ELECTRIC POWER RESEARCH INSTITUTE

MRP **Materials Reliability Program** MRP 2015-043

(via email)

December 2, 2015

Secretary, U.S. Nuclear Regulatory Commission
Washington, DC 20055-001
ATTN: Rulemakings and Adjudications Staff

Subject: 10CFR50.55a Proposed Rulemaking Comments
RIN 3150–AI97 (Docket ID NRC–2011–0088)

Dear Sir or Madam,

This letter provides comments to the subject proposed rulemaking on behalf of the Electric Power Research Institute staff in the Materials Reliability Program.

Two comments have been drafted to respond to the NRC's proposed rulemaking on the incorporation of ASME Code Case N-729-4 with conditions into 10 CFR 50.55a. Specifically, the first comment addresses the proposed NRC condition to increase the bare metal visual examination frequency to every outage for cold heads without previously detected PWSCC, unless surface examinations of the welds are performed. The second comment addresses the application of surface examination acceptance criteria to eddy current examinations.

<u>COMMENT #1</u>

NRC proposed wording of 10 CFR 50.55a(6)(ii)(D)(3) [1]:

> Bare metal visual frequency: Instead of Note 4 of ASME BPV Code Case N-729-4, the following shall be implemented; If EDY<8 and if no flaws are found that are attributed to PWSCC; (a) a bare metal visual examination is not required during refueling outages when a volumetric or surface examination is performed, (b) If a wetted surface examination has been performed of all of the partial penetration welds during the previous non-visual examination, the reexamination frequency may be extended to every third refueling outage or 5 calendar years, whichever is less, provided an IWA-2212 VT-2 visual examination of the head is performed under the insulation through multiple access points in outages that the VE is not completed. This IWA-2212 VT-2 visual examination may be performed with the reactor vessel depressurized.

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Comment on the proposed NRC condition:

Introduction

For the reasons discussed below, the proposed 10 CFR 50.55a(g)(6)(ii)(D)(3) condition [1] to the inspection requirements of ASME Code Case N-729-4 for PWR reactor vessel top heads with Alloy 600 nozzles is not necessary to provide reasonable assurance of the structural integrity of the reactor coolant pressure boundary.

The EPRI Materials Reliability Program (MRP) recently performed a review of the recent operating experience and re-evaluation of the ASME Code Case N-729-1 technical basis that were documented in EPRI report MRP-395 [2] and presented at an NRC public meeting [3]. Section 5 of MRP-395 concluded that the current requirements for periodic visual examinations for evidence of pressure boundary leakage (per ASME Code Case N-729-1 as currently conditioned by 10 CFR 50.55a(g)(6)(ii)(D)) remain valid to address the concern for potential boric acid corrosion. It is concluded that, for heads with effective degradation years (EDY) < 8 (predominantly heads with Alloy 600 nozzles operating in U.S. at the reactor cold-leg operating temperature, Tcold, known as "cold heads") and no previously detected primary water stress corrosion cracking (PWSCC), the original technical basis for a bare metal visual examination (VE) interval of every third refueling outage or 5 calendar years, whichever is less, remains valid. The discussion below supplements the MRP-395 technical basis by addressing the specific concerns expressed in the NRC proposed rulemaking [1] that are the rationale for the proposed 10 CFR 50.55a(g)(6)(ii)(D)(3) condition.

NRC Concern Regarding the Susceptibility of Cold Heads to PWSCC

For the following reasons, the current VE interval requirements are adequate to address the concern expressed by NRC regarding the detections of PWSCC in cold heads:

- No through-wall cracking has been observed in the U.S. after the first in-service volumetric or surface examination was performed of all CRDM or CEDM nozzles in a given head. Additionally, there have been relatively few instances of PWSCC of leaking welds that have not been accompanied by PWSCC in the nozzle that is detectable by the periodic volumetric examinations. Compared with the frequency of PWSCC initiation and the size of flaws detected in heads operating at temperatures above Tcold, operating experience continues to demonstrate a relatively low susceptibility to cracking for cold heads. The operating experience for top heads clearly makes apparent the substantial relative benefit of operation at Tcold in terms of both initiation time and crack growth rates [2]. The MRP technical basis for the current inspection requirements does not presume that cold heads will not experience PWSCC. Nevertheless, no leakage (due to cracking in the nozzle or due to cracking in the J-groove weld) has been detected in any of the U.S. cold heads.
- The best indicator of the PWSCC susceptibility of an individual head is its own inspection results. All heads with Alloy 600 nozzles still in service have had multiple volumetric examinations. If PWSCC has been detected in a head, the VE interval

must already be every refueling outage per the current requirements. The option to perform the VE every third refueling outage, or 5 calendar years, whichever is sooner, is only permitted for the currently operating cold heads in the case that the past multiple volumetric and visual examinations have not detected PWSCC. Furthermore, as discussed below a VT-2 visual examination under the insulation through multiple access points must be performed during the refueling outages when a VE is not performed.

- In addition to temperature, the material variability is a known significant factor in PWSCC susceptibility. Only one material category of cold heads has exhibited PWSCC at this time, heads with nozzle material produced by a particular supplier of Alloy 600 nozzle material. It has been recognized since 2004 that heads with this material supplier have the highest relative incidence of PWSCC ([2], [4]). The five cold heads with reports of PWSCC are all within this material category, and under the current requirements the VE interval for these heads is already every refueling outage. There is a sixth head in this material category that has not reported indications of PWSCC. Plans have been announced for five of the six cold heads in this material category for head replacement or PWSCC mitigation by peening, including the head without previously detected PWSCC. A VE of the head without announced plans for mitigation or replacement is already being performed every refueling outage as PWSCC was previously reported for it. Thus, as a practical matter, the proposed NRC condition would have little effect on the subset of cold heads that has experienced PWSCC. The 13 U.S. cold heads not in this material category have all had multiple volumetric examinations without any reports of PWSCC. The predominant effect of the proposed NRC condition would be to require these heads, which have demonstrated a low susceptibility to PWSCC, to have a VE examination almost every refueling outage.

Moreover, there is widespread acceptance among PWSCC researchers ([5], [6]) that changes in temperature at the crack location have a consistent and well characterized effect on the PWSCC crack growth rate, with a relatively large benefit of operating near the cold-leg temperature. The expected reduction factor for the PWSCC crack growth rate using the standard thermal activation energy of 31 kcal/mole ([5], [6]) is between 4.6 and 3.1 for the range of cold leg temperatures at U.S. PWRs of about 547°F to 561°F versus a temperature of 605°F, which bounds the operating temperature for currently operating heads in the U.S. with Alloy 600 nozzles. These reduction factors result in substantially longer times for through-wall cracking to be produced, for circumferential flaws located above the weld to grow to a significant size, and for leaking cracks to grow larger and produce the leak rate magnitudes necessary for significant volumes of material loss to be produced via boric acid corrosion. As demonstrated by testing and analysis [7], the leak rate is the key parameter for determining whether relatively rapid and sustained boric acid corrosion may occur. Under current requirements, the VE interval for a head operating at a temperature of 605°F is each refueling outage regardless of whether PWSCC was previously detected. This corresponds to up to 2 calendar years of operation. Applying a reduction factor of 3.1 results in an equivalent time between examinations of 6.2 years, which is substantially greater than the 4.5 years corresponding to three 18-month cycles for a cold head. (All U.S. cold heads operate on nominal 18-month fuel cycles.) Thus, the reduction in PWSCC crack growth rate for cold heads supports the current VE interval requirements.

<u>NRC Concern Regarding the Potential for Boric Acid Corrosion due to Leakage Through the Weld</u>

The NRC proposed rulemaking [1] emphasizes the concern under current requirements that "leakage from a crack in the weld of a 'cold head' plant could start and continue to grow for the 5 years between the required bare metal visual examinations to detect leakage through the partial penetration weld." The NRC rulemaking discussion does not credit the current requirement that an ASME IWA-2212 VT-2 visual examination be performed of the head under the insulation through multiple access points in refueling outages that the VE is not completed. This examination was included in the original N-729-1 requirements precisely for the purpose of addressing the boric acid corrosion concern that a leak could originate just after the time of the most recent VE. As all U.S. cold heads operate on a nominal 18-month fuel cycle, a VE or VT-2 under the insulation through multiple access points must already be performed about every 1.5 years at all cold head plants.

The PWR plant experience for PWSCC of Alloy 600 J-groove nozzles, including that for reactor vessel top head nozzles, ([8] as summarized in [9] and presented at an NRC public meeting [10]) shows that periodic visual examinations performed under the insulation at appropriate intervals are highly effective in detecting any leakage caused by PWSCC before any discernible material loss is produced via boric acid corrosion of carbon or low-alloy steel pressure boundary components. In addition to the visual indications, other indicators that leakage rates may be sufficient to cause significant boric acid corrosion are the progression of the unidentified primary system leakage rate, clogging of the containment air coolers, and plugging of the containment radiation monitor filters [4]. Mock-up testing and analyses documented in MRP-308 [7] and presented at an NRC public meeting ([11], [12]), including photographs of deposit buildup on test mockups, show that large volumes of boric acid deposits necessarily accompany cases of significant boric acid corrosion. These large volumes of deposits would be readily visible in the VT-2 examination under the insulation through multiple access points already required. Thus, the current visual examination requirements are already sufficient to address the boric acid corrosion concern for cold heads. The current VT-2 requirement limits the duration of active leakage that could cause significant material loss to occur.

<u>Conclusions</u>

Cold heads that have not exhibited any flaws attributable to PWSCC are already subject to a visual assessment of the top head condition under the insulation every 18 months. Either a VT-2 under the insulation through multiple access points or a bare metal VE is performed every refueling outage. Operating experience and boric acid corrosion testing demonstrate that this program of periodic visual examinations would detect any leakage prior to significant material loss occurring due to boric acid corrosion.

For heads where PWSCC has previously been detected, a bare metal VE is already required each refueling outage. Heads without previously detected PWSCC have a low susceptibility to PWSCC demonstrated by multiple volumetric and visual examinations. Plant experience with Alloy 600 reactor vessel top head nozzles continues to demonstrate a low probability of pressure boundary leakage given the currently required periodic volumetric examinations. No leakage has been detected for any of the U.S. cold heads. Furthermore, plans for mitigation by peening or head replacement have been announced for five of the six heads in the one material category of cold heads for which cracking has been detected, and the remaining head in this group is already required to perform a bare metal VE each refueling outage. For these reasons, the concern for the "increasing trend" in cold head cracking cited in the proposed rulemaking is already addressed by the existing requirements.

In summary, the predominant effect of the proposed NRC condition would be to require the subset of cold heads with a demonstrated low susceptibility to PWSCC (i.e., no PWSCC detections to date) to have a VE examination most every refueling outage. This is unnecessary as the current requirement for a VE or a VT-2 under the insulation through multiple access points about every 1.5 years ensures that any potential leakage through the partial penetration welds is identified prior to significant degradation of the low-alloy steel head material. Consequently, the imposition of the proposed 10 CFR 50.55a(g)(6)(ii)(D)(3) condition on ASME Code Case N-729-4 is not necessary to provide reasonable assurance of the structural integrity of the reactor coolant pressure boundary.

Proposed Revision to Paragraph: 50.55a (g) (6) (ii) D (3) Bare metal visual frequency:

It is respectfully commented that this condition should not be included in the final rulemaking.

References

1. U.S. Nuclear Regulatory Commission, Proposed Rule, 10 CFR Part 50, NRC-2011-0088, RIN 3150-AI97, "Incorporation by Reference of American Society of Mechanical Engineers Codes and Code Cases," 7590-01-P. [NRC ADAMS Accession No.: ML14065A203]
2. Materials Reliability Program: Reevaluation of Technical Basis for Inspection of Alloy 600 PWR Reactor Vessel Top Head Nozzles (MRP-395), EPRI, Palo Alto, CA: 2014. 3002003099. [freely available on www.epri.com]
3. G. White, K. Schmitt, K. Fuhr, and C. Harrington, "Update of Technical Basis for Inspection of Alloy 600 PWR Reactor Vessel Top Head Nozzles," Presented at NRC Public Meeting, October 31, 2014. [NRC ADAMS Accession No. ML14304A076]

4. Materials Reliability Program Reactor Vessel Closure Head Penetration Safety Assessment for U.S. PWR Plants (MRP-110): Evaluations Supporting the MRP Inspection Plan, EPRI, Palo Alto, CA: 2004. 1009807. [NRC ADAMS Accession No. ML041680506]
5. Materials Reliability Program (MRP) Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick-Wall Alloy 600 Materials (MRP-55) Revision 1, EPRI, Palo Alto, CA: 2002. 1006695. [freely available on www.epri.com]
6. Materials Reliability Program Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Alloy 82, 182, and 132 Welds (MRP-115), EPRI, Palo Alto, CA: 2004. 1006696. [freely available on www.epri.com]
7. Materials Reliability Program: Boric Acid Corrosion Testing: Implications and Assessment of Test Results (MRP-308), EPRI, Palo Alto, CA: 2011. 1022853. [freely available on www.epri.com]
8. Materials Reliability Program: Boric Acid Corrosion Guidebook, Revision 2: Managing Boric Acid Corrosion Issues at PWR Power Stations (MRP-058, Rev 2), EPRI, Palo Alto, CA: 2012. 1025145.
9. G. White, R. Jones, J. Gorman, C. Marks, J. Collin, and R. Reid, "Revision 2 of the EPRI Boric Acid Corrosion Guidebook," 16th International Conference on Environmental Degradation of Materials in Nuclear Power Systems—Water Reactors, 2013.
10. R. Jones and G. White, "Boric Acid Corrosion: Revision to BAC Guidebook," Presented at NRC Public Meeting, February 29, 2012. [NRC ADAMS Accession No. ML120690185]
11. R. Jones and G. White, "Boric Acid Corrosion: Implications Assessment of BAC Test Programs," Presented at NRC Public Meeting, February 29, 2012. [NRC ADAMS Accession No. ML120690182]
12. R. Reid, "Boric Acid Corrosion Testing Program Overview," Presented at NRC Public Meeting, February 29, 2012. [NRC ADAMS Accession No. ML120690174]

COMMENT #2

Paragraph: 50.55a (g) (6) (ii) D (4) Surface exam acceptance criteria:
In addition to the requirements of paragraph -3132.1(b) of ASME BPV Code Case N-729-4, a component whose surface examination detects rounded indications greater than allowed in Paragraph NB-5352 in size on the partial-penetration or associated fillet weld shall be classified as having an unacceptable indication and corrected in accordance with the provisions of paragraph-3132.2 of ASME BPV Code Case N-729-4.

Comment:
The acceptance criteria stated in NB-5352 is based on the detection capability of the dye-penetrant examination method. However the paragraph does not provide distinction on the examination method that is applied, and, hence, is applied to all surface examination techniques irrespective of the NDE method. This criteria detrimentally affects the

application of eddy current in two ways: first, it provides a detection target that is at the threshold of ET's detection capability since the paragraph implies that the defect is isolated and rounded without any associated subsurface cracking; second, it gives ET no credit for its capability to detect the subsurface cracking associated with PWSCC cracking that would not be detectable by dye-penetrant testing. The detrimental aspect of this combining of ET into a PT acceptance criteria is that the examiners will then be forced to resort to designing their ET examination techniques with "high resolution" sensors and filtering procedures, thus making the examination susceptible to "false calls".

Proposed Revision to Paragraph: 50.55a (g) (6) (ii) D (4) Surface exam acceptance criteria:
In addition to the requirements of paragraph -3132.1(b) of ASME BPV Code Case N-729-4, a component whose dye-penetrant surface examination detects rounded indications greater than allowed in Paragraph NB-5352 in size on the partial-penetration or associated fillet weld shall be classified as having an unacceptable indication and corrected in accordance with the provisions of paragraph-3132.2 of ASME BPV Code Case N-729-4.

We appreciate the opportunity to provide comments to this proposed rulemaking. Should you have any questions pertaining to the comments provided in this letter, please contact Jack Spanner for clarification.

Sincerely,

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