

ENCLOSURE 2

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NEDO-33856, Revision 8

GEH Marathon and Ultra Control Rod Lifetime Surveillance
Update

Non-Proprietary Information

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GE Hitachi Nuclear Energy

NEDO-33856

Revision 8

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Non-Proprietary Information

GEH Marathon and Ultra Control Rod

Lifetime Surveillance Update

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Revision Summary

Revision No.	Content
0	2014 Update (Note that all prior updates were issued under different document numbers.)
1	2015 Update
2	2016 Update
3	2017 Update
4	2018 Update
5	2019 Update
6	2020 Update
7	2021 Update
8	2022 Update

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Acronyms and Abbreviations

Term	Definition
ABWR	Advanced Boiling Water Reactor
B-10	Boron-10
BWR	Boiling Water Reactor
GEH	GE-Hitachi Nuclear Energy Americas LLC
IASCC	Irradiation Assisted Stress Corrosion Cracking
NRC	Nuclear Regulatory Commission
SER	Safety Evaluation Report

1. Introduction

GE-Hitachi Nuclear Energy Americas LLC (GEH) actively maintains a surveillance program consisting of visual inspections of Marathon, Ultra MD, and Ultra HD control rods in accordance with the requirements of their respective Nuclear Regulatory Commission (NRC) Safety Evaluation Reports (SERs): Marathon (Reference 1), Ultra MD (Reference 2), and Ultra HD (Reference 3). A summary of the status of this surveillance program was last forwarded to the NRC via M210093 (Reference 4) and was also provided to the Boiling Water Reactor (BWR) fleet via Reference 5.

This report updates Reference 5, including:

- New inspection results for Marathon and Ultra control rods.
- A listing of planned inspections for Marathon and Ultra control rods.

GEH will continue to provide updates of the Marathon and Ultra control rod surveillance programs on an annual basis.

2. Marathon Control Rod Description

As described in Reference 1, the Marathon control rod consists of 'square' absorber tubes, edge welded together to form the control rod wings. The 'lobes' of the square absorber tubes provide both a welding surface area and act as a wear surface. The four wings are welded to central tie rod segments to form a cruciform shape. A cross-sectional view of the control rod absorber section is shown in Figure 1.

The square absorber tubes are filled with capsules containing compacted boron carbide powder, empty capsule plenums, or hafnium rods. [[

absorber contents are sealed within the absorber tubes by welded end plugs. A handle and velocity limiter are attached at the top and bottom respectively to complete the assembly (Figure 1).
[[

]]

Figure 1: Marathon Control Rod Diagram

Figure 2 shows a design modification that was made to the geometry of the D/S lattice 'square' absorber tube. Implementation of this modification began in 2006. Two changes were made:

1. [[

2.

]]

[[

]]

Figure 2: Marathon Control Rod Diagram

In February 2011, GEH issued Reference 6, which reduced the lifetime of all D and S lattice Marathon control rods. This lifetime reduction was done in response to mechanical failures observed as part of the Marathon surveillance program. [[

]]

In June 2022, GEH issued Reference 9, which reduced the lifetime of Marathon-C+ control rods. This lifetime reduction was issued in response to observed cracking of Marathon-C+ control rods. [[

]].

Current lifetime recommendations for all GEH control rods are found in Reference 7.

3. Ultra Control Rod Description

GEH has transitioned to the Ultra MD (licensed as Marathon-5S in Reference 2) and Ultra HD (licensed as Marathon-Ultra in Reference 3) control rods. These control rods use the same basic inner capsule within an outer absorber tube design as the Marathon control rod, but include conservative design features intended to prevent the type of cracking observed in Marathon control rods. The primary difference is the use of a simplified absorber tube geometry, shown in Figure 3. Like the Marathon design, the absorber tubes are laser welded together to form the wings of the control rod assembly and are filled with boron carbide and empty capsules ([
]), and hafnium rods ([
]). For the Ultra design, a single full-length central tie rod joins the wings of the control rod, rather than the tie rod segments used in the Marathon design.

[
]

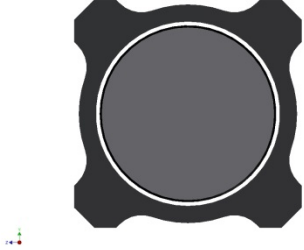
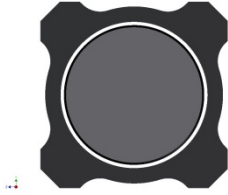
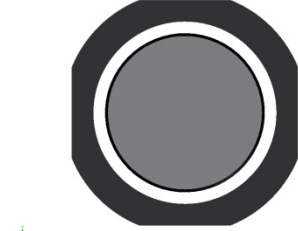

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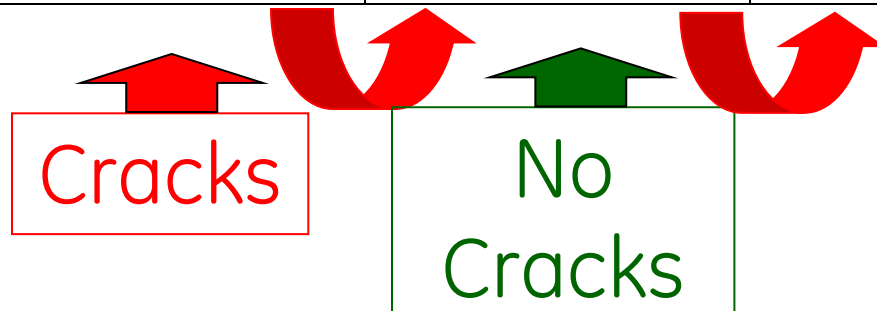
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Figure 3: Ultra Control Rod Diagram

Table 1: Marathon and Ultra Control Rod Design Comparison

Parameter	Marathon D/S	Marathon C	Ultra D/S/N	Ultra C
Absorber Tube				
Local B-10 Depletion at Capsule Contact	[[
Swelling Induced Strain at 100% Local Depletion				
Local B-10 Depletion Cracking Threshold]]	



[[

]]

4. Inspection Data

Tables 2 through 5 contain a summary of [[] visual inspections of Marathon and Ultra control rods that GEH has performed or reviewed to date. Since the previous annual report (Reference 5), [[] additional inspections of C lattice Marathon control rods have been performed, which are shown in bold in Table 3. Also, [[] additional inspections of Ultra MD control rods and [[] additional inspections of Ultra HD control rods are added to Tables 4 and 5, respectively.

Tables 2 through 5 show the serial number of each control rod inspected, as well as the year the control rod was delivered to the plant, and the month and year of the inspection. It is noted that in some cases, the same control rod has been inspected during multiple outages as it has been irradiated. For D/S lattice Marathon control rods, Table 2 indicates whether the control rods used the 'old' or 'new' square tube geometry, as discussed in Section 2.

The depletion of each control rod is represented using three measures:

- The percent B-10 depletion of the peak $\frac{1}{4}$ segment, expressed as a percent.
- The peak local B-10 depletion, at the highest depletion node and tube location, also expressed as a percent.
- For control rod inspections with crack indications, the range of local B-10 depletion at which cracks are observed.

Tables 2 and 3 also identify those control rods that are part of the 'etch-affected' population described by Reference 8. For a certain population of Marathon control rods manufactured between 1997 and 2002, an incomplete cleaning operation prior to an annealing process at the absorber tubing vendor left localized locations on the tubes that are potentially sensitized to IASCC. In response, GEH reduced the lifetime of these control rods, and embarked on a campaign of visual inspections to determine the actual effect. Recommended lifetime limits for etch-affected Marathon control rods are contained in References 7 and 8. As noted in Table 3, [[] of the [[] new Marathon control rod inspections are of etch-affected control rods. The effort to acquire additional inspection data for highly irradiated etch-affected control rods is ongoing. Ultra control rods are not affected by the etch issue.

As shown in Table 3, [[]
]] As discussed in Section 2, this has resulted in a reduced lifetime limit recommendation as discussed in Reference 9.

As shown in Tables 4 and 5, [[]
]]

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Table 2: D/S Lattice* Marathon Control Rod Inspection Results

[illegible]

* “D/S” absorber tubes are used for GEH D lattice (BWR/2-4) and S lattice (BWR/6) applications.

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Table 2: D/S Lattice* Marathon Control Rod Inspection Results (Continued)

Plant	Serial Number	Ship Year	Inspection Date	1/4-Segment B-10 Depletion (%)	Peak Local B-10 Depletion (%)	Crack Indications?	Local B-10 Depletion at Crack Location (%)	Etch-Affected?	Square Tube Geometry
Plant D (International BWR)	[[
Plant E (US BWR/2)									
Plant J (International BWR)									
]]

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Table 2: D/S Lattice* Marathon Control Rod Inspection Results (Continued)

Plant	Serial Number	Ship Year	Inspection Date	$\frac{1}{4}$ -Segment B-10 Depletion (%)	Peak Local B-10 Depletion (%)	Crack Indications?	Local B-10 Depletion at Crack Location (%)	Etch-Affected?	Square Tube Geometry
Plant J (International BWR)									
Plant K (International BWR)									
Plant L (US BWR/6)									
Plant M (US BWR/4)									
Plant N (International BWR)									
Plant O (International BWR/6)									
Plant P (International BWR)									

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Table 2: D/S Lattice* Marathon Control Rod Inspection Results (Continued)

Plant	Serial Number	Ship Year	Inspection Date	¹ / ₄ -Segment B-10 Depletion (%)	Peak Local B-10 Depletion (%)	Crack Indications?	Local B-10 Depletion at Crack Location (%)	Etch-Affected?	Square Tube Geometry
Plant Q (US BWR/4)									
Plant T (International BWR/6)]]

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Table 3: C Lattice* Marathon Control Rod Inspection Results

Plant	Serial Number	Ship Year	Inspection Date	¼-Segment B-10 Depletion (%)	Peak Local B-10 Depletion (%)	Crack Indications?	Local B-10 Depletion at Crack Location (%)	Etch-Affected?
Plant B (International BWR)	[[
Plant C (International BWR)								
Plant F (US BWR/4)								
Plant G (International BWR)								
]]

* “C” absorber tubes are used for GEH C lattice (BWR/4,5) applications.

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Table 3: C Lattice* Marathon Control Rod Inspection Results (Continued)

Plant	Serial Number	Ship Year	Inspection Date	¼-Segment B-10 Depletion (%)	Peak Local B-10 Depletion (%)	Crack Indications?	Local B-10 Depletion at Crack Location (%)	Etch-Affected?
Plant X (US BWR/4)	[[
]]

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Table 4: Ultra MD Control Rod Inspection Results

Plant	Serial Number	Ship Year	Absorber Tube Size*	Inspection / Discharge Date	¼-Segment B-10 Depletion (%)	Peak Local B-10 Depletion (%)	Crack Indications?
Plant M (US BWR/4)	[[
Plant N (Int'l BWR)							
Plant R (Int'l BWR/4)							
Plant S (US BWR/5)]]

Note:

* “D/S/N” absorber tubes are used for GEH D lattice (BWR/2-4), S lattice (BWR/6), and N lattice (ABWR) applications. “C” absorber tubes are used for GEH C lattice (BWR/4,5) applications.

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Table 5: Ultra HD Control Rod Inspection Results

Plant	Serial Number	Ship Year	Absorber Tube Size*	Inspection / Discharge Date	¼-Segment B-10 Depletion (%)	Peak Local B-10 Depletion (%)	Crack Indications?
Plant N (Int'l BWR)	[[
Plant P (Int'l BWR)							
Plant J (Int'l BWR)							
Plant U (US BWR/6)							
Plant O (Int'l BWR/6)							
Plant V (US BWR/4)							

Note:

* “D/S/N” absorber tubes are used for GEH D lattice (BWR/2-4), S lattice (BWR/6), and N lattice (ABWR) applications. “C” absorber tubes are used for GEH C lattice (BWR/4,5) applications.

¹ The Plant P, GE0098 data is a partial inspection due to a technical issue with the digital video copy.

5. Evaluation

[[

]] GEH continues to pursue inspection data for irradiated Marathon control rods to confirm these cracking thresholds.

GEH also continues to gather inspection data for irradiated Ultra MD and Ultra HD control rods, exceeding the surveillance requirements of References 2 and 3. As shown in Tables 4 and 5, good performance has been observed, with no crack indications identified to date.

6. Planned Inspections

In accordance with the Marathon SER (Reference 1), GEH is continuing to pursue visual inspections of high depletion Marathon control rods in order to confirm the new lifetime limits contained in References 6 and 7. Currently, there are no planned inspections for Marathon control rods.

For Ultra control rods, visual inspections of lead depletion and permanently discharged control rods are planned in accordance with the requirements of the Reference 2 and 3 SERs. Additional inspections of lower depletion Ultra control rods are also planned. Table 6 shows a listing of planned Ultra control rod inspections.

Table 6: Planned Ultra Control Rod Inspections

Plant	Type	Number	Absorber Tube Size ¹	Ship Year	Inspection / Discharge Date	¼-Segment B-10 Depletion (%)	Peak Local B-10 Depletion (%)
Plant U (US BWR/6)	[[
Plant W (US BWR/3)]]

Notes:

1. “D/S” absorber tubes are used for GEH D lattice (BWR/2-4), S lattice (BWR/6), and N lattice (ABWR) applications. “C” absorber tubes are used for GEH C lattice (BWR/4,5) applications.
2. Control rods were discharged at Plant U in fall 2021. Inspection is currently planned for the spring of 2023.

Figures 4 and 5 track lead depletion Ultra MD and Ultra HD control rods, respectively. Since the prior annual report, the world-wide lead depletion Ultra MD control rods were inspected at Plant M-B (Table 4), and the lead depletion Ultra HD control rods were inspected at Plant V (Table 5), all with no crack indications. From Table 6, control rods that will become the lead depletion Ultra HD rods will be inspected in the fall of 2022 at Plant W.

Per the surveillance program requirements of Reference 2, the first 12 discharged Ultra MD control rods of each lattice type must be inspected. Table 7 summarizes the status of permanently discharged Ultra control rod inspections.

Table 7: Inspections of Permanently Discharged Ultra Control Rods

Control Rod Type	Plant	Discharge Date	No. Inspected	Total Inspected For Type
Ultra MD D/S Lattice	Plant M-A	10/20	3	6
	Plant M-B	10/21	3	
Ultra MD C Lattice	None to Date	--	--	0
Ultra HD D/S Lattice	Plant O	8/20	4	7
	Plant U	10/19	3	
Ultra HD C Lattice	None to Date	--	--	0

[[

]]

Figure 4: Ultra MD Control Rod Inspections

[[

]]

Figure 5: Ultra HD Control Rod Inspections

7. References

1. GE Nuclear Energy, “GE Marathon Control Rod Assembly,” NEDE-31758P-A, October 1991.
2. GE Hitachi Nuclear Energy, “Marathon-5S Control Rod Assembly,” NEDE-33284P-A, Revision 2, October 2009.
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4. Letter from Michelle Catts (GEH) to Document Control Desk (NRC), Subject: Marathon and Ultra Control Rod Lifetime Surveillance Update, M210093, July 30, 2021.
5. GE Hitachi Nuclear Energy, “GEH Marathon and Ultra Control Rod Lifetime Surveillance Update,” NEDC-33856P, Revision 7, August 2021.
6. Safety Communication SC 11-01, “Part 21 Reportable Condition Notification: Design Life of D and S Lattice Marathon Control Blades,” February 2011.
7. GE Hitachi Nuclear Energy, “GEH BWR Control Rod Lifetime,” NEDE-30931P, Revision 19, July 2022.
8. Safety Communication SC 07-02, “Update: Etch Indications on Marathon Control Rod Blade Absorber Tubes,” January 2007.
9. Safety Communication SC 22-03, “Updated Lifetime Limits for Marathon-C+ Control Rods”, June 2022.