NRC Staff Perspective on MRP-227-A Action Item 7

November 19, 2013

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Action Item 7 -Background

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- CASS – Subject to loss of toughness due to thermal embrittlement (TE) and irradiation embrittlement (IE)
- For RVI, staff concerned about “synergistic” effect of IE +TE.
- Prior to MRP-227, guidance in GALL AMP XI.M13 for evaluating CASS RVI components (based on “Grimes Letter”)
- Industry intended MRP-227 to replace the former GALL program
- MRP-227 approach for CASS differs from existing NRC guidance

Staff Concerns Motivating AI 7

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- Implementation of GALL AMP requirements –
  - XI.M13 component-specific evaluation
- Uncertainty about threshold for IE, and existence of "synergistic effect" –
  - Existing data shows toughness decrease 0.3 dpa (2E20 n/cm^2) - 1 dpa, (6.7E20 n/cm^2)
  - lack of data 0.05 dpa (1E17 n/cm^2) to 0.3 dpa (2E20 n/cm^2)
  - MRP uses 1 dpa (6.7E20 n/cm^2) as threshold for IE of CASS
- Fracture toughness can get very low at fluences > 5 dpa (3.3E21 n/cm^2),
  - very small flaws could cause failure under normal operating loads
  - inspection resolution may be inadequate to detect such flaws
- Inspection accessibility limited for some components

Action Item 7

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- For CASS components requiring aging management, perform plant-specific analysis or evaluation demonstrating the components will maintain functionality during PEO.
- MRP-227-A SE, Section 4.2.7: “The applicant/licensee shall include the plant-specific analysis as part of their submittal to apply the approved version of MRP-227.”
- Acceptable Evaluation Approaches
  - Screening, TE and IE or stress
  - Functionality analysis
  - Component specific flaw evaluation

Applicable To

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- B&W
  - IMI guide tube assembly spiders - Primary
  - CRGT spacer castings - Primary
- CE
  - Core support columns (welds are Primary)
- Westinghouse
  - lower core support column bodies - Expansion

Westinghouse Lower Support Column Body

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- Only CASS expansion component
- High neutron fluence (>1E21 n/cm^2) in top few inches of column.
- TE and IE screened in in MRP-227-A
- Inspection required if cracking found in CRGT lower flange weld
- Accessibility for inspection is limited, EVT-1 inspection may be difficult.

Westinghouse Lower Support Column Bodies

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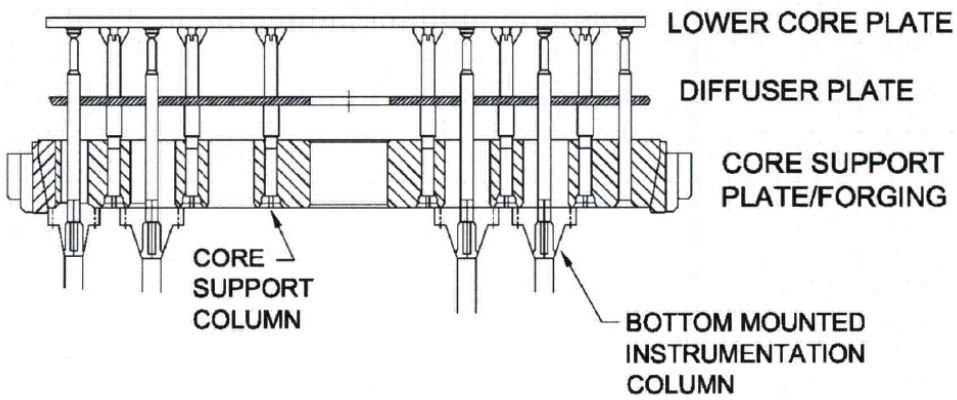
- Large population of redundant components
- Minimum pattern analysis should be feasible
- Mostly compressive loading
- Medium failure likelihood, low core damage likelihood
- FMECA Group 1



Lower Support Column Assembly Detail →

Plant-Specific Components Subject to TE

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- Other CASS, martensitic and PH stainless components may be determined to require aging management, for example through AI 2
- The plant-specific evaluation under AI 2 may identify TE as an applicable aging mechanism.
- If so, these components are also subject to the requirements of AI 7.

Licensee Responses to AI 7 (to date)

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- Level of detail provided in responses to AI 7 has generally not been sufficient to reach a safety conclusion
- Some licensees proposed commitments to provide the analysis at a later date

WCAP-17096-NP

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- Provides evaluation methodologies for Primary and Expansion CASS components
- These methodologies would be acceptable for Action Item 7 analyses, with caveat that:
  - WCAP methodologies assume inspection has been done, thus inspection data available as input to functionality

Screening Approach

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- Screen components for susceptibility to TE and IE
- May use May 19, 2000, "License Renewal Issue No. 98-0030, *Thermal Aging Embrittlement of Cast Stainless Steel Components"* (NRC ADAMS Accession No. ML003717179)
  - Allows screening based on chemistry and ferrite content if fluence < 1E17 n/cm^2
  - Allows screening based on low tensile/compressive stress if fluence ≥ 1E17 n/cm^2
  - MRP-227-A screening criteria for IE of CASS is fluence ≥ 6.7E20 n/cm^2

Functionality Approach

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- Based on structural redundancy
- Determine maximum numbers and locations of failed structural components
- Does not rely on knowledge of fracture toughness properties
- May rely on conservative assumptions, such as component with a crack completely failed
- Similar approach successful for baffle-former bolts

Flaw Tolerance Approach

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- Postulated or observed cracks (service-induced cracking not seen in CASS to date)
- Evaluate for a set time (EOL or next inspection)
- Crack growth prediction
- Crack stability evaluation at set time
- Requires fracture toughness properties
- No agreed-upon model for irradiated CASS toughness at present

Considerations for All CASS Plant-Specific Analyses

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- Include with RVI Inspection Plan/AMP submittal
- Provide for Primary or Expansion category CASS component
- For Primary CASS components, ok to provide within one year of initial inspection
- If staff cannot accept the analysis for CASS Expansion components, licensees should consider inspecting these components as Primary

Considerations for Screening Approach

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- Follow Grimes letter guidance, e.g., can't use TE criteria if fluence ≥1E17 n/cm^2;

OR

- Provide a robust technical basis for applicability of TE screening criteria at higher fluences
- Can also screen based on low (<5 ksi) tensile stress, or compressive stress (mechanical loading assessment)
- Should have material-specific chemistry, ferrite, or justify assumptions.

Considerations for Functionality Approach

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- Sufficient level of detail must be provided
  - Assumptions
  - Inputs – stresses, conditions and transients (must consider design basis events consistent with plant's licensing basis)
- For Expansion components, need basis for assumed failures, since no inspection data
  - ASME Section XI Exam Results?
  - Operating Experience
- Without inspection, and possibility of very low toughness, is functionality approach feasible?

Functionality Analysis – Low Toughness

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- Existing data (NUREG/CR-7027) shows CASS toughness can be very low at fluences ≥ 5 dpa
- Some CASS RVI, e.g. lower core support columns, predicted to exceed this fluence in local areas
- For Expansion CASS components, no inspection data will be available to rule out small manufacturing flaws
- Considering low toughness, need demonstration that functionality would be maintained considering the presence of small flaws (even if service-induced cracking is unlikely)

Considerations for Flaw Tolerance Approach

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- Use conservative model for fracture toughness
- Initial flaw size assumption must be justified
- Provide inputs and assumptions to analysis, e.g. stress, fluence
- Use plant-specific fluence and stress
- Address small flaws (if toughness very low)

Key Messages

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- Address embrittlement of CASS in near term

OR

- Plan to inspect “Expansion” CASS components as “Primary” components