ENCLOSURE 2

MFN 09-156

Request for Additional Information (RAI) Response Regarding the Marathon-5S Control Rod

Non-Proprietary Information

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 09-156 from which the proprietary information has been redacted. Portions of the document that have been removed are indicated by white space with open and closed double square bracket as shown here [[ ]].

NRC Request

Provide a detailed description of this model and its supporting empirical database. Relate this model and predicted release fractions to the 3-sigma approach used in the previous Marathon LTR.

GEH Response

For the original Marathon design, GE used a constant, [[ ]] helium release fraction, which bounded all of the helium release data GE had gathered (Reference 1, Response 1a(iv)). This same statement is reflected in paragraph 3.4 of the Marathon SE (NEDE-31758P-A), when discussing high temperature data. Current design work uses [[

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For current design work, GEH uses a model for helium release fraction [[

]] As shown in Figure 1, and discussed in Section 3.6.3 of the LTR (NEDE-33284P Rev. 1), helium release data shows that the helium release fraction has a [[
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[[

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Figure 1: Helium Release Fraction Design Basis and Test Results

Figure 1 shows the design basis model for helium release fraction, for a compacted boron carbide powder at [[ ]] of theoretical density. In addition, the helium release fractions that are used for the Marathon and Marathon-5S designs, versus boron carbide temperatures, are shown on the graph and in Table 1. The Marathon-5S temperatures and helium release fractions are the same as those shown in Table 3-12 of the LTR.

Application	Average B_4C Temperature at Peak Location (°F)	Helium Release Fraction (%)
Marathon D/S	[[	
Marathon C		
Marathon-5S D/S Nominal		
Marathon-5S D/S Worst Case		
Marathon-5S C Nominal		
Marathon-5S C Worst Case		]]

Table 1: GEH Marathon Control Rod Design Basis Helium Release Fractions

GEH has conducted two tests to evaluate helium release fractions in BWR control rods. The coolant temperature and measured helium release fractions for these tests are shown in Table 2, and plotted against the design basis model in Figure 1. Note that the use of coolant temperature is conservative, as the temperature of the boron carbide will be higher than the coolant temperature due to the heat generation of the neutron capture.

In the first test, three test capsules were irradiated in a commercial BWR with a coolant temperature of 550 °F. In the second test, two test capsules were inserted in the instrument tubes of two fuel assemblies, and irradiated in a commercial BWR.

As shown in Table 2 and Figure 1, the measured helium released fractions are much smaller than the design basis model predicts. This indicates that there is significant conservatism in the design basis helium release fraction model.

Test	Coolant Temperature (°F)	Measured Helium Release Fraction (%)
Test 1	550	[[
	550	
	550	
Test 2	750	
	750	]]

Table 2: GEH Helium Release Fraction Test Results

Ultimately, the purpose for defining helium release fractions is to predict the pressurization of the Marathon absorber tubes due to helium generation as the boron carbide is irradiated. This methodology, as described in Sections 3.6 and 4.6 of the LTR starts with a thermal analysis to determine the temperature of the boron carbide during operation (LTR Section 3.6.3). Then, the helium release fraction is determined as a function of temperature using the design basis helium release fraction model shown in Figure 1 (LTR Section 3.6.3). Using the helium release fraction and absorber column dimensional data, a computer simulation is run to correlate pressure within the absorber tube to the average depletion of the tube (LTR Section 4.6). Based on this correlation, along with the allowable pressure limit of the tube, an average depletion limit for each absorber tube is established. This limit is then used to determine the mechanical depletion limit for the control rod (LTR Section 4.6).

There are several conservatisms in this methodology:

- Thermal analysis uses worst-case dimensions and maximum heat generation from the peak absorber tube axial location (LTR Section 3.6.3). By basing the thermal analysis, and therefore the helium release fraction, on this worst-case condition, it is assumed that all locations on the control rod wing have are at this worst-case condition. In reality, interior absorber tubes will be at a lower temperature and helium release, as will axial locations away from the top of the absorber section.

- The thermal analysis uses peak beginning-of-life heat generation rates, combined with maximum end-of-life crud build-up (LTR Section 3.6.3).

- The pressurization analysis correlating absorber tube internal pressure to average B-10 depletion considers worst-case capsule and absorber tube dimensions, maximum boron carbide swelling rates, and maximum absorber tube initial moisture content (LTR Section 4.6).

- The resulting 4-segment mechanical lifetime limits are greater than the ¼ segment nuclear limit. In reactor operation, the 4-segment average depletion will always be somewhat less than the peak ¼-segment depletion. Therefore, the nuclear limit will always be limiting over the mechanical limit (LTR Section 4.6).

GEH completed a Post-Irradiation Examination (PIE) of an irradiated Marathon control rod in 2008. As part of this examination, pressure measurements were taken from two intact absorber tubes from one wing of the control rod.

The laboratory hot cell utilized is equipped with a gas collection system that is capable of measuring the pressure of the Marathon absorber tubes by puncturing the tube inside a sealed connection to gas sampling equipment. Using this apparatus, pressures were measured inside two absorber tubes of the Marathon control rod.

Table 3 shows the absorber tube pressures predicted by the pressurization methodology described above, which is at plant operating temperatures. These predicted pressures are scaled to room temperature pressures using the ideal gas law. The pressures measured by the test at room temperature are shown for comparison.

Case	Predicted Pressure at Operating Temperature (psia)	Predicted Pressure at Room Temperature (psia)	Measured Pressure (psia)
Tube # 4	[[		
Tube # 11			]]

Table 3: Marathon Post-Irradiation Examination Absorber Tube Internal Pressures versus Predicted

As shown in Table 3, the actual measured pressures are less than the predicted pressures by a wide margin.

In summary, the methodology used by GEH to evaluate the pressurization of Marathon and Marathon-5S absorber tubes is significantly conservative. Results from irradiated test capsules, and from a destructive examination of an irradiated Marathon control rod suggest that the pressurization methodology, including the helium release fraction design basis, is significantly conservative. Therefore, it is concluded that the mechanical lifetime of the Marathon-5S control rod will exceed the nuclear lifetime.

References

1. Letter from GE to USNRC, “Response to Additional Questions on GE Marathon Control Rod Designs From November 26, 1990 Conference Call”, February 20, 1991.