SAND2014-20301PE

Used Fuel Disposition Campaign

Interim Storage Canister Mock-Up

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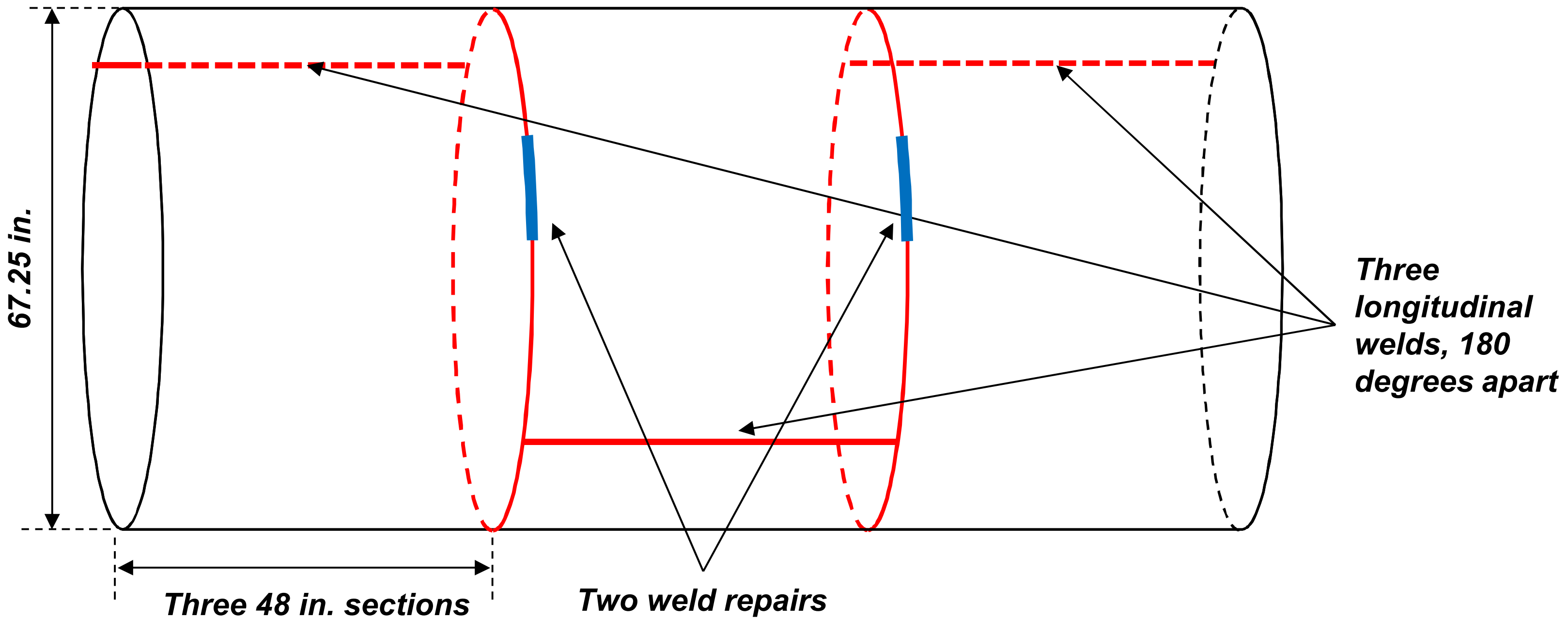
Full Scale Mock-Up Assembled to Directly Measure Residual Stresses



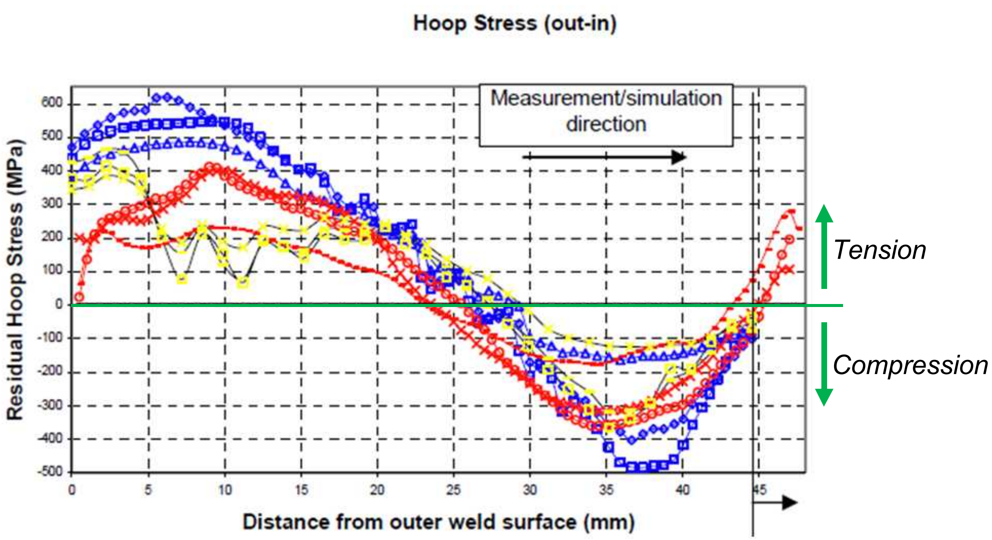
- ***Wall material: 304 SS welded with 308 SS***
- ***Wall thickness, overall diameter, weld joint geometry: standard geometry for NUHOMS 24P***
- ***Welds:***
  - *Full penetration and inspected per ASME B&PVC Section III, Division 1, Subsection NB (full radiographic inspection)*
  - *Double-V joint design, Submerged Arc welding process*

Weld Design

- **Longitudinal welds**
  - Double-V edge preparation
  - Submerged Arc welding technique
  - 3 passes on the ID, 4 passes on the OD
- **Circumferential welds**
  - Double-V edge preparation
  - Tacked with GTAW
  - Submerged Arc welding technique for primary passes
  - 3 passes on the ID, 4 or 5 passes on the OD
- **Repair welds**
  - Section of weld removed (indications made on container wall 6” from weld to indicate start and finish of repaired region)
  - Weld repair done on OD via GTAW technique
- **Full radiographic inspection done of all welds and repaired regions**
  - No indications observed on any welds

Where do we need to measure the residual stress?

- **Is there sufficient residual stress within the container wall to support propagation of a through-wall crack?**
- **Many complicating factors**
  - Weld procedure (start/stop, technique, etc.)
  - Weld repairs



K. Ogawa, et al, "Measuring and Modeling of Residual Streses in Stainless Steel Girth Welds", PVP 2008 61542, July 27-31, 2008, Chicago, IL.

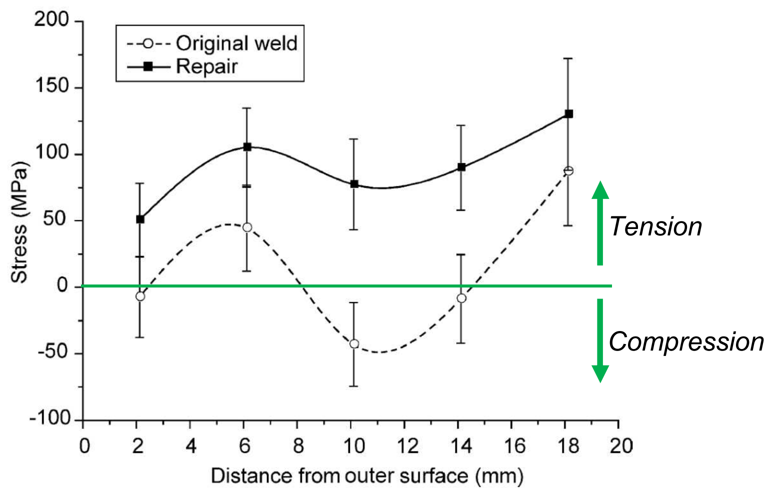


Fig. 14. Hydrostatic residual stress profile (17.5 mm from weld centre-line).

L. Edwards, et al, "Direct Measurements of the Residual Stresses near a "Boat-Shaped" repair in a 20mm Thick Stainless Steel Tube Butt Weld", International Journal of Pressure Vessels and Piping, 82 (2005), pp. 288-298

Residual Stress Measurement

- **Residual stress state will be high in the weld due to the constraint imposed by the cylindrical geometry of the mock-up**
- **Removal of the mechanical constraint (i.e., cutting up the container) will relax the residual stress state at the weld**
  - Want to make measurements in the undisturbed state (or have a way to reference back to that state)
- **Variety of techniques are available and being considered for the analysis of the container**
  - Deep hole drilling
  - Contour measurement
  - Neutron diffraction
- **There are advantages and disadvantages for each method**
  - Most require the material to be sectioned (stress relaxation can be monitored)
  - A combination of techniques is needed to assess the stress state

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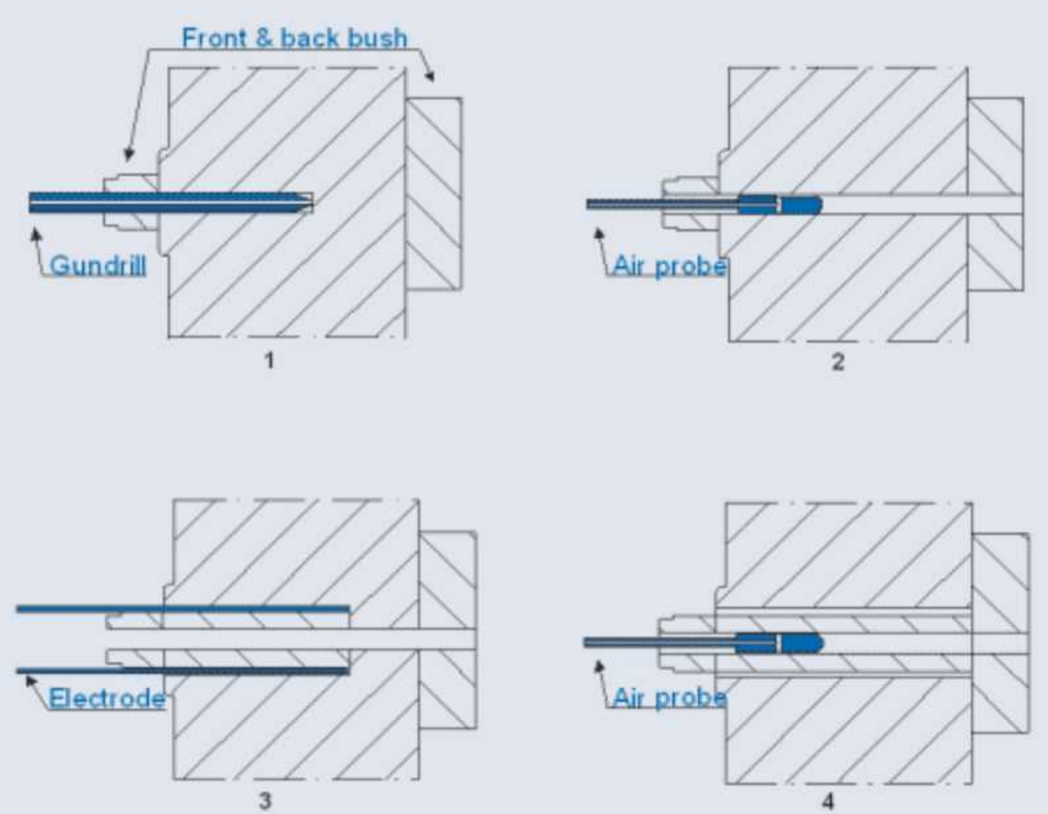
Deep Hole Drilling



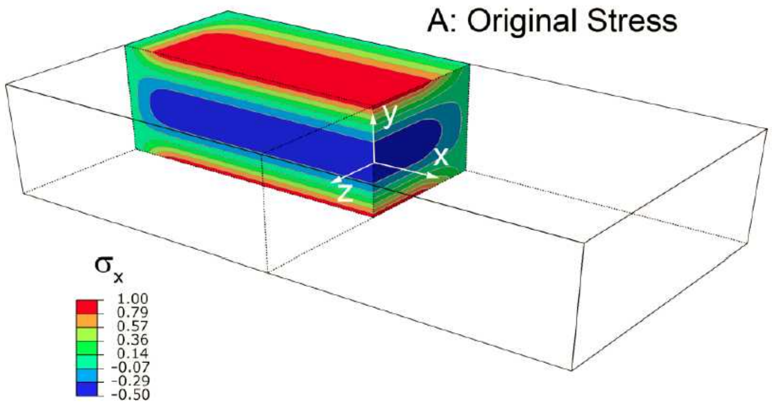
Images from www.veqter.co.uk/residual-stress-measurement/deep-hole-drilling

- **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)**

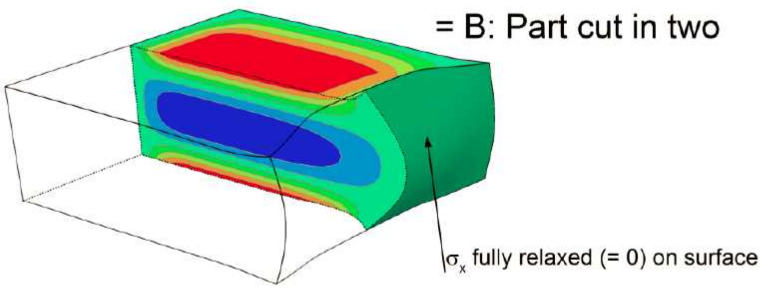
- Get one dimensional map of initial stress state without cutting up structure
- Semi-destructive, labor intensive ($)

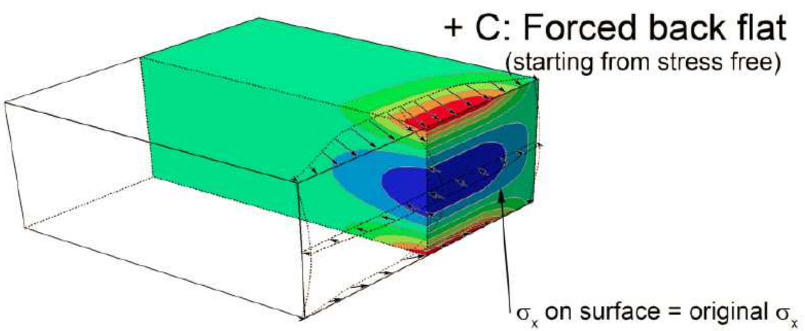
The Contour Method

Start with material containing a residual stress



Cut across region to be characterized – material distorts due to loss of constraint





Based upon the distortion of the cut surface, the original stress state can be calculated

M. B. Prime and A.T. DeWald, 2013, "The Contour Method," Chapter 5 in Practical Residual Stress Measurement Methods, G. S. Schajer, (ed.), Wiley-Blackwell, pp. 109-138.

- Get two dimensional map of initial stress state (can combine with XRD for 3-D)
- Destructive, requires careful monitoring as the sample is sectioned

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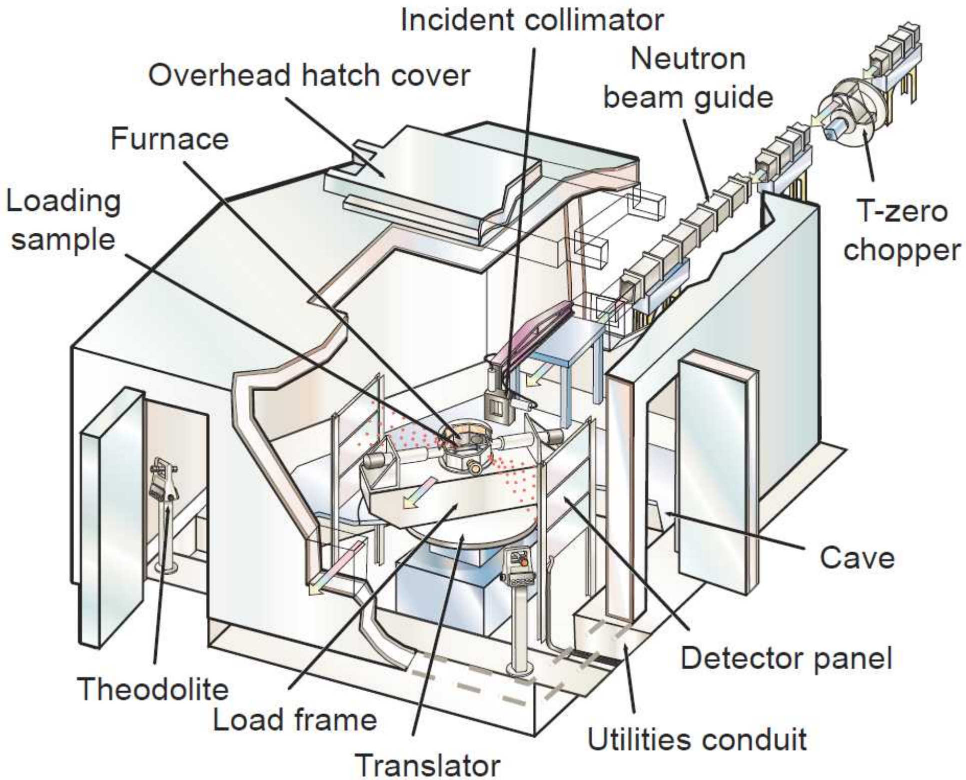
Neutron Diffraction



Los Alamos Spectrometer for Materials Research at Temperature and Stress (SMARTS)

- Material is placed in a beam of collimated neutrons
- Diffracted neutrons used to measure lattice spacings of the stressed sample
- Diffracted neutrons then used to measure lattice spacings of an unstressed sample
- Based upon the distortions of the stressed sample relative to the unstressed sample, the stress state can be calculated

- Nominally non-destructive, but sample geometry may be limited
- Requires unstressed sample of same composition and microstructure as a baseline
- Time intensive process

Current plan for residual stress characterization

- **Container will be cut in half (strain gauges used to monitor any relaxation)**
  - One half used to perform deep hole drilling and contour measurements (will be cut up)
  - One half used for neutron diffraction (will be cut as little as possible)
- **Circumferential weld**
  - Deep hole drilling through fusion zone and heat affected zone (2 measurements)
  - Contour method map across the weld.
  - Neutron diffraction map across the weld
- **Repaired region (on circumferential weld)**
  - Deep hole drilling through fusion zone and heat affected zone (2 measurements)
  - Contour method map across the weld.
  - Neutron diffraction map across the weld
- **Longitudinal weld**
  - Contour method map across the weld.
  - Neutron diffraction map across the weld
- **Base metal (far from any welds)**
  - Deep hole drilling (1 measurements)

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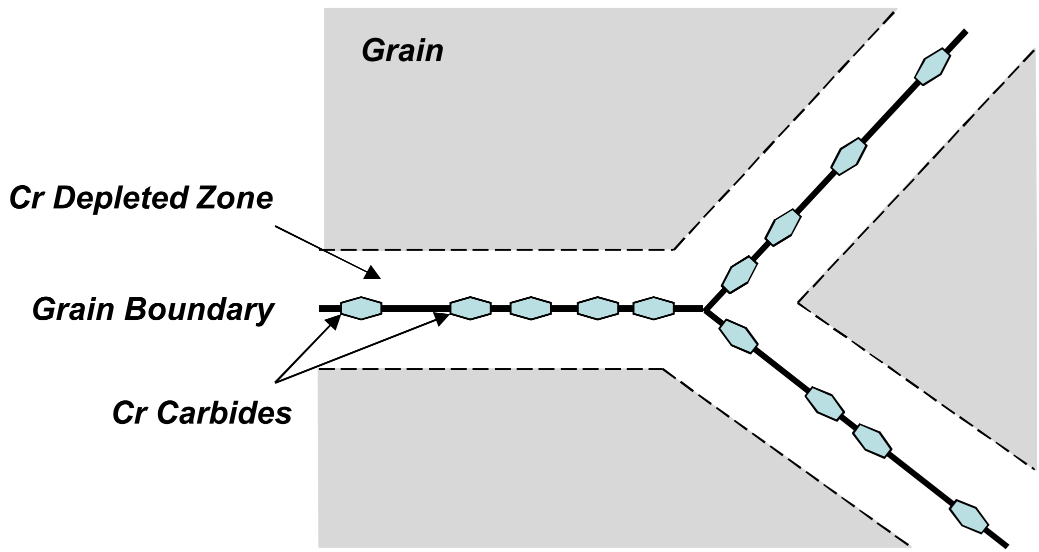
What about sensitization in the weld HAZ?



- **Welding carbon bearing austenitic stainless steels such as 304 will result in sensitization**
- **Increased susceptibility to localized corrosion and SCC**
  - Active path along grain boundaries
- **Sensitization of HAZ will be mapped through thickness via double loop EPR**

Summary and Future Direction

- **Large existing fleet of storage containers made from welded 304SS, located at both marine and inland sites**
  - Material known to be susceptible to SCC
  - Chloride bearing salts likely in some locations
  - Residual stresses at welds could be significant and tensile in nature

- **Moving Forward, research will focus on**
  - Understanding potential brine chemistry on container surface
  - Quantifying residual stress state at welds and weld repairs in full scale mock-container
  - Exploring susceptibility of welded material to both localized corrosion and stress corrosion cracking initiation and propagation

We want your input!

- **Many researchers have expressed interest in samples taken from the mock-up**
- **First priority is characterization of the residual stress state**
- **Need to assemble a prioritized list of samples which are needed by various organizations, with the understanding that some samples (e.g., a large ring) may preclude the production of other samples**