Serial No. NA3-16-001
Docket No. 52-017

ENCLOSURE 3

GEH Technical Report

003N0526 Revision 0

Seismic Qualification of Spent Fuel in the Spent Fuel Racks

HITACHI

003N0526
Revision 0
Class 1
November 2015

NORTH ANNA 3 SEISMIC QUALIFICATION OF SPENT FUEL IN THE SPENT FUEL RACKS

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1. INTRODUCTION

1.1 Purpose

This report demonstrates the seismic adequacy of GE14E fuel in the spent fuel storage racks for the North Anna 3 (NA3) ESBWR when subjected to a site-specific safe shutdown earthquake (SSE). The NRC Standard Review Plan Section 3.8.4, Appendix D ("Guidance on Spent Fuel Pool Racks"), provides guidance related to spent fuel racks and ensuring fuel integrity during storage in the racks. This analysis looks specifically at the seismic response of spent fuel while it is stored in the fuel storage racks (FSR) located in both the spent fuel pool and the buffer pool deep pit. The results demonstrate that the GE14E fuel is qualified to withstand the NA3 site-specific seismic demand.

1.2 Background

GEH Letter to the NRC (Reference 1) was sent as part of the Design Control Document (DCD) approval process in response to NRC questions related to the adequacy of the fuel stored in the spent fuel racks of the ESBWR standard plant during an SSE event. The letter contained an enclosed engineering evaluation (Reference 2) which analyzed the adequacy of the in-rack fuel using the GEH methodology stipulated in NEDE 21175-3-P-A (Reference 3) for in-core fuel. This methodology ensures the adequacy of fuel by demonstrating that the peak accelerations in the horizontal and vertical direction are below allowable values. Due to the lack of GE14E peak acceleration acceptance criteria at this time, the acceptance criteria for GE14 fuel are utilized. The GE14 bundles are designed for the longer core length of existing Boiling Water Reactor (BWR) designs and have similar cross-sectional mechanical properties. Given the increased bending flexibility of the longer GE14 design, the limiting peak acceleration for GE14 will bound that of GE14E. For a full discussion of the application of GE14 acceptance criteria to the GE14E design see Reference 2.

2. ANALYSIS SUMMARY

For the current report, the transient analysis of the fuel in the fuel rack used for determining the peak fuel acceleration was repeated for NA3. Reference 4 contains the updated transient analysis for the spent fuel pool racks and Reference 5 contains the updated analysis for the buffer pool deep pit racks.

All models, assumptions, methods and load combinations were retained in the Reference 4 and Reference 5 analyses from their standard plant versions. The only difference is the results were generated using the NA3 site-specific SSE input response spectra and corresponding synthesized time histories for this evaluation of the limiting fuel accelerations in the fuel storage racks. This analysis provides information on the generation of the limiting acceleration results and comparisons to the allowable values.

<u>Design Criteria</u>

Reference 2 provides the GE14 horizontal and vertical peak accelerations at the in-core temperature [[ ]], bulk pool temperature limit [[ ]] and the maximum fuel rack exit temperature [[ ]]. The temperature dependent values are provided to account for the considerably lower temperature in the fuel pools than in the reactor. See Reference 2 for a full discussion of the generation of the temperature dependent acceleration limits for the spent fuel and the conservatism of using GE14 fuel limits for a GE14E evaluation.

<u>Time-History Analysis</u>

The transient analysis of the fuel in the fuel rack used for determining the peak fuel acceleration was performed as part of the qualification of the adequacy of the racks to the NA3 seismic demand. Reference 4 contains the analysis for the spent fuel pool racks and Reference 5 contains the updated analysis for the buffer pool deep pit racks.

The models used in these transient analyses are simplified finite element models of the fuel storage rack and fuel bundle. The fuel bundle was modeled as a continuous beam with gap elements at both the top and bottom of the bundle.

An element damping value of 4% was used for both the racks and the fuel bundles. A damping value of 4% is appropriate for the racks per Reg. Guide 1.61 as the racks are made of welded steel. However applying a damping value of 4% to the fuel is extremely conservative. GEH design criterion (Reference 6) states 6% damping is to be used for fuel bundle analysis.

The time history results from the top node, middle node and bottom node of the fuel were extracted from the time history analyses. The maximum vertical accelerations were taken at each node for the racks. In the horizontal direction, the middle node peak accelerations in the X and Y direction are combined by Square Root of the Sum of Squares (SRSS). To add conservatism, the non-time consistent accelerations are combined, meaning the maximum accelerations across the entire time history for a given fuel bundle are combined by SRSS regardless of the actual timing of these peaks in the analysis.

3. RESULTS

Table 1 contains a repeat of Table 1 from Reference 2. The left half of Table 1 shows the *standard plant* peak acceleration acceptance criteria for the fuel at three temperatures. The right half of Table 1 provides the peak acceleration results for each of the fuel racks in the horizontal and vertical direction. Note that for the standard plant design, the vertical fuel acceleration in the buffer pool deep pit exceeds the allowable value at the in-core temperature of [[ ]]. This was justified in Reference 2 because it is not reasonable to analyze the fuel in the spent fuel racks at the reactor internal temperature. To show the fuel in the racks is adequate, the allowable acceleration limits were also calculated for the bulk fuel pool temperature limit [[ ]] and the maximum exit temperature from the rack [[ ]]. These limits show that the spent fuel acceleration will remain below the allowable for any reasonable pool temperature for the standard plant.

Table 2 is identical to Table 1 with the exception that the peak accelerations have been updated to the NA3 site-specific values. The NA3 site-specific peak accelerations are all below the allowable values at even the in-core temperature. This demonstrates that the GE14E fuel design is adequate for the NA3 seismic demands that it will be subject to in the spent fuel storage racks located in either the spent fuel pool or the buffer pool deep pit.

The results show that there is a reduction in the peak horizontal accelerations in both the spent fuel and buffer pools for NA3 relative to the standard plant design. In the vertical direction, the buffer pool spent fuel saw a reduction in the acceleration from the standard plant design. A small increase was seen in the spent fuel pool vertical acceleration which increased at NA3 to 2.11 g's. Given the allowable acceleration at the more conservative in-core temperature of [[ ]] was [[ ]] g's, this increase does not affect the SSE qualification of the fuel in this location.

Table 1 - Peak Spent Fuel Acceleration - Standard Plant

	GE14 Fuel Design Criteria (In-core @ [[ ]]), g	GE14 Corrected Acceleration Limits (Pool @ [[ ]), g	GE14 Corrected Acceleration Limits (Pool @ [[ ]]), g	Spent Fuel Pool, g			Buffer Pool (Deep Pit), g		
Horizontal	[[ ]]	[[ ]]	[[ ]]	Middle			Middle		
				[[ ]]			[[ ]]		
Vertical	[[ ]]	[[ ]]	[[ ]]	Top	Middle	Bottom	Top	Middle	Bottom
				[[ ]]	[[ ]]	[[ ]]	[[ ]]	[[ ]]	[[ ]]

Table 2 – Peak Spent Fuel Acceleration – North Anna 3

	GE14 Fuel Design Criteria (In-core @ [[ ]]), g	GE14 Corrected Acceleration Limits (Pool @ [[ ]]), g	GE14 Corrected Acceleration Limits (Pool @ [[ ]]), g	Spent Fuel Pool, g			Buffer Pool (Deep Pit), g		
Horizontal	[[ ]]	[[ ]]	[[ ]]	Middle			Middle		
				[[ ]]			[[ ]]		
Vertical	[[ ]]	[[ ]]	[[ ]]	Top	Middle	Bottom	Top	Middle	Bottom
				[[ ]]	[[ ]]	[[ ]]	[[ ]]	[[ ]]	[[ ]]

4. CONLUSION

The above document, in addition to the existing documentation in Reference 2 describing the methodology, demonstrate that the GE14E fuel design is adequate for the NA3 seismic demand that it will be subject to in the spent fuel storage racks located in either the spent fuel pool and the buffer pool deep pit.

5. REFERENCES

1) MFN 11-204, Jerald G. Head letter to the NRC, Clarifications Requested by NRC Staff on Economic Simplified Boiling Water Reactor Fuel Design.

2) DRF Section 0000-0139-1108 Rev. 0, "ESBWR Spent Fuel Seismic Qualification," September 2011.

3) NEDE 21175-3-P-A, "BWR Fuel Assembly Evaluation of Combined SSE and LOCA Loadings (Amendment No. 3)," October 1984.

4) Document # 092-322-F-M-00001 Rev. 1, "Design Report of the Spent Fuel Storage Racks in the Fuel Building for North Anna 3," June 2015.

5) Document # 092-322-F-M-00003 Rev. 1, "Design Report of the Spent Fuel Storage Racks in the Reactor Building for North Anna 3," June 2015.

6) ESBWR Design Control Document/Tier 2, Rev. 10, Table 3.7-1, Damping Values for SSE Dynamic Analysis.

ENCLOSURE 4

GEH Technical Report

002N8467 Revision 2

Fuel Rack Seismic Analysis

002N8467 Revision 2
NORTH ANNA 3 FUEL RACK SEISMIC ANALYSIS
Changes from Revision 1 to Revision 2

Rev. 2 addresses changes discussed with the NRC in seismic Audit 1, Action Item 0910GEN02. The major changes are summarized below:

1. Section 1.0 ("Introduction") has been split into Section 1.1 ("Purpose") and Section 1.2 ("Scope"). 2nd Paragraph of Section 1.1 now references the Standard Review Plan (SRP) section used in the performance of the analysis, clarifies that this report provides only a summary of the full stress evaluations that were performed, and identifies design changes implemented as a result of site-specific seismic demands.
2. Section 2.0 ("Spent Fuel Racks in the Spent Fuel Pool") now has new subsections 2.1 ("Analysis Summary"), 2.2 ("Seismic Demand"), and 2.3 ("Results"):
    a. Section 2.1 now provides information about the following: description of the racks, analysis methods, design code, load combinations, analysis procedure for response spectrum analysis (RSA) and transient analysis, stress calculation discussion, and stress limits. Much of this information is repeated from the standard design analysis report (Licensing Topical Report NEDO-33373), as the same analysis was performed with site-specific response spectra.
    b. Section 2.2 provides an overview of how the site-specific response spectra were generated. Reference to the acceleration time-history generation document was added. This reference shows target response spectra compared to the response spectra of the time-history.
    c. Section 2.3 provides the analysis summary results and now includes a comparison of the total horizontal displacement of the rack compared to the minimum distance from the rack to the pool wall.
    d. Figures 4, 5, and 6 showing the acceleration time histories have been added.
3. Section 3.0 ("Spent Fuel Racks in the Buffer Pool Deep Pit") now has new subsections 3.1 ("Analysis Summary"), 3.2 ("Seismic Demand"), and 3.3 ("Results"). Section 3.4 ("Design Changes") is from Section 3.1 of 002N8467, Rev. 1.
    a. Section 3.1 contains additional information about the buffer pool deep pit FSR evaluation, similar to the change in Section 2.1 discussed above.
    b. Section 3.2 contains information on how the site-specific response spectra were generated and now discusses the acceleration time-histories used in the evaluation.
    c. Section 3.3 provides the results of the analysis as well as additional discussion of these results.
    d. Section 3.4 is retained from Section 3.1 of 002N8467, Rev. 1.

4. Section 4.0 ("New Fuel Racks in the Buffer Pool") now has new subsections 4.1 ("Analysis Summary"), 4.2 ("Seismic Demand"), and 4.3 ("Results"). Section 4.4 ("Design Changes") is from Section 4.1 of 002N8467, Rev. 1.
    a. Section 4.1 contains additional information about the new FSR evaluation, similar to the change in Section 2.1 discussed above.
    b. Section 4.2 contains information on how the site-specific response spectra were generated, and includes reference to the acceleration time-history generation document, which shows target response spectra compared to the response spectra of the time-history.
    c. Section 4.3 provides the results of the analysis as well as additional discussion of the results.
    d. Section 4.4 is retained from Section 4.1 of 002N8467, Rev. 1.
    e. Figures 14 and 15 showing the acceleration time histories have been added.
5. Minor editorial changes to Section 5.0 ("Conclusion").