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Technical Basis for Reexamination Interval for Alloy 690 PWR Reactor Vessel Top Head Penetration Nozzles (MRP-375)

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Introduction/Objective

- Sufficient data now to support revised inspection intervals:
  - Up to 24 years of plant service for Alloys 690/52/152
  - Additional laboratory data for PWSCC initiation and growth
- Objective: Apply existing plant experience and laboratory data to develop a technically based alternative inspection regime for reactor vessel heads with resistant Alloy 690/52/152 material
- Technical basis prepared and published (MRP-375)
- Supports revision to ASME Code Case N-729 and licensee relief from current requirements:
  - ASME Code process is in progress
  - First Relief Request has been submitted to NRC

Background

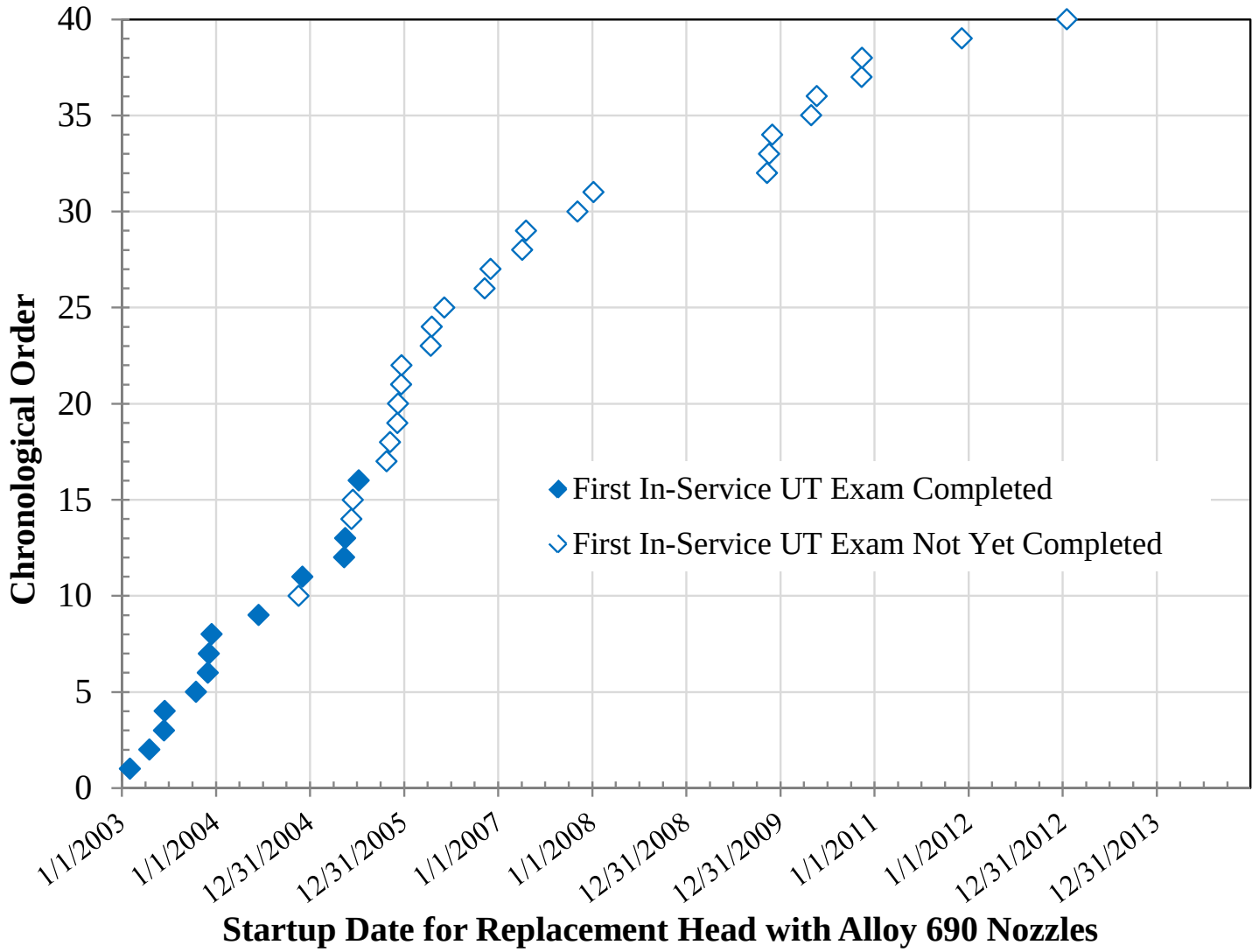
- Current inspection requirements for reactor vessel heads with Alloy 690 nozzles per ASME Code Case N-729-1 and 10CFR50.55a(g)(6)(ii)(D):
  - Volumetric/surface (and leak path) exam of all nozzles, with nominal frequency of 10 calendar years
  - Direct visual examination (VE) for evidence of leakage every third refueling outage or 5 calendar years, whichever is less
- These inspection requirements were developed to be conservative and subject to reassessment:
  - ASME Technical Basis for Code Case N-729 (September 14, 2004):
    - Treatment of A690 heads in N-729 was intended to be conservative and subject to reassessment once “additional laboratory data and plant experience on the performance of Alloy 690 and Alloy 52/152 weld metals become available”
- Data now supports a technically based longer volumetric/surface examination interval using appropriate analytical tools

Background (cont'd)

- As for all other Alloy 690/52/152 applications, there have been no reports of PWSCC detected in Alloy 690 top head nozzles:
  - Currently, more than 100 replacement and new heads with Alloy 690 nozzles and Alloy 52/152 attachment welds are in service worldwide
- Currently 65 PWRs are in operation in U.S.:
  - 40 with replacement heads with Alloy 690 nozzles (installed starting in 2003)
  - 25 with original Alloy 600 heads (20 of which operate at reactor cold-leg temperature)
- New plants plan to have heads with Alloy 690 nozzles
- The Alloy 690 nozzles in about 13 of the 40 U.S. replacement heads have been ultrasonically/surface (and leak path) examined to date, with no reports of PWSCC indications
  - Most of these examined in 2012-2014

Background

UT Inspection Status vs Head Replacement Date for U.S. PWRs



Background (cont'd)

- In France, all 58 operating PWRs have heads with Alloy 690 nozzles:
  - ISI is currently performed every 10 years on three of the heads
  - ET applied to the nozzle ID is the detection method
  - UT and visual exam are applied as characterization methods if the ET threshold is reached
  - The three heads in the program are among the earliest placed into service
  - The approach being applied in France is based on the existing knowledge regarding the resistance of Alloys 690/52/152 to PWSCC, including the latest set of inspection results

Tech Basis for Revised Inspection Requirements

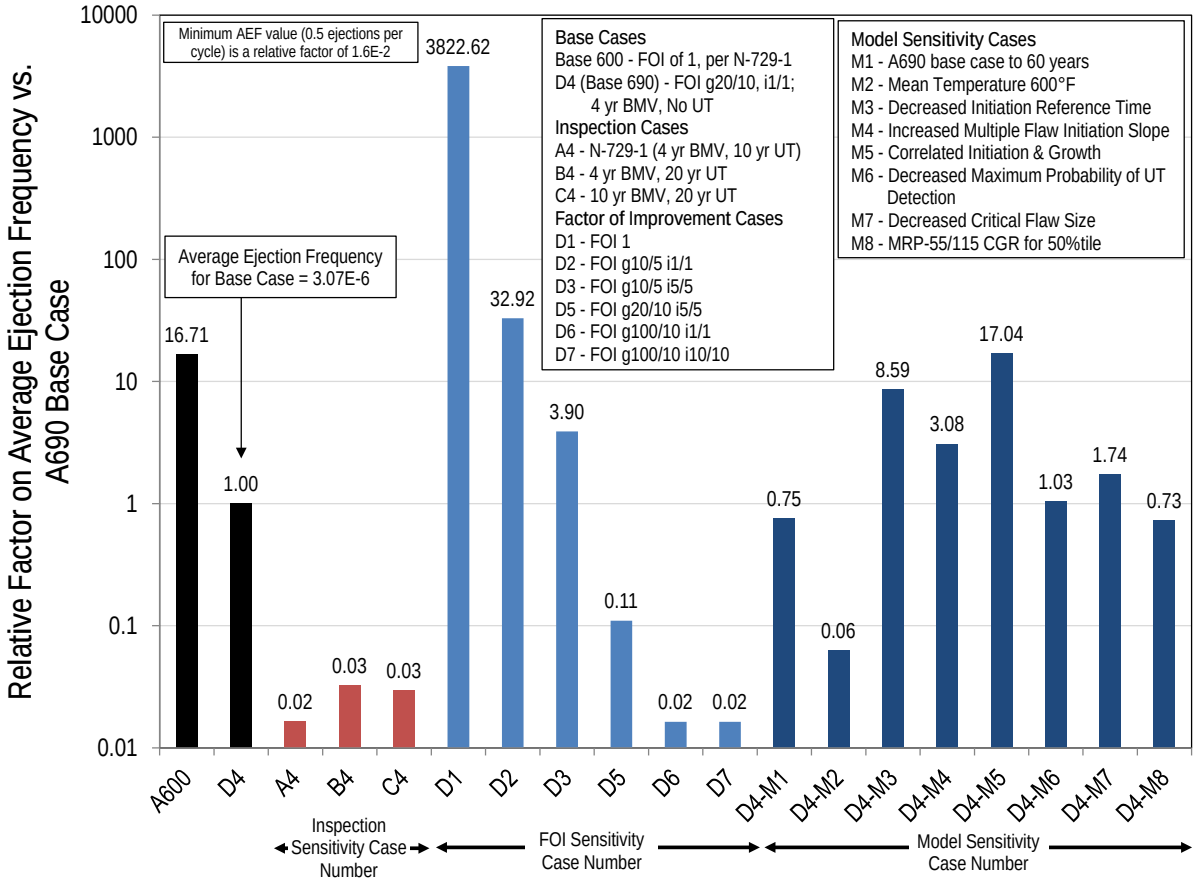
Approach

- Detailed technical basis is documented in MRP-375 (EPRI 3002002441), February 2014 (freely downloadable at www.epri.com)
- Deterministic and probabilistic calculations based on standard approaches for heads with Alloy 600 nozzles, with conservatively small credit for improved PWSCC performance through factors of improvement (FOI) applied to crack growth rates and crack initiation times:
  - Most cases include no credit for longer crack initiation times compared to Alloys 600/82/182 (i.e., initiation FOI = 1)
  - Conservatively small FOI values on crack growth rate justified by the latest set of lab crack growth rate data collected by the PWSCC Expert Panel
  - Applies the probabilistic model developed in the MRP-335R1 (EPRI 3002000073) topical report on peening mitigation to assess the frequency of through-wall cracking and nozzle ejection
  - Assesses results in terms of absolute acceptance criteria, as well as in terms of reduced risk versus heads with Alloy 600 nozzles examined per N-729-1

Tech Basis for Revised Inspection Requirements

Example Probabilistic Results

- Figure shows average ejection frequency results for range of cases
- Base case here assumes:
  - crack growth rate FOI of 20 for Alloy 690 base metal and 10 for weld metal and Alloy 690 HAZ
  - UT inspection after 40 years (effectively no UT for 40 year period)



Tech Basis for Revised Inspection Requirements

Conclusions

- Taking conservatively small credit for reduced crack growth rate of Alloy 690 (FOIs of 5 to 20) supports extending volumetric/surface reexamination interval to 40 years on basis of the nuclear safety concern of nozzle ejection
  - Effect on nuclear safety is acceptably small
  - Safety risk is substantially reduced compared to Alloy 600
- Taking conservatively small credit for improved resistance to initiation results in a low probability of leakage
- Taking more realistic credit for improved resistance to initiation results in a very low probability of leakage
- As discussed in Section 5.2.3 of the report, the existing visual exam (VE) interval of no more than 5 calendar years supplements the volumetric/surface exam requirement and conservatively addresses the potential concern for boric acid corrosion

Tech Basis for Revised Inspection Requirements

Proposed Inspection Requirements

Volumetric/Surface Reexamination Interval

- Extension of the nominal 10-year interval (one Section XI interval) to two intervals (nominally 20 years)
- Options for sample examination schedule for pair of "sister heads":
  - "Sister heads" are defined as having a similar or identical design, same nozzle material supplier, and same head fabricator
  - Option 1: Perform volumetric/surface examination of one sister head nominally every 15 calendar years, alternating between the heads
  - Option 2: Perform volumetric/surface examination of one sister head nominally every 20 calendar years, alternating between the heads
  - Option 3: Nominal 20-year interval for 1st sister head, and nominal 40-year interval for 2nd sister head
  - Predicated on no PWSCC being detected in either sister

Direct Visual Examinations (VEs) for Leakage

- Maintain the schedule of VEs per N-729-1 as a conservatism

ASME Code Activities

- ASME Code process is in progress:
  - October 28, 2013 meeting in Atlanta of Section XI Task Group High Strength Nickel Alloys Issues (TGHSNAI)
    - Introduced approach and technical basis work
  - February 10, 2014 meeting in San Diego of TGHSNAI
    - Presented results and conclusions of MRP-375 technical basis report
  - May 12, 2014 meeting in Bellevue, Washington of TGHSNAI
    - Initiated revision to N-729
  - August 18, 2014 meeting in Washington, DC of TGHSNAI
    - Anticipate completion of changes to N-729 to address inspection requirements for heads with Alloy 690 nozzles
- Changes to N-729-4 are being considered in combination with proposed changes to credit peening mitigation of heads with Alloy 600 nozzles

Industry Implementation

- Relief Request process per 10CFR50.55a:
  - A first request for an alternative volumetric/surface exam frequency was submitted for one PWR unit on April 28, 2014
    - ADAMS Accession No. ML14118A477
    - Requests a limited extension of approximately 2.5 calendar years beyond the nominal 10 calendar year interval per N-729-1
      - The limited extension in the relief request is based on the utility's assumptions for the time needed by the NRC to review and approve a relief request with a longer extension
  - Other Relief Requests (some for full additional 10 years) are in preparation
- EPRI MRP has initiated a project to develop a Relief Request template
  - Supports more standardized submittals for efficient review and approvals

Discussion

Back-up Slides

Tech Basis for Revised Inspection Requirements

Option for "Sister Head" Approach

- The approach is analogous to that taken in Paragraph IWL-2421 of ASME Section XI for inspection of unbonded post-tensioning systems of concrete containments. IWL-2421 recognizes the value of coordinating inspections of similar items at multiple plants. The sample program approach ensures that inspection data continue to be regularly collected for the full range of head designs, nozzle material suppliers, and head fabricators.
- The sister head definition from page 5-3 of MRP-375 is as follows:
  - "Before applying this sample option, the licensee shall confirm that each of the two 'sister' heads has a similar or identical design, same nozzle material supplier, and same head fabricator. The two 'sister' heads may be located in two different plants at the same site, or in two plants at different sites whether operated by the same or different utilities."
  - The definition may be extended to make clear that (1) the CRDM/CEDM nozzles in each sister must have been fabricated from material of the same material specification and (2) both heads must be located in the U.S.
- MRP-375 recommends that the sister with higher temperature be examined first if there is more than a 10°F difference in nominal head operating temperature.
- Appropriate transition time should be defined if indications interpreted as PWSCC were to be detected in one sister.

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