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NRC Peening Validation Program Update

February 28, 2017

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Outline

- Briefing Purpose:
  - Provide overview of program
- Program Areas
  - Validate uncertainty in x-ray diffraction residual stress measurements
  - Validate locations on CRDM nozzles where residual stress measurements should be made
  - Validate effect of peening on ability of UT/ET in finding pre-existing cracks
  - Validate effectiveness of peening in reducing initiation of PWSCC
- Outcome:
  - Understanding of the current program

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Uncertainty, X-ray Diffraction

- Objective
  - Determine uncertainty of x-ray diffraction
    - Plate
    - Welds
- Basis
  - X-ray diffraction reported to have high uncertainty, especially on welds
  - Measurement uncertainty excluded from MRP-335 at industry request

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Uncertainty, X-ray Diffraction

- Experimental
  - Peen one 3-foot weld on plate
  - Perform XRD measurements
    - Statistically sufficient sample
    - Allow EPRI option of performing measurements

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Stress Measurement Locations

- Objective
  - Identify locations of high tensile stress in CRDM nozzles and welds.
- Basis
  - Weld residual stress measurements on the mockup are necessary to confirm the effectiveness of the peening methodology on a component.
  - Weld residual stress measurements performed on a mockup should include areas of high tensile stress.

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Stress Measurement Locations

- Experimental
  - Perform finite element analysis to determine weld residual stresses in three CRDM nozzles and associated welds.
  - Measure stresses on un-peened component at high tension areas identified by finite element analysis
    - At surface
    - At required nominal depth of compression stresses (0.25 or 1 mm as appropriate)
    - Use x-ray diffraction

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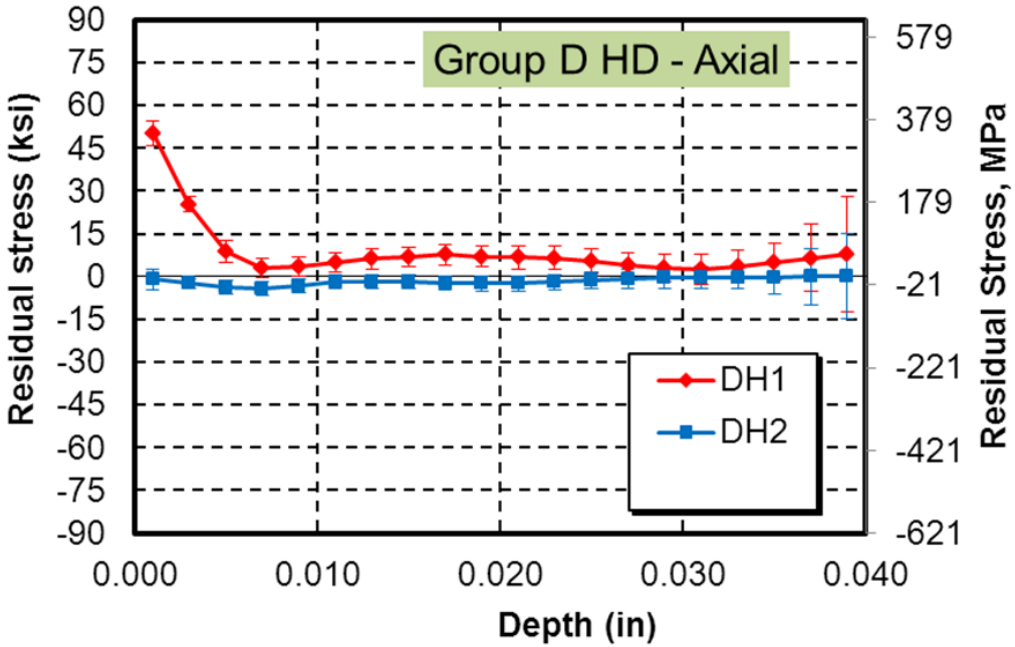
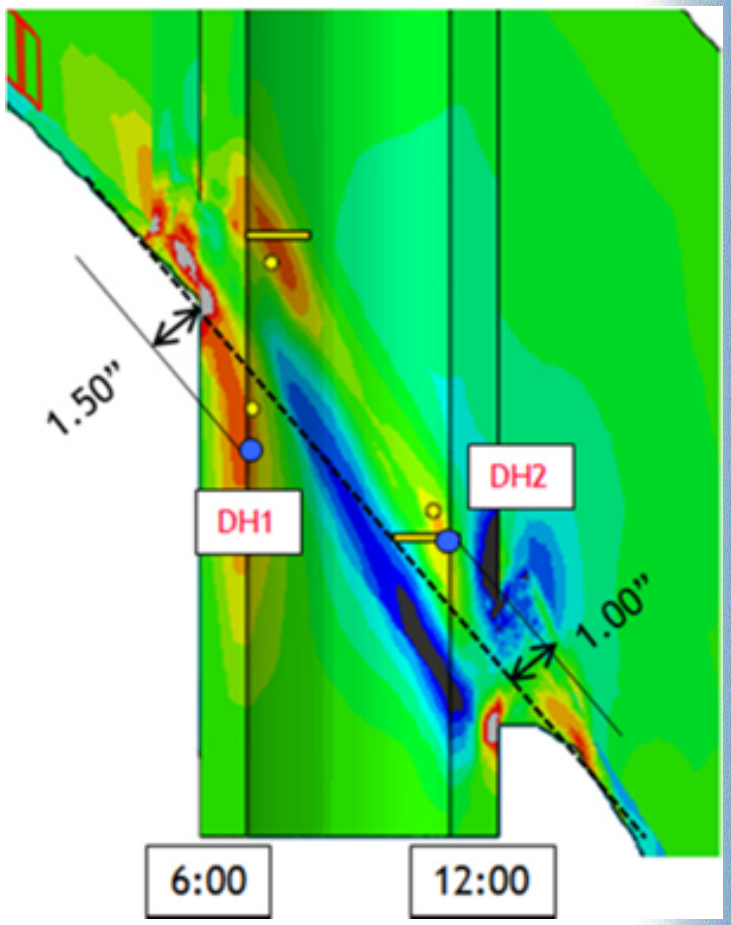
Generic Location Choices





The location of these measurements was based on a generic WRS model. Both had high tensile stresses identified by the model. However, DH1 is greater than 10 ksi for only about half of the thickness and DH2 is in compression.

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Non-destructive Examination

- Objective
  - Validate effect of peening on ability of ultrasonic and eddy current testing in finding pre-existing cracks
- Basis
  - Eddy current and ultrasonic examinations of peened dissimilar metal welds require the probe to be in contact with the peened surface.
  - Does the surface effect, produced by peening on a component, affect the examinations ability to detect cracking?

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Non-destructive Examination

- Experimental
  - Use existing DMW mockup with existing implanted flaws
  - Perform baseline encoded ultrasonic and eddy current examinations
  - Peen DMW
  - Perform encoded ultrasonic and eddy current examinations again
  - Validate effectiveness of NDE to identify implanted flaws.

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PWSCC Crack Initiation

- Objective
  - Validate efficacy of peening with respect to initiation of PWSCC cracks.
- Basis
  - Peening has long history of effectiveness in mitigating fatigue cracks
  - Initiation mechanism for fatigue and PWSCC are different
  - Peening improvement factor for PWSCC initiation vs. unpeened specimens will confirm volumetric inspection frequency relief

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Crack Initiation Validation Plan

- Experiment
  - 32 alloy 182 4pt bend specimen
  - 16 alloy 600 4pt bend specimen
  - Obtain baseline initiation times
  - 2nd set of 4pt bend specimens
  - Peen specimens
  - Load to operating conditions in PWR environment at +10 ksi
  - Test time to support change in volumetric inspection frequency

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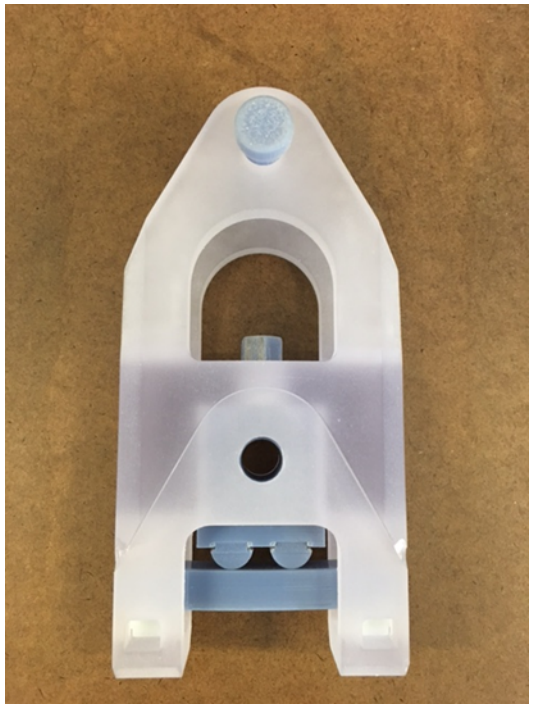
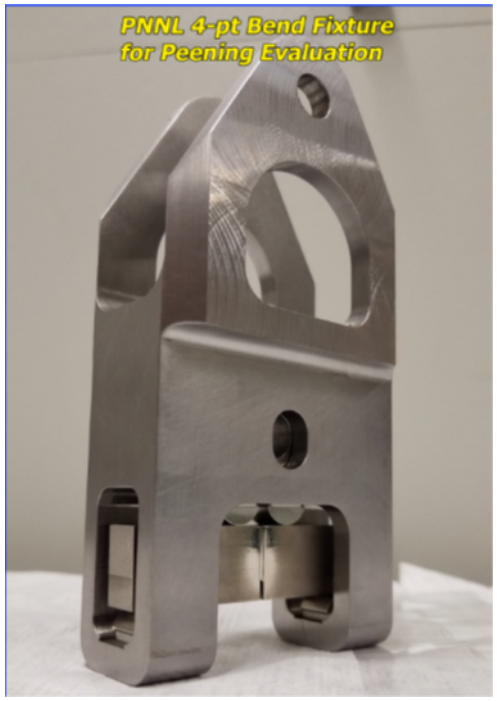
Peening Specimen

- 4-point bend bar specimens





PNNL concept for crack arrest specimen by Dr. Mychailo Toloczko

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Validation Work Completion

- Summer 2017
  - Weld residual stress measurement locations on CRDM work
- Fall 2017
  - Non-destructive examination work
  - Weld residual stress measurement uncertainty work
- February 2020
  - Crack initiation validation

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Optional Validation Work

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Optional Validation Work

- Optional validation work
  - NRC is considering these additional activities
  - Requesting feedback on the following items
  - Value in potentially reducing NRC conservative positions in areas
    - Address NRC conditions
    - Address changes from MRP-335R1 to MRP-336R3A

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Optional Crack Arrest Program

- Validate the initial flaw size for the deterministic flaw analysis calculations
  - Validate the basis for the timing of the inspections after peening
  - Analysis of crack growth of flaws within the nominal depth of compression zone will validate initial flaw size for deterministic basis of NDE inspection frequencies.

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Optional Crack Arrest Program

- Validate the initial flaw size for the deterministic flaw analysis calculations
  - Analysis of crack growth of flaws outside the nominal depth may support MRP-335R3A statements of conservatism, and be used to extend inspection frequencies
    - Cold leg temperature component volumetric inspection frequency
    - Visual inspection frequencies
  - PNNL design allows operational loads to be applied after peening

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Optional Crack Arrest Validation Plan

- 16 alloy 182 4pt bend specimen
- 8 alloy 600 4pt bend specimen Initiate PWSCC flaws
- Machine specimens for flaw size ranges
- Peen specimens
- Load to operating conditions in PWR environment
- Test time to support change in volumetric inspection frequency

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Optional WRS Measurement Validation Plans

- Validate all MRP-335 weld residual stress methods effectiveness on weld and plate
  - Compare all measurement methods identified in MRP-335R3A to examine relative uncertainties between methods on same weld on plate
  - Perform measurements pre-peened and post-peened condition
  - Evaluate eddy current measurement technique
    - Provide in-situ examination method to assure peening coverage on peened components
    - Provide basis for extended volumetric or visual inspection relief for cold leg temperature components

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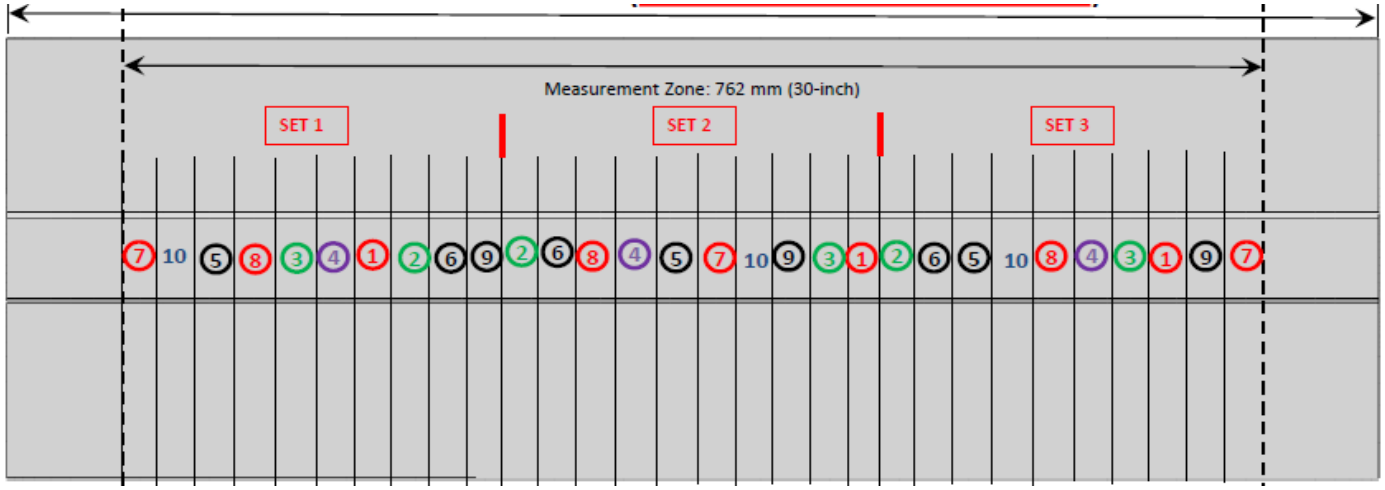
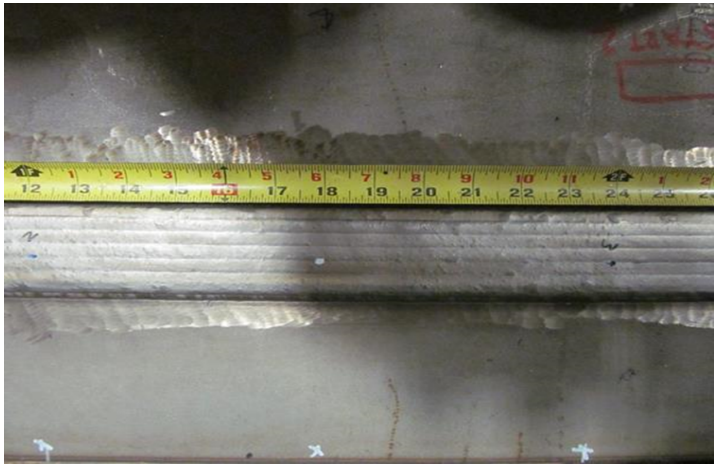
Optional Plan for Weld on Plate Measurements





Initial weld on plate specimen with identification of 3 sets of 10 measurements

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Optional Validation Plan for CRDM Nozzles

- Peen CRDM nozzles used in the weld residual stress measurement location validation plan
- Measure peened surface and nominal depth of compression stresses in same locations
- Validate peened stresses meet the requirements of MRP-335R3A
- Value added
  - Provide an independent validation of peening process on CRDMs for benchmarking NRC staff reviews
  - Address questions raised by the measurement validation program (see next slide)

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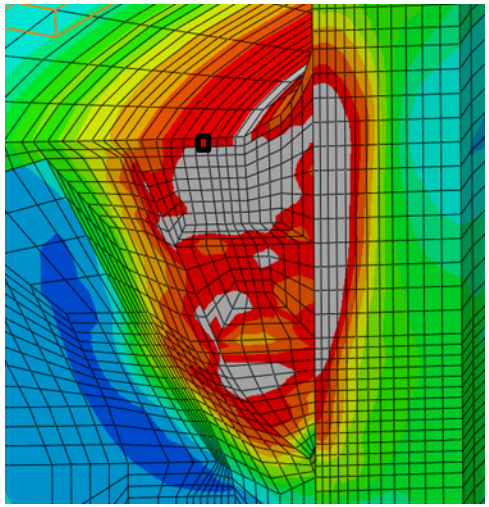
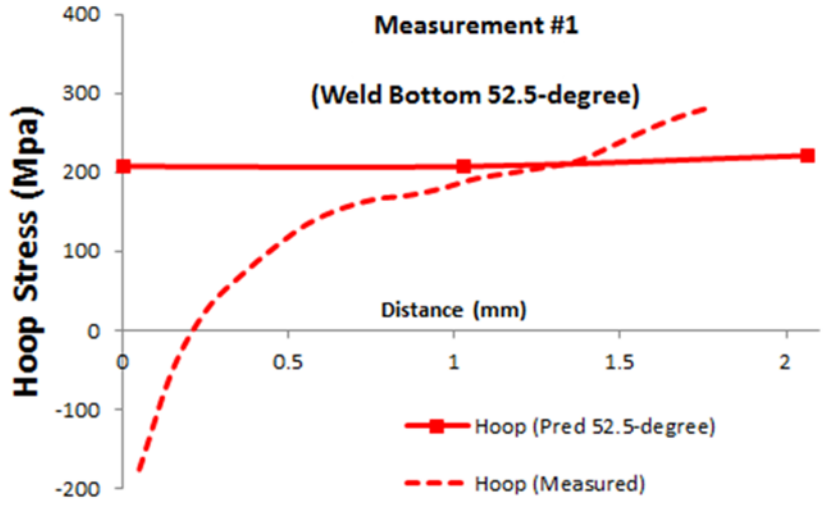
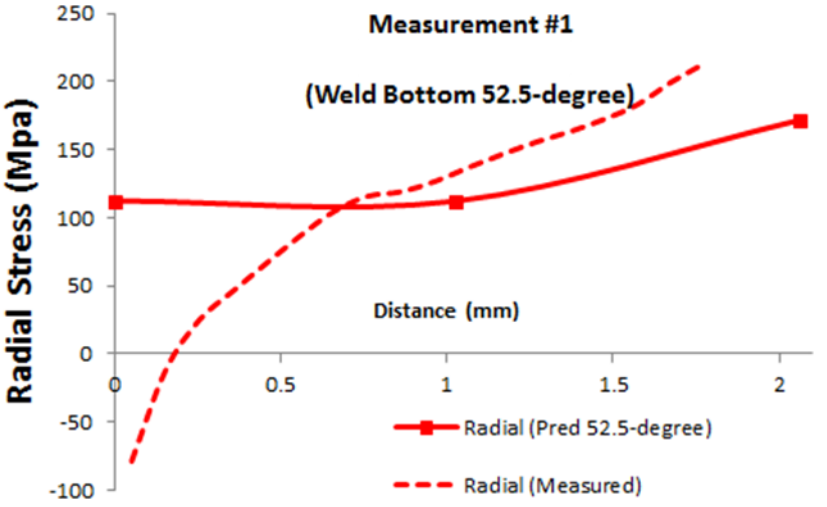
Draft Initial Pre-Peened Weld Residual Stress Results







Concerns about variety of stress profiles identified may be alleviated by peening and evaluation of the final peened stresses

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Optional CRDM NDE Validation Plan

- Validate eddy current and ultrasonic inspection to detect flaws CRDM nozzles
- Validate minimum flaw size detectable
  - Confirm the adequacy of the initial flaw size of the deterministic flaw evaluations.
- Value added
  - Independently confirm MRP-335R3 work
  - Surface exam inspection could provide relief from the bare metal visual inspection requirements

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Optional Section Conclusion

- Optional areas
  - Crack arrest
  - Multiple weld residual stress measurement technique evaluation
  - Peened CRDM stress measurement validation
  - CRDM non-destructive evaluation program
- Questions?