ENCLOSURE 2 to AEP-NRC-2015-69

Pressurized Water Reactor Owners Group (PWROG)-15066-NP, Revision 1

Responses to Follow-Up NRC RAI 2 on the DC Cook Units 1 and 2 Reactor Internals Aging Management Program

PRESSURIZED WATER REACTOR OWNERS GROUP

PWROG-15066-NP
Revision 1

WESTINGHOUSE NON-PROPRIETARY CLASS 3

Responses to Follow-Up NRC RAI 2 on the DC Cook Units 1 and 2 Reactor Internals Aging Management Program

Materials Committee

PA-MSC-0983, Revision 1, Task 8

October 15, 2015

Westinghouse

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PA-MSC-0983, Revision 1, Task 8

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Overview

Revision 0 of report PWROG-15066-NP, dated July 28, 2015, was created to respond to a set of follow-up requests for additional information (RAIs) from the U.S. Nuclear Regulatory Commission (NRC) on the D.C. Cook Units 1 and 2 reactor vessel internals aging management program submittal [1]. Revision 0 was submitted to the NRC as Enclosure 2 of Reference 2.

Revision 1 of this report expands on the responses to request part b of follow-up RAI 2 adding clarifications to address questions received verbally from the NRC staff during the September 23, 2015 public meeting summarized in Reference 3. The NRC staff's questions during that meeting were focused on the last four of the six points made in the original response to follow-up RAI 2b and can be summarized as follows:

- Provide the basis for stating that "thermal embrittlement of cast austenitic stainless steel (CASS) does not result in complete loss of fracture toughness. Even with complete thermal embrittlement, a significant amount of fracture toughness would remain in the card."
- Provide information to support the claim that the VT-3 Primary Component inspection for wear will detect cracking in time to prevent loss of function for the guide cards.
- Provide information on the redundancy of the guide cards to support the statement that "failures at multiple cards would be required for the control rods to slip out of place and the failure of the control rods in one CRGT assembly to insert would not preclude safe shutdown."
- Provide information on the existing plant practices for periodic monitoring of control rod functionality.

The specific clarifications and additional information addressing these concerns have been incorporated in the relevant sections of the original response to follow-up RAI 2, part b provided in Revision 0 of this report. These updates can be found in the revised section "Response to Request Part (b)" in Revision 1 of this report and are marked with change bars.

References

1. U.S. Nuclear Regulatory Commission Letter, "Donald C. Cook Nuclear Plant, Units 1 and 2 – Follow-Up Request for Additional Information Concerning the Reactor Vessel Internals Aging Management Program Submittal (TAC Nos. MF0050 and MF0051), May 5, 2015, (ADAMS Accession Number ML15119A339).
2. Indiana Michigan Power Letter, AEP-NRC-2015-69, "Donald C. Cook Nuclear Plant Units 1 and 2 Response to Follow-Up Request for Additional Information Concerning the Reactor Vessel Internals Aging Management Program," Docket Nos. 50-315 and 50-316, August 6, 2015, (ADAMS Accession Numbers ML15223A435 and ML15223A436).
3. U.S. Nuclear Regulatory Commission Meeting Announcement, "Summary of September 23, 2015, Public Meeting with Indiana Michigan Power Company Regarding Donald C. Cook Nuclear Plant, Units 1 and 2 (TAC Nos. MF0050 and MF0051)," October 5, 2015, (ADAMS Accession Number ML15271A046).

From Nuclear Regulatory Commission Letter, "Donald C. Cook Nuclear Plant, Units 1 and 2 – Follow-Up Request for Additional Information Concerning the Reactor Vessel Internals Aging Management Program Submittal (TAC Nos. MF0050 and MF0051)," May 5, 2015.

Follow-Up RAI-2 - Response to AI 7 and RAI-6 Regarding CASS Components
Background
In accordance with AI 7 of the MRP-227-A SE, the licensee provided its evaluation of the cast austenitic stainless steel (CASS) RVI components for DC Cook 1 and 2 in Attachments 3 and 4, respectively, of Westinghouse LTR-RIAM-14-24, Revision (Rev.) 1, "Reports for D.C. Cook, Units 1 and 2 for PWROG PA-MSC-0983 Cafeteria Tasks 3, 4, and 5 Deliverables (Non-Proprietary)" - heretofore referred to as the AI 7 reports. These reports were included as Enclosure 6 of the licensee's final RAI response, dated October 22, 2014 (ADAMS Accession No. ML 14316A449).

Additional information is required in order to demonstrate that the MRP-227-A guidelines are adequate for aging management of the CASS components identified in Table 1 below. Table 1 summarizes the licensee's determination of the components' susceptibility to thermal embrittlement (TE) and irradiation embrittlement (IE) in the AI 7 reports, the generic material and FMECA classification from MRP-191, and the additional information required for each CASS component. The licensee determined susceptibility to TE based on the screening criteria established for non-irradiated CASS in the U.S. NRC letter from C. Grimes, Office of Nuclear Reactor Regulation, dated May 19, 2000, "License Renewal Issue No. 98-0030, Thermal Aging Embrittlement of Cast Austenitic Stainless Steel Components" (ADAMS Accession No. ML003717179, the C. Grimes Letter). The licensee determined susceptibility to IE based on the MRP-191 generic IE threshold for CASS components. Screening of CASS components for the synergistic effects of IE and TE using more recent IE and TE thresholds for irradiated CASS promulgated by staff in a June 2014 white paper (ADAMS Accession No. ML 14163A112) has not yet been addressed for DC Cook 1 and 2.

Table 1 – DC Cook CASS RVI Components Requiring Further Evaluation

CASS Component	Plant-Specific TE Susceptibility Based on May 2000 C. Grimes Letter	Generic IE Susceptibility Based on MRP-191	Generic MRP-191 Material and FMECA[(3)] Group	Additional Information Needed
		DC Cook 1		
CRGT[(1)] Assembly – Guide Plates/Cards	YES[(2)]	NO	304 SS Group 3	Plant-Specific Evaluation and Inspection Criteria for Cracking
CRGT[(1)] Assembly – Housing Plates	YES[(2)]	NO	304 SS Group 0	Justification for AI 1 Resolution[(4)]

CASS Component	Plant-Specific TE Susceptibility Based on May 2000 C. Grimes Letter	Generic IE Susceptibility Based on MRP-191	Generic MRP-191 Material and FMECA(3) Group	Additional Information Needed
		DC Cook 1		
Upper Instrumentation Conduit and Supports – Brackets, Clamps, Terminal Blocks, Conduit Straps	YES(2)	NO	304 SS Group 0	Justification for AI 1 Resolution(4)
Lower Support Column Assemblies – Lower Support Column Bodies	YES(2)	YES	CF8 CASS Group 1	Plant-Specific Functionality Analysis or Inspection Plan
		DC Cook 2		
Upper Instrumentation Conduit and Supports – Brackets, Clamps, Terminal Blocks, Conduit Straps	YES(2)	NO	304 SS Group 0	Justification for AI 1 Resolution(4)
Upper Support Plate Assembly – Plate, Flange, and Upper Support Ring or Skirt	NO	NO	304 SS Group 2 – Ring or Skirt Group 0 – Plate and Flange	Justification for AI 1 Resolution(4)
Lower Support Column Assemblies – Lower Support Column Bodies	NO	YES	CF8 CASS Group 1	Plant-Specific Functionality Analysis or Inspection Plan(4)

Notes:

(1) *Control rod guide tube (CRGT) components are assumed to be CASS by the licensee since documentation of constructional materials was not located.*

(2) *Susceptibility to TE is due to lack of CMTR data and assumed delta ferrite greater than 20 percent, as indicated in Tables 3.1-1 and 4.1-1 of the licensee's AI 7 reports in Attachments 3 and 4 of LTR-RIAM-14-24 .*

(3) *FMECA – Failure Modes, Effects, and Criticality Analysis. Generic FMECA results for Westinghouse RVI are provided in MRP-191, Table 6-5.*

(4) *The staff's recent IE and TE screening criteria for irradiated CASS were provided in a June 2014 white paper. Synergistic effects of IE and TE based on these 2014 screening criteria should be considered for these components, as part of the justification, evaluation, or functionality analysis.*

For those components identified in Table 1 as needing "Justification for AI 1 Resolution", the licensee's reports for AI 1 (Attachments 1 and 2 of LTR-RIAM-14-24) state that "[a] FMECA expert panel review applying the same methodology as used in the development of MRP-191 was conducted for these components ... [and] concluded that the aging management strategies of MRP-227-A were still applicable based on a consideration of the likelihood of failure and the likelihood of damage and the resulting classification of components." No additional details were provided regarding this determination.

Request Part (a) for Follow-Up RAI-2

For those confirmed CASS components designated in Table 1 as needing "Justification for AI 1 Resolution," provide justification for the determination that the MRP-227-A guidelines are still applicable to the above components based on the MRP-191 methodology, in accordance with AI 1. This justification should include the plant-specific screening results for all aging mechanisms, explanation of the likelihood of component failure, the likelihood of core damage, the resulting FMECA group for the components, the categorization and ranking of the components, and a discussion of how the final aging management strategy was determined. The justification must account for the additional embrittlement mechanisms (IE and/or TE) for CASS that were not generically considered for these components due to their treatment as non-CASS in MRP-191. This justification must take into consideration the potential synergistic effects of IE and TE for the CASS components. Screening criteria for IE and TE of irradiated CASS that are acceptable are detailed in a June 2014 white paper (ADAMS Accession No. ML 14163A112).

Request Part (b) for Follow-Up RAI-2

The CRGT assembly guide plates/cards are generically analyzed as 304 stainless steel in MRP-191 and assigned to FMECA Group 3 in that report. MRP-227-A specifies that the Guide Plates/Cards are to be inspected as primary components for loss of material (wear) using the VT-3 visual examination method on the 10-year inservice inspection (ISI) interval. At DC Cook 1, the CRGT guide plates/cards are assumed to be CASS and susceptible to TE. Additionally, MRP-191 indicates that the guide cards screened in for cracking due to SCC (welds) and fatigue, for the generic guide card material. Given that the susceptibility of the CASS guide plates/cards to TE would make these components more likely to fail if cracks were present, provide an evaluation of the susceptibility of the guide cards to cracking. If the guide cards are susceptible to cracking, propose plant-specific inspection criteria for these components that would be sufficient for detecting cracking, or provide an evaluation of the components justifying that no additional inspections, other than the MRP-227-A inspection criteria, are necessary for these CASS components considering their susceptibility to cracking.

Request Part (c) for Follow-Up RAI-2

The DC Cook 1 lower support column (LSC) bodies are susceptible to TE and IE and therefore require an analysis to demonstrate their functionality during the period of extended operation, considering aging degradation of the LSC bodies due to TE and IE. The DC Cook 2 LSC bodies screened as not susceptible [to] TE based on the criteria of the May 2000 C. Grimes Letter for non-irradiated CASS, but are susceptible to IE based on MRP-191. However, if the DC Cook 2 LSC bodies have delta ferrite greater than 15 percent, synergistic effects of both TE and IE are applicable, based on the more recent IE and TE thresholds for irradiated CASS established in the June 2014 white paper.

The licensee indicated in response to RAI-6(b) that the methodology for demonstrating the functionality of the LSC bodies is currently under development by the PWROG. An alternative to the functionality analysis could involve a plant-specific change to the inspection criteria for these expansion components. Any plant-specific inspection criteria should take into account the following: The LSC bodies are categorized as "Expansion" components in MRP-227-A for cracking due to IASCC and IE. However, the "Primary" linked component in MRP-227-A for the LSC bodies, the CRGT lower flange welds, is not a good predictor for either IASCC or IE because of the low neutron fluence exposure for the CRGT lower flange welds.

Submit the analysis to demonstrate the functionality of the DC Cook 1 and 2 LSC bodies during the period of extended operation, considering aging degradation due to the synergistic effects of IE and TE, or propose a plant-specific change to the inspection criteria for these components.

Responses:

Response to Request Part (a):

The components in Table 1 of follow-up RAI 2 that are designated as needing "Justification for AI 1 Resolution" are repeated in the following list:

- Unit 1
  - Control rod guide tube (CRGT) Assembly – Housing plates
  - Upper instrumentation conduit and supports – brackets, clamps, terminal blocks, conduit straps
- Unit 2
  - Upper instrumentation conduit and supports – brackets, clamps, terminal blocks, conduit straps
  - Upper support plate assembly – Plate, flange, and upper support ring or skirt

Table 1 summarizes the plant-specific results of the DC Cook Units 1 and 2 expert panel elicitation [1]. This elicitation was conducted under the guidance of the process described in MRP-191, Section 6 [2]. Table 1 includes the plant-specific screening results, likelihood of failure, likelihood of core damage, and resulting FMECA group determined by the expert panel elicitation for these five components. In each case, the likelihood of component failure and likelihood of core damage were determined by the expert panel evaluating the component in light of the different material of construction and revised aging degradation mechanism screening by applying the expert panel ranking system provided in MRP-191, Tables 6-2 and 6-3. Note that the resulting FMECA group was then determined based on the chart in Table 6-4 of MRP-191.

After the determination of the FMECA group, the expert panel considered each component for any impacts on the aging management strategies provided in MRP-227-A [4]. This was done by considering the FMECA ranking, the existing operating experience for the component, and how the potential degradation of that component would rank relative to other components with the same degradation mechanism(s) and a relevant situation (such as geometry or stress). The ranking consideration followed the "waterfall" concept used in the original MRP-227-A development. The upper support ring or skirt is already included in the MRP-227-A aging management strategy as an Existing Component. The expert panel determined that the addition of TE as a degradation mechanism did not increase the FMECA grouping and that the current Existing Component inspection requirement was still adequate for the component [1]. For the other four components or component groups in Table 1, the expert panel determined that even with the addition of TE as a degradation mechanism, the Primary, Expansion, and Existing Components strategies in MRP-227-A are adequate and appropriate for managing potential aging in these components with fabrication material different from the original MRP-191 assumption.

To address the potential for synergistic effects of TE and IE, Indiana Michigan Power (I&M) is currently working with the Electric Power Research Institute (EPRI) Industry Working Group and the Pressurized Water Reactor Owners Group (PWROG) to resolve the impact of the revised NRC staff TE threshold limits guidance [3] on the previous evaluations of RVI CASS component embrittlement. The revised threshold limits that have been proposed by the NRC are still under active discussion as recently as a meeting on June 2-4, 2015 [6]. It is noted that previous evaluations, including this current evaluation for DC Cook Units 1 and 2, have been performed using the screening process identified in MRP-191 [2], which formed the basis for the component rankings and recommended inspections identified in MRP-227-A [4]. The DC Cook Units 1 and 2 responses to A/LAI 7 were based on TE threshold criteria identified in Reference 5, as recommended in the NRC safety evaluation of MRP-227-A.

The process in Reference 5 is less complex than that outlined in the revised NRC guidelines, but has slightly different and, in some cases, more conservative thresholds. The PWROG program is expected to deliver a resolution of this issue by the fourth quarter of the present calendar year. Note that in the case of the components listed in Table 1, the potential synergistic effects of TE and IE are not expected to occur because all of these components are sufficiently removed from the active core to have irradiation exposure levels below both the limits of MRP-191 [2] and Reference 3 screening [1].

References

1. Westinghouse Letter, LTR-RIAM-14-87, Revision 1, "Summary of DC Cook Units 1 and 2 Expert Elicitation Panel Meeting Minutes for Reactor Internals Components, and Materials," September 26, 2014.
2. *Materials Reliability Program: Screening, Categorization, and Ranking of Reactor Internals Components for Westinghouse and Combustion Engineering PWR Design (MRP-191)*. EPRI, Palo Alto, CA: 2006. 1013234.
3. U.S. Nuclear Regulatory Commission Document, "NRC position on Aging Management of CASS Reactor Vessel Internal Components" (ADAMS Accession Number ML14163A112).
4. *Materials Reliability Program: Pressurized Water Reactor Internals Inspection and Evaluation Guidelines (MRP-227-A)*. EPRI, Palo Alto, CA: 2011. 1022863.
5. U.S. Nuclear Regulatory Commission Letter, "License Renewal Issue No. 98-0030, Thermal Aging Embrittlement of Cast Austenitic Stainless Steel Components," May 19, 2000 (NRC ADAMS Accession No. ML003717179).
6. U.S. Nuclear Regulatory Commission Document, "Summary of June 2-4, 2015, Annual Materials Programs Technical Information Exchange Public Meeting," July 14, 2015 (NRC ADAMS Accession No. ML15162A925).

Table 1: Expert Panel FMECA Results (Revised based on Expert Panel Elicitation)

Assembly	Subassembly	Component	Material	Screened-in Degradation Mechanisms	Likelihood of Failure L, M, H	Likelihood of Damage L, M, H	FMECA Group
Upper Internals Assembly	Control Rod Guide Tube Assemblies and Flow Downcomers	Housing Plate	CF8	5	L	M	1
	Upper Instrumentation Conduit and Supports	Brackets, Clamps, Terminal Blocks, and Conduit Straps	CF8	5	L	L	1
	Upper Support Plate Assembly	Flange	CF8	5	L	M	1
		Upper Support Plate	CF8	5	L	M	1
		Upper Support Ring or Skirt	CF8	1A, 4, 5	M	M	2

FMECA Groups			
Failure Likelihood	**Consequence (Damage Likelihood)**		
	Low	**Medium**	**High**
High	2	3	3
Medium	1	2	3
Low	1	1	2
None	0	0	0

Degradation Mechanisms	
SCC	1
SCC of Welds	1A
IASCC	2
Wear	3
Fatigue	4
Thermal Embrittlement	5
Irradiation Embrittlement	6
Void Swelling	7
Irradiation ISR/IC; Thermal SR	8
None (Values for mechanisms did not exceed screening threshold values.)	None

Response to Request Part (b):

The susceptibility of the potentially CASS guide cards at DC Cook Unit 1 was evaluated as part of the expert panel elicitation performed in support of responding to A/LAI 1 and 2 [1]. It should be noted that CASS CF8 is only listed as an alternate material for the guide cards, and it is expected that the primary material, wrought Type 304 stainless steel, is the more likely material used. However, in the absence of confirmatory records showing that the cards were fabricated from the primary material on the drawings, Type 304 stainless steel, and not the alternate CASS CF8 material, the expert panel made the conservative assumption that CASS material should be considered.

The expert panel review was conducted as part of the effort to revise the RVI aging management program for DC Cook Unit 1 to conform to MRP-227-A. The expert panel was conducted under the guidance of the process described in MRP-191, Section 6 [2]. Table 2 includes the plant-specific screening results, likelihood of failure, likelihood of damage, and resulting FMECA group determined by the expert panel elicitation for CASS guide cards. In each case, the likelihood of component failure and likelihood of core damage were determined by the expert panel evaluating the component in light of the potential different material of construction and revised aging degradation mechanism screening by applying the expert panel ranking system provided in MRP-191, Tables 6-2 and 6-3. Note that the resulting FMECA group was then determined based on the chart in Table 6-4 of MRP-191.

The conclusion of the expert panel review was that the CASS guide cards did not have enough increased susceptibility due to the addition of TE as an aging degradation mechanism to require changes to the current aging management strategy at DC Cook Unit 1 under MRP-227-A [1, 3]. The expert panel assigned the same categorization and ranking for the CASS guide cards as for the Type 304 SS guide cards in MRP-191 in order to manage the potential for wear degradation of the cards.

Aging degradation mechanism screening was conducted using the criteria provided in MRP-175 [4] and used in MRP-191 [1]. TE was the only additional aging degradation mechanism that screened in for the CASS guide cards. Irradiation effects, including irradiation embrittlement, were considered for screening but were eliminated due to the distance of the guide cards from the active core region (this would be true for either the original screening criteria or the proposed revised criteria [5]). SCC of the welds and fatigue were maintained as degradation mechanisms because there are still welds present on the CASS guide cards and the switch to CASS did not significantly affect the screening criteria from MRP-175 for these two mechanisms. SCC of the guide card away from the welds was considered, but this was determined to not be an issue based on comparison of the CASS and Type 304 SS screening criteria and the fact that a change in the material between the two would not be accompanied by a change in the stresses in the guide card.

The conclusion that cracking effects would not become more of a concern for the CASS guide cards than they were for assumed guide cards fabricated from Type 304 SS was based primarily on three observations [1]:

- Changing between CASS CF8 and Type 304 SS for a component where both are provided as alternate materials would not result in a difference in the stress, function, or geometry of the part. This factored into both the assignment of the likelihood of failure and the likelihood of damage.
- Welds on a component fabricated from CASS material would be similar to those on the chemically equivalent wrought material (such as for CF8 and Type 304 SS). A weld locally melts material and then it re-solidifies. The same process occurs for welds on castings or on forgings.
- Thermal embrittlement of CASS does not result in a complete loss of fracture toughness. Even with complete thermal embrittlement, a significant amount of fracture toughness would remain in the card.

  This conclusion is based on the allowable alternate CASS material being CF8 [1] and industry data showing that even fully embrittled ("saturation thermal embrittlement") CF8 material retains significant toughness. These data were presented to the NRC staff in a meeting on September 16, 2015, as provided in Reference 6. The data presented at that meeting showed that the CF8 material manufactured for PWR reactor vessel internals components has significant remaining fracture toughness even after reaching full thermal embrittlement. Based on the compiled industry experience, the minimum saturation fracture toughness is 100 kJ/m^2 above the 255 kJ/m^2 screening value which the NRC has indicated is sufficient to ensure adequate fracture toughness in light water reactor applications [7]. The basis method of calculating the saturation fracture toughness of a CASS material based on its composition was that detailed in NUREG-4513 [8].

The final conclusion that the potential presence of CASS guide cards at DC Cook Unit 1 does not require a change to the aging management strategy of MRP-227-A was based on several considerations [1].

- The determinations of screened-in degradation mechanisms, likelihood of failure, likelihood of damage, and FMECA group and ranking provided by the expert panel when assuming CASS material.

  The expert panel review determined that the FMECA group and ranking provided for MRP-191 and used in MRP-227-A for Type 304 stainless steel guide cards were also applicable to CASS guide cards [1]. It was determined that potential TE of the guide cards did not require additional aging management requirements.
- The scope of the current VT-3 Primary Component inspection for wear required under MRP-227-A [3], which would detect gross failures.
  - The requirements of a VT-3 inspection are provided in ASME code, Section XI [9] with additional details specific to the reactor vessel internals inspections of MRP-227-A provided in the "Inspection Standard for PWR Internals," MRP-228 [10]. WCAP-17451-P, Section 5.5 [11] provides further information on accuracy and coverage requirements. Following these procedures would be adequate to detect cracking prior to loss of function of guide cards because the general condition visual examination (VT-3), while being primarily used to evaluate wear on each card by assessing its profile, would detect damage such as deformed

sections of the cards or missing card ligaments which could have an impact on the guide card functionality. The VT-3 examination is not expected to detect fine cracking if present, but such fine cracking is not expected to impact the function of the guide card unless it becomes extensive enough to result in multiple instances of the types of more significant damage which are detectable by the general visual inspection (see discussion of guide card redundancy below).

  - Given that the VT-3 examination of guide cards is established as adequate to detect damage of significance prior to loss of function of the CRGT assembly, the coverage of the examination must be considered to determine if it also is adequate to ensure confidence in maintained functionality. This is ensured by the industry inspection requirements:
    - As with other components in MRP-227-A, the inspection requirements provided in WCAP-17451-P [11] are a sampling strategy and do not require inspection of every CRGT assembly; however, the guidance of WCAP-17451-P, Section 5.5 recommends inspecting every assembly and provides requirements to inspect a significant percentage of the assemblies to ensure adequate statistical understanding of the uninspected population.
    - The inspection requirements of WCAP-17451-P, Section 5.5 are focused on measuring the locations with highest wear – the lowest guide cards and the continuous assembly – but state that video should be captured of the remaining guide cards.
- The redundancy of the component – failures at multiple cards would be required for the control rods to slip out of place and the failure of the control rods in one CRGT assembly to insert would not preclude safe shutdown.
  - The failure criteria for CRGT guide card wear provided in WCAP-17451-P [11] include consideration of how many sequential guide cards in a single CRGT assembly must fail (allow the control rod to slip out of place) before the function of that particular CRGT assembly is impacted (See Table 4-1 and Figure 2-21 of WCAP-17451-P for identification of DC Cook Unit 1 identification and use that in Section 5.2 and Table 5-10 of WCAP-17451-P for the number of allowable, consecutive failed cards—the number of guide cards provided in Table 5-10 plus one more consecutive guide card must fail in a CRGT assembly before affecting functionality). Based on the previous discussions of remaining fracture toughness of full embrittled material and the low risk and FMECA ranking assigned by the expert panel, fracture of a single guide card is considered unlikely. Thus, fractures in multiple consecutive guide cards in a single assembly are considered extremely unlikely.
  - The design specifications of the control rods and CRGT assemblies require that the failure of any one control rod assembly to insert not impact the safe shutdown of the reactor. Thus, for the loss of overall function, multiple assemblies would have to lose their functionality. Since it is unlikely that fractures resulting from thermal embrittlement would appear simultaneously in multiple assemblies, the large number of assemblies and the inspections required by WCAP-17451-P provide the basis for the expectation that the redundancy of the system would be adequate to maintain function of the control rod insertion system.

- The periodic monitoring of control rod functionality under current plant procedures.

  Control rod testing provides periodic demonstration of the continuing performance of the control rods. Continued acceptable performance of the control rods in these tests provides evidence of the absence of damage impacting the functionality of the guide cards on a continuing basis.

These factors were all taken into account by the expert panel in determining the FMECA results and rankings for the potential that the guide cards at DC Cook Unit 1 could have been fabricated from CF8 CASS material and in considering what changes may be required in the aging management strategy. Based on these considerations, the expert panel concluded that the potential presence of CF8 CASS guide cards at DC Cook Unit 1 does not require changes to the aging management strategies provided in MRP-227-A.

Table 2: Expert Panel FMECA Results for CRGT Guide Plates/Cards (Revised based on Expert Panel Elicitation)

Assembly	Subassembly	Component	Material	Screened-in Degradation Mechanisms	Likelihood of Failure L, M, H	Likelihood of Damage L, M, H	FMECA Group
Upper Internals Assembly	Control Rod Guide Tube Assemblies and Flow Downcomers	Guide Plates/Cards	CF8	1A, 3, 4, 5	H	M	3

FMECA Groups			
Failure Likelihood	Consequence (Damage Likelihood)		
	Low	Medium	High
High	2	3	3
Medium	1	2	3
Low	1	1	2
None	0	0	0

Degradation Mechanisms	
SCC	1
SCC of Welds	1A
IASCC	2
Wear	3
Fatigue	4
Thermal Embrittlement	5
Irradiation Embrittlement	6
Void Swelling	7
Irradiation ISR/IC; Thermal SR	8
None (Values for mechanisms did not exceed screening threshold values.)	None

References

1. Westinghouse Letter, LTR-RIAM-14-87, Revision 1, "Summary of DC Cook Units 1 and 2 Expert Elicitation Panel Meeting Minutes for Reactor Internals Components, and Materials," September 26, 2014.
2. *Materials Reliability Program: Screening, Categorization, and Ranking of Reactor Internals Components for Westinghouse and Combustion Engineering PWR Design (MRP-191)*. EPRI, Palo Alto, CA: 2006. 1013234.
3. *Materials Reliability Program: Pressurized Water Reactor Internals Inspection and Evaluation Guidelines (MRP-227-A)*. EPRI, Palo Alto, CA: 2011. 1022863.
4. *Materials Reliability Program: PWR Internals Material Aging Degradation Mechanism Screening and Threshold Values (MRP-175)*. EPRI, Palo Alto, CA: 2005. 1012081.
5. U.S. Nuclear Regulatory Commission Document, "NRC position on Aging Management of CASS Reactor Vessel Internal Components" (ADAMS Accession Number ML14163A112).
6. Pressurized Water Reactors Owners Group Presentation, WAAP-9551-NP, Revision 1, "PA-MSC-1288R0: PWR Materials Assessment Results," September 2015.
7. U.S. Nuclear Regulatory Commission Letter, "License Renewal Issue No. 98-0030, Thermal Aging Embrittlement of Cast Austenitic Stainless Steel Components," May 19, 2000 (NRC ADAMS Accession No. ML003717179).
8. U.S. Nuclear Regulatory Commission Report, NUREG-4513, Revision 1, "Estimation of Fracture Toughness of Cast Stainless Steels during Thermal Aging in LWR Systems," August 1994.
9. ASME Boiler & Pressure Vessel Code, Section XI, Division 1, "Rules for Inservice Inspection of Nuclear Power Plant Components," American Society of Mechanical Engineers, New York, NY, 2004 Edition.
10. *Materials Reliability Program: Inspection Standard for PWR Internals—2012 Update (MRP-228, Rev 1)*. EPRI, Palo Alto, CA: 2012. 1025147.
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Response to Request Part (c)

The strategy for managing the aging degradation of the DC Cook Units 1 and 2 CASS lower support column bodies was developed in compliance with the Inspection and Evaluation Guidelines, MRP-227-A [1]. The aging degradation screening of the CASS lower support column bodies is recorded in MRP-191, Table 5-1 [2], which is a basis document for MRP-227-A. In MRP-191, the CASS lower support column bodies were screened in as susceptible to irradiation assisted stress corrosion cracking (IASCC), void swelling (VS), and the embrittlement mechanisms, thermal embrittlement (TE) and irradiation embrittlement (IE). The expert panel conclusions documented in MRP-191 [2] served as the basis for the aging management program guidelines provided in MRP-227-A [1]. The NRC is concerned that there may be a combined effect of TE and IE, which is discussed in new guidelines issued by the NRC [3].

The EPRI Industry Working Group and the PWROG are working to resolve the impact of the revised NRC staff thermal embrittlement threshold limits guidance [3]. There are slight differences between the industry's position and the revised NRC guidance. The industry's position with regard to the susceptibility of low molybdenum content CASS (CF3 and CF8) material to IE is more conservative than the NRC guidance (1 dpa vs. 1.5 dpa). The new NRC guidance for the potential for susceptibility to combined TE and IE is more restrictive than the industry criterion for IE alone, (i.e. ferrite content 15 percent vs. 20 percent and fluence 0.45 dpa vs 1.0 dpa). The NRC has recently discussed the guidance for IE and TE for CASS [6] and more information on the NRC guidance and a resolution of the NRC and industry positions are expected to be forthcoming. The PWROG program is expected to deliver a resolution of this issue by the fourth quarter of the present calendar year.

The DC Cook lower support column bodies are static cast, A296, Grade CF8. For the DC Cook Unit 1 lower support column bodies, the certified material test reports (CMTRs) were not located. Thus, their ferrite content values are conservatively assumed to have potentially exceeded 20 percent, screening the DC Cook Unit 1 lower support column bodies as potentially susceptible to TE.

For DC Cook Unit 2 lower support column bodies, the ferrite contents were calculated using the appropriate equations for the Hull's equivalent factors and using the chemical compositions provided by the CMTRs. However, not all of the elemental chemical compositions required for the Hull's equivalent factors are provided in the located CMTRs. Specifically, the molybdenum (Mo) and nitrogen (N) contents, which affect the chromium equivalent and nickel equivalent factors, respectively, are not reported in plant vintage CMTRs. Thus, the calculations of the ferrite content of the DC Cook Unit 2 lower core support column bodies assume a maximum Mo content (0.5%) and a representative nitrogen content from typical melt processing (0.04%). The 96 lower support column bodies in DC Cook Unit 2 have calculated ferrite contents ranging from a minimum of 9.8 percent to a maximum of 14.3 percent. Thus, all 96 DC Cook Unit 2 lower support column bodies have ferrite content less than or equal to 20 percent and therefore, are not susceptible to TE, based on the guidelines of [4].

It is recognized that the DC Cook Unit 1 and Unit 2 lower support column bodies screen as susceptible to IE. Thus, the DC Cook Unit 1 lower support column bodies screen-in as susceptible to IASCC, VS, and both embrittlement mechanisms, TE and IE, while the DC Cook Unit 2 lower support column bodies screen-in for the same aging mechanisms, with the exception of TE.

In addition, it is noted that the PWROG has advised the NRC staff that a project, PA-MSC-1103, to provide a generic functionality evaluation of the lower support structure has been undertaken by the industry. An update on this project was provided during meetings between the industry and the NRC staff as recently as June 2015 [6]. The summary report for the first phase of PA-MSC-1103 was requested by the NRC and submitted by the PWROG for the NRC's information under Reference [7]. The project will develop a methodology which will form the basis for generic or plant-specific functionality analyses and complete the first steps in substantiating the qualitative safety argument. The project has an expected completion date of 2017.

References

1. *Materials Reliability Program: Pressurized Water Reactor Internals Inspection and Evaluation Guidelines (MRP-227-A)*. EPRI, Palo Alto, CA: 2011. 1022863.
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3. U.S. Nuclear Regulatory Commission Document, "NRC position on Aging Management of CASS Reactor Vessel Internal Components" (ADAMS Accession Number ML14163A112).
4. U.S. Nuclear Regulatory Commission Document, "License Renewal Issue No. 98-0030, Thermal Aging Embrittlement of Cast Austenitic Stainless Steel Components," (ADAMS Accession No. ML003717179).
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6. U.S. Nuclear Regulatory Commission Document, "Summary of June 2-4, 2015, Annual Materials Programs Technical Information Exchange Public Meeting," July 14, 2015 (NRC ADAMS Accession No. ML15162A925).
7. PWR Owners Group Letter OG-15-83, "Submittal of PWROG-14048-P, Revision 0, "Functionality Analysis: Lower Support Columns" to the NRC for Information Only (PA-MSC-1103), March 13, 2015 (ADAMS Accession Number ML15077A113).