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U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Subject: **Part 21 Reportable (10CFR 21.21(d)) and Non-Reportable (closure of 10CFR21.21(a)(2)) Notification: Control Rod Drive Mechanisms (CRDM) Contaminated with Chlorides**

By the referenced letter dated April 19, 2017, GE-Hitachi Nuclear Energy (GEH) submitted an interim report pursuant to 10 CFR 21.21(a)(2) that provided information regarding an on-going evaluation of chloride contamination of Control Rod Drive Mechanisms refurbished by GEH. The investigation into this issue is complete.

Pursuant to 10 CFR 21.21(d)(4), GEH is providing the final report with the conclusion that, in limited cases, the chloride contamination could create a substantial safety hazard. Attachment 1 identifies the potentially impacted plants and Attachment 2 contains the final report information. The enclosure provides additional details of the evaluation.

If you have any questions, please call me at (910) 547-0990.

Sincerely,

Dale E. Porter
Safety Evaluation Program Manager
GE-Hitachi Nuclear Energy Americas LLC

Reference:

1. 10CFR 21.21(a)(2) 60 Day Interim Notification - Part 21 60-Day Interim Report Notification: Control Rod Drive Mechanisms (CRDM) Contaminated with Chlorides, Issued April 19, 2017.

Attachments:

1. US BWR Plants Potentially Affected
2. Reportable Condition [21.21(d)]

Enclosures:

1. Description of Evaluation, Non-Proprietary Information – Class I (Public)

cc: J. Golla, USNRC
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PLM Spec 004N2410 R1

Attachment 1

US BWR Plants Potentially Affected

RC	SC	Utility	Plant
		Detroit Edison Co.	Fermi 2
		Dominion	Millstone 1
		Energy Northwest	Columbia
		Entergy	Grand Gulf
	X	Entergy	River Bend
		Exelon	FitzPatrick
		Entergy	Pilgrim
		Entergy	Vermont Yankee
		Exelon	Clinton
		Exelon	Dresden 2-3
	X	Exelon	LaSalle 1-2
		Exelon	Limerick 1-2
		Exelon	Nine Mile Point 1-2
		Exelon	Oyster Creek
		Exelon	Peach Bottom 2-3
		Exelon	Quad Cities 1-2
		FirstEnergy Nuclear Operating Co.	Perry 1
		Florida Power & Light	Duane Arnold
		Nebraska Public Power District	Cooper
		Talen Energy	Susquehanna 1-2
		Progress Energy	Brunswick 1-2
		PSEG Services Corp.	Hope Creek
X*	X*	Southern Nuclear Operating Co.	Hatch 1 - 2
	X	Tennessee Valley Authority	Browns Ferry 1-3
		Xcel Energy	Monticello
		North East Utilities	Millstone

* A portion of the CRDMs at the Hatch Plant are Reportable while the remainder are not.
RC – Reportable Condition
SC – Safety Information Communication

Attachment 2 – Reportable Condition [21.21(d)]

(i) Name and address of the individual or individuals informing the Commission.

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(ii) Identification of the facility, the activity, or the basic component supplied for such facility which fails to comply or contains a defect.

See Attachment 1 for a list of potentially affected U.S. plants

(iii) Identification of the firm constructing the facility or supplying the basic component which fails to comply or contains a defect.

GE-Hitachi Nuclear Energy Americas LLC

(iv) Nature of the defect or failure to comply and the safety hazard which is created or could be created by such defect or failure to comply.

The inappropriate addition of chlorinated water from container box desiccants into the CRDMs during leak testing after rebuild could potentially initiate Intergranular Stress Corrosion Cracking (IGSCC) or Transgranular Stress Corrosion Cracking (TGSCC). These two types of SCC were initially considered for the potential to cause a separation of the stop piston or separation of the index tube contained within the CRDMs that are constructed of 304 Stainless steel. The completed evaluation indicates that a stop piston separation could cause a slower scram speed and damage the drive so it could not be withdrawn. The potential exists for the control rod to drift out. The piston tube located within the CRDM is a reactor coolant pressure boundary (RCPB) and is an ASME component. The possibility of cracking causing RCPB leakage was eliminated by the evaluation. An index tube separation was eliminated as a potential failure mode. Likewise, the potential for SCC initiation on the Cylinder Tube and Flange (CTF) area of the CRDM resulting in a separation that could prevent a scram or normal insertion/withdrawal of a CRD was eliminated.

The long-term evaluation concluded there is no concern for TGSCC. This evaluation also determined the stop piston to piston tube separation is the only failure mechanism that could occur, and only if those components were manufactured from 304 SS.

(v) The date on which the information of such defect or failure to comply was obtained.

A potential reportable condition evaluation in accordance with 10 CFR Part 21 was initiated on February 27, 2017 and the evaluation period was extended on April 19, 2017 by a 10CFR 21.21 (a)(2) 60 Day Interim Notification.

Attachment 2 – Reportable Condition [21.21(d)]

(vi) In the case of a basic component which contains a defect or fails to comply, the number and location of these components in use at, supplied for, being supplied for, or may be supplied for, manufactured, or being manufactured for one or more facilities or activities subject to the regulations in this part.

Plant Description	Customer Name	Shipped Date	Shipped Quantity	Part Description	Safety Class	Customer PO Number
River Bend	Entergy	2017	15	CRDM	Q	10478763
LaSalle Unit 2	Exelon	2017	24	CRDM	Q	00414787-66
Hatch Unit 2	Southern Nuclear	2017	15	CRDM	Q	SNG50295-0001 SNG50295-0002
Browns Ferry Unit 2	TVA	2017	32	CRDM	Q	2424171

For the above plants, only Hatch Unit 2 has 13 CRDMs with index and/or piston tubes fabricated from 304 SS. Of those CRDMs, 12 have piston tubes fabricated from 304 SS. The index tubes and piston tubes for the remaining 73 CRDMs are fabricated from XM-19.

(vii) The corrective action, which has been, is being, or will be taken; the name of the individual or organization responsible for the action; and the length of time that has been or will be taken to complete the action.

GEH initiated a Root Cause Evaluation (RCA) to determine why this event occurred and has implemented process changes to ensure that the condition does not reoccur. Actions to prevent recurrence, such as eliminating the desiccant material and flushing the closed loop water system, have been completed.

For Hatch Unit 2, the 12 CRDMs that have the 304 SS piston tubes should be replaced prior to those CRDMs exceeding 10 years in service. See table below:

CRDM S/N	Piston Tube
SE0474	304 SS
A8737	304 SS
A9423	304 SS
A6791	304 SS
3095	304 SS
A8729	304 SS
7253	304 SS
A6786	304 SS
SE0368	304 SS
A5409	304 SS
7080	304 SS
A9484	304 SS

Attachment 2 – Reportable Condition [21.21(d)]

(viii) Any advice related to the defect or failure to comply about the facility, activity, or basic component that has been, is being, or will be given to purchasers or licensees.

Interim Reports were issued to River Bend, LaSalle Unit 2, and Hatch Unit 2 providing the results of an evaluation that concluded the condition would not create a substantial safety hazard or potentially cause a Technical Specification Safety Limit violation for a minimum of one operating cycle. The Browns Ferry Unit 2 drives were shipped but were not installed prior to recall, thus a short-term evaluation for Browns Ferry was not provided.

GEH has completed the long-term CRDM evaluation with the following results:

A Safety Information Communication is being issued to River Bend, LaSalle Unit 2, and Browns Ferry Unit 2 stating that the CRDMs exposed to the chloride intrusion will not cause a substantial safety hazard, or cause a Technical Specification Safety Limit violation and is therefore not reportable (see enclosure 1 for details).

For Hatch Unit 2, the introduction of chlorides could cause a substantial safety hazard for the 12 CRDMs that were manufactured from 304 SS material, and is therefore a reportable condition per 10CFR 21.21(d); however, the 3 CRDMs manufactured from XM-19 material would be considered not reportable.

The results of the short-term evaluations for all three plants where CRDMs were installed remains valid.

(ix) In the case of an early site permit, the entities to whom an early site permit was transferred.

Not Applicable.

ENCLOSURE 1

M170087 R1

Description of Evaluation

Non-Proprietary Information - Class I (Public)

Summary

Based on the long-term evaluations of the subject condition, GEH has concluded that CRDMs supplied to River Bend, LaSalle Unit 2, and Browns Ferry Unit 2 with the subject condition would not create a future Substantial Safety Hazard or Technical Specification Safety Limit violation, and therefore a reportable condition does not exist. River Bend, LaSalle Unit 2, and Browns Ferry Unit 2 will be issued a Safety Information Communication documenting this status.

A long-term evaluation of crack growth due to either IGSCC and TGSCC on individual Control Rod Drive Mechanism (CRDM or drive) components for Hatch Unit 2 determined a reportable condition exists for extended operation for 12 CRDMs manufactured from 304SS material past 10 years of operation. This document is a 10CFR Part 21 Reportable Condition [21.21(d)] Notification applicable to those 12 Hatch Unit 2 CRDMs. The 3 CRDMs manufactured from XM-19 material are acceptable for long-term use and that conclusion will be communicated to Hatch.

Introduction

The CRDM is a double-acting, mechanically latched hydraulic cylinder, using water as the operating fluid. The CRDM is capable of inserting or withdrawing a control rod blade at a slow controlled rate for normal reactor operation. It also provides a rapid control rod insertion (scram) in the event of an emergency requiring rapid shutdown of the reactor.

The CRDM contains various components including the cylinder, tube, and flange (CTF), the index tube, and the piston tube. The CTF consists of an inner cylinder, an outer tube, and a flange, all fabricated from 304 SS. The flange provides a means by which the CRDM is mounted to the CRD housing flange below the vessel. The outer diameter of the cylinder and the inner diameter of the tube form an annulus through which water is applied to the collet piston to unlock the index tube during the withdraw cycle.

The index tube is the moving part of the CRDM that positions the control rod blade. The upper end of the index tube attaches to the coupling spud and the lower end attaches to the drive piston. Locking grooves are spaced every 6 inches along the outside of the tube that are engaged by the collet mechanism to hold the drive stationary.

The piston tube is a stationary component mechanically attached to the drive flange. The piston tube has a stop piston at the upper end which seals the drive operating pressures from the reactor and provides a mechanical stop at the upper end of drive travel. In function, the piston tube serves as a hydraulic cylinder with graphitar seals mounted in the index tube's drive piston that run against its outer surface. The inside of the piston tube provides a flow path to and from the upper side of the drive piston. A buffer mechanism at the upper end of the tube acts as a hydraulic buffer to decelerate the drive at the end of the scram stroke.

The BWR/6 CRDs, and later production BWR/4 and 5 CRDs, were supplied with index tubes and piston tubes fabricated from XM-19. For the older plants, the index and piston tubes were fabricated from 304 SS. Many of these older plants have replaced the 304 SS tubes with the newer XM-19 material as recommended by SIL 179, "Control Rod Drive Material Improvements," for the index and piston tubes. Both the index tubes and the piston tubes of either material are nitride coated to increase surface hardness for galling prevention. Both the moving piston at the bottom of the index tube and the stop piston located on top of the piston tube contain graphitar seals. These seals prevent leakage for normal operation of the CRDMs and prevent wear from metal to metal contact.

The Control Rod Drive Mechanism (CRDM) functions:

- The piston tube and stop piston provide isolation of the drive pressures from reactor pressures and provide a flow path to and from drive piston during normal rod movement and scram. Some areas of the piston tube assembly, including the indicator tube internal to the piston tube, are also part of the reactor pressure boundary and are ASME components.
- The index tube assembly moves rapidly for insertion of the control rod blade to safely shutdown the reactor during a scram.
- The index tube has notches that will keep it in the full in position after a scram to maintain the reactor in a safe shutdown condition in conjunction with the collet piston.
- The index tube also moves normally during insert/withdraw sequences for reactivity control.

Potentially affected safety functions:

- The ability to scram (safely shutdown the reactor) and maintain it in a safe shutdown condition (CTF, piston tube, index tube, coupling spud, collet piston and drive/stop pistons).
- The piston tube assembly and the CTF are part of the reactor pressure boundary and are ASME components.

Description of Discovery

During a receipt inspection prior to installation of the CRDMs at Browns Ferry (a BWR/4) the GEH under vessel team observed orange and black crud coming out of the withdraw port of one drive. Borescope visual inspection confirmed other drives had a similar condition and subsequently all onsite refurbished CRDMs (32 drives) were shipped back to the GEH Wilmington Field Services Center (WFSC) to investigate and address the condition.

This issue was caused by inappropriate dumping of chlorinated water from desiccants used in the CRDM storage and transport boxes. The desiccant was a chloride based material (primarily calcium chloride). The accumulated liquid from the desiccant entered the closed loop water used for leak rate testing of the drives by being dumped on the rebuild tables that drained to this closed loop deionized (DI) water supply system. The drives that were subsequently leak tested were contaminated by the chlorinated water.

Extent of Condition

GEH has completed an extent of condition review and determined four plants had either receipt accepted and/or installed CRDMs leak checked with chlorinated water. Those plants are River Bend, LaSalle Unit 2, Hatch Unit 2 and Browns Ferry Unit 2. Browns Ferry Unit 2 CRDMs were not installed in the plant but were accepted at the site and are thus within the evaluation requirements of 10CFR Part 21.

Plant Description	Customer Name	Shipped Date	Shipped Quantity	Part Description	Safety Class	Customer PO Number
River Bend	Entergy	2017	15	CRDM	Q	10478763
LaSalle Unit 2	Exelon	2017	24	CRDM	Q	00414787-66
Hatch Unit 2	Southern Nuclear	2017	15	CRDM	Q	SNG50295-0001 SNG50295-0002
Browns Ferry Unit 2	TVA	2017	32	CRDM	Q	2424171

For the above plants, only Hatch Unit 2 has 13 CRDMs with index and/or piston tubes fabricated from 304 SS. Of those CRDMs, 12 have piston tubes fabricated from 304 SS. The index tubes and piston tubes for the remaining 73 CRDMs are fabricated from XM-19.

Potential Safety Significance

The consequences of degraded parts can be logically grouped into four categories of failures. The most likely of these is degradation of the nitride surfaces of the piston and index tubes due to pitting corrosion and/or crevice corrosion. Any damage to the seal surface (e.g., pitting) could reduce sealing effectiveness if any significant pit areas or a significant amount of lesser pitting were involved, and the diameter of the pits exceeds the width of the graphitar seals. The increase in surface roughness in the pitted area caused by the corrosion deposits could also accelerate seal wear. The graphitar seals are not attacked by chlorides, but would slowly degrade with increasing surface roughness. The typical consequences of extensive pit formation would be increased seal leakage which would result in operational difficulties (e.g., notching) and degraded buffer performance. However, the scram function of the CRDM would not be affected. These operational issues, if they were to occur, would only result in the necessity of early CRDM maintenance or replacement.

The second category of degradation is stress corrosion cracking in the base metal of the index or piston tube. This category is less likely to occur than the potential pitting or crevice corrosion noted above. If these cracks extended through the wall of either tube it may result in increased internal CRD leakages. The consequence of this leakage, if significant, would be operational anomalies such as notch-in and notch-out and degraded buffer performance. Significant leakage which invariably causes operational problems may also result in a slightly slower scram time on the affected CRDM. In no case would the control rod scram capability be significantly degraded, and in no case would this potential CRDM cracking affect the vessel pressure boundary integrity. Also, this type of degradation would necessitate early CRDM maintenance.

The third category and the least likely type of CRDM part failure is sufficient cracking leading to complete separation of either the piston or index tube. In the unlikely event of a piston tube separation, the most probable location for this to occur is at the top of the piston tube. This failure is most likely to occur at the end of the scram stroke when the maximum tensile load is applied. A failure of this type would likely result in an inability to withdraw the control rod. However, under extreme cold scram conditions the upper end of the drive piston may enter the collet piston area and damage the collet in such a way that it would not support the weight of the control rod, allowing it to drift out of the core. In the case of the index tube, if the cracking resulted in separation at the upper end near the coupling spud, it would be equivalent to the coupling failure previously analyzed in the Rod Drop Accident (RDA) analysis.

A fourth category would consist of a separation of the CTF as described in SIL 139, "Control Rod Drive Collet Retainer Tube Cracking." SCC initiation on the Cylinder Tube and Flange (CTF) area of the CRDM could result in a separation that could prevent a scram or normal insertion/withdrawal of a control rod.

Evaluation

Short Term (≤ 2 year operating cycle)

Of the four categorizations of failure, the only one GEH deems credible within one operational cycle is pitting and crevice corrosion of the nitride surfaces of the piston and index tubes. This conclusion is based on the relatively low chloride concentration the drives were exposed to, the short time of exposure, and the drive materials used.

Long Term (> 2 years of operation)

Where present, the XM-19 index and piston tube material is resistant to chlorides initiating any SCC at the chloride concentrations to which all drives were exposed. Therefore, there is not a significant increase in risk associated with initiation and growth of IGSCC for piston tubes and index tubes fabricated from XM-19.

However, those tubes manufactured from 304 SS are not sufficiently resistant to IGSCC for GEH to conclude that there's insignificant risk associated with crack initiation and growth in the creviced locations. To evaluate these areas, GEH conservatively assumed a through wall crack occurred at the time of CRDM installation at the most limiting creviced locations on the piston tube and index tubes. These cracks were then assumed to initially propagate at an accelerated rate[1], considered to be conservative, to account for the potential presence of chlorides when the components were first placed in service, then at a reduced rate based on the estimated SCC growth rates provided in SIL 148 Supplement 1, "Water Quality for the Control Rod Drive System." These cracks were then compared to an allowable flaw size determined by a fracture mechanics evaluation. The allowable flaw sizes were conservatively based on worst case tensile load created during a scram with a failed buffer. The likely cracking areas of the piston and index tube were chosen based on historical cracking areas of 304 SS as described in SIL 179 S1. This evaluation concluded that the index tubes manufactured from 304 SS would not fail in the CRDM lifetime due to the larger circumference and allowable flaw size. However, the evaluation found that failure could potentially occur at the top of the 304 SS piston tubes after a minimum of 10 years of operation.

The indicator tube located within all piston tubes (i.e. older 304 SS tubes and newer XM-19 tubes) is manufactured from 316 SS. This area of the CRDM has more flow that will flush chlorides and there are no crevices which would mitigate the indicator tube from leaking due a through wall crack and developing a reactor pressure boundary leak. Therefore, there is not a significant increase in risk associated with initiation and growth of IGSCC for the indicator tubes.

The CTFs are fabricated from 304 SS. As established above, 304 SS is susceptible to IGSCC. However, all areas of the CTF would have a higher water flow, lack of crevices and lower loading. Therefore, there would not be a significant increase in risk associated with initiation and growth of IGSCC for the CTFs.

GEH also evaluated the potential for transgranular stress corrosion cracking (TGSCC) in all components discussed above. TGSCC is a potential concern for stainless steels when exposed to very high chloride concentrations in combination with high tensile stresses. GEH's evaluation concluded that the chloride concentration to which all the drives were exposed was not high enough to create a TGSCC concern.

There are no reactor water chemistry concerns for chlorides released into the reactor pressure vessel by installation of the contaminated drives for any of the plants impacted.

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[1] The accelerated growth was based upon GEH and Industry experimental data and engineering judgment.

Conclusions

The potential for IGSCC initiation and propagation at the chloride concentrations to which the drives were exposed is insignificant for CRDMs with XM-19 index tubes and piston tubes. River Bend, LaSalle Unit 2, and Browns Ferry Unit 2 CRDMs have piston and index tubes manufactured only from XM-19 material. Thus, those plants do not have a reportable condition.

Hatch Unit 2 installed 15 CRDMs of which 3 had piston tubes manufactured from XM-19 material. The 3 CRDMs with XM-19 piston tubes present no issues from exposure to chlorides. The remaining 12 CRDMs have piston tubes manufactured from 304 SS and thus have a potential for piston tube failure, creating a potential safety issue of the associated control rods drifting out of the reactor core upon a stop piston separation from the piston tube. This issue is thus determined to be a reportable condition.

This failure mechanism will not occur in ≤ 10 years.

ABWR and ESBWR Design Certification Documentation Applicability

Not applicable as this is a component specific issue.

Recommendations

1. No additional trending or monitoring of CRDMs is recommended other than the normal CRDM trending, such as:
   - Insert and withdraw stall flows
   - Sluggish movement
   - Double notching
   - Age of CRDM
2. For Plant Hatch Unit 2, the 12 CRDMs that have the 304 SS piston tubes should be replaced prior to those CRDMs exceeding 10 years in service.

Corrective/Preventive Actions

1. WFSC has stopped the use of the desiccants.
2. The WFSC closed loop water system was cleaned and successfully sampled.
3. A Root Cause Evaluation (RCA) was completed to determine the cause of the issue and further actions needed to prevent reoccurrence.