North Anna Fuel/Control Blade Seismic Issues

The staff has examined SER-DMN-044 and 003N5344 and provides the following comments:

SER-DMN-044:

1. **In section 3 of the report, it states that the possible eight directional combinations are considered in calculating the two horizontal accelerations at each time step. Please clarify the meaning of the "eight directional combinations".**

Response: Eight combinations are considered related to the direction of the horizontal response where the horizontal accelerations can be oriented northward or south ward ($\pm a_{xi}$) or eastward or westward ($\pm a_{yi}$). These eight combinations for the acceleration in NS direction are:

1. $a_X(t) = a_{xx}(t) + a_{xy}(t) + a_{xz}(t)$
2. $a_X(t) = -a_{xx}(t) + a_{xy}(t) + a_{xz}(t)$
3. $a_X(t) = a_{xx}(t) - a_{xy}(t) + a_{xz}(t)$
4. $a_X(t) = -a_{xx}(t) - a_{xy}(t) + a_{xz}(t)$
5. $a_X(t) = a_{xx}(t) + a_{xy}(t) - a_{xz}(t)$
6. $a_X(t) = -a_{xx}(t) + a_{xy}(t) - a_{xz}(t)$
7. $a_X(t) = a_{xx}(t) - a_{xy}(t) - a_{xz}(t)$
8. $a_X(t) = -a_{xx}(t) - a_{xy}(t) - a_{xz}(t)$

where: $a_{xj}(t)$ is the maximum NS acceleration response at time (*t*) due to the input motion in j= x, y and z- direction.

Since the direction of the horizontal NS and EW accelerations does not affect the magnitude of the horizontal acceleration resultant, the calculations can be simplified as follows:

$$a_X(t) = abs\,|a_{xx}(t)| + abs|a_{xy}(t)| + abs|a_{xz}(t)|$$

Section 3 of the report was revised to note that the magnitudes of the NS and EW accelerations are calculated by summing the absolute values of the response accelerations as shown in the equation above.

2. **In section 3 of the report, it cites the use of the Newmark 100:40 equation in calculating the resultant earthquake force, in determining which cases are limiting, instead of using time history analysis. The following equation is used:**

$$\boldsymbol{a_h = \sqrt{\left(max|a_x, a_y|\right)^2 + \left(0.4min|a_x, a_y|\right)^2}}$$

Instead of the equation below from RG1.92, ASCE 4 and Newmark (1972) (which GEH references as the methodology):

$$a_h = max|a_x, a_y| + 0.4min|a_x, a_y|$$

Please provide information and clarification of the equation used in calculating the resultant earthquake load, and its acceptability for use in the calculation.

Reference:
Newmark, N.M. (1975). "Seismic design criteria for structures and facilities: Trans Alaska pipeline system, "Proceedings of the U.S. National Conference on Earthquake Engineering, Ann Arbor, Michigan, June 18-20, 1975. (Available through ADAMS ML060870055).

Response: As noted in Section 3, the approximate approach is used to calculate the resultant horizontal accelerations of the fuel from the maximum NS and EW accelerations calculated for the whole duration of the earthquake. As described in Section 1 of the report, the SRSS method is used to combine the responses due to the 3 components of the earthquake and calculate these maximum NS and EW accelerations. The purpose of these calculations is to provide reference values that are used to determine the governing analysis cases among the 18 site-specific SSI analyses performed for the RB/FB. Since these calculations do not provide input used for the design, the use of the approximate method is deemed acceptable for this purpose. Application of any other approach including the one suggested will not affect the conclusions of the comparisons.

In RG 1.92, the Newmark 100:40:40 approach is specified as acceptable for combining responses due to different directions of the input earthquake motion for use in the response spectra analysis. R_1, R_2 and R_3 in Equation (13) in RG 1.92, represent the responses in a single direction due to the three components of the earthquake, i.e. R_1 is the maximum calculated response in direction "I" due to one component of the earthquake, R_1 and R_2 are the maximum calculated responses in direction "I" due to other 2 components of the earthquake. This is also how the methodology is described in the Newmark, N.M. (1975) paper as shown in the highlighted text below:

Combining Horizontal and Vertical Seismic Motions. For those parts of structures or components that are affected by motions in various directions, in general, the net response may be computed by either one of two methods.

The first method involves computing the responses for each of the directions independently and then taking the square root of the sums of the squares of the resulting stresses in a particular direction at a particular point as the combined response. Alternatively, one can use the procedure of taking the seismic forces corresponding to 100 percent of the motion in one direction, combined with 40 percent of the motions in the other two orthogonal directions, then adding the absolute values of these, to obtain the maximum resultant forces in a member or at a point in a particular direction, and computing the stresses corresponding to the combined effect. In general, this alternative method is slightly conservative for most cases and is quite adequate since its degree of conservatism is relatively small.

The suggested equation $a_h = max|a_x, a_y| + 0.4min|a_x, a_y|$ is not applicable because a_x and a_y are acceleration responses of the fuel in x(NS) and y (EW) directions due to the three components of the earthquake. The SRSS method has been applied to calculate a_x and a_y as described in Section 1 of the report.

The following vector algebra equation is applied to calculate the resultant vector of the accelerations in two horizontal directions:

$$a_h = \sqrt{(a_X)^2 + (a_Y)^2}$$

in order to account for the phasing effects of the two horizontal accelerations, it is assumed that at the time instance when one of the horizontal accelerations is maximum, the acceleration response in the other horizontal direction is 40% of the maximum value calculated for the whole duration of the earthquake. This assumption is based on the Newmark observation for phasing characteristics of the input motion and as shown in the SER-DMN-044 tables provides values for the resultant horizontal accelerations that are reasonably close to the values calculated in the time domain. Although these calculations are not always conservative, they are adequate for the purpose of determining the governing analysis cases.

In summary, the 100:40 adaptation of the Newmark equation is used to screen the 18 cases to select the most critical cases. The 6 cases presented with the detailed time step analysis are those that were identified by this equation as the most critical cases. A comparison with results from the 6 cases indicates the 100:40 is a good approximation for screening purposes. 100:40 is not used to determine the "resultant earthquake load."

3. **The staff noted that for all six calculated time domain cases, resultant accelerations at the upper nodes of the fuel bundle model are less than one directional (NS) acceleration. Please explain the probable causes of this general discrepancy between the time history method and the one directional (NS) acceleration. Also, please provide information/confirmation in the report that the time history file used for the SER-DMN-044 calculation results is the same time history file used in FSAR 3.7.**

Response: As part of the verification process, it was found that the values presented in the draft version of the report were calculated considering only the following one combination of the directional responses:

$$a_X(t) = a_{xx}(t) + a_{xy}(t) + a_{xz}(t)$$

As noted in the response to the first question, the report has been revised to calculate the maximum horizontal acceleration by summing the absolute values of the response

accelerations. The revised calculation yields values that are slightly higher than the SER-DMN-044 draft reviewed by the NRC. The maximum value for the resultant horizontal seismic acceleration increases by less than 2.2 percent.

The issued version of SER-DMN-044 will confirm that the time history files used for the SER-DMN-044 calculation results are the same time history files used in FSAR 3.7.

In addition to the above new comments, the staff is including the following comments which were previously discussed at a high level during the closed portion of the public call on 4/20/16 in order to include more detail:

Revised RAI response to NRC RAI Letter 130:

1. **Staff does not consider the reporting of a single horizontal directional acceleration, as was done for a DCD RAI response, to be a method or approach. The revised RAI response should refer instead only to the referenced comprehensive methodology, as presented in Revision 1 to WG3-002N9544 in demonstrating whether the fuel meets GDC2. Further, the RAI response is revised, not supplemented, and as such should stand alone without reference to a prior version of the response.**

Response: The RAI response is revised to supersede and replace the original response. It no longer discusses the single horizontal directional acceleration. Also, it no longer refers to the DCD method or approach, but refers to the NA3 site-specific evaluation report as the basis for the demonstrating the fuel design is acceptable.

a. **On page 4, the last full paragraph from the bottom, the first sentence should therefore be deleted. The second sentence, the first clause should be deleted, and instead read, "An assessment of combined loads on the fuel assemblies has been completed and is described in ~~a revision to~~ Reference 3." Further, the last sentence should not refer to a "DCD approach" with respect to whether or not the fuel is acceptable to NA3, and should read, "The results indicate that the combined load accelerations meet the acceptance criteria."**

Response: The response has been simplified to focus on the NA3 evaluation and refer to Reference 3. The sentence providing the results is revised to state: "The results of the site-specific evaluation indicate that the combined load accelerations meet the acceptance criteria."

b. **The last paragraph starting on page 4 should have the first sentence referring to a "DCD approach" deleted, and the next sentence should instead refer to the assessment performed as a NA3 site-specific control rod assessment.**

Response: The term “DCD approach” is no longer used in the RAI response. The response refers to the NA3 site-specific control rod evaluation.

2. **On page 6, the second paragraph under the bullet, “Completing the ITAAC for Control Rods,” the second sentence should mention scram time requirements/verification in addition to what is already noted for stresses and strain requirements.**

Response: The following is added to the paragraph:

“The analysis will also confirm that the maximum horizontal fuel channel oscillation amplitude calculated for the final as-built combined loads is within the acceptance limit of 40 mm, as described in Reference 4.”

WG3-002N9544, Rev. 1:

1. **Please change the document to a licensing technical report or other appropriate title instead of a supplement/supplementary information for the topical report.**

Response: The report type and title have been changed to Technical Report WG3-002N9544, “North Anna 3 Site-Specific GE14E Fuel Assembly Mechanical Design Report.”

2. **On page 5, the second paragraph under 3.2.2, the paragraph should be edited to identify the reported DCD and NA3 acceleration values shown as single direction accelerations only. Also, because the acceleration limits for GE14E are based on seismic (full methodology, not single direction) and hydrodynamic loads, the phrase ending the second sentence of that paragraph, “…these accelerations are less than the demonstrated capability of the GE14 fuel,” should be deleted. Further, the last sentence of that paragraph should be deleted. Alternately, the paragraph could be deleted entirely.**

Response: The second paragraph of 3.2.2 is deleted.

3. **Similarly, on page 5, the third paragraph under 3.2.2, the first clause should be deleted, and instead the sentence should read, “A site-specific analysis, using approved DCD methods, has been performed to ~~provide more detailed information regarding the margin available in response to follow-up questions from the NRC~~ demonstrate the capability of the GE14E fuel to meet the NA3 site-specific combined loads.**

Response: Comment incorporated.

4. **Both sections 3.2.2 (current analysis) and 3.3 (ITAAC analysis) should state that all nodes of the fuel bundle are compared to the acceptance limits.**

Response: Comment incorporated.

002N8005, Rev. 2

1. **The analysis presented should provide some estimate or representative values for the hydrodynamic loads in demonstrating the acceptance limits are met.**

Response: Quantitative information is included by assuming conservative loads for LOCA and SRV.

2. **On page 1, paragraph 2, the reference should be provided for the NA3 site-specific seismic evaluation.**

Response: Reference 4 is added to the paragraph and to the list of references in Section 5 of the report:

"This value from Table 4.4-1 of Reference 4 is less than 10% higher than the value used in Reference 1.
…

4) SER-DMN-019 Rev. 1, "RB/FB Seismic Analyses Bounding Results and In-Structure Response Criteria", March 2016."

3. **On page 1, paragraph 2, and in section 2.3, the values for fuel channel displacement should be referred to as single directional displacement and it should be indicated that final values will be determined at the ITAAC stage (or otherwise clarify if this is not the case).**

Response: Comment incorporated by adding information to Sections 1 and 2.3.

4. **On page 3, the last paragraph of section 2.2, the first sentence states "the maximum stress remains well below the material allowable stress." The "allowable stress" should be changed to the "true ultimate tensile strength."**

Response: Comment incorporated.