

## ENCLOSURE 2

M200112

NEDO-33856, Revision 6

GEH Marathon and Ultra Control Rod Lifetime Surveillance  
Update

Non-Proprietary Information

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**HITACHI**

**GE Hitachi Nuclear Energy**

NEDO-33856

Revision 6

August 2020

*Non-Proprietary Information*

## **GEH Marathon and Ultra Control Rod**

### **Lifetime Surveillance Update**

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**Revision Summary**

| <b>Revision No.</b> | <b>Content</b>  |
|---------------------|---|
| 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   |

## TABLE OF CONTENTS

|   |    |
|---|----|
| 1. Introduction.....                      | 1  |
| 2. Marathon Control Rod Description ..... | 2  |
| 3. Ultra Control Rod Description.....     | 4  |
| 4. Inspection Data .....                  | 7  |
| 5. Evaluation .....                       | 15 |
| 6. Planned Inspections .....              | 16 |
| 7. References.....                        | 20 |

## LIST OF TABLES

|   |    |
|---|----|
| Table 1: Marathon and Ultra Control Rod Design Comparison.....      | 6  |
| Table 2: D/S Lattice* Marathon Control Rod Inspection Results ..... | 8  |
| Table 3: C Lattice* Marathon Control Rod Inspection Results.....    | 12 |
| Table 4: Ultra MD Control Rod Inspection Results .....              | 13 |
| Table 5: Ultra HD Control Rod Inspection Results .....              | 14 |
| Table 6: Planned Ultra Control Rod Inspections .....                | 16 |

## LIST OF FIGURES

|  |    |
|--|----|
| Figure 1: Marathon Control Rod Diagram.....      | 2  |
| Figure 2: Marathon Control Rod Diagram.....      | 3  |
| Figure 3: Ultra Control Rod Diagram.....         | 5  |
| Figure 4: Ultra MD Control Rod Inspections ..... | 18 |
| Figure 5: Ultra HD Control Rod Inspections.....  | 19 |

**Acronyms and Abbreviations**

| <b>Term</b> | <b>Definition</b>                              |
|-------------|--|
| 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 M190136 (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. [[

]] All 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. [[

]] 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.

[[

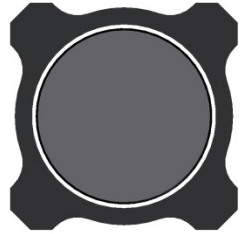

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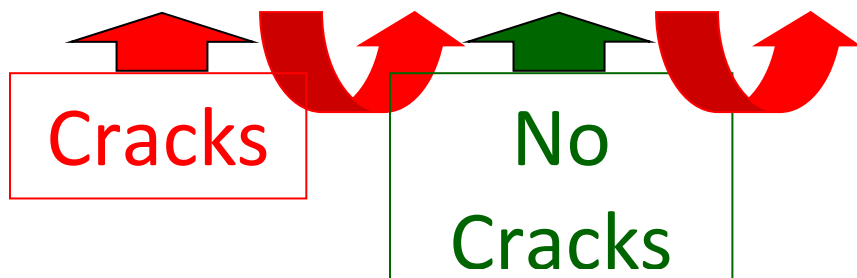
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]]

**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 |   |  |   | ]]  |



[[

]]

#### 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 Marathon control rods using D/S lattice absorber tubes have been performed, which are shown in bold in Table 2. 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 the-affected Marathon control rods are contained in References 7 and 8. As noted in Table 2, [[ ] 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 Tables 2, 4 and 5, [[ ]  
]]

**Table 2: D/S 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? | Square Tube Geometry |
|-----------------------|---------------|-----------|-----------------|------------------------------|-------------------------------|--------------------|--|----------------|----------------------|
| Plant A<br>(US BWR/4) | [[            |           |                 |                              |                               |                    |  |                |                      |
|                       |               |           |                 |                              |                               |                    |  |                |                      |
|                       |               |           |                 |                              |                               |                    |  |                |                      |
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|                       |               |           |                 |                              |                               |                    |  |                | ]]                   |

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

NEDO-33856 Revision 6  
Non - Proprietary Information

**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<br>(International BWR) | [[            |           |                 |                                |                               |                    |  |                |                      |
|                                |               |           |                 |                                |                               |                    |  |                |                      |
|                                |               |           |                 |                                |                               |                    |  |                |                      |
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|                                |               |           |                 |                                |                               |                    |  |                |                      |
| Plant E<br>(US BWR/2)          |               |           |                 |                                |                               |                    |  |                |                      |
|                                |               |           |                 |                                |                               |                    |  |                |                      |
|                                |               |           |                 |                                |                               |                    |  |                |                      |
| Plant J<br>(International BWR) |               |           |                 |                                |                               |                    |  |                |                      |
|                                |               |           |                 |                                |                               |                    |  |                |                      |
|                                |               |           |                 |                                |                               |                    |  |                |                      |
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NEDO-33856 Revision 6  
Non - Proprietary Information

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

| Plant                            | Serial Number | Ship Year | Inspection Date | <sup>1</sup> / <sub>4</sub> - 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<br>(International BWR)   |               |           |                 |  |                               |                    |  |                |                      |
|                                  |               |           |                 |  |                               |                    |  |                |                      |
|                                  |               |           |                 |  |                               |                    |  |                |                      |
|                                  |               |           |                 |  |                               |                    |  |                |                      |
| Plant K<br>(International BWR)   |               |           |                 |  |                               |                    |  |                |                      |
| Plant L<br>(US BWR/6)            |               |           |                 |  |                               |                    |  |                |                      |
|                                  |               |           |                 |  |                               |                    |  |                |                      |
|                                  |               |           |                 |  |                               |                    |  |                |                      |
| Plant M<br>(US BWR/4)            |               |           |                 |  |                               |                    |  |                |                      |
|                                  |               |           |                 |  |                               |                    |  |                |                      |
|                                  |               |           |                 |  |                               |                    |  |                |                      |
| Plant N<br>(International BWR)   |               |           |                 |  |                               |                    |  |                |                      |
|                                  |               |           |                 |  |                               |                    |  |                |                      |
| Plant O<br>(International BWR/6) |               |           |                 |  |                               |                    |  |                |                      |
|                                  |               |           |                 |  |                               |                    |  |                |                      |
| Plant P<br>(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<br>(US BWR/4)            |               |           |                 |                                |                               |                    |  |                |                      |
|                                  |               |           |                 |                                |                               |                    |  |                |                      |
|                                  |               |           |                 |                                |                               |                    |  |                |                      |
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| Plant T<br>(International BWR/6) |               |           |                 |                                |                               |                    |  |                | ]]                   |

NEDO-33856 Revision 6  
Non - Proprietary Information

**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? | Etch-Affected? |
|--------------------------------|---------------|-----------|-----------------|------------------------------|-------------------------------|--------------------|----------------|
| Plant B<br>(International BWR) | ]]            |           |                 |                              |                               |                    |                |
|                                |               |           |                 |                              |                               |                    |                |
|                                |               |           |                 |                              |                               |                    |                |
|                                |               |           |                 |                              |                               |                    |                |
| Plant C<br>(International BWR) |               |           |                 |                              |                               |                    |                |
|                                |               |           |                 |                              |                               |                    |                |
|                                |               |           |                 |                              |                               |                    |                |
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| Plant F<br>(US BWR/4)          |               |           |                 |                              |                               |                    |                |
|                                |               |           |                 |                              |                               |                    |                |
| Plant G<br>(International BWR) |               |           |                 |                              |                               |                    |                |
|                                |               |           |                 |                              |                               |                    |                |
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|                                |               |           |                 |                              |                               |                    | ]]             |

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

**Table 4: Ultra MD Control Rod Inspection Results**

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

**Table 5: Ultra HD Control Rod Inspection Results**

| Plant                  | Serial Number | Ship Year | Absorber Tube Size* | Inspection Date | ¼-Segment B-10 Depletion (%) | Peak Local B-10 Depletion (%) | Crack Indications? |
|------------------------|---------------|-----------|---------------------|-----------------|------------------------------|-------------------------------|--------------------|
| Plant N<br>(Int'l BWR) | [[            |           |                     |                 |                              |                               |                    |
|                        |               |           |                     |                 |                              |                               |                    |
|                        |               |           |                     |                 |                              |                               |                    |
|                        |               |           |                     |                 |                              |                               |                    |
| Plant P<br>(Int'l BWR) |               |           |                     |                 |                              |                               |                    |
|                        |               |           |                     |                 |                              |                               |                    |
|                        |               |           |                     |                 |                              |                               |                    |
|                        |               |           |                     |                 |                              |                               |                    |
| Plant J<br>(Int'l BWR) |               |           |                     |                 |                              |                               |                    |
|                        |               |           |                     |                 |                              |                               |                    |
|                        |               |           |                     |                 |                              |                               |                    |
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**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.

## 5. Evaluation

[[

]]. These data suggest that the design basis cracking threshold is adequate to ensure that Marathon control rods can perform their safety functions up to the lifetime limits in References 6 and 7.

GEH 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 <sup>1</sup> | Ship Year | Discharge Date | ¼-Segment B-10 Depletion (%) | Peak Local B-10 Depletion (%) |
|----------------------------------|------|--------|---------------------------------|-----------|----------------|------------------------------|-------------------------------|
| Plant P<br>(International BWR)   | [[   |        |                                 |           |                |                              |                               |
| Plant U<br>(US BWR/6)            |      |        |                                 |           |                |                              |                               |
| Plant M-A<br>(US BWR/5)          |      |        |                                 |           |                |                              |                               |
| Plant M-B<br>(US BWR/5)          |      |        |                                 |           |                |                              |                               |
| Plant O<br>(International BWR/6) |      |        |                                 |           |                |                              | ]]                            |

**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. Inspections were completed by the utility in the fall of 2018. New export control laws in the country of origin are preventing delivery of the inspection videos to GEH for review. The utility reports that the inspections showed no crack indications. GEH continues to pursue a solution so that a GEH review of the videos may be performed.
3. Control rods were discharged for inspection in the summer of 2019. The inspections are planned to be performed in the fall of 2020.
4. Control rods are to be discharged at Plant M-A in fall 2020. They will be inspected along with Plant M-B control rods in the fall of 2021.
5. Control rods are discharged in the summer of 2020 and will be inspected in the spring or summer of 2021.

NEDO-33856 Revision 6  
Non - Proprietary Information

Figures 4 and 5 track lead depletion Ultra MD and Ultra HD control rods, respectively. Specifically, for Ultra MD, the world-wide lead depletion control rods at Plant M-B will be inspected in the fall of 2021. Also, the first known permanently discharged Ultra MD control rods will be inspected at Plant M-A, also in the fall of 2021. Per the surveillance program requirements of Reference 2, the first 12 discharged Ultra MD control rods of each lattice type must be inspected. For Ultra HD, the world-wide lead depletion control rods at Plant U were discharged in the fall of 2019 and will be inspected in fall of 2020.

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**Figure 4: Ultra MD Control Rod Inspections**

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**Figure 5: Ultra HD Control Rod Inspections**

## 7. References

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