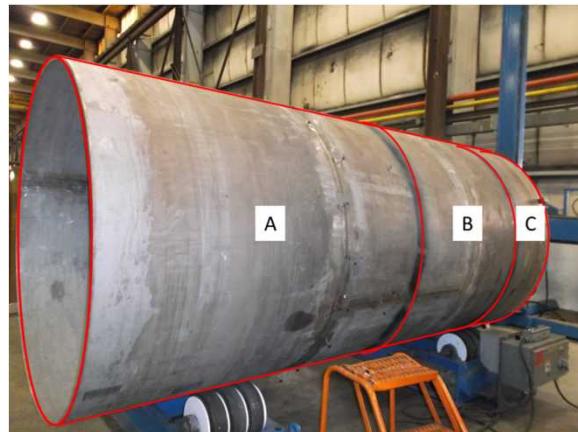
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EPRI ESCP Meeting

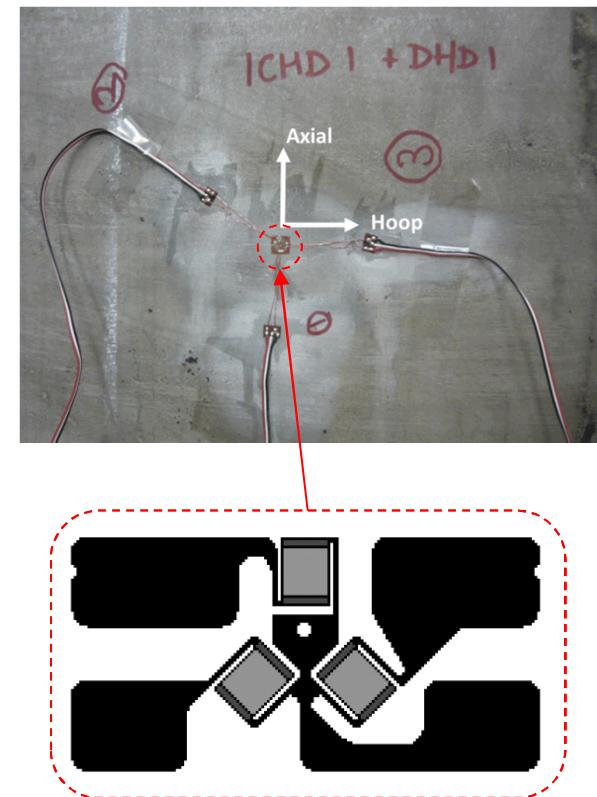
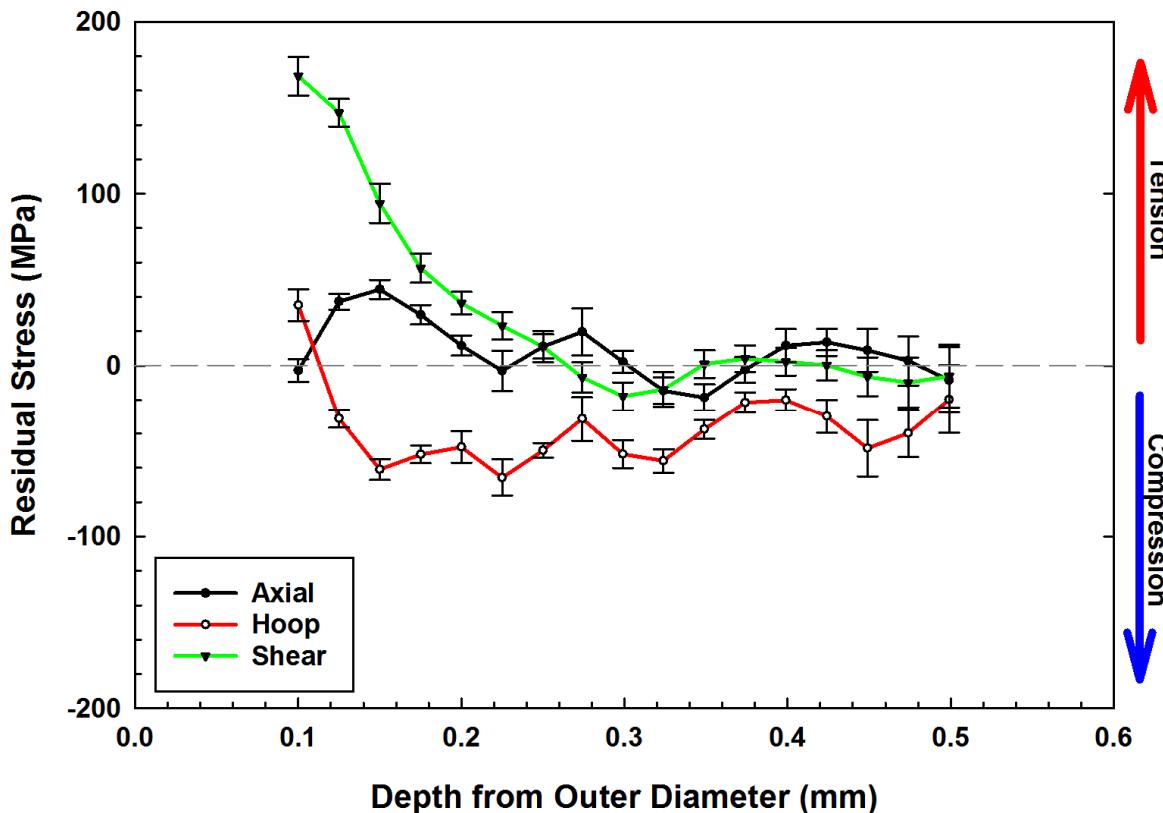
December 2nd, 2015

- **Goal:** Establish if there is sufficient through-wall tensile stresses to support SCC crack propagation
- Full-scale mockup container simulating a NUHOMS 24P container (produced at Ranor using procedures established for containers at Calvert Cliffs ISFSI)
- Series of key areas are being assessed
 - Base metal (far from welds)
 - Circumferential Weld (Centerline and HAZ)
 - Longitudinal Weld (Centerline and HAZ)
 - Weld Repair



Near Surface Stresses Assessed Via Incremental Center Hole Drilling

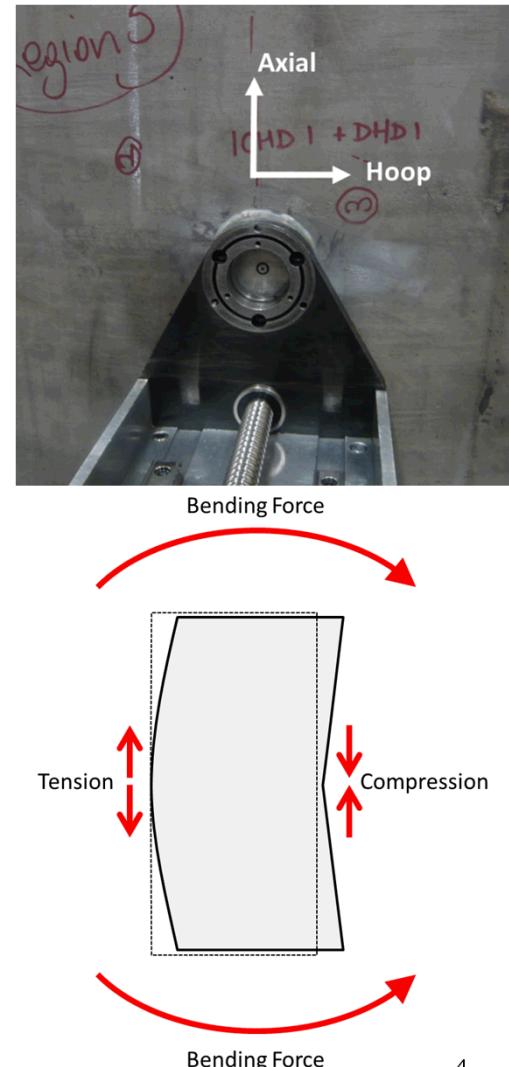
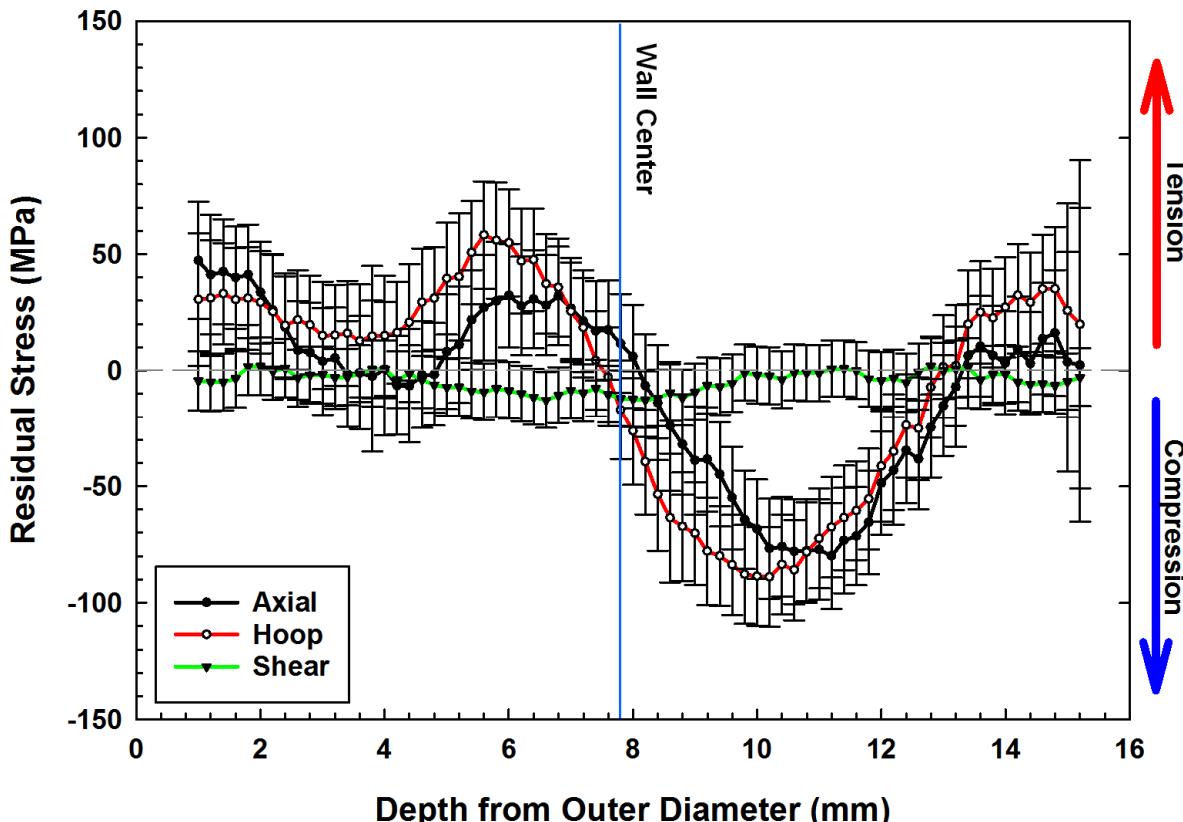
- DHD is not able to resolve strains accurately very near the metal surface (first 0.5mm or so)
- iCHD used to make these measurements



Residual Stresses in the Base Metal Far from Welds

■ Stress state consistent with forming process

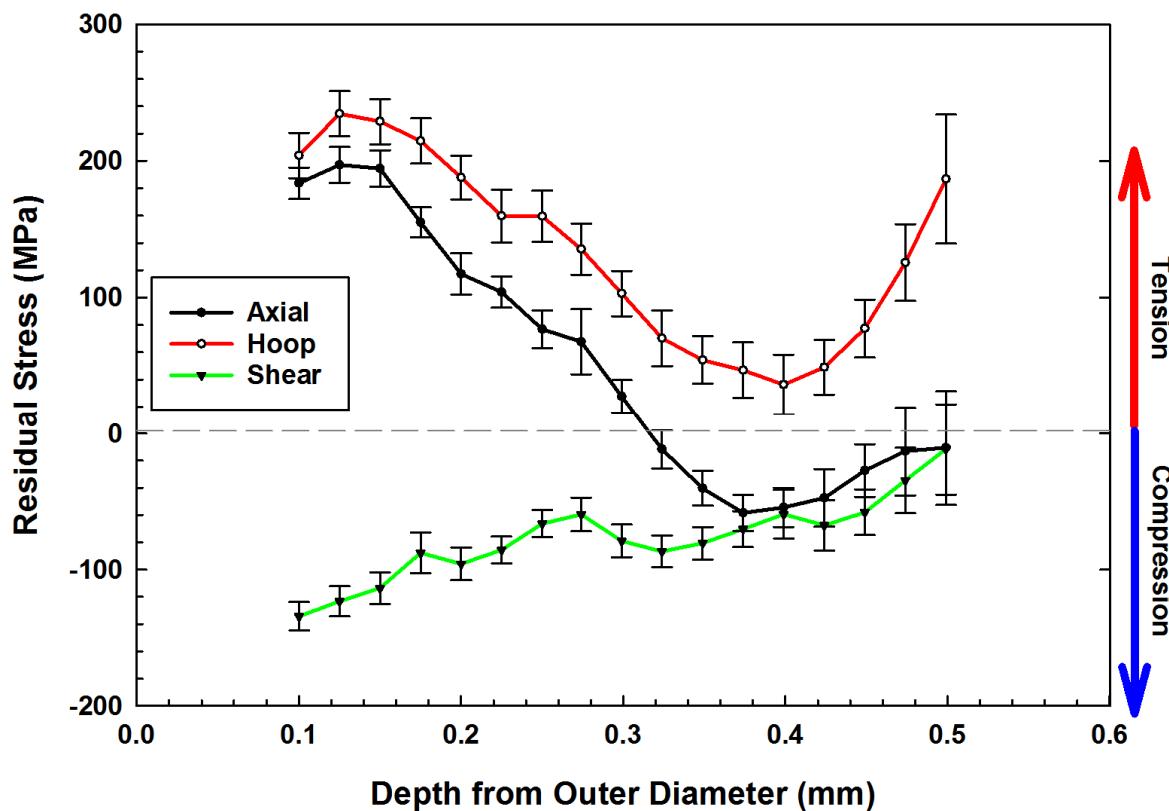
- Stresses on OD tensile
- Stresses in ID compressive
- Consistent with bending process used to form cylinder



Note – locations where temporary supports have been welded and removed will be different...

Residual Stresses in Circumferential Weld (Centerline)

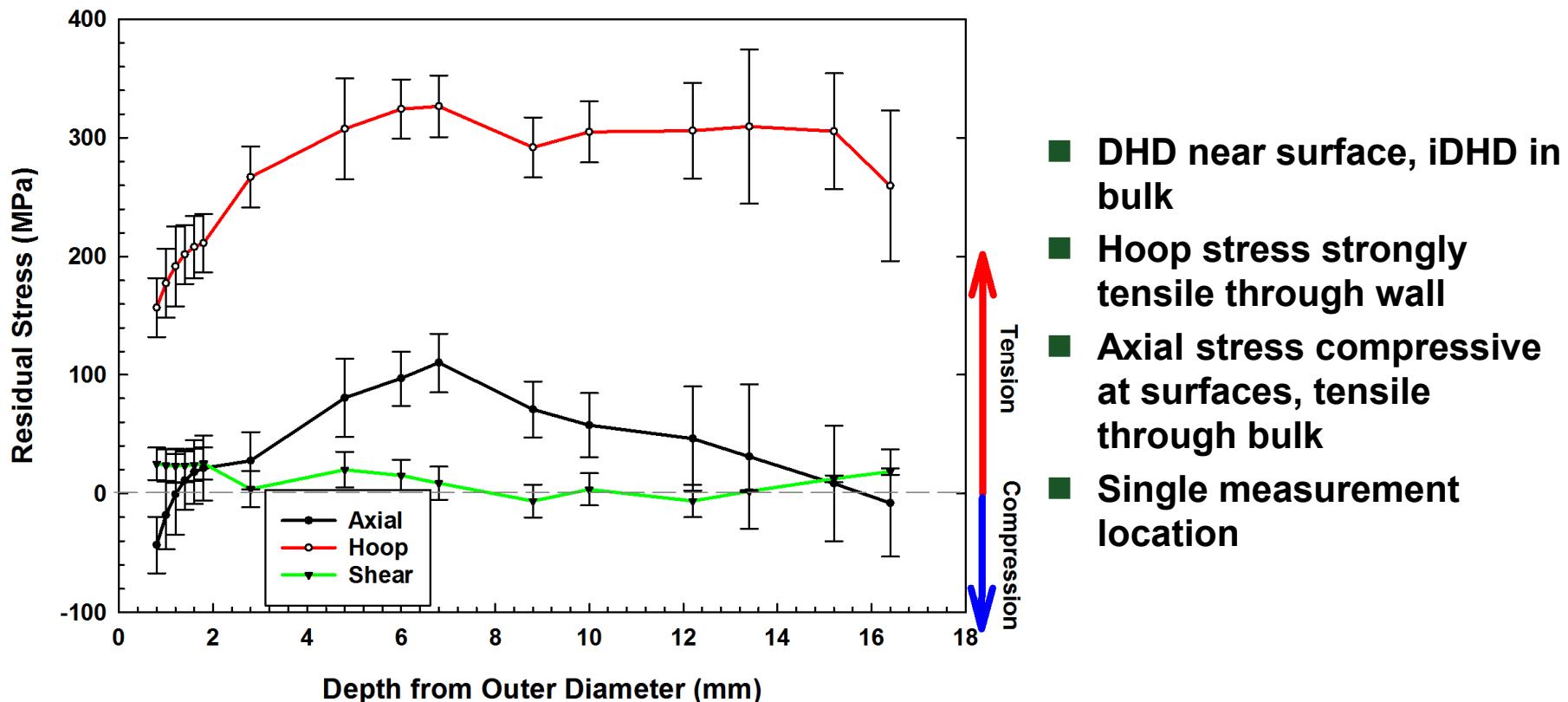
- iCHD used to assess stress state in region very close to the surface of the container (on the OD)



- Both axial and hoop stresses strongly tensile near surface
- iCHD measurements likely to exhibit some positional variability
 - Single test location
 - Consider qualitatively

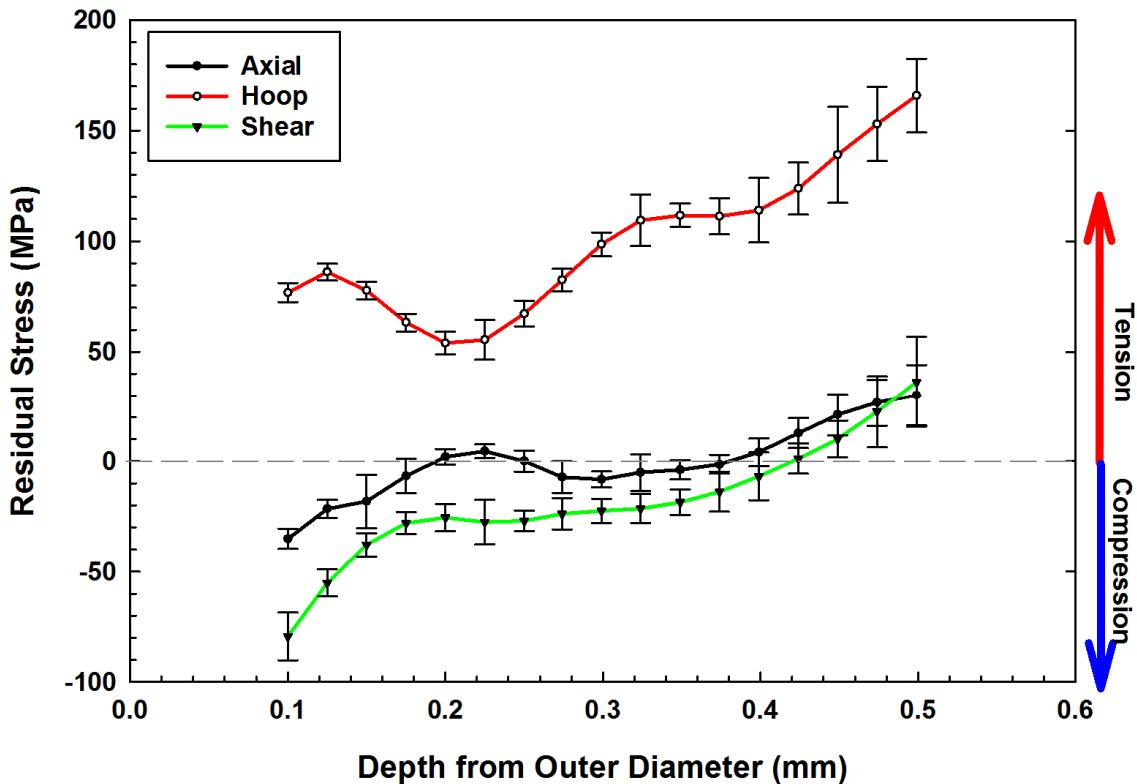
Residual Stresses in Circumferential Weld (Centerline)

- Due to large stresses present in weld, material will yield as the core is cut for traditional DHD – as a result, incremental DHD measurements are made



Residual Stresses in Circumferential Weld (HAZ)

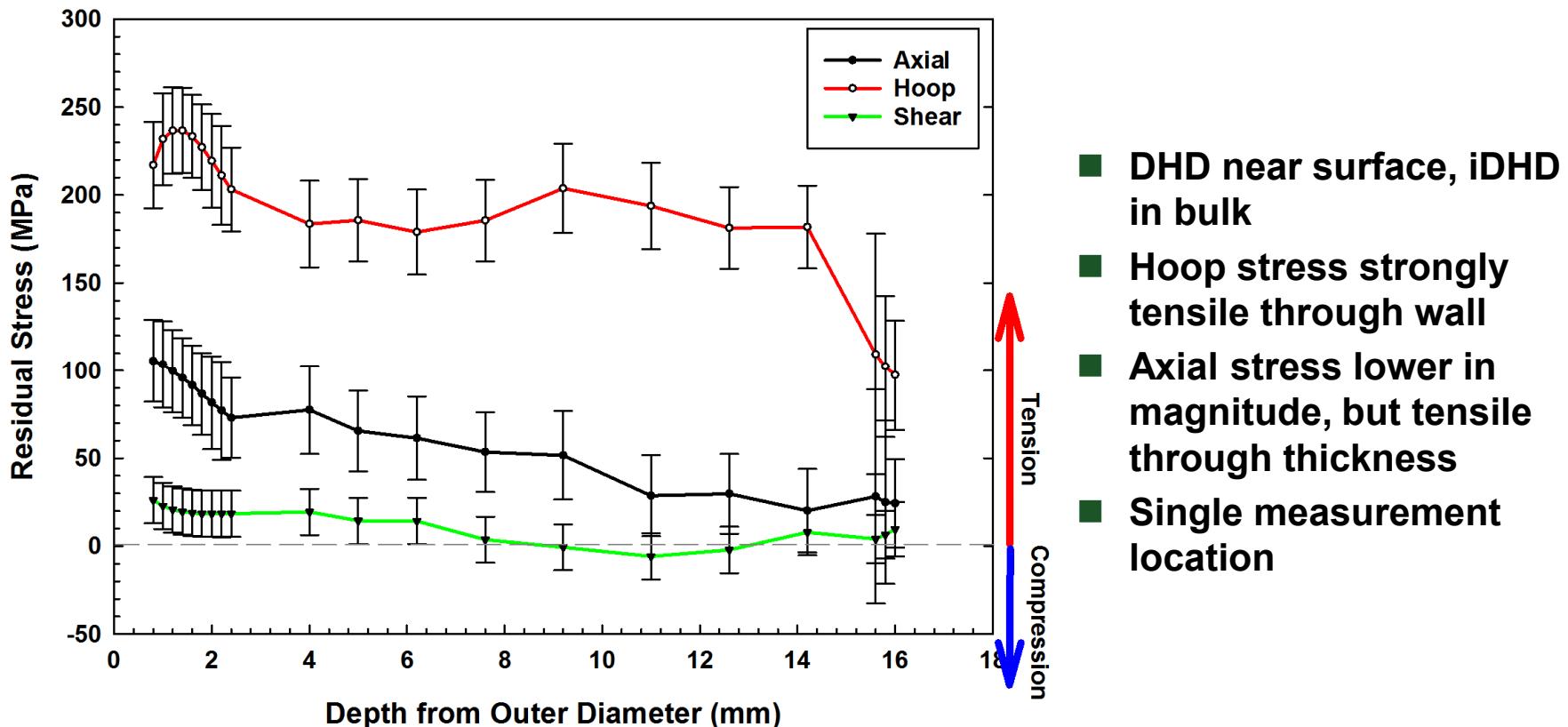
- Looking at 4mm from weld toe
- iCHD used to assess stress state in region very close to the surface of the container (on the OD)



- Hoop stress tensile at surface, increasing with depth
- Axial stress low and slightly compressive, becoming tensile with depth
- iCHD measurements likely to exhibit some positional variability
 - Single test location
 - Consider qualitatively

Residual Stresses in Circumferential Weld (HAZ)

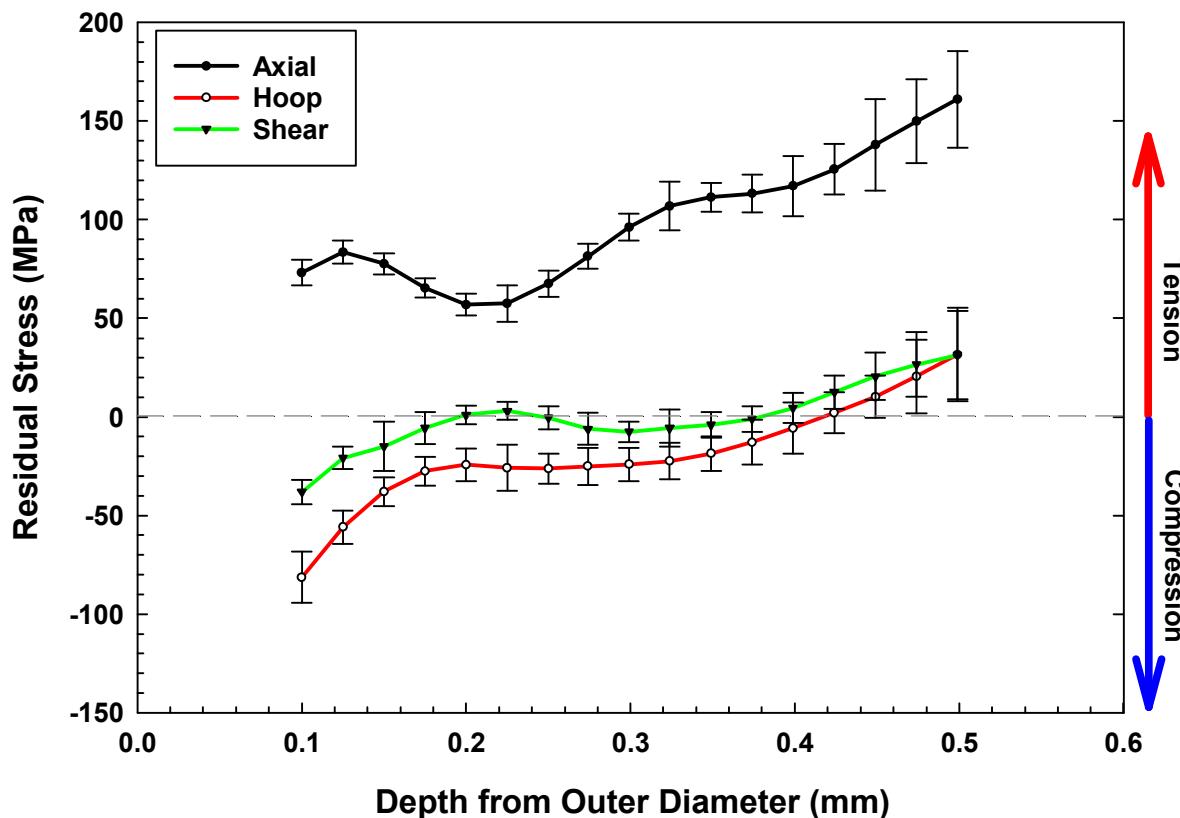
- Due to large stresses present in weld, material will yield as the core is cut for traditional DHD – as a result, incremental DHD measurements are made



- DHD near surface, iDHD in bulk
- Hoop stress strongly tensile through wall
- Axial stress lower in magnitude, but tensile through thickness
- Single measurement location

Residual Stresses in Longitudinal Weld (Centerline)

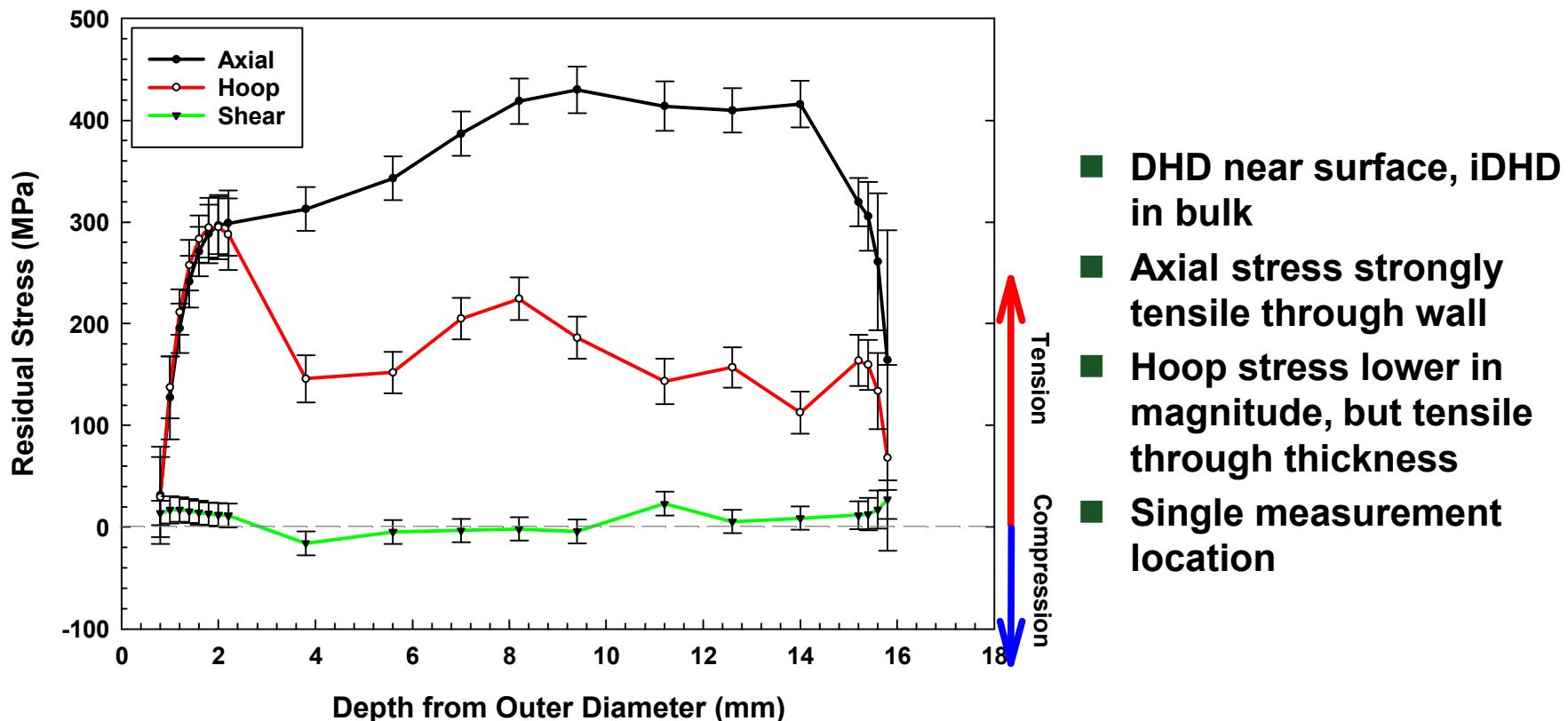
- iCHD used to assess stress state in region very close to the surface of the container (on the OD)



- Axial stresses strongly tensile near surface
- iCHD measurements likely to exhibit some positional variability
 - Single test location
 - Consider qualitatively

Residual Stresses in Longitudinal Weld (Centerline)

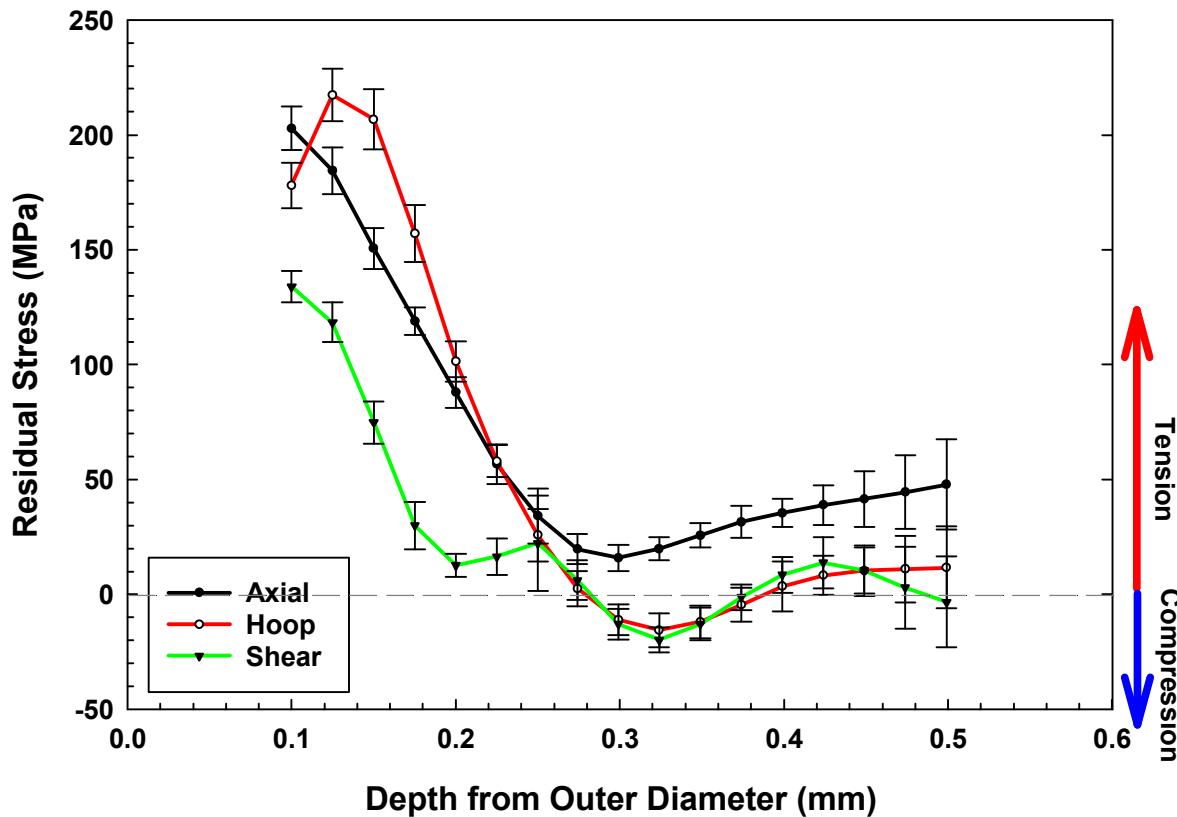
- Due to large stresses present in weld, material will yield as the core is cut for traditional DHD – as a result, incremental DHD measurements are made



- DHD near surface, iDHD in bulk
- Axial stress strongly tensile through wall
- Hoop stress lower in magnitude, but tensile through thickness
- Single measurement location

Residual Stresses in Longitudinal Weld (HAZ)

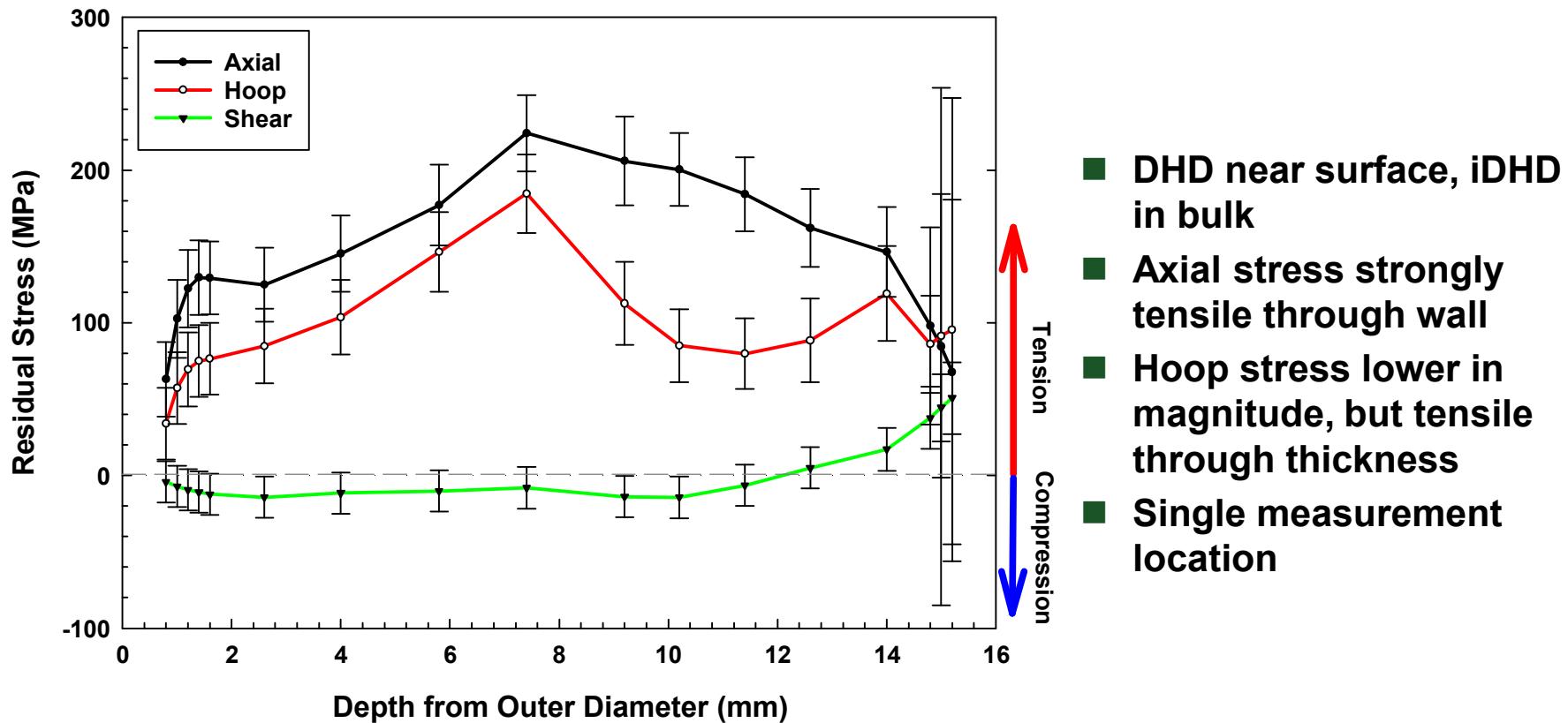
- Looking at 4mm from weld toe
- iCHD used to assess stress state in region very close to the surface of the container (on the OD)



- Both Axial and Hoop stress tensile at surface, decreasing with depth
- iCHD measurements likely to exhibit some positional variability
 - Single test location
 - Consider qualitatively

Residual Stresses in Longitudinal Weld (HAZ)

- Due to large stresses present in weld, material will yield as the core is cut for traditional DHD – as a result, incremental DHD measurements are made



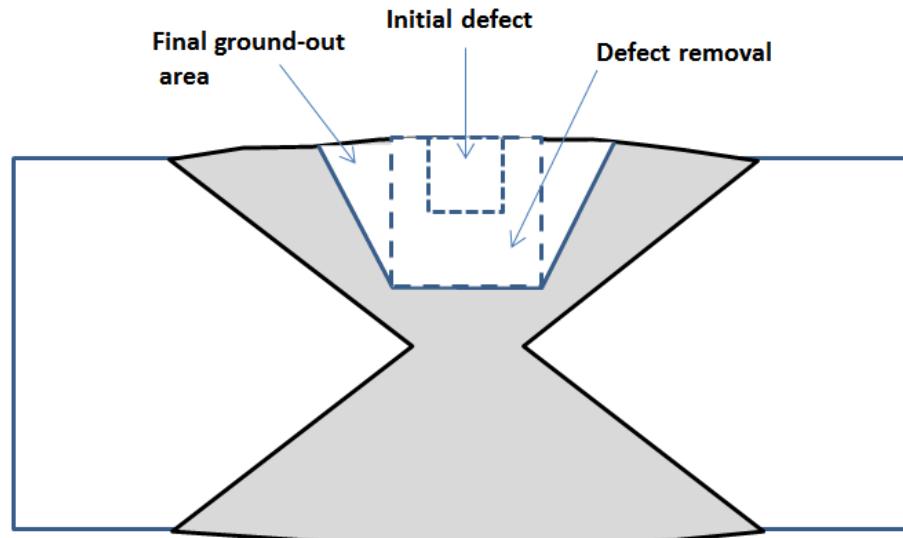
- DHD near surface, iDHD in bulk
- Axial stress strongly tensile through wall
- Hoop stress lower in magnitude, but tensile through thickness
- Single measurement location

- **Residual stress measurements in progress at VEQTER – anticipated to complete in early 2016**
 - Repair region
 - Contour measurements
 - Stress relaxation during sample cutting – how small can the coupons be?
- **Are there regions which we are not covering that should be covered?**
 - Now is the time to speak up if there is data you need!
- **Once stress analyses are complete, container will be subdivided and distributed**
 - Of considerable interest to UFD, NEUP, and EPRI
 - Information will be solicited from each group to identify where samples are needed and the data that they will yield
 - Prioritized list of coupons will be assembled, then material will be distributed

Backup Slides

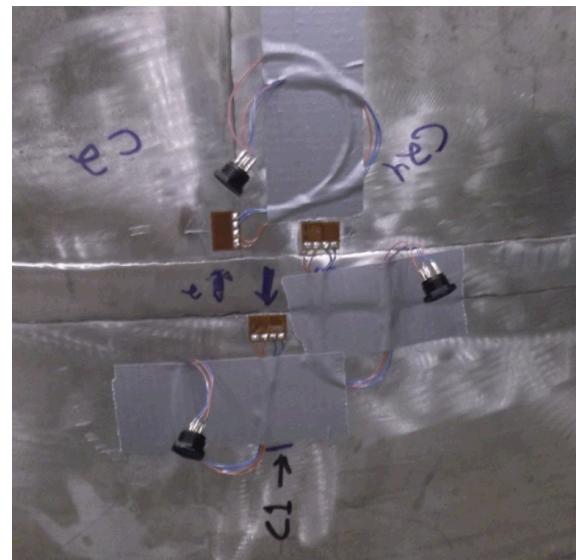
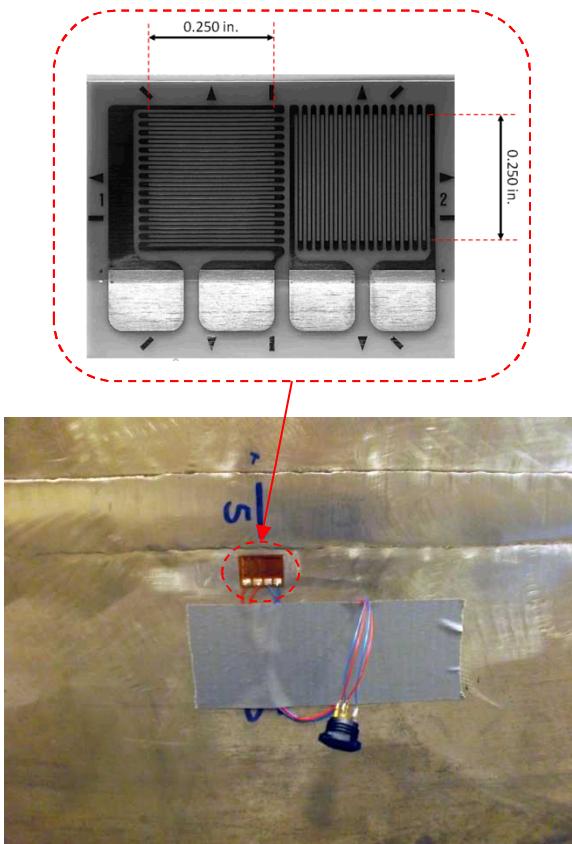
Weld Repairs on Circumferential Welds

- Welds were fabricated via submerged arc welding using a well defined protocol/schedule – very low defect density
- Manufacturer (Ranor) created a repair typical for this type of weld (simulating a local defect due to entrained slag at a weld stop/start point, etc.)
- mock defect into the container by drilling a 1/8" diameter hole partially into the center of the weld root. They then went back and “removed” that defect, by drilling out additional material using a 1/4" drill, after which they ground the edges of the site such that the opening of the hole was approximately 0.5" wide. Repair completed via TIG.



Strain Gauge Positioning

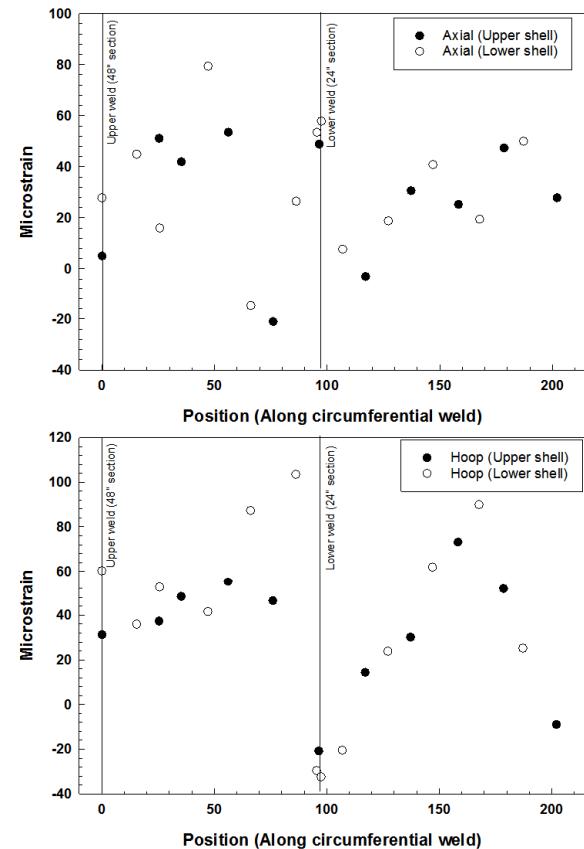
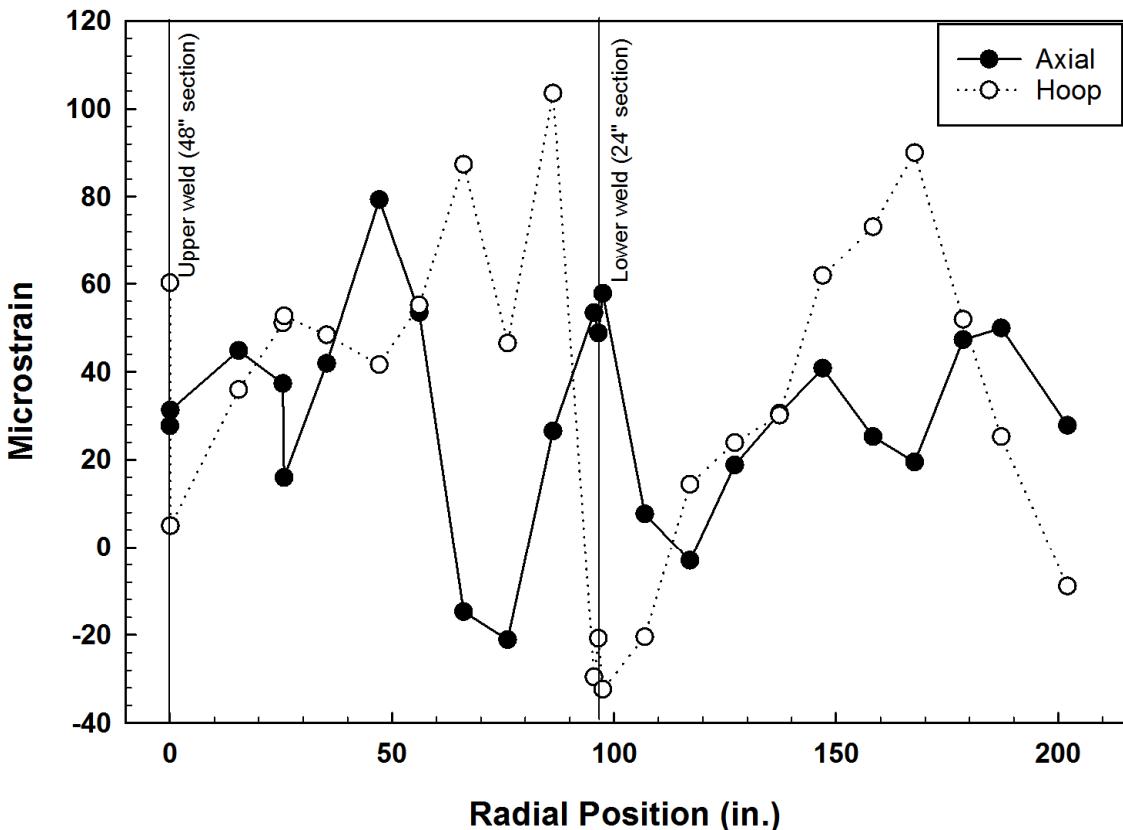
- Gauges positioned such that one grid was parallel and one perpendicular to the weld
- Positioning required that a region with no heterogeneities be identified



Surface Strain Gauge Data Circumferential Welds

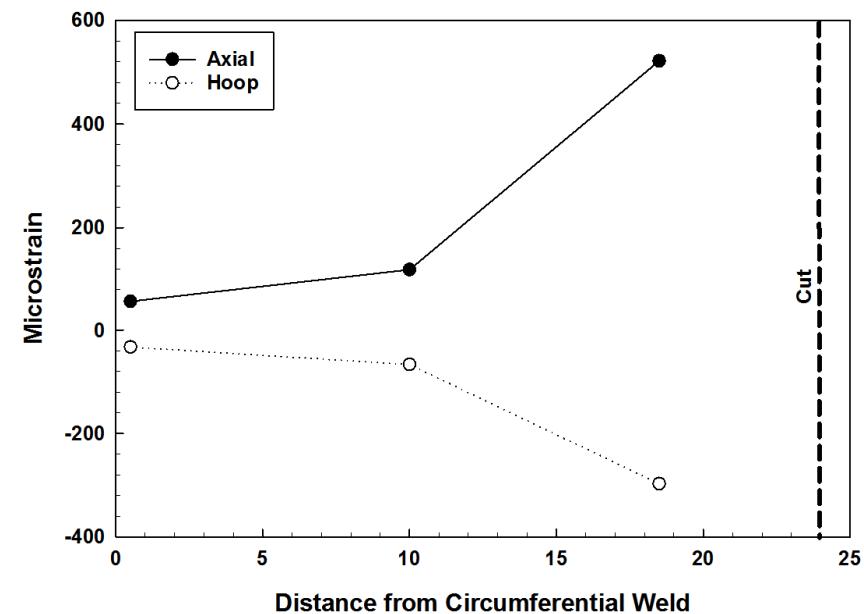
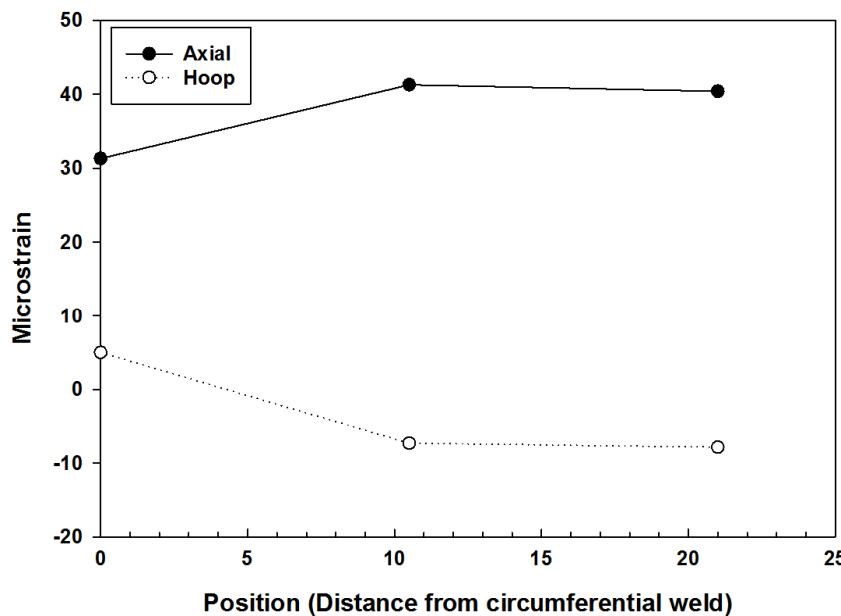
■ Minimal impact of cutting operation on the circumferential weld

- Also assessed if measurements made on the upper vs. lower shell mattered (cut was on the lower shell)

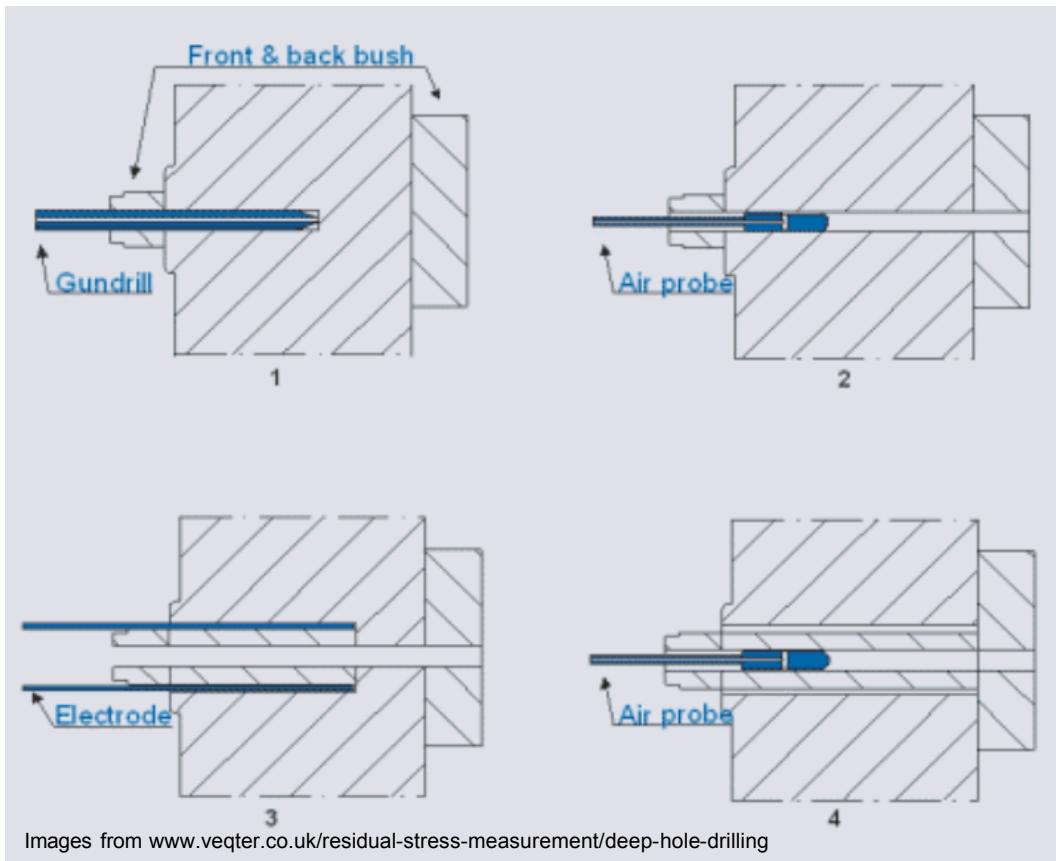


Surface Strain Gauge Data Longitudinal Welds

- **Upper weld (shell which was not cut) not disturbed by the cutting operation**
- **Lower weld (shell which was not cut) impacted by cut**
 - Some deformation of the cylinder occurred near the cut, despite the high wall thickness



Deep Hole Drilling



- Hole precisely drilled through region to be characterized
- Air probe used to measure the inner diameter of the hole as a function of position
- EDM used to cut core around the hole, relaxing the constraint placed by the surrounding material
- Air probe used to measure the resulting distortion of the hole inner diameter
- Stress state calculated from displacements
- Complicated when stresses are high (requires modified technique)

- Get one dimensional map of initial stress state without cutting up structure
- Semi-destructive, labor intensive (\$)