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May 21, 2010
L-10-151

10 CFR 50.90

ATTN: Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT:
Beaver Valley Power Station, Unit No. 2
Docket No. 50-412, License No. NPF-73
Response to Request for Additional Information Related to Beaver Valley Power Station Unit No. 2 Spent Fuel Pool Rerack License Amendment Request (TAC No. ME1079)

By letter dated April 9, 2009 (Reference 1) as supplemented by letters dated June 15, 2009 (Reference 2); January 18, 2010 (Reference 3); and March 18, 2010 (Reference 4), FirstEnergy Nuclear Operating Company (FENOC) requested an amendment to the operating license for Beaver Valley Power Station (BVPS) Unit No. 2. The proposed amendment would revise the Technical Specifications to support the installation of high density fuel storage racks in the BVPS Unit No. 2 spent fuel pool. By letter dated March 19, 2010 (Reference 5), the Nuclear Regulatory Commission (NRC) staff requested additional information to complete its review of the license amendment request. By letter dated May 3, 2010 (Reference 6), FENOC provided the NRC the responses to 20 out of 23 of the request for additional information (RAI) contained in Reference 5. This letter provides the responses to the remaining three RAIs (numbers 8, 13, and 20) that were not provided in the May 3, 2010 RAI response letter (Reference 6).

The responses for RAI numbers 8, 13, and 20 are provided in the Attachment. The information provided by this submittal does not invalidate the no significant hazard evaluation submitted by Reference 1.

There are no regulatory commitments contained in this letter. If there are any questions or if additional information is required, please contact Mr. Thomas A. Lentz, Manager – FENOC Fleet Licensing, at 330-761-6071.

A047
NRR

I declare under penalty of perjury that the foregoing is true and correct. Executed on May 21, 2010.

Sincerely,

Paul A. Harden

Attachment:
Response to March 19, 2010 NRC Request for Additional Information Related to Beaver Valley Power Station Unit No. 2 Spent Fuel Pool Rerack License Amendment Request

References:

1. FENOC Letter L-09-086, "License Amendment Request No. 08-027, Unit 2 Spent Fuel Pool Rerack," dated April 9, 2009 (Accession No. ML091210251).
2. FENOC Letter L-09-162, "Additional Technical Information Pertaining to License Amendment Request No. 08-027 (TAC No. ME1079)," dated June 15, 2009 (Accession No. ML091680614).
3. FENOC Letter L-10-001, "Response to Request for Additional Information for License Amendment Request No. 08-027, Unit 2 Spent Fuel Pool Rerack (TAC No. ME1079)," dated January 18, 2010 (Accession No. ML100191805).
4. FENOC Letter L-10-082, "Response to NRC Staff Request for Additional Information Regarding Criticality Analyses Supporting a Spent Fuel Pool Re-rack for Unit 2 (TAC No. ME1079)," dated March 18, 2010 (Accession No. ML 100820165).
5. NRC Letter dated March 19, 2010, titled "BEAVER VALLEY POWER STATION, UNIT NO. 2 - REQUEST FOR ADDITIONAL INFORMATION RE: SPENT FUEL POOL RERACK LICENSE AMENDMENT (TAC NO. ME1079)" (Accession No. ML100760584).
6. FENOC Letter L-10-121, "Response to Request for Additional Information Related to Beaver Valley Power Station Unit No. 2 Spent Fuel Pool Rerack License Amendment Request (TAC No. ME1079)," dated May 3, 2010.

cc: NRC Region I Administrator
NRC Senior Resident Inspector
NRR Project Manager
Director BRP/DEP
Site Representative (BRP/DEP)

To complete its review, the Nuclear Regulatory Commission (NRC) staff has requested additional information regarding FirstEnergy Nuclear Operating Company (FENOC) spent fuel pool (SFP) rerack license amendment request (LAR) No. 08-027. The staff's request is provided below in bold text followed by the FENOC response for Beaver Valley Power Station (BVPS) Unit No. 2.

Mechanical and Civil Engineering Branch Review

8. Section 5.9 of Enclosure C of Reference 1, "Interface Loads on SFP Structure," included a table summarizing the SFP structure safety factors following the proposed re-rack of the pool at BVPS-2. As stated in this section, the safety factors have been determined based on the moment capacity of the individual walls and slab of the pool structure. Please provide a tabulated summary of the safety factors based on one-way and two-way shear capacity of the aforementioned elements or provide justification for utilizing only moment capacities as the structural qualification measure. Additionally, provide more information relative to the temperature rise in the pool and its effects on determining the BVPS-2 safety factors for individual walls, the slab, and the liner of the SFP structure.

Response:

The following table summarizes the punching (two-way) shear load, the two-way shear capacity, and the corresponding safety factor for each of the spent fuel pool (SFP) walls. The SFP walls are not governed by beam action (that is, one-way action) since they are supported along three edges and their height-to-width ratios are between 1 and 2. Per American Concrete Institute (ACI) 318/318R (Reference 9), for shear strength evaluation of slabs (and walls), differentiation must be made between a long and narrow slab or footing acting as a beam, and a slab or footing subject to two-way action.

SFP Wall	Shear Load (kips)	Shear Capacity (kips)	Safety Factor
East	2,713	5,440	2.01
West	5,104	11,665	2.29
North	5,439	25,064	4.61
South	3,505	19,312	5.51

The SFP reinforced concrete slab is 10-feet thick and founded on grade; therefore, a shear failure of the SFP slab is not limiting. This is evident from the response to RAI number 5 (Reference 10), which shows that the slab has a safety factor greater than 13 (without taking credit for the subgrade) against punching shear failure due to the rack drop event. The safety factors against shear failure for the east-south wall and the south-east wall are bounded by the safety factor for the east wall in the table above. This is because (a) the east-south wall and the south-east wall are at least two times thicker than the east wall and (b) the wetted area of the east-south wall and the south-east wall are significantly less than the east wall.

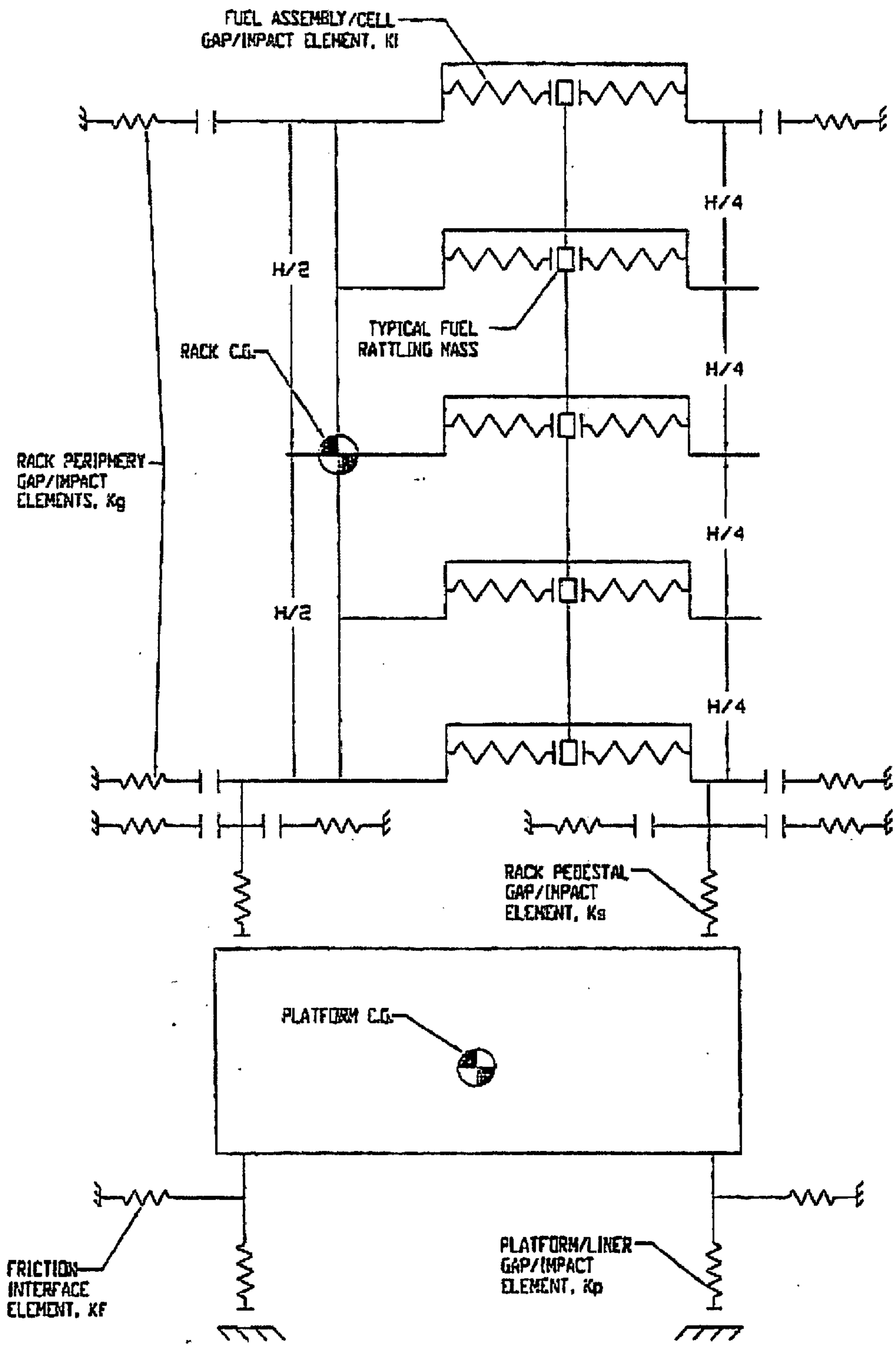
The maximum concrete temperature and the corresponding temperature gradients through the SFP walls and slab are calculated in Holtec report HI-2084135 (Reference 7). Since the thermal moment is directly proportional to the square of the wall (or slab) thickness and the corresponding temperature gradient, an adjustment factor is calculated for each wall/slab, which enables the thermal moments for the BVPS-2 SFP to be calculated from the BVPS-1 moment results (Reference 8). As described in Section 5.9 of Enclosure C in Reference 1, linear interpolation from the BVPS-1 moment results is used to calculate the results for BVPS-2. Once the thermal moments for BVPS-2 are known, the applicable ACI load factors are applied and the final safety factors (shown in Section 5.9 of Enclosure C in Reference 1) against bending (moment) failure are determined for the BVPS-2 SFP structure.

The shear safety factors reported above are not adversely affected by the temperature rise in the pool since thermal loads tend to cause net compression in the SFP slab and wall cross-sections, which has a positive (increasing) effect on shear capacity. Also, the small increase in the pool water temperature due to the reracking does not compromise the stability of the SFP liner since liner buckling is resisted by the concrete slab or wall in one direction and by the hydrostatic pressure from the SFP water in the opposite direction.

13. Section 5.7 of Enclosure C in Reference 1, "Cask Pit Rack Platform Analysis," stated that a single rack analysis is performed to evaluate the seismic loads induced on the cask pit rack platform. Due to the dynamic characteristics of the cask pit platform, there may be possible amplification of seismic input motion. Provide justification relative to the decoupling of the rack and the cask pit platform in the seismic analysis.

Response:

To assess the seismic amplification due to the dynamic characteristics of the cask pit platform, the seismic analysis documented in Reference 3 has been re-performed using a coupled model, which includes both the rack and the cask pit platform. The figure below shows a schematic of the coupled model, which is implemented using the computer program DYNARACK.



The cask pit platform is modeled as a six degree of freedom rectangular body of appropriate size and mass, which is capable of twisting, rocking, and sliding relative to the cask pit floor. The spent fuel rack sits atop the platform in a freestanding manner.

A combination of non-linear gap elements and friction elements are used to define the contact interfaces between the rack support pedestals and the platform, and the platform and the cask pit floor.

The results obtained from the decoupled rack model and the coupled rack/platform model are summarized in the table below.

Result	Decoupled Rack Model	Coupled Rack/Platform Model
Maximum (Max.) Compressive Force (lbf):		
Pedestal 1	179,900	148,800
Pedestal 2	232,100	247,800
Pedestal 3	206,000	210,500
Pedestal 4	172,000	186,400
Max. Friction Force in X-Direction (Dir.) (lbf):		
Pedestal 1	36,200	50,550
Pedestal 2	46,700	61,130
Pedestal 3	42,500	67,570
Pedestal 4	41,500	62,190
Max. Friction Force in Y-Dir. (lbf):		
Pedestal 1	64,400	50,800
Pedestal 2	50,900	44,870
Pedestal 3	63,000	68,110
Pedestal 4	88,800	71,410
Max. Horizontal Displacement in X Dir. (in):		
Top of Rack	0.697	1.289
Bottom of Rack	0.064	0.264
Max. Horizontal Displacement in Y Dir. (in):		
Top of Rack	0.390	0.493
Bottom of Rack	0.045	0.231

Based on the above table, the seismic response of the cask pit rack is slightly amplified when the platform is included in the model. The displacements shown above are insignificant, and will neither cause the rack to slide off the platform nor to tip over. Therefore, the stress analysis of the cask pit rack platform has been re-performed (Reference 3) using the maximum pedestal forces from the coupled rack/platform model. The calculated stresses in the platform continue to meet the Level D stress limits per American Society of Mechanical Engineers (ASME) Code, Section III, Subsection NF (Reference 4). The minimum calculated safety factor is 1.084, where the safety factor must exceed 1.0 to meet the level D stress limits. A future supplement to the LAR will reflect the revised analysis.

20. As discussed in Section 5.4.2.1 of Reference 1, a simplified 3-D lumped mass dynamic model of the single rack structure is used in the whole pool multi-rack analysis. Response 6 in Reference 2 indicated that the use of a single-beam and two-node to model a BVPS-2 rack module is justified because the lowest natural frequency of the rack cellular structure is above 33 Hertz. Please provide more information relative to benchmarking of this model against a detailed finite element model to demonstrate the adequacy of the simplified mass model to predict the anticipated time history seismic responses.

Response:

The 3-D lumped mass single rack model is the basic building block for this whole pool multi-rack (WPMR) analysis, which is carried out using the Holtec proprietary code DYNARACK. The DYNARACK code was developed in the late 1970s and has been periodically updated since that time to incorporate technology advances such as multi-body fluid coupling, which is a computer code based on the Component Element Method (CEM) (Reference 5). The chief merit of the CEM is its ability to simulate friction, impact, and other nonlinear dynamic events with accuracy. The high density racks designed by Holtec International are ideally tailored for the CEM-based code because of their honeycomb construction (HCC). Through the interconnection of the boxes, the HCC rack essentially simulates a multi-flange beam. The beam characteristics of the rack (including shear, flexure, and torsion effects) are appropriately modeled in DYNARACK using the CEM "beam spring". Each rack is modeled as a prismatic 3-D structure with support pedestal locations and the fuel assembly aggregate locations set to coincide with their respective center of gravity (C.G.) axes. The rattling between the fuel and storage cells is simulated in exactly the same manner as it would be experienced in nature, namely, impact at any of the four facing walls followed by rebound and impact at the opposite wall. Similarly, the rack pedestals can lift off or slide as the instantaneous dynamic equilibrium would dictate throughout the seismic event. The rack structure can undergo overturning, bending, twist, and other dynamic motion modes as determined by the interaction between the seismic (inertia) impact, friction, and fluid coupling forces.

Figure 5.1 and figure 5.4 of Holtec report HI-2084175 (Enclosure C to Reference 1) depicts the flexible elements used to model the dynamic behavior of the rack modules. The elements allow shear and bending deformation in each of the two horizontal directions perpendicular to the face of the racks. Additional elements are included in the model to allow axial deformation and torsional rotation.

The stiffness values were determined by considering each rack module as a beam with multiple flanges and webs comprised of the rack cell walls. The stiffness values were computed by deriving the appropriate formula from the Principle of Complementary Energy found in Advanced Mechanics of Materials (Reference 11). The resulting stiffness values accurately reproduce the stiffness matrix for a beam.

The computed rack stiffness values indicate considerable rigidity within the rack module. Consequently, the rack exhibits primarily rigid body motion during the dynamic earthquake event. The selection of six degrees of freedom (three translations and three rotations) at the top of the rack and of six degrees of freedom at the bottom of the rack provides adequate representation of the rigid body motion and captures first mode elastic response.

Ten additional degrees of freedom are added to represent fuel rattling within the storage rack cells. The fuel assembly mass represents the largest component of the dynamic rack-fuel system model and dominates the behavior of a filled storage rack module. Therefore, the entire assemblage is comprised of 22 degrees of freedom (dof), which are adequate to represent the dynamic behavior of each rack module.

This modeling construct has been used consistently by Holtec for more than two decades to analyze spent fuel racks on numerous dockets, and it has been reviewed by the Atomic Safety and Licensing Board (ASLB), the NRC staff, and NRC consultants (Brookhaven National Laboratory and Franklin Research Center). Notwithstanding past history, a benchmark comparison between the 22-dof single rack model and a detailed finite element model has been performed to further demonstrate the adequacy of the simplified mass model to predict the anticipated time history seismic responses.

In 2008, Holtec developed a detailed finite element model of a 12 by 12 pressurized water reactor (PWR) spent fuel rack (Reference 6) for Sizewell nuclear plant. This nuclear power plant is located in England and operated by British Energy. The model, which is shown below in the Figure RAI-20-1, was built using LS-DYNA.

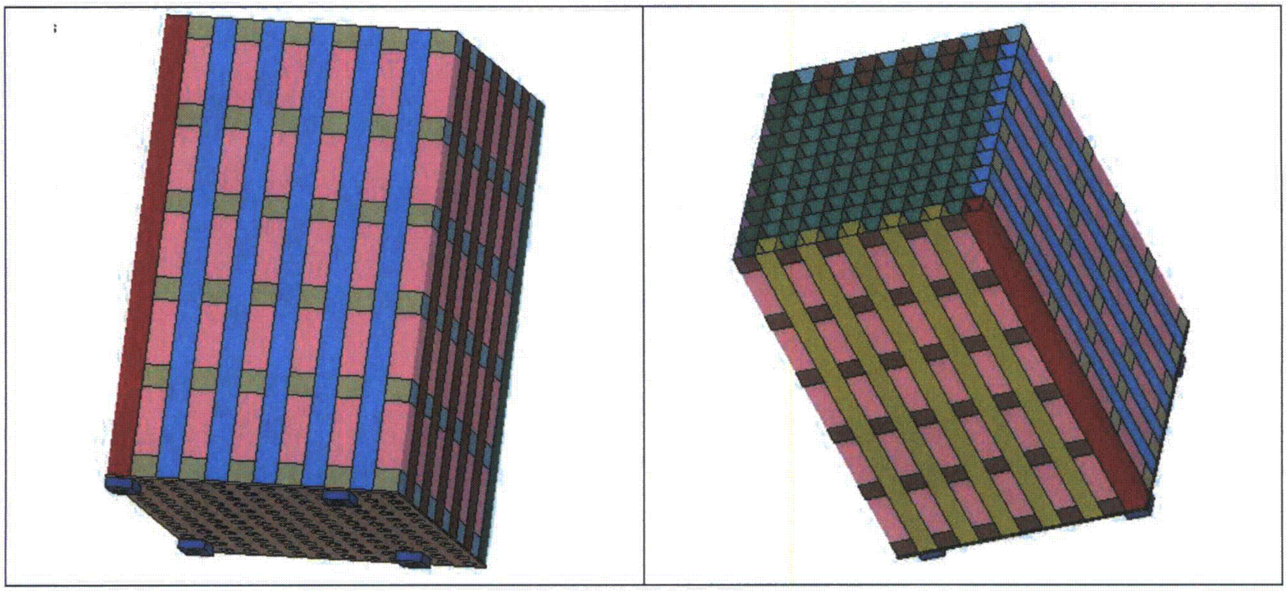


Figure RAI- 20-1 LS-DYNA Model of 12 x 12 Sizewell Rack

As shown in the figure above, all load bearing components of the spent fuel rack, including the support pedestals, the base plate, the cell walls, and the weld connections, were modeled explicitly using a combination of thick shell, shell, and solid elements. In addition to the rack structural components, the stored fuel assemblies were individually modeled in LS-DYNA as separate bodies and positioned within every storage cell location. Appropriate contact interfaces were defined between the cell walls, the base plate, and the fuel assemblies to allow each fuel assembly to rattle freely inside its storage cell under the applied loading. The entire model included nearly 200,000 elements.

A seismic analysis of the 12 by 12 Sizewell rack was performed by simultaneously applying three orthogonal acceleration time histories to the LS-DYNA model. For this analysis, the spent fuel rack was assumed to be freestanding in air (rather than in water) since it is difficult to model fluid-structure interactions in LS-DYNA directly. To offset this conservative assumption, an attenuation factor was applied to the horizontal input accelerations to account for the effect of the water.

In parallel with the LS-DYNA work, a separate analysis was performed using DYNARACK for the same 12 by 12 Sizewell rack in air, under the same earthquake and fuel assembly loading conditions. Additionally, the Sizewell rack was modeled in DYNARACK using the standard modeling approach (that is, two-node, single beam rack model). Table RAI-20-1 summarizes the results predicted by both models.

Table RAI-20-1 Benchmarking for 12 x 12 Sizewell Rack

Result	LS-DYNA Model	DYNARACK Model
Max. Horizontal Displacement at Top of Rack (in): North-South Direction East-West Direction	 0.761 0.999	 1.526 1.772
Max. Horizontal Displacement at Base of Rack (in): North-South Direction East-West Direction	 0.216 0.228	 1.132 0.929
Maximum Instantaneous Fuel-to-Cell Impact Load (per assembly average) (lbf):	624	> 859

As expected, the DYNARACK model predicts larger rack displacements than LS-DYNA mainly because of the conservative manner in which rattling fuel assemblies are modeled in DYNARACK. The DYNARACK model assumes that all fuel assemblies rattle in-phase by virtue of the fact that the total mass of the stored fuel assemblies is lumped into a single fuel column. By contrast, the fuel assemblies are individually modeled in LS-DYNA, and therefore they are capable of rattling out-of-phase (as would actually occur in a seismic event). Out-of-phase rattling reduces the net impact between the stored fuel and the spent fuel rack, which in turn leads to smaller rack displacements. Thus, the simplified mass model utilized in DYNARACK provides a conservative prediction of the maximum rack displacements and fuel-to-cell impact load.

Even though the benchmarking was performed for a Sizewell rack, the conclusion is valid for nearly all Holtec designed spent fuel racks (including BVPS-2) since there is minimal change in the fabrication materials and the cell geometry across rack designs for different plants. To emphasize this point, the key characteristics of the 12 by 12 Sizewell rack, which is the focus of the benchmarking study, and the BVPS-2 spent fuel racks are summarized in the following table.

Table RAI-20-2

	Sizewell	BVPS-2
Cell wall material	SA-240 304	SA-240 304/304L
Cell height above base plate (in)	168.625	169
Cell wall thickness (in)	0.075	0.075
Cell inside dimension (in)	8.87	8.80
Cell pitch (in)	9.07	9.03

Based on the data in Table RAI-20-2 and the size of the rack (for example, 12 by 12 or 10 by 14), the equivalent beam stiffness values for the rack cell structure are computed for input to the two-node, single beam DYNARACK model. The following table summarizes the stiffness values for the 12 by 12 Sizewell rack and the 10 by 14 BVPS-2 rack as analyzed in Reference 3.

Table RAI-20-3

	12 x 12 Sizewell Rack	10 x 14 BVPS-2 Rack
Shear Stiffness in X Dir. (lbf/in)	3.200E+06	2.788E+06
Shear Stiffness in Y Dir. (lbf/in)	3.200E+06	3.327E+06
Axial Stiffness (lbf/in)	3.410E+07	3.305E+07
Bending Stiffness about X Axis (lbf-in/rad)	3.690E+10	4.750E+10
Bending Stiffness about Y Axis (lbf-in/rad)	3.690E+10	2.500E+10
Torsional Stiffness (lbf-in/rad)	3.973E+09	3.671E+09

To further establish the link between the Sizewell benchmark study and the spent fuel racks to be installed at BVPS-2, four additional DYNARACK runs have been performed. The following table summarizes the key parameters for each run.

Table RAI-20-4

Run No.	Rack Analyzed	Surrounding Fluid	Input Earthquake	Fuel Assemblies
1	12 x 12 Sizewell Rack	Water	Sizewell SSE	Sizewell
2	10 x 14 BVPS-2 Rack	Water	Sizewell SSE	Sizewell
3	12 x 12 Sizewell Rack	Water	BVPS-2 SSE	BVPS-2
4	10 x 14 BVPS-2 Rack	Water	BVPS-2 SSE	BVPS-2

Run Numbers 1 and 2 are developed to show that both the Sizewell rack and the BVPS-2 rack respond similarly when submerged in water and subjected to the Sizewell design basis earthquake. Run Numbers 3 and 4 are developed to show that both the Sizewell rack and the BVPS-2 rack respond similarly when submerged in water and subjected to the BVPS-2 design basis safe shutdown earthquake (SSE). The results from these four runs are summarized below in Table RAI-20-5.

Table RAI-20-5

Result	Run No. 1	Run No. 2	Run No. 3	Run No. 4
Max. Horizontal Displacement at Top of Rack (in):				
X Dir.	0.889	0.799	0.803	0.702
Y Dir.	0.861	0.465	0.767	0.394
Max. Horizontal Displacement at Base of Rack (in):				
X Dir.	0.023	0.041	0.112	0.069
Y Dir.	0.028	0.023	0.182	0.048
Maximum Fuel-to-Cell Impact Load (per assembly average) (lbf):	813	586	729	717

To summarize, the two-node, single beam rack model implemented in DYNARACK has been compared against a detailed LS-DYNA finite element model, and as shown in Table RAI-20-1, DYNARACK provides a more conservative prediction of the time history seismic response. Although the benchmark comparison is performed for a 12 by 12 Sizewell rack, the results are valid for nearly all Holtec designed spent fuel racks, including those to be installed at BVPS-2, because of the similarities in fabrication materials and cell geometry. The similarity between the 12 by 12 Sizewell rack and the BVPS-2 spent fuel racks is further demonstrated by the DYNARACK results in Table RAI-20-5.

References

1. Letter from P. P. Sena, FirstEnergy Nuclear Operating Company, to NRC Document Control Desk, "Beaver Valley Power Station, Unit No. 2 Docket No. 50-412, License No. NPF-73, License Amendment Request No. 08-027, Unit 2 Spent Fuel Pool Rerack," with Enclosure B (proprietary) and Enclosure C (non-proprietary), "Licensing Report for Beaver Valley Unit 2 Rerack," dated April 9, 2009. (ADAMS Accession Nos. ML091210251 (letter) and ML091210263 (Enclosure C))

2. Letter from R. A. Lieb, FirstEnergy Nuclear Operating Company, to NRC Document Control Desk, "Beaver Valley Power Station, Unit No. 2 Docket No. 50-412, License No. NPF-73, Response to Request for Additional Information for License Amendment Request No. 08-027, Unit 2 Spent Fuel Pool Rerack (TAC No. ME1079)," dated January 18, 2010. (ADAMS Accession No. ML100191805)

3. Holtec Report HI-2084165, "Structural Evaluation of Cask Pit Platform", Revision 4.

4. ASME, "Boiler & Pressure Vessel Code", Section III, Subsection NF, 1998 edition.

5. Levy, S. and Wilkinson, J., The Component Element Method in Dynamics, McGraw-Hill, Inc., 1976.

6. Holtec Report HI-2084009, "Seismic/Structural Analysis of Spent Fuel Rack D4 at Sizewell Nuclear Plant", Revision 1.

7. Holtec Report HI-2084135, "Beaver Valley Unit 2 Spent Fuel Pool Structure Temperature Gradients", Revision 3.

8. Holtec Report HI-90567, "Fuel Pool Structural Analysis of Beaver Valley Unit 1 with Maximum Density", Revision 2.

9. American Concrete Institute, "Building Code Requirements for Reinforced Concrete (ACI 318-89) (Revised 1992) and Commentary - ACI 318R-89 (Revised 1992)".

10. FENOC Letter L-10-121, "Response to Request for Additional Information Related to Beaver Valley Power Station Unit No. 2 Spent Fuel Pool Rerack License Amendment Request (TAC No. ME1079)," dated May 3, 2010.

11. Boresi, P. et al., Advanced Mechanics of Materials, John Wiley & Sons, Inc., Fifth Edition.