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Inspection of CASS Update

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Winter PDI and PDI/NRC Meetings

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Contents

- Summary of EPRI NDE projects involving CASS material
  - Completed Projects (4)
  - Ongoing Projects (6)

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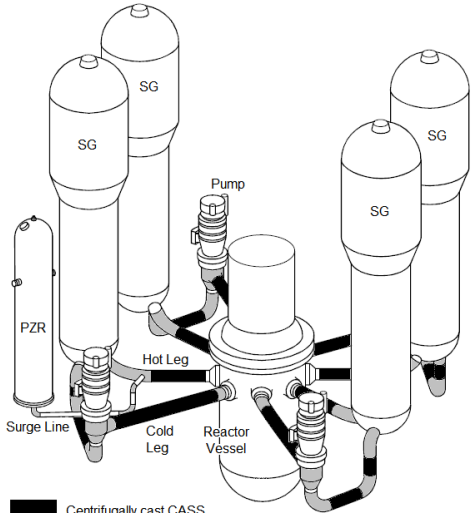
Completed Projects

Flaw Tolerance Evaluation of Thermally Aged CASS (Determinitistic Approach)

- Objective
  - Determine critical flaw size for CASS material throughout the industry
  - Develop suitable flaw acceptance criteria for ASME Sect.XI



- Method
  - Calculations based on fracture mechanics and flaw growth analysis
  - Using a range of material properties and operating conditions that encompass the industry
  - Include a safety margin that follows the current ASME methodology

- Results
  - Large variations in the essential variables were noted throughout the industry
  - Most likely not the appropriate solution for industry wide critical flaw size determination
  - Results published in Report 1019128

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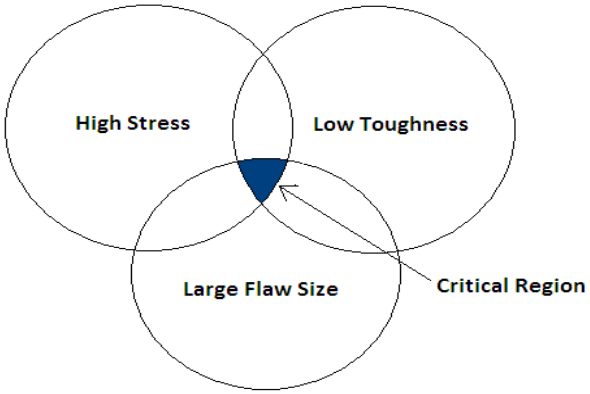
Completed Projects
Probabilistic Model for the Reliability of Thermally Aged CASS (Phase I)

- Objective
  - Predict failure probability vs. time at temp with respect to ranges of critical flaw sizes
  - Bypasses the need for conservative bounding values
  - Used to predict thermal embrittlement
  - Results used to determine critical flaw sizes in CASS



- Method
  - Generate computer model similar to PRAISE Code for probabilistic evaluation of degraded piping
  - Estimate the distributions of random variables
  - Define and run example problem

- Results
  - The results of Phase 1 are currently being reviewed
  - A draft report has been generated and is expected to be published later in 2011

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Completed Projects

Guidelines for the Inspectability of New Components (Including CASS)

- Objective
  - Provide guidelines for fabrication and design of new nuclear systems
  - Necessary steps for effective pre-service and in-service NDE
  - Prevent known problems that the existing nuclear fleet is experiencing
  - Provide a document that aids the newest generation of engineers in the development of nuclear components
- Method
  - Compile information pertaining to NDE problems and solutions experienced throughout the industry
  - Tap “aging resources” to prevent the loss of important knowledge

- Results
  - A large amount of information was obtained and documented
  - The 2010 report includes a section dedicated to CASS components
  - Results published in Report 1021160

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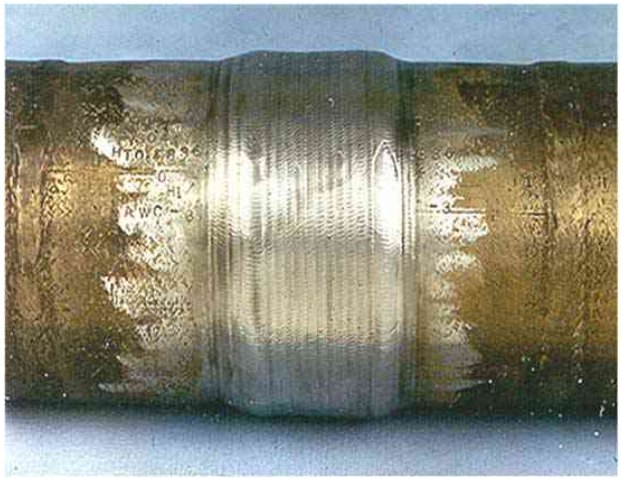
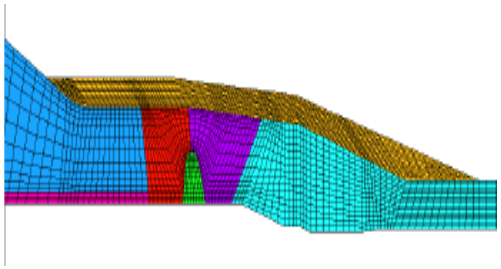
Completed Projects
Low Frequency UT for WOL on CASS Base Material

- Objective
  - Investigate the effectiveness of low frequency UT on WOL specimens with CASS base material
  - Compare low frequency UT techniques and traditional higher frequency techniques
  - Determine current limitations of CASS base material examinations through WOL material





Method

- Utilize mockups recently manufactured for the PDI WOL program
- Mockups have a limited number of indications in the CASS base material that were intended for research only
- Inspect the mockups with various low frequency instruments and search units

- Results
  - Improvement noted over standard higher frequency techniques
  - Some flaws could not be detected and others were difficult to fully characterize
  - Results from this study suggest that current low frequency techniques could result in an increased level of false calls
  - Results published in Report 1021145

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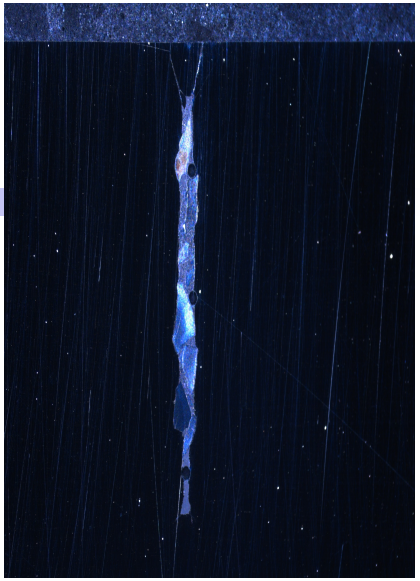
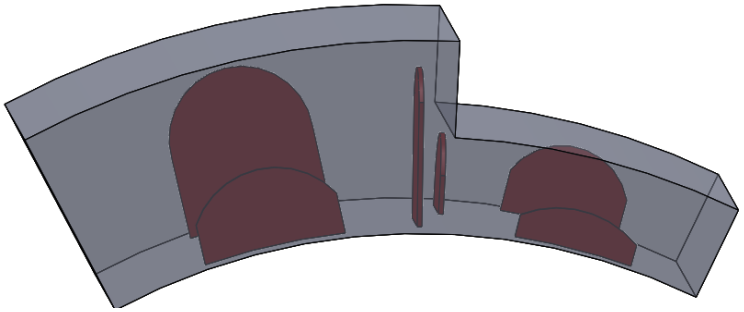
Ongoing Projects
Flaw Fabrication in CASS Components



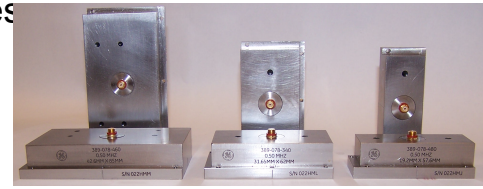
- Objective
  - Supply the industry with an open set of flawed mockups that provide realistic NDE responses
  - Discover a way to implant flaws into CASS base material without disturbing the unique grain structure



Method

- Determine the limitations of current flaw making technology
- Work with mockup manufactures to develop new flaw making techniques
- Test flawed mockups with the latest NDE technology to determine if the response is realistic (no tell tale signs)

- Results
  - 500 kHz 45°/60°L conventional UT data collected on both the thick and thin sides
    - 45°L focused at the inside surface provided better signal-to-noise ratios.
    - 60°L focused near the notch tip yielded improved depth sizing results.
  - PNNL has requested to collect ultrasonic phased array data on this specimen.
  - Currently discussing alternative flaw fabrication techniques with domestic and international companies
  - Results to date are published in Report 1021146



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Ongoing Projects
Acquisition and Analysis of CASS Material

- Objective
  - Identify sources for non-contaminated vintage CASS material
  - Negotiate the purchase or donation of vintage CASS material
  - Identify a reliable source for additional material

- Method
  - Scour the earth for leads to sources for material
  - Work with foundries to manufacture new “old” material
  - Perform grain structure analysis on the material and catalog the results
- Results
  - Obtained four statically cast main loop elbows and a centrifugally cast surge line pipe from two US utilities
  - Recently took receipt of the first simulated vintage CASS material and awaiting results of the grain structure analysis
  - Results to date are published in Report 1021146

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Ongoing Projects
Inspection Results on CASS Less than 2” Thick

- Objective
  - Determine if current NDE techniques are capable of reliably detecting and characterizing flaws in CASS material less than 2” thick
  - Aid in the development of a code case for the inspection of CASS components less than 2” thick
- Method
  - Obtain as many vintage CASS specimens as possible and expose them to currently qualified UT techniques
  - Perform and catalog the grain structure analysis for as many of the specimens as possible
  - Utilize both conventional and phased array UT techniques
- PNNL Cast Elbow Data Acquired by EPRI (Next Slide)
  - TruFlaw Thermal Fatigue Crack Dimensions:
    - 19.3 mm by 3.4 mm
    - 25.3 mm by 6.0 mm

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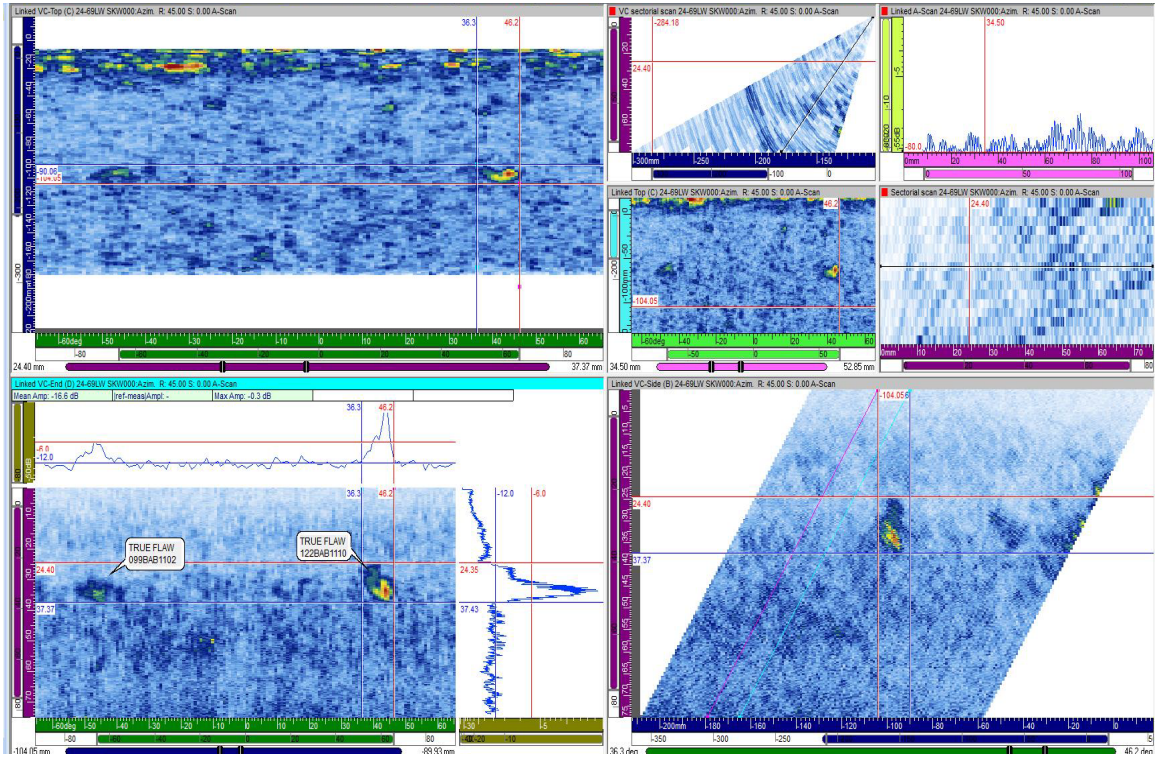
Ongoing Projects

Inspection Results on CASS Less than 2” Thick PNNL Cast Elbow Data (True Flaws)



- Results
  - Small reflectors (10% to 20%) are difficult to detect in some CASS material
  - Precise length and depth sizing is difficult and in some instances unobtainable
  - Some CASS material affects the UT propagation more than others (beam bending, attenuation, and reduced sensitivity)
  - The ultrasonic instrument characteristics impacted results (pulse voltage, pulse width, bandwidth, etc.)
  - The scanning direction may influence results.
  - The ultrasonic phased array data was generally better than the conventional data (by as much as 5 dB).
  - This study included a very limited number of specimens and reflectors

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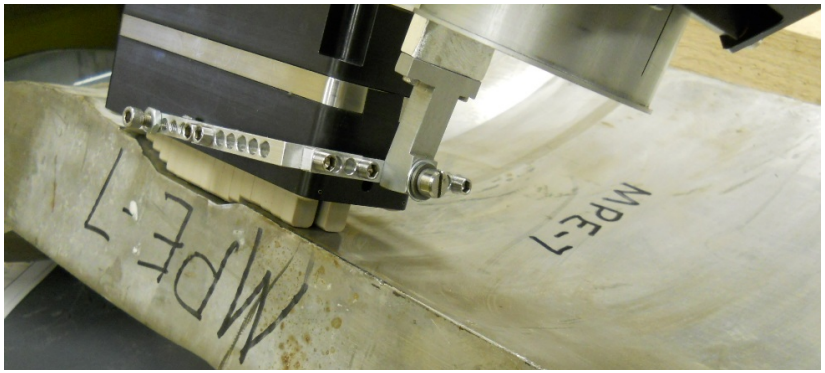
Ongoing Projects
Evaluation of Inside Surface Examination Techniques for CASS

- Objective
  - Evaluate and develop UT and ET techniques deployable from the ID surface of CASS components
  - Determine if ID connected flaws can be reliably detected from the inside surface of a CASS component



- Method
  - Investigate new technologies and procedures for ET techniques
  - Evaluate and possibly expand currently qualified ID UT inspection procedures

- Results
  - An inspection vendor has finished scanning one set of the ID samples
  - Other vendors have expressed an interest in working on this project
  - Report 1022928 has been published which describes the preliminary results of this project

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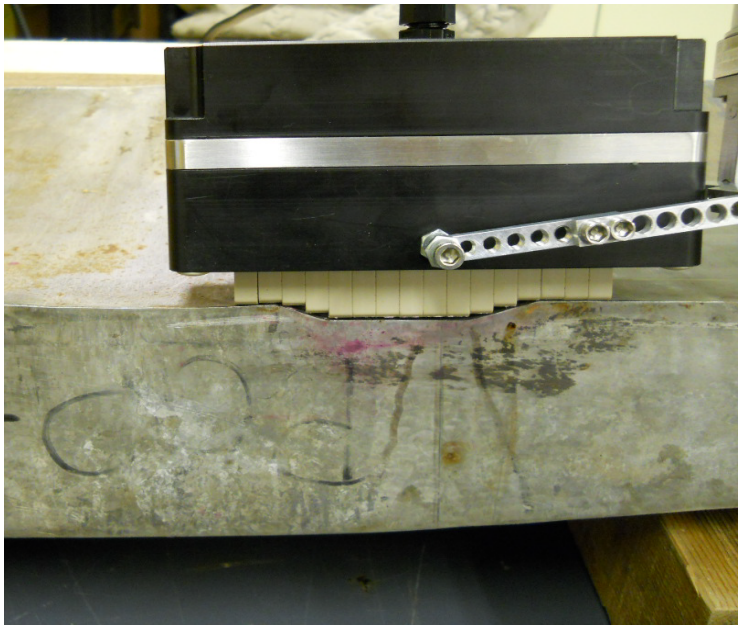
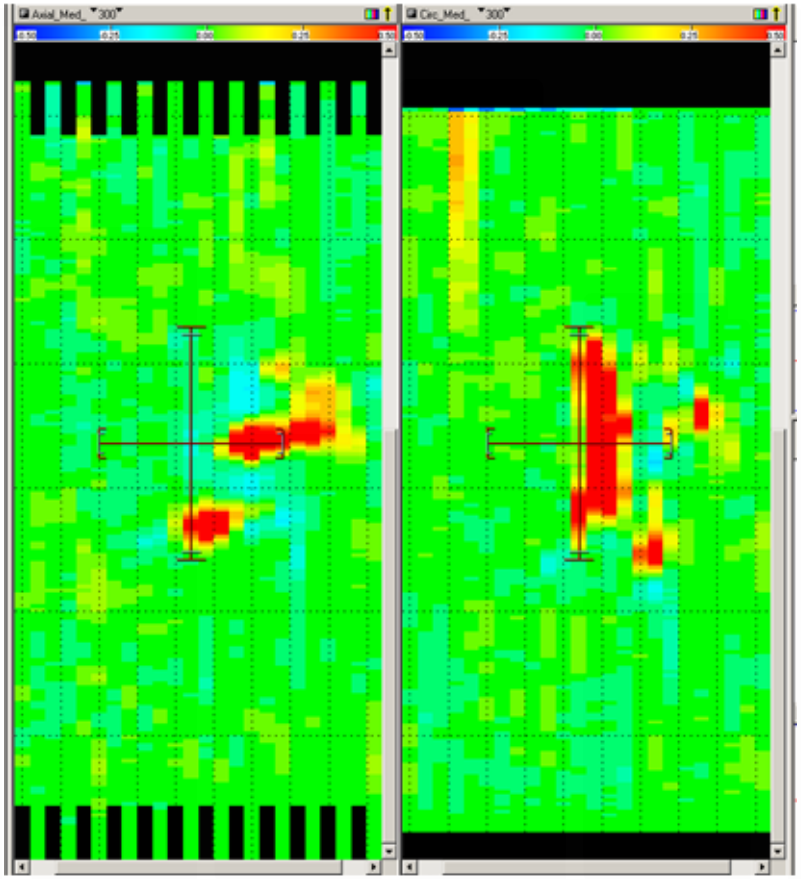
Ongoing Projects
Evaluation of Inside Surface Examination Techniques for CASS

EPRI Results

– ET array provides good signal-to-noise ratio for crack detection



ET Array Scanning ID of WOG Sample



Axial Channels Circumferential Channels

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Ongoing Projects

Signal Processing Advancements for CASS UT Examinations

- Objective
  - Develop signal processing algorithms for more reliable flaw detection during UT inspections of CASS
  - Increase signal to noise ratio by eliminating some of the material noise while amplifying the signal response from indications
- Method
  - Develop the software and hardware necessary to perform the advanced signal processing
  - Test the signal processing routines on specimens with known reflectors
- Results
  - The results of this project have been published in the 1022950 report

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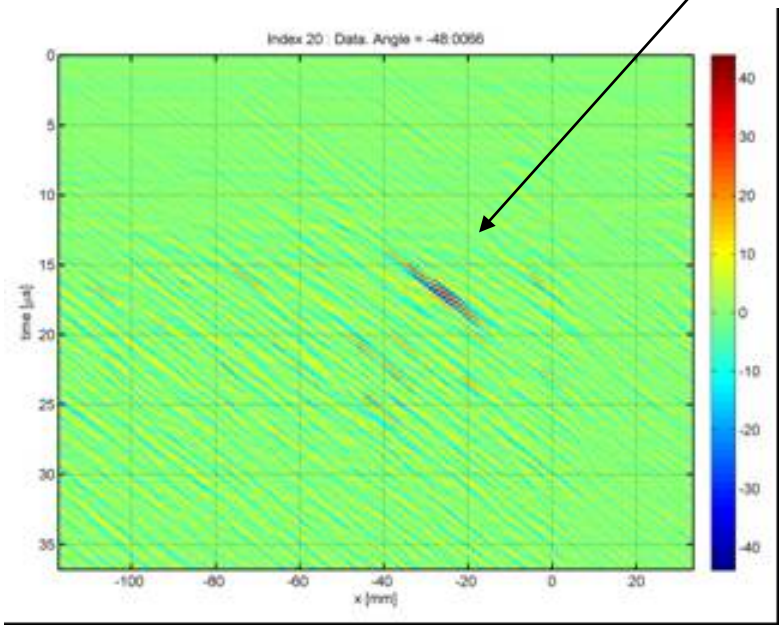
Ongoing Projects

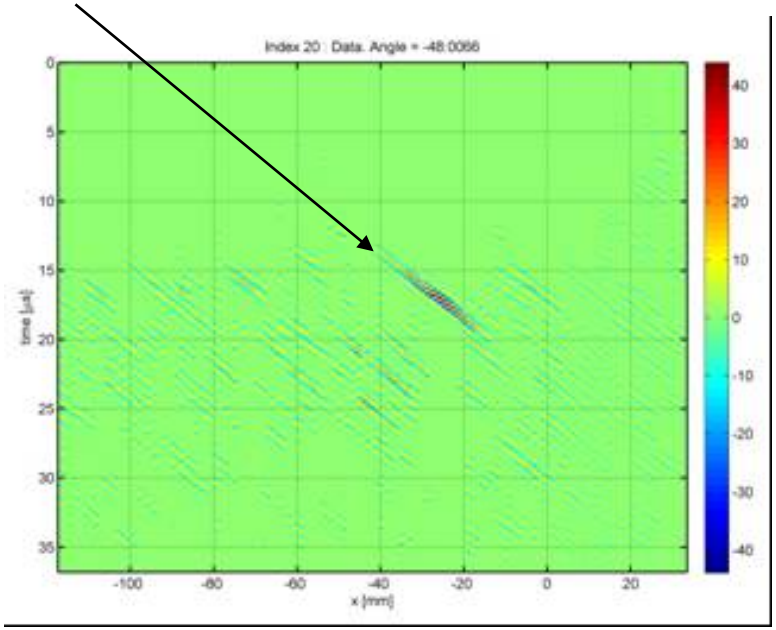
Signal Processing Advancements for CASS UT Examinations

UT Data Images Obtained From Thermal Fatigue Flaws in Cast Stainless Steel Piping

Flaw Responses



Original Data Image



Processed Data Image using Matlab

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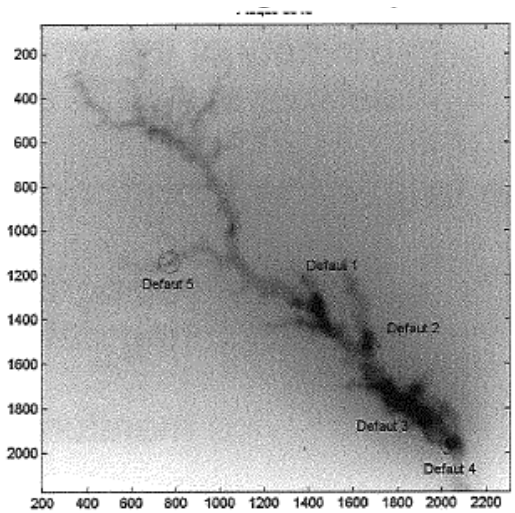
Ongoing Projects

Probabilistic Model for the Reliability of Thermally Aged CASS (Phase II)

- Objective
  - Develop final code for model
  - Develop detection probability and crack size distribution statistics



- Method
  - Refine model developed in Phase I
  - Document final input assumptions
  - Consider additional variable such as pore sharpening
  - Continue research on inspection capabilities
  - Characterize load inputs
- Results
  - The results of this project will be summarized in a report to be published in early 2012
  - Preliminary results will be published in the 2011 annual CASS Study report

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Ongoing Projects
Inspection Results on CASS Greater than 2” Thick

- Objective
  - Determine optimum NDE parameters for flaw detection and characterization in heavy wall CASS materials
- Method
  - Utilize both conventional and phased array UT techniques
  - Multiple Frequencies (0.5 MHz to 1.5 MHz)
- Cast Data Acquired by EPRI (Next Slide)
  - 35-inch (889.0 mm) diameter cast stainless steel pipe with a thickness of 4.72-inch (120.0 mm)
  - TruFlaw Thermal Fatigue Crack Dimensions:
    - 31.3 mm by ?
    - 38.8 mm by ?

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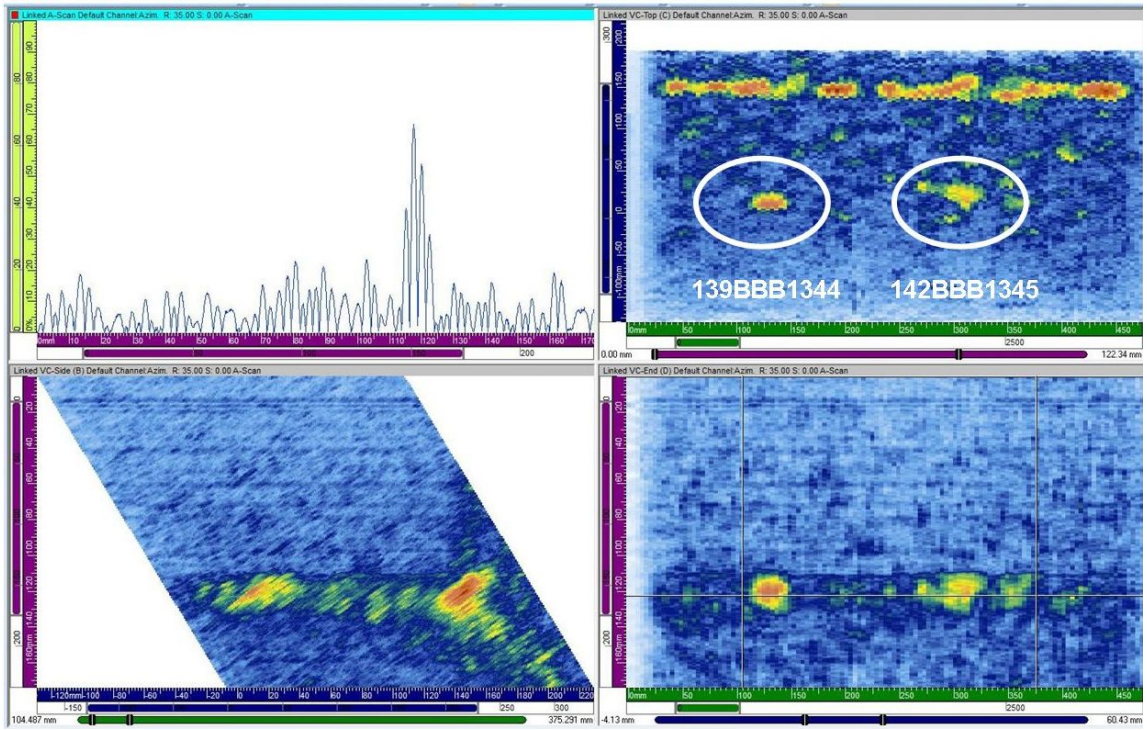
Ongoing Projects
Inspection Results on CASS Greater than 2” Thick (True Flaws)



- Results
  - Inspection angles larger than 40° were not effective for flaw detection.
  - Ultrasonic frequencies greater than 0.5 MHz were not useful.
- This result is consistent with past observations related to the ultrasonic inspection of cast austenitic stainless steel material.
- The higher frequency sound waves have difficulty propagating through CASS materials due to the large grain structure.
- The lower frequency ultrasonic probes have improved detection capability but are not adequate for defect sizing.

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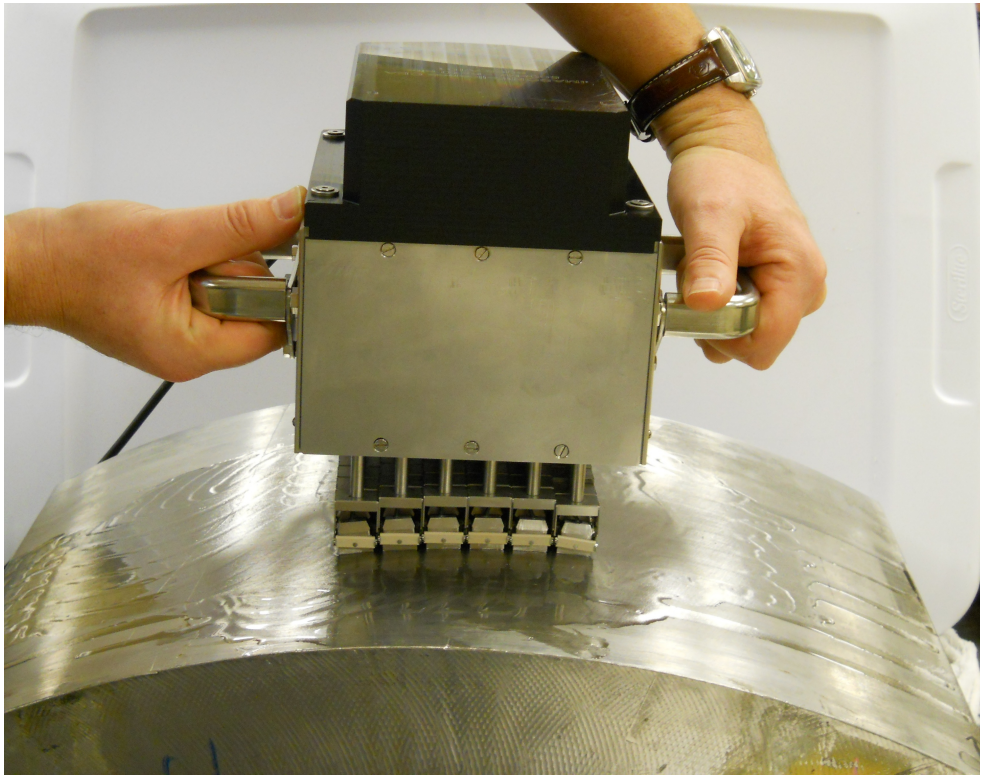
Ongoing Projects
Inspection Results on CASS Greater than 2” Thick



6x10 500 kHz Flexible Array

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