NRC NDE Research Programs at PNNL
NRC/Industry Coordination Meeting

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Effectiveness and Reliability of NDE

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- "Reliability of Nondestructive Examination (NDE) for Nuclear Power Plant (NPP) Inservice Inspection"
  - Project Objectives:
    - Evaluate accuracy and reliability of NDE methods used for ISI
    - Assess adequacy of proposed industry changes to ISI programs
    - Assess NDE methods
    - Evaluate effectiveness of ISI techniques for detecting service degradation. Examples:
      - PWSCC in Alloy 600, 82, 182 dissimilar metal welds and J-groove penetrations
      - IGSCC in austenitic welds
      - Potential degradation in cast stainless steel and weldments
    - PNNL provides technical assistance on NDE and related issues to NRC program offices on as-needed basis

5-Year Program

- Period of performance
  - July 2, 2007 – May 31, 2012
- Eight major tasks
  - PNNL also working on projects such as xLPR (General Design Criterion 4), Proactive Materials Degradation Management, and Program for the Inspection of Nickel-Alloy Components
  - 29 NUREGs or Technical Letter Reports currently scheduled
    - 9 delivered to date

DMWs, Overlays/Inlays, Stress Improvement, Far-Side Inspection

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- Reasons for Research
  - Ensure that reliable and effective examinations are being performed
    - Full coverage of area of interest, including adequate portion of base metal
  - Address uncertainties relative to 10 CFR Part 50, Appendix A, General Design Criterion 4
    - …probability of fluid system piping rupture is extremely low..
    - Industry strategies for mitigating PWSCC in LBB systems include overlays, inlays/onlays
    - Verify adequacy of volumetric examination

DMWs, Overlays/Inlays, Stress Improvement, Far-Side Examination (cont'd)

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- DMW as-built conditions impact successful UT
  - Austenitic weld materials and buttering attenuate and re-direct sound fields, and may produce excessive noise
  - OD surface features (diametrical shrinkage, weld crowns, tapers) cause transducer "lift-off" and/or limit accessible volumes of weld
  - Safe end-to-component (nozzle, valve, etc.) geometries primarily limit examinations to single side (from safe end)
  - Other piping welds in close proximity (safe end-to-pipe) may also impact these examinations
  - ID counterbore and weld root conditions
    - Provide reflectors that may mask small PWSCC
    - Can impact examinations performed from the ID

Reasons to Investigate CASS

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- CASS materials used in RCS piping
- Objective:
  - Determine influence of thermal aging embrittlement on reliability and integrity
  - Industry evaluations have determined that certain heats of material used in current plants are susceptible
- French have been replacing certain components during outages
  - Problems in U.S. reactors highly likely during extended operation
- Examinations must be conducted from CASS side (far-side) for certain configurations
- Certain locations cannot be weld overlaid

CASS (cont'd)

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- Completed phased array work on several CASS PZR line specimens
  - PNNL TLR No. 18596
  - All flaws easily detected; some tips available for depth sizing
    - Microstructure much less of an issue than for 2 inch thick specimens than for large diameter specimens
- Specimens sent to EPRI for corroborating UT
  - PNNL and EPRI staff currently discussing preliminary results
- Results of PNNL study proposed as basis for draft Code Case on performance demonstration for less than 2.0-inch thick CASS piping welds
    - Similar to Supplement 12
    - "add-on" to Supplement 10 qualifications

CASS (cont'd)

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- EPRI funded initiative at Structural Integrity Associates (SIA) to assess potential for a probabilistic model
  - The problem of managing CASS components and their associated contributions to risk is compounded by the difficulty of detecting crack-like defects in the coarse grained microstructure of these cast components.
  - Flaw tolerance evaluations show that critical flaw sizes for the estimated design loads are very large. However, current Code safety factors and conservative bounding assumptions for material properties, loads, and flaws to demonstrate structural margins result in maximum allowable flaw depths that are often below the sizes that could be reliably detected by practical UT inspection techniques.

CASS (cont'd)

- PNNL has initiated discussions with SIA relative to potential to continue assessment of probabilistic model
  - Industry participation would be helpful

VT

- Utilities have expressed interest in greater use of visual testing (VT-1)
- VT significantly relied upon for vessel examinations
- Literature searches by PNNL revealed few published studies in this area
- Better understanding of the effectiveness and reliability of VT needed

Factors Affecting the Reliability of VT

- VT is very subjective and the reliability of a VT-1 test is a function of many factors:
  - Visual acuity of the system
  - Size of indications
  - Contrast between indication and surface
  - Scanning Speed
  - Surface conditions
  - Light levels
  - Lighting angle
  - Camera Angle
  - Many human factors

Issues/Concerns

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- That current standards in VT tests are not rigorous enough to assure reliable examinations
- VT Standards do not address, for example:
  - Pixel Size (magnification and pixel count)
  - Resolution Standards
  - Scanning Speed
- Wires Make a Poor Sensitivity, Resolution, and Contrast (SRCS) Standard
- Many of the reported cracks in reactor components have a crack opening dimension (COD) near or below the reliable detectable limit

Research Plan

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- Assess capabilities and limitations of remote visual (ASME VT-1) examinations to detect cracking in RPV internal components
  - Define parameters affecting reliable examinations
    - COD
    - System calibration (resolution) standards
    - Magnification and lighting effects
    - Scanning speed
- Conduct round-robin exercise to assess equipment, procedures, and personnel
  - Quantify effectiveness of current practice
  - Round robin specimens have been created
  - Vendors have agreed to participate
  - NRC and EPRI developing test plan
    - As part of addendum to MOU

HDPE

- Code Case N-755
  - "Use of Polyethylene (PE) Plastic Pipe for Section III, Division 1, Construction and Section XI Repair/Replacement Activities"
    - Code Case required only VT and hydro test
- PNNL tasked to conduct review/assessment
  - Identify potential NDE methods
- Focus of work is on cold fusion since this is hardest condition to reliably detect
  - Volumetric methods to inspect the thermal fusion butt weld configuration

Volumetric Examination of Fusion Butt Weld

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- Most extensive study underway is a study by Edison Welding Institute for the DOT and industry of small diameter MDPE for butt and electro-fusion welds
  - More than 250 joints manufactured; many carefully manufactured with cold fusion to try to simulate possible field conditions
- Studies using various NDE techniques have shown promising results although the kissing bond or lack of fusion (LOF) condition can be very difficult to detect using some methods
  - Evisive claims microwave technique always detects LOF
  - Other methods showing promise under investigation by industry are
    - Time of flight diffraction (TOFD)
    - Thermography

Future Work

- PNNL continuing to assess industry work on phased arrays, TOFD, and microwave methods
- NRC and EPRI have discussed addressing HDPE NDE under addendum to NRC/EPRI MOU

Reliability and Effectiveness of Vessel Examinations

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- Commission considered "Final Rule Alternate Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events (10 CFR 50.61a)" in August 2009
  - Chairman Jaczko shared Advisory Committee on Reactor Safeguards (ACRS) concerns
    - Comments in SECY-09-0059
    - "staff should undertake an effort to verify and document the capability of nondestructive examination (NDE) procedures that will be used to characterize the flaw distributions in reactor vessels"
  - Staff commitment to respond by August 2010

Current Status

- RES will be developing a regulatory guide to provide guidance to licensees on how to relate their NDE results to the flaw information presented in 10 CFR 50.61a
  - Of particular interest to this guidance is the impact of NDE sizing and detection uncertainties
- Staff currently reviewing:
  - PDI data to assess RPV inspection reliability
  - Information from specific plant examinations
- RES has discussed issue with EPRI
  - Goal is to provide response to Commission coordinated with industry

PINC

- *Program for the Inspection of Nickel-Alloy Components*
  - **Document** the range of locations and crack morphologies associated with primary water stress corrosion cracking (PWSCC)
  - **Correlate** observed nondestructive evaluation (NDE) responses with PWSCC
  - **Fabricate** /obtain representative NDE mock-ups with flaws to simulate the NDE responses of tight PWSCC cracks
  - **Identify** & **quantitatively assess** NDE methods for accurately detecting, sizing and characterizing tight cracks such as PWSCC
  - **Incorporate findings from other PWSCC research programs**
  - **Reports are intended to be public**, but proprietary information will be protected

Partners

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Bilateral agreements with

- Swedish radiation safety authority
- Japan Nuclear Energy Safety Organization (JNES)
  - Japan Power Engineering and Inspection Corporation (JAPEIC)
- Japanese PWR Industry Group
  - Represented by Kansai Electric Power Co.
  - Includes Mitsubishi Heavy Industries, other utilities, a research institute
- Tohoku University
- VTT Technical Research Centre of Finland & Helsinki University
- Agreement with Korean Institute of Nuclear Safety included
  - Korea Atomic Energy Research Institute (KAERI)
  - Industry Group represented by Doosan Heavy Industry
  - Other consortium members
- EPRI

Mockups

- Test Mockups were shipped to the various organizations for application of chosen NDE methods
  - Some examiners/methods well qualified; some “research” quality
- Dissimilar Metal Welds
  - 9 Test Blocks
    - Cracks in 4 size ranges
      - 1-9% through-wall
      - 10-30% through-wall
      - 31-60% through-wall
      - 61-100% through-wall

Mockups (cont'd)

- Bottom-mounted Instrumentation Nozzles
  - 14 Mockups
    - Six USA (NRC/PNNL)
    - One Swedish (SKI/SQC)
    - Four Japanese (JNES)
    - Three Korean (KINS)
  - Crack types
    - Stress Corrosion Cracking (SCC)
    - Weld Solidification Cracks (WSC)
    - Thermal Fatigue Cracks (TFC)

Summary of PINC

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- PINC offers one of the first opportunities to capture PWSCC morphology and corresponding NDE responses
- In addition to quantifying NDE performance, a goal is to understand how relative performance of NDE techniques relates to morphology
- The PINC Atlas will be a tool to assist in distinguishing PWSCC from other degradation, geometry responses, fabrication conditions, etc
- A reliable NDE technique for volumetric inspection of seal welds in CRDM and BMI penetrations has not been demonstrated
- Round robin testing of mockups completed
  - NUREG/CR report under development

PARENT

- Program to Assess Reliability of Emerging Nondestructive Techniques (PARENT)
- Planned for FY11
  - Evaluate best techniques from the PINC round robin tests
    - Assess cracks in dissimilar weld piping and other NPP components, including PWSCC and hot cracks
    - Assess results relative to fabrication welds in new reactors
    - Update Atlas
      - Crack morphology and corresponding NDE results

Addendum

- RES continuing to work with NDE Center on addendum to NRC/EPRI Memorandum of Understanding
- NRC and industry have initiated similar tasks
- Cooperation on research activities is beneficial
  - From a resource viewpoint
  - From an implementation viewpoint

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