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June 22, 1984

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Ms. E. G. Adensam, Chief
Licensing Branch No. 4

Re: McGuire Nuclear Station
Docket Nos. 50-369, 50-370

Dear Mr. Denton:

Please find attached additional information concerning the McGuire Nuclear Station spent fuel pool two region rerack modifications. This additional information was requested by a June 7, 1984 telecopy from Franklin Research Center to Duke Power which concerns the spent fuel rack design and analysis. If there are further questions regarding this matter, please contact us.

Very truly yours,

H.B. Tucker / [illegible]

Hal B. Tucker

WHM/ibh

cc: Mr. J. P. O'Reilly, Regional Administrator
U. S. Nuclear Regulatory Commission
Region II
101 Marietta Street, NW, Suite 2900
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Mr. W. T. Orders
Senior Resident Inspector
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DUKE POWER COMPANY
McGUIRE NUCLEAR STATION
Spent Fuel Pool Rerack Modifications
Additional Information

1. Please provide a detailed stress report and relevant design drawings for the fuel racks being analyzed for our review.

   RESPONSE: Although both the detailed stress reports and relevant design drawings for the fuel racks constitute proprietary information and must, therefore, be maintained in house, all materials are available for your review at our facility. We welcome the opportunity to discuss with you any concerns or questions you may have.

2. With regard to the simplified non-linear finite element model, please provide the following:

   a. Confirm whether this is a 2-D analysis. If it is a 2-D model, explain how the simultaneous application of a vertical and one horizontal seismic loading component can be accommodated in the analysis.

   b. Discuss how the time step of integration is selected in the analysis relative to solution stability and convergence.

   c. Explain how the gaps between the individual cell and the rigid wall is established in the model.

   RESPONSE: a. The nonlinear analysis is performed on a 2-D finite element model using a time history input of a horizontal shock and a vertical shock. The linear model used in the analysis is a 3-D model which is run for two horizontal directions. The loads for each horizontal direction are adjusted by load factors from the nonlinear analysis, and thus include the effects of both a horizontal and a vertical event. The results of the two direction loads are then combined by the SRSS to account for the three seismic events.

   b. A time step study is performed for a range of time steps. From the results of this study, it is possible to determine the time step which gives a converged solution. Refinement of the time step beyond this value will not significantly affect the results.

2b. Time Step Study

Time step values of 0.005, 0.0025, and 0.00125 seconds were investigated. As shown by the following table, the values at time 0.005 were not converged, values at time 0.0025 were very close to convergence, and the values at time 0.00125 were converged. The final analysis was conducted at a time step of 0.00125 seconds.

Time Step	Support Pad Vertical Load
Seconds	Lbs.
.005	$2x10^{22}$
.0025	1690
.00125	1680

c. The absolute value of the gap between the cell and rigid pool wall is not specifically used in the nonlinear model. However, the effects of the gap between the pool wall and the fuel racks are used in the calculation of the hydrodynamic mass which is used between the cell and pool wall. The value of this hydrodynamic mass is based upon the gaps between the perimeter cells and the pool wall and the gaps between the interior cells using the method outlined in the paper by R. J. Fritz ("The Effect of Liquids on the Dynamic Motions of Immersed Solids", ASME Journal of Engineering for Industry, February 1972).

3. Please provide information on how the load correction factors are derived from the non-linear time history model to be used in the detailed seismic model.

RESPONSE: The non-linear model accurately represents the non-linearities of the fuel to cell interaction and the interface between the rack base and pool floor (potential lift off and sliding). As a result, the non-linear model accurately predicts the loads at the rack to environment interface (rack base loads).

The linear model accurately represents the load and stress distribution in the cells and rack structure within the rack module.

The load correction factors based upon the loads at the interface between the rack base and pool floor are used to adjust the overall stresses within the linear model in order to account for the non-linear effects incorporated in the non-linear analysis. The load correction factors are determined based on the ratio of the rack base to pool floor interface loads obtained in the non-linear analysis to the loads obtained in the linear analysis.

4. Please elaborate on the procedure to establish the hydrodynamic coupling effects between adjacent racks, and between fuel cell and fuel assembly.

RESPONSE: Hydrodynamic Effects Between Racks - The close proximity of adjacent racks, as well as the size of the racks relative to the gap between racks, is such that extremely large hydrodynamic masses are produced if the racks attempt to respond out of phase. It is this large hydrodynamic mass which causes the racks to respond in phase. The seismic analysis for the McGuire racks treats the racks as if they are hydrodynamically coupled (move in phase).

Hydrodynamic Effects Between Fue' and Cell - The hydrodynamic mass between the fuel and cell is based upon the fuel rod array size and cell inside dimensions using the technique of potential flow and kinetic energy. The hydrodynamic mass is calculated by equating the kinetic energy of the hydrodynamic mass with the kinetic energy of the fluid flowing around the fuel rods. The concept of kinetic energy of the hydrodynamic mass is discussed in a paper by D. F. DeSanto ("Added Mass and Hydrodynamic Damping of Perforated Plates Vibrating in Water", ASME Journal of Pressure Vessel Technology, May 1981).

5. Please provide a list of assumptions used in the analysis.

RESPONSE: The basic assumptions for the seismic analysis are as follows:

Structural Damping: A structural damping value of 2% was used for both OBE and SSE events.

Material Damping: The material damping was neglected.

Fluid Damping: The fluid damping was neglected.

Fuel Impact Damping: A damping value of 15% was used to represent the impact damping of the fuel assembly intermediate grids.

6. Please identify the fuel modules being analyzed in Regions 1 and 2, and provide results of stresses and horizontal displacements for the following cases: μ =0.2, 0.4, 0.6 and 0.8.

RESPONSE: The fuel rack modules analyzed are as follows:

Region 1: The 11 x 13 rack is the module analyzed. This is the only rack size in Region 1.

Region 2: The 12 x 16 rack is the module analyzed. This rack size is evaluated since it has the smallest pad spacing (12 cell direction) and thus has the greatest potential for lift off and rocking.

Fuel rack stresses and displacements for friction coefficients of μ = 0.2 and 0.8 are analyzed. The maximum sliding distance (rack base horizontal displacement) of the rack module is obtained for the μ =0.2 case. The maximum rack loads and structural deflections are obtained for the μ = 0.8 case. These two cases envelop the values of intermediate friction coefficients.

Please refer to page 2.3-5 of the McGuire Safety and Environmental Analysis for the maximum rack sliding distance and to Tables 2.3-1 and 2.3-2 of the same report for the stress results.

7. Please indicate the loading pattern of the module used in the analysis (i.e., fully loaded, symmetrically loaded, or diagonally loaded, etc).

<u>RESPONSE</u>: The maximum loads for the McGuire racks are obtained based on a fully loaded condition. This is to be expected since the significant loading mechanism is the interaction between the fuel and the cells (fuel impact on cell). For a condition of the rack being partially loaded with fuel, there are less opportunities for fuel impact and thus the rack loads are less than for the fully loaded condition.

For the evaluation of the rack stability (potential rack overturn), however, the rack is evaluated for both partially and fully loaded conditions.

The support pad vertical displacements for the partial loading and fully loaded conditions are given in the following table for Region 2 fuel racks in the 12 cell direction (the direction of maximum lift-off). It is seen that the maximum lift off is produced by the partial loading of 3 rows of fuel. This condition produces the minimum factor of safety against overturn of (>100) which is much larger than the 1.5 minimum requirement.

Fuel Loading	1 Row	2 Rows	3 Rows	4 Rows	Full
Support Pad Vertical Displacement (Inches)	.006	.010	.011	.010	.005

8. Please indicate the mode of vibration in assessing the hydrodynamic coupling effects between adjacent racks (i.e., symmetric or anti-symmetric).

<u>RESPONSE</u>: The mode of vibration of adjacent racks is symmetric (in phase) due to the strong hydrodynamic coupling effects as discussed in response to question #4.