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Beaver Valley Power Station
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May 3, 2010
L-10-121

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.

The responses to the NRC request for additional information (RAI), with the exception of RAI numbers 8, 13, and 20 are provided in the Attachment. Based on a conference call conducted on March 19, 2010 between members of the NRC staff and FENOC personnel concerning RAI number 20, FENOC has determined that the level of information that needs to be included in this RAI response will require additional man-hours beyond those that were planned. Therefore, FENOC will provide the response to RAI number 20 in future written correspondence to the NRC. In addition, due to the scope of work required to adequately address the concerns presented in RAI numbers 8 and 13, FENOC will also provide the response to these two RAIs in future written correspondence to the NRC. The delay in responding to these three RAIs has been previously communicated to the NRC staff. The information provided by this submittal does not invalidate the no significant hazard evaluation submitted by Reference 1.

A001
NRR

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.

I declare under penalty of perjury that the foregoing is true and correct. Executed on May 3, 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).

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 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

1. **Table 1.9-1 of the BVPS-2 Updated Final Safety Analysis Report (UFSAR) indicated that, for the design of other Seismic Category I Structures, Section 3.8.4 of the Standard Review Plan (NUREG-0800 or SRP) Revision 1, is the guidance associated with the design of BVPS-2. Section 9.1.2 of the BVPS-2 UFSAR indicates (through BVPS-2 UFSAR Section 3.8.4) that the SFP, SFP liner, and associated structures, including the SFP racks, are Seismic Category I structures designed against the criteria found in SRP Section 3.8.4, Revision 1. Enclosure C of Reference 1 indicates that Section 3.8.4 of the SRP, including Appendix D, was utilized in the analysis of the replacement SFP racks; however, the revision used by Holtec is not indicated in the Reference section of this report. Please indicate the revision of SRP Section 3.8.4 criteria for which the analyses were compared against and if this revision differs from the BVPS-2 licensing basis, please provide justification regarding any variations.**

Response:

Reference [5.1] in Holtec report HI-2084175 (Enclosure C of Reference 1) indicates that the analysis of the replacement SFP racks is in accordance with Revision 2 of SRP Section 3.8.4, which is the latest revision issued by the NRC. The use of SRP Section 3.8.4, Revision 2 (as opposed to Revision 1) is acceptable since there is no difference in the structural acceptance criteria or the applicable load combinations between Revision 1 and Revision 2. The variations between Revision 1 and Revision 2, with respect to Appendix D, are either editorial or for clarification.

2. **In response to the NRC request for additional information (RAI) regarding the impact load analysis, the licensee indicated in Response 11 of Reference 2, that upon review of the original analyses in support of developing the RAI response, the reinforcement bars that are located near the top portion of the proposed racks were altered due to non-conservatisms present in the**

original analyses used in Reference 1. The NRC staff requests the following information related to the RAI Question No. 11 response:

a) Describe the non-conservatisms identified during the review of the impact load analyses performed in support of the response to the aforementioned RAI.

Response:

In the previous impact load analysis, the critical buckling stress for the rack cell wall was calculated based on the equation provided in table number 35 (case 1b) of Reference 5 for a rectangular plate with clamped edges on all four sides. The use of this formula was non-conservative since the top edge of the cell wall is free rather than clamped. To correct this issue, the impact load analysis was re-performed using the finite element program ANSYS. This approach allowed the boundary conditions to be modeled more accurately.

b) Based on the non-conservatisms identified, RAI response 11.c on page 17 of Reference 2, indicated that additional reinforcement was added to the top of the rack structures. Please indicate whether a revised Whole Pool Multi-Rack (WPMR) analysis was performed with the revised design to determine a revised value for the maximum impact force utilized in the LS-DYNA analysis performed to demonstrate the structural adequacy of the rack structures. If a new WPMR analysis was not performed, provide justification indicating what factors negated the need to re-perform a WPMR analysis for the revised rack structures.

Response:

A revised WPMR analysis was not performed as a result of the changes to the reinforcement bars located near the top of the rack. The reason that the WPMR analysis was not revised is because (i) the thickness of the reinforcement bars was not changed, and therefore the rack-to-rack and rack-to-wall clearance gaps were unaffected, and (ii) the modifications to the reinforcement bars had a negligible effect on the weight of the racks.

c) Section 5.6.10.1 of Enclosure C in Reference 1 stated that the allowable local buckling stresses in the fuel cell walls is obtained using classical plate buckling analysis, as taken from Section 9.2 of *Theory of Elastic Stability* (Timoshenko and Gere). Revision 1 of SRP Section 3.8.4, Appendix D, states that when the new SFP rack design considers buckling loads, the criteria provided in American Society of Mechanical

Engineers Code, Section III, Division 1, Appendix XVII should limit the structural acceptance criteria. Discuss the relationship between the buckling criteria used in Section 5.6.10.1 and the criteria provided in the SRP and provide justification that the buckling criteria used in the BVPS-2 re-rack analysis provided an adequate level of conservatism.

Response:

The cell wall buckling analysis presented in Section 5.6.10.1 of Holtec report HI-2084175 (Enclosure C of Reference 1) is in accordance with the buckling criteria provided in SRP 3.8.4 (Reference 11). This is because Section I.6 of Reference 11 invokes the buckling criteria provided in American Society of Mechanical Engineers (ASME) Code, Section III, Division 1, Appendix XVII. Appendix XVII provided the rules for linear support design until the winter 1982 addenda when a major revision to Article NF-3000 was published. The rules for linear support design are now provided in Subarticle NF-3300. With respect to buckling, NF-3321.1(b) (formerly XVII-2110(b)) states:

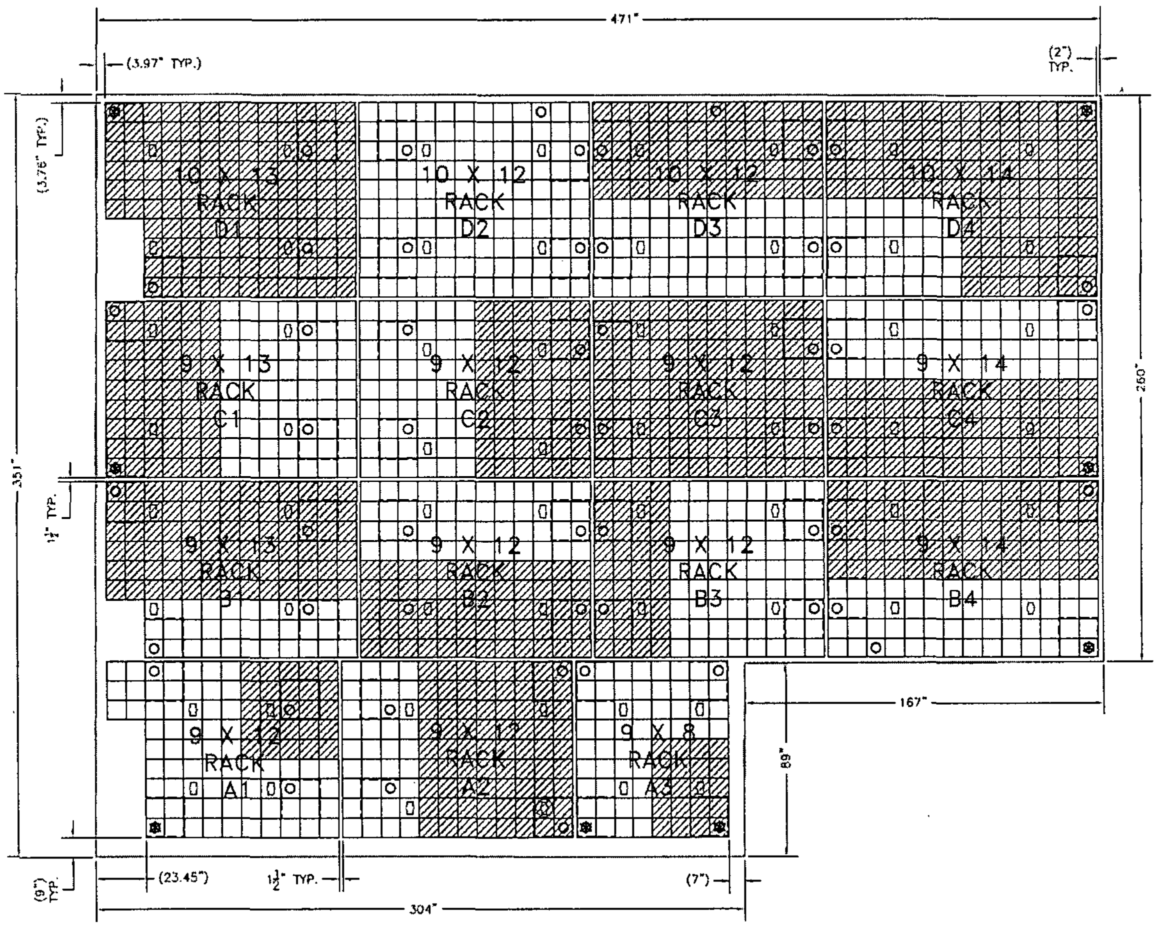
> To avoid column buckling in compression members, local instability associated with compression flange buckling in flexural members, and web buckling in plate girders, the allowable stress shall be limited to two-thirds of the critical buckling stress.

Subarticle NF-3300, however, does not provide any specific guidance or formula for calculating the critical buckling stress. Thus, for the local cell wall buckling analysis the critical buckling stress is calculated using classical plate buckling formula given in Section 9.2 of Reference 6. Per Section 5.6.10.1 of Holtec report HI-2084175, the critical buckling stress for the cell wall is 15,928 psi, and two-thirds of this stress value is 10,619 psi. Since the maximum calculated compressive stress in the cell wall under Safe Shutdown Earthquake (SSE) loading is 9,380 psi, the buckling criteria provided in SRP 3.8.4 and the ASME Code are satisfied. Limiting the compressive stress to two-thirds of the critical buckling stress as specified in the ASME Code provides an adequate level of conservatism.

3. **Page 5-22 of Enclosure C of Reference 1 indicated that all seven simulations performed for the proposed re-rack of the BVPS-2 SFP modeled fully-loaded racks. Page 5-8 of Enclosure C of Reference 1 indicated that partially-loaded racks can be modeled within DYNARACK. Given that interim conditions will exist in which the BVPS-2 SFP is partially-loaded with various rack configurations, provide a justification that the fully-loaded rack condition induces the most limiting conditions with respect to the seismic analysis and the structural adequacy of the SFP, the SFP liner, the SFP racks, the SFP cask pit, and the SFP cask pit platform.**

Response:

In general, the fully loaded rack condition is limiting because it maximizes the vertical compressive load and the horizontal friction force on rack support pedestals, and it tends to produce the maximum rack displacements. Nevertheless, to insure that a partially loaded rack is not limiting, a new WPMR simulation has been performed for the interim condition shown in the figure below (cross hatched areas indicate loaded cells).



INTERIM FUEL LOADING CONDITION

The results of the new WPMR simulation for the interim fuel loading condition, along with the maximum results from the fully loaded simulations (that is, Run Nos. 1, 2, and 3 in Enclosure C of Reference 1), are summarized in the following table:

Result	Interim Fuel Loading Condition	Fully Loaded Condition (Based on Run Nos. 1, 2, and 3 in Enclosure C of Reference 1)
Max. Stress Factor	0.234	0.367
Max. Vertical Load on a Single Pedestal (lbf)	189,000	326,000
Max. Shear Load on a Single Pedestal (lbf)	71,200	122,000
Max. Fuel to Cell Wall Impact Force (lbf)	537	610
Max. Rack to Rack Impact Force (lbf)	63,190	101,800
Max. Top of Rack Displacement (in)	1.67	2.79
Max. Bottom of Rack Displacement (in)	0.54	1.00

The above table shows that the results for the interim fuel loading condition are bounded by the results for the fully loaded rack condition. Furthermore, the maximum stress factor, the maximum pedestal vertical load, the maximum pedestal shear load, and the maximum fuel to cell impact force for the interim fuel loading condition are associated with racks C3 and D1, which are the only fully loaded racks in the interim fuel loading condition (see figure above). This demonstrates that the most severely loaded racks are the ones that hold the most fuel assemblies. Thus, the fully-loaded rack condition is the limiting condition with respect to the seismic analysis and the structural adequacy of the SFP, the SFP liner, the SFP racks, the SFP cask pit, and the SFP cask pit platform.

4. **Section 2.3 of Enclosure C of Reference 1 indicated the codes and standards applicable to the proposed re-rack of the BVPS-2 SFP. In this section, Electric Power Research Institute Report NP-60415L, *A Methodology for Assessment of Nuclear Power Plant Seismic Margin*, Revision 1, was indicated as one of the codes and standards documents utilized in the analysis for the proposed re-rack. Discuss the applicability of this report to the current licensing basis of BVPS-2 and its applicability to the design and analysis of the proposed re-rack.**

Response:

It should be noted that the correct Electric Power Research Institute (EPRI) report number is NP-6041-SL, not NP-60415L as stated above and in Section 2.3 of Enclosure

C of Reference 1. EPRI Report NP-6041-SL is not used for the design and analysis of the BVPS-2 spent fuel racks, and is not applicable to the current licensing basis for BVPS-2.

5. **Section 7.5.3 of Enclosure C of Reference 1, the analyses summary of the "Rack Drop Event" mechanical accident, only discussed the local damage of the SFP floor slab in the event of rack drop. Provide information relative to the global behavior of the SFP floor slab in absorbing the imparted energy.**

Response:

The BVPS-2 SFP floor consists of a 10-foot thick reinforced concrete slab founded on grade. Thus, the only credible failure mode for the SFP floor slab, due to the rack drop event, is a punching shear failure directly beneath the impacting rack. Per Reference 12, the rack drop event causes a peak impact load of 156,090 lbf between the SFP floor and each of four spent fuel rack support pedestals. Therefore, the total impact load transmitted by the rack to the SFP floor is 624,360 lbf. The punching shear capacity of the reinforced concrete slab is calculated as follows (in accordance with Reference 7):

$F_{impact} := 624360 lbf$	Peak impact load transmitted to SFP floor due to rack drop event (Reference 12)
$f_c := 3000 psi$	Concrete compressive strength (Reference 13)

For conservatism, the punching shear capacity is calculated based on the planar dimensions of the smallest rack (A3) even though the impact load is computed in Reference 12 based on the heaviest rack.

$L := 81.565 in$	Module envelope size for rack A3 in the North-South direction (Reference 17)
$W := 72.535 in$	Module envelope size for rack A3 in the East-West direction (Reference 17)
$d := 117 \cdot in$	Distance between top surface of slab and centerline of tensile rebar (Reference 13)

The perimeter length (b_o) of the punching shear area is:

$$b_o := 2 \cdot [(L + d) + (W + d)] \qquad b_o = 776.2 in$$

Per ACI 318-71, the shear capacity (V_u) of the rectangular area bounded by the perimeter b_o is:

$$V_u := 0.85 \left(2 \cdot \sqrt{f_c \cdot psi}\right) \cdot b_o \cdot d \qquad V_u = 8.456 \times 10^6 \cdot lbf$$

Therefore the safety factor (SF) against punching shear failure is:

$$SF := \frac{V_u}{F_{impact}} \qquad SF = 13.54$$

Based on the above punching shear evaluation, the SFP slab has ample capacity to absorb the impact from the rack drop event.

6. Section 3.8.4 of the SRP and the NRC position paper on spent fuel storage and handling applications (Reference 3) indicated that differential thermal expansion loads under normal conditions (To) and differential thermal expansion loads under abnormal conditions (Ta) are to be used in combination with primary stresses in loading combinations, when

determining the structural adequacy of the SFP rack structures. Section 5.6.10.2 of Enclosure C of Reference 1 stated that thermal stresses are not combined with primary stresses from other loading conditions for welds at cell-to-cell joints in the replacement racks at BVPS-2. Please provide justification for evaluating the secondary and primary stresses separately in the structural analyses of the cell-to-cell welds for the proposed replacement rack structures. Additionally, please confirm that the guidance of SRP 3.8.4 and Reference 3, relative to combining thermal and primary loads, has been considered in the BVPS-2 SFP re-rack analysis and design.

Response:

The guidance of SRP 3.8.4 (Rev. 2) and Reference 3 has been followed in the design and analysis of the BVPS-2 spent fuel racks. Specifically, SRP 3.8.4 and Reference 3 state that the spent fuel racks be designed per the requirements of the ASME Section III Code, Division 1, Subsection NF for Class 3 component supports. Subparagraph NF-3121.11 of the ASME Code states:

> Thermal stress is a self-equilibrating stress produced by a nonuniform distribution of temperature or by differing thermal coefficients of expansion. Thermal stress is developed in a solid body whenever a volume of material is prevented from assuming the size and shape that it normally would under a change in temperature. Evaluation of thermal stress is not required by this Subsection.

This guidance is repeated in note 5 below Table NF-3523(b)-1, which states:

> Thermal stresses within the support as defined by NF-3121.11 need not be evaluated.

Thus, in accordance with ASME III Subsection NF requirements, the thermal stresses in the spent fuel rack are not combined with the primary stresses due to dead (D), live (L), and seismic loads (E, E'). However, the allowable stress limits for each load combination (for example, D + L + To + E) are computed based on the yield and ultimate tensile strengths of the material at a temperature that bounds the temperature distribution in the spent fuel rack under To and Ta, as applicable.

In addition, SRP 3.8.4, as well as Reference 3, does go on to state that:

> The temperature gradient across the rack structure that results from the differential heating effect between a full and an empty cell should be indicated and incorporated in the design of the rack structure.

The above requirement is the genesis for Section 5.6.10.2 in Holtec report HI-2084175 (Enclosure C of Reference 1). The purpose of Section 5.6.10.2 is to (a) quantify the thermal gradient across the boundary between a full and empty cell and (b) insure that cell-to-cell welds are strong enough to withstand the shear stresses induced by the temperature gradient.

The approach described above has been applied consistently by Holtec on spent fuel rack licensing applications for the last two decades.

7. **Section 5.8 of Enclosure C of Reference 1, "Bearing Pad Analysis," indicated that the design code of record used in the structural qualification of the three bearing pad types is American Concrete Institute (ACI) 349-85, *Code Requirements for Nuclear Safety Related Concrete Structures*. Discuss the applicability of ACI 349-85 to the BVPS-2 current licensing basis.**

Response:

According to the BVPS-2 UFSAR Table 1.9-2, the applicable ACI Code for the reinforced concrete Spent Fuel Pool slab is ACI 318-71, not ACI 349-85. However, the two codes are identical with respect to the allowable concrete bearing stress limit and the applicable load combinations for the bearing pad analysis. The reference to ACI 349-85 instead of ACI 318-71 has no impact on the evaluation results, and does not change the current licensing basis code of record being ACI 318-71.

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:

This request for additional information will be resolved in future correspondence.

9. Section IV(1)(b) of Reference 3 specified that an inclined drop of a fuel assembly must be postulated for the purposes of assessing the structural adequacy of the rack structures. While it is understood by the NRC staff that the impact of the vertical component of an inclined fuel assembly drop remains bounded by the shallow drop scenario and the kinetic energy imparted on the rack is maximized when the fuel assembly is completely vertical, provide justification regarding the effects of the horizontal component of impact of an inclined fuel assembly, i.e., the effects on the lateral rack displacements and/or deformation.

Response:

An inclined fuel drop has been considered. However, the horizontal component of impact of an inclined fuel assembly is negligible based on the physical realities of the fuel assembly and its handling operation. This conclusion is based on the following:

a) The fuel assembly is handled in the vertical orientation; therefore, the most probable fuel assembly drop accident is a near vertical drop.

b) The fuel assembly cross-section is quarter symmetric over the length of the fuel assembly; therefore, the gravity forces and drag forces on the fuel assembly are also symmetric, which prevent the fuel assembly from rotating out of the vertical position.

c) Per the BVPS-2 fuel handling practices, the maximum lift height of a fuel assembly above the top of the spent fuel racks is less than 24 inches, which greatly diminishes the likelihood of a significant horizontal velocity component prior to impact.

Based on the above information, an inclined fuel assembly drop was not explicitly analyzed. The most damaging fuel assembly drop accident is a straight vertical drop onto the top of the rack. The horizontal component of impact of an inclined fuel assembly is negligible in terms of lateral rack displacements and/or deformation.

10. Section IV(3) of Reference 3 specified that seismic excitation along three orthogonal directions should be imposed simultaneously when the new racks are subjected to seismic loading. Confirm that seismic excitation along three orthogonal directions were imposed simultaneously for the proposed new rack design and analysis.

Response:

The seismic excitation along three orthogonal directions (North-South, East-West, and Vertical) were imposed simultaneously for the proposed new rack design and analysis (as described in Section 5.4 of Enclosure C in Reference 1).

11. Section 5.6.7(a) of Enclosure C in Reference 1 stated that a simple conversion factor, based on area ratios, was used to determine weld stresses using a corresponding stress factor in the rack material. The stress factor R6, for example, is for the combined flexure and tension (or compression) condition. Ordinarily, section modulus is used to determine flexural stresses and area is used to determine axial stress. Provide some information to validate the conservatism within the aforementioned approach of converting stress factors for members to welds, using a factor based on area ratios, to take into account both flexural stresses and axial stresses.

Response:

The use of a conversion factor based on area ratios is acceptable because the area moment of inertia of the gross cell cross section and the cell-to-base plate weld group are dominated by the parallel axis terms ($A \times d^2$) where "A" is the individual cell wall/weld area and "d" is the offset distance from the centroid of the individual cell wall/weld to the centroid of the gross cell/weld cross section. Moreover, since the offset distance "d" for each individual cell-to-base plate weld is the same as the offset distance for the corresponding cell wall, the area moment of inertia ratio of the gross cell cross section versus the cell-to-base plate weld group is nearly equal to the area ratio. To prove this assertion, the area and area moment of inertia properties have been calculated for the gross cell cross section and the cell-to-base plate weld group of a 10 x 12 spent fuel rack to be installed at BVPS-2. The following table summarizes the results:

	Area (in^2)	**Moment of Inertia About Centroidal X Axis (in^4)**	**Moment of Inertia About Centroidal Y Axis (in^4)**
Gross Cell (Base Metal) Cross Section	173.7	184,500	130,300
Cell-to-Base Plate Weld Group	69.5	73,440	51,810
Ratio	2.50	2.51	2.51

From the above table, the calculated area and moment of inertia ratios agree within 1% of each other. Therefore, given the small percentage difference in the results, the use of a conversion factor based solely on the area ratio is acceptable for converting stress factors from base metal components to welds. Finally, it is noted that the stress factor conversion performed in Section 5.6.7 of Holtec report HI-2084175 (Enclosure C in Reference 1) uses a factor of 2.51, which is the highest calculated value in the table above.

12. Section 7.5.4 of Enclosure C in Reference 1, "Uplift Force Evaluation," stated that the fuel racks are adequate to withstand 5000 pounds uplift load, due to a stuck fuel assembly. Section 9.1.4.2.3.2 of the BVPS-2 UFSAR indicated that each of the two trolley and hoist sets on the motor-driven platform crane in the BVPS-2 fuel-handling area has a capacity of 10 tons. Confirm that adequate administrative controls or other means are in place to ensure that, in the actual event of a stuck fuel assembly, the BVPS-2 motor-driven platform crane uplift force will be maintained below this value, such that the rack will continue to meet the acceptance criteria outlined in Reference 3 for postulated fuel handling accidents (FHAs).

Response:

The current BVPS-2 site procedures require that the two crane hoist load cells are set to trip below 2000 pounds force when the fuel building motor-driven platform crane is utilized for moving loads over fuel assemblies stored in the spent fuel pool. Loads over fuel assemblies include removing or inserting fuel assemblies in the spent fuel pool racks. The verification of the load cell trip set point is performed at a prescribed interval per the BVPS-2 Licensing Requirements Manual. Therefore, based on the load cell trip set point being maintained below 5000 pounds when moving loads over fuel assemblies in the spent fuel pool, the BVPS-2 motor-driven platform crane uplift force will be maintained such that the rack will continue to meet the acceptance criteria outlined in Reference 3 for postulated fuel handling accidents.

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.

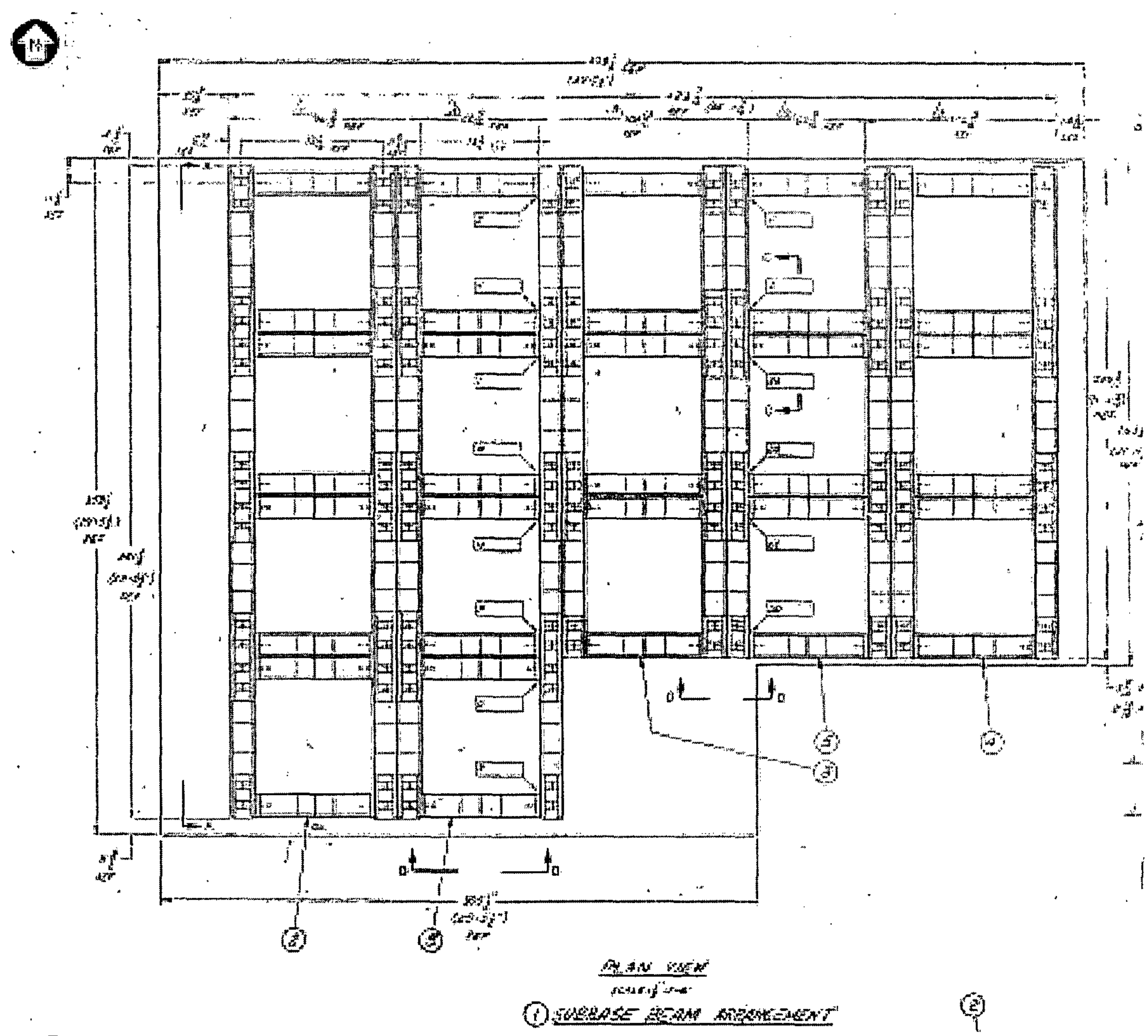
Response:

This request for additional information will be resolved in future correspondence.

14. Section 5.8 of Enclosure C in Reference 1, "Bearing Pad Analysis," indicated that a number of the existing beam structures resting on the BVPS-2 SFP will be providing structural support to a few of the new racks. Please provide information relative to this beam structure (configuration, connection of rack to the beam (if any), load path to the supporting concrete floor, safety margins, etc.), such that a determination can be made regarding the structural adequacy of these beam structures.

Response:

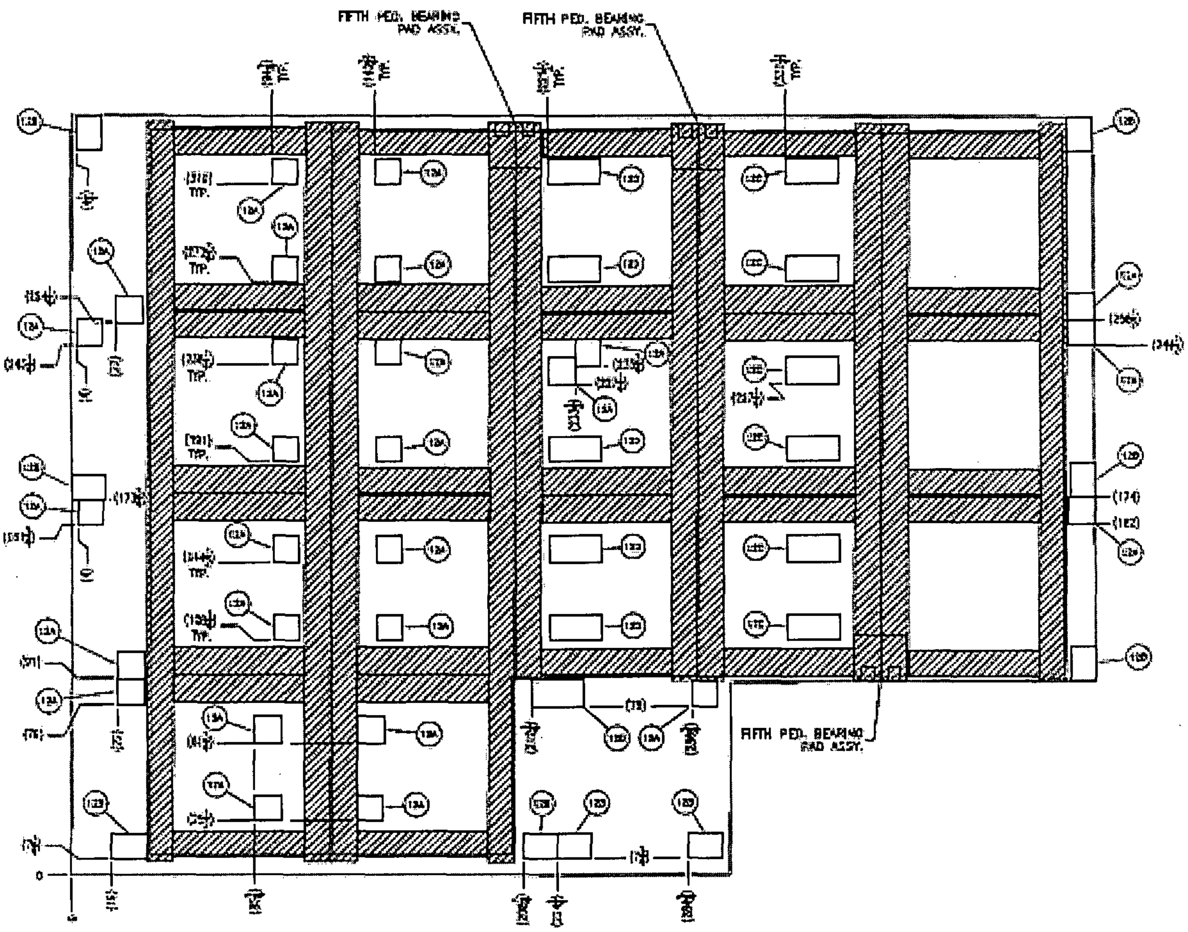
The existing spent fuel racks installed in the BVPS-2 SFP are bolted down to a sub-base structure, which consists of a grid work of U-shaped beams. The following figure shows the general arrangement of the beams.



Note: Text contained in the Drawing above is not relevant to the RAI response

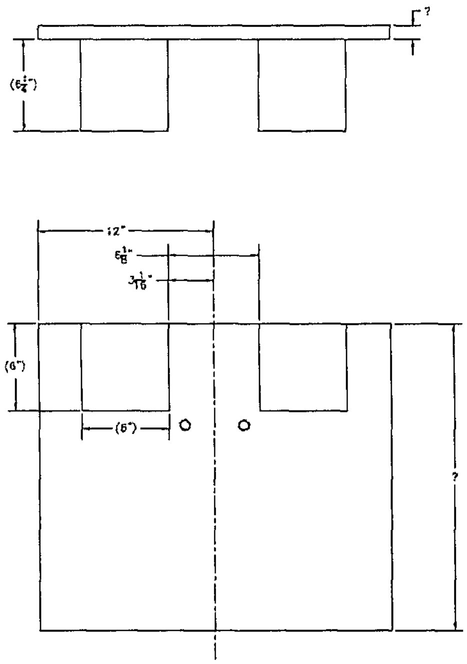
During the SFP re-racking, the existing racks will be unbolted and removed from the SFP. The sub-base structure, however, will remain in place.

The new spent fuel racks are designed as freestanding structures. The new spent fuel racks will not be secured to the sub-base structure. The size, number, and arrangement of the new fuel racks, including the individual support pedestal locations, have been carefully planned such that new spent fuel racks do not interfere with the existing sub-base structure, to the extent practicable. The following figure, which is excerpted from Reference 17, shows the locations of the support pedestal bearing pads relative to the existing sub-base structure.

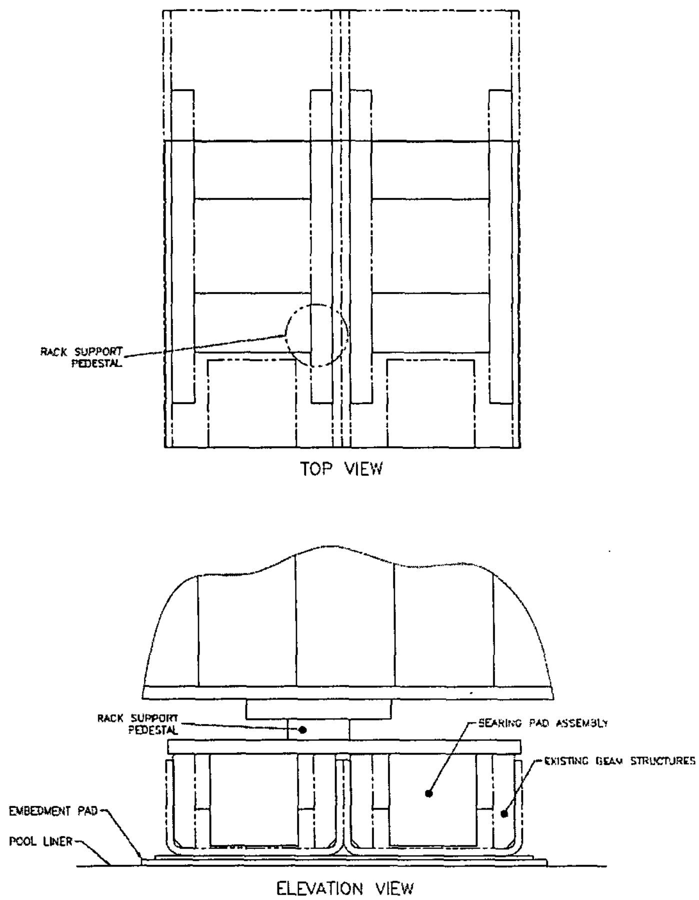


Note: Text contained in the Drawing above is not relevant to the RAI response

Of the 63 total support pedestal locations, 60 out of 63 of these locations are not in contact with the sub-base structure. At the other three locations (one each on racks D2, D3, and B4), special bearing pads have been designed that allow the support pedestal to rest on top of the sub-base structure. The configuration of the rack support pedestal, the bearing pad, and the sub-base structure at these three locations is depicted in the following sketch.



BEARING PAD ASSY



FIFTH PED. BEARING PAD ASSY
INSTALLATION, TYP.

Note: Text contained in the Drawing above is not relevant to the RAI response

Based on the above sketch, the vertical load travels from the rack support pedestal to the bearing pad, from the bearing pad to the 4 inch x 4 inch x 8 inch cross bar, from the cross bar to the 6-3/8 inch x 21-7/16 inch x 1-1/2 inch thick parallel plates that are welded to the inside of the U-shaped beam, from the 1-1/2 inch thick plates to the base of U-shaped beam, from base of the U-shaped beam to the pool floor embedment pad, and finally from the embedment pad to the concrete slab. The limiting component in the load path are the end welds between the 4 inch x 4 inch x 8 inch cross bar and the 1-1/2 inch thick plates. The calculated safety factor for the end weld is 1.42.

15. Considering the dynamic model of the fuel building, as shown in Figure 3.7B-10 of the BVPS-2 UFSAR, discuss the effects of SFP reracking on the overall seismic analysis of the fuel-handling building.

Response:

The increase in mass associated with the SFP re-racking is small in comparison to the lumped masses considered in the fuel building dynamic model, which is depicted in Figure 3.7B-10 of the BVPS-2 UFSAR. Therefore, the effect of the SFP re-racking on the overall seismic analysis of the fuel building is not significant.

The following table summarizes the mass assigned to each of the mass numbers identified in BVPS-2 UFSAR Figure 3.7B-10.

Mass Number	Building Elevation	Mass Value (kip-sec^2/ft)
2	729.5'	588.7
3	767.33'	252.2
4	798.0'	80.8
5	812.5'	64.9
6	733.75'	14.8
7	798.0'	3.0
Total Mass (sum of mass numbers 2 through 7)	-	1004.4

The spent fuel racks are located in the spent fuel pool at fuel building elevation 727'-4", and therefore their mass contribution is included in mass number 2. The existing seismic analysis is based on a mass contribution from the spent fuel racks of 37.5 kip-sec^2/ft, which accounts for 6.4% of total mass assigned to mass number 2.

Per Reference 13, the total weight of the new spent fuel racks to be installed at BVPS-2, assuming that the racks are fully populated with fuel assemblies, is 3,004 kips, which corresponds to a mass of 93.3 kip-sec^2/ft. Thus, the increase in mass associated with the SFP re-racking is 55.8 kip-sec^2/ft [= 93.3 kip-sec^2/ft – 37.5 kip-sec^2/ft]. Since the mass increase represents less than 10% of the total mass assigned to mass number 2, and less than 6% of the total fuel building mass, the effect of the SFP re-racking on the overall seismic response of the fuel building is not considered to be significant. Consequently, the seismic analysis of the fuel building does not need to be revised.

16. As stated in Section 3.8.4.1.4 of the BVPS-2 UFSAR, the fuel building is supported on a continuous foundation mat. Please discuss the effects of the SFP re-racking on the soil bearing pressure, overall sliding and overturning of the building, and the associated safety factors determined in accordance with the BVPS-2 current licensing basis.

Response:

The SFP re-racking will cause a slight increase in the soil bearing pressure beneath the BVPS-2 Fuel Building foundation mat. Thus, the safety factors for the soil bearing capacity have been slightly reduced. FENOC has performed an assessment to determine the actual reduction in bearing capacity safety factors for the fuel building listed in Table 2.5.4-4 of the BVPS-2 UFSAR. The safety factor for static loading conditions will be reduced from 11 to 10, and the safety factor for dynamic loading conditions will be reduced from 6 to 5 under the proposed rerack LAR. This slight decrease is acceptable, as the safety factors continue to exceed the minimum required safety factor of 3.0 for bearing capacity.

The SFP re-racking has no adverse effect on the overall sliding of the BVPS-2 fuel building since the SFP capacity expansion increases the dead load on the foundation mat, which in turn increases the frictional resistance between the foundation mat and the subgrade. The existing sliding analysis for the BVPS-2 fuel building is bounding since it conservatively neglects the dead weight of spent fuel racks plus fuel when determining the available friction force. The current design basis safety factors against sliding for the BVPS-2 fuel building under tornado and SSE loads are 2.37 and 1.14, respectively.

The BVPS-2 fuel building overturning calculations, like the overall sliding evaluation of the BVPS-2 fuel building, conservatively neglect the weight of the spent fuel racks and in doing so underestimate the restoring moment that prevents overturning. Thus, the SFP re-racking is bounded by the existing overturning analysis. The minimum calculated safety factor against overturning is 1.7 for the SSE load combination.

17. In response to an NRC RAI regarding the analysis methodology for the shallow drop accident (Response 3.c, Reference 2), it was indicated that the true stress-strain relationship was used as an input to the LS-DYNA computer code to model the replacement rack material behavior under the shallow drop loading conditions. Furthermore, Response 2 of Reference 2 indicated that the true stress-strain curve used in this analysis yields a failure strain of 1.204. Please provide justification regarding the appropriateness of using a failure strain magnitude that does not account for standard deviations from the mean failure strain, triaxiality factors and safety

factors, which must be present when performing these design basis evaluations using a strain based criteria.

Response:

The true stress-strain relationship was used for modeling the base material (SA240-304L) of the rack storage cells, as stated in Response 3.c, Reference 2, in order to obtain a realistic damage assessment of the impacted cell wall. On the other hand, the bilinear engineering stress strain relationship of the base material, as noted in the previous response to RAI 2.c, Reference 2, was used to conservatively model the stitch welds that join the impacted periphery cell wall (that is, filler panel) to adjacent rack cell boxes. Moreover, the strain rate effect is not considered in the rack material models for conservatism. The LS-DYNA code expects true stress-strain relationships in conjunction with strain rate effects for modeling materials that could experience significant plastic deformation in a high-speed impact event.

Based on the minimum strength properties from the ASME Code, Section II, Part D (Reference 18), the failure strain of cell wall material SA240-304L was determined to be 1.204 inch/inch (in/in) for the uniaxial tensile loading condition (see the response to the previous RAI 2.d, Reference 2). The actual strength properties of the material used for the rack fabrication are typically 10 to 20% higher than the ASME minimum strengths. No additional safety factors need to be considered in the material model, since the drop analysis is intended to assess the actual damage of the rack, which is then compared with the acceptance criterion set forth for the drop event. The acceptance criterion for the shallow drop event is that the plastic deformation in the cell wall must be limited in the region above the "poison zone," which starts from 19.75 inches below the top of the rack.

Under the shallow drop condition, the stress states of the impacted thin cell wall are essentially biaxial. Depending on the instantaneous stress state of the cell wall, the effective true failure strain varies during the course of the shallow drop accident. There is no relevant SA240-304L material test data available to utilize those LS-DYNA material models [(for example, the Johnson-Cook model (Reference 20)] that can automatically adjust the effective failure strain according to the current stress state (that is, triaxiality), strain rate, and so forth. Nevertheless, an estimation of the minimum failure strain for biaxial stress states can be derived by using the Stress Modified Critical Strain model developed by Hancock and Mackenzie (Reference 21).

According to the Hancock and Mackenzie model, the ductile crack initiation occurs when the plastic strain exceeds the critical value, i.e., the failure strain, which is a function of the triaxiality as described in Equation (1).

$$\varepsilon^f = \alpha \times \exp\left(-3\frac{\sigma_m}{\sigma_{vm}}\right) \qquad (1)$$

where σ_m and σ_{vm} are the mean principal stress and Von-Mises stress, respectively, and α is a material constant. The ratio of the mean principal stress to the Von-Mises stress is defined as triaxiality. Equation (1) implies that the greater the traixiality, the smaller the failure strain. The material constant α can be obtained by substituting the known failure strain ε_1^f obtained from the uniaxial tensile test and the corresponding triaxiality (that is, 1/3) into Equation (1) to yield:

$$\alpha = 1.6487 \times \varepsilon_1^f \qquad (2)$$

Therefore, Equation (1) can be expressed as:

$$\varepsilon^f = 1.6487 \times \varepsilon_1^f \times \exp\left(-3\frac{\sigma_m}{\sigma_{vm}}\right) \qquad (1A)$$

For an arbitrary biaxial stress state where the two principal (tensile) stresses are expressed as σ and $x\sigma$, the corresponding triaxiality can be calculated as:

$$\frac{\sigma_m}{\sigma_{vm}} = \frac{1+x}{3\sqrt{x^2 - x + 1}} \qquad (3)$$

It can be shown that the maximum triaxiality value expressed in Equation (3) is 2/3, which occurs when the two principal stresses are equal (that is, x=1). With the maximum triaxiality value for biaxial stress states, Equation (1A) can be utilized to calculate the corresponding minimum failure strain:

$$\varepsilon_2^f = 0.6065 \times \varepsilon_1^f \qquad (4)$$

The above derivation demonstrates that the minimum failure strain for biaxial stress state is about 60% of the failure strain obtained from the uniaxial tensile test. Applying the above conclusion to the BVPS-2 shallow drop analysis, the minimum failure strain for the impacted rack cell wall is about 0.72 in/in [= 60% of uniaxial failure strain = 0.6 × 1.204], which is greater than the predicted maximum plastic strain of 0.513 in/in (as described in the previous response to RAI 3.c, Reference 2).

It is understandable that additional conservatisms on the failure strain may be imposed in general design practices. For example, British Nuclear Fuels Limited (BNFL) requires that the minimum failure stress shall be established per Section 9.2 of Reference 19, where it concludes that "a strain limit of about 40% of the uniaxial rupture strain is conservative for all biaxial stress states (tensile or compressive)." Accordingly, the most pessimistic strain limit for the impacted cell wall for the BVPS-2 shallow drop analysis would be 0.482 in/in [= 40% of uniaxial failure strain = 0.4 x 1.204 in/in], which is very close to the LS-DYNA predicted maximum plastic strain without considering the strain rate effect. Therefore, at worst the shallow drop event could result in some local through-thickness cracks in the impacted cell wall if we followed the BNFL procedure. If the strain rate effect of the material is considered, the predicted maximum plastic strain could be significantly reduced.

Based on the reported safety margin and the above discussion on the material failure strain and strain rate effect, there is reasonable assurance that the conclusion obtained from the current shallow drop analysis remains valid.

18. Table 5.4.3 of Enclosure C in Reference 1 provided the material property data (SA-240-304L Stainless Steel at 200 degrees Fahrenheit) for the rack material used in the rack structural analyses in support of Reference 1. Table 7.4.2 of Enclosure C in Reference 1 also included material properties data for various materials used in the mechanical accident analyses performed. This table also included data for the proposed rack design material (SA240-304L Stainless Steel). However, Table 7.4.2 contains material data which does not appear to be consistent with the material data for the rack structural materials in Table 5.4.3. Please provide justification for this discrepancy and confirm that the material data used in both the rack structural analyses (Section 5.0 of Enclosure C in Reference 1) and the mechanical accident analyses (Section 7.0 of Enclosure C in Reference 1) is consistent with the spent fuel pool environment following the proposed rerack.

Response:

Table 7.4.2 of Enclosure C in Reference 1 includes material property data for various materials (including SA240-304L Stainless Steel) at 150 degrees Fahrenheit. Table 5.4.3 of Enclosure C in Reference 1 provides the material property data for SA240-304L Stainless Steel at 200 degrees Fahrenheit. Based on the different reference temperature, the material properties are stated as different values for the same material. However, both analyses used the SA240-304L Stainless Steel material properties at 200 degrees Fahrenheit. A footnote applicable to SA240-304L Stainless Steel values in Table 7.4.2 stating that the properties at 200 degrees Fahrenheit were conservatively used in the calculation was inadvertently not transferred from Section 4.3 of the mechanical accident calculation provided in Reference 12 to Table 7.4.2 of Enclosures B and C in Reference 1. The use of the material property data at 200 degrees Fahrenheit in both the rack structural analysis and the mechanical accident analysis is consistent with the maximum calculated water bounding local water temperature in the spent fuel racks of 202.8 degrees Fahrenheit stated in Table 6.7.1 of Enclosure C in

Reference 1. The spent fuel pool cooling system is designed to maintain the bulk pool temperature at or below 170 degrees Fahrenheit during a normal full core offload with a single train of pool cooling in service. The use of material properties at a higher than expected normal pool temperature is conservative since the material strength properties are lower with increasing temperatures.

19. **Table 7.4.2 of Enclosure C in Reference 1 provided the concrete properties utilized for the mechanical accidents performed. Additionally, Section 5.9 of Enclosure C of Reference 1 outlined the analyses performed to demonstrate the BVPS-2 SFP structure's ability to withstand the additional loading imposed by the proposed reracking. However, the concrete properties associated with the analyses summarized in Section 5.9 are not provided. Section 3.8.4.6 of the BVPS-2 UFSAR indicates that, "The 28-day minimum compressive strength of the concrete is predominantly 3,000 psi in these [Other Seismic Category I] structures, with 4,000 and 5,000 psi being used in a limited number of areas." Please confirm that concrete properties utilized in the proposed reracking LAR are in compliance with the BVPS-2 licensing basis.**

Response:

The spent fuel pool structure calculation associated with Section 5.9 of Enclosure C in Reference 1 used the minimum design compressive strength of 3,000 psi for the concrete. In addition, the mechanical accident calculation associated with Table 7.4.2 of Enclosure C in Reference 1 acknowledged that the design compressive strength of the spent fuel pool concrete foundation mat is 3,000 psi minimum. However, the calculation assumed that due to the concrete aging effect, the actual strength of the concrete is higher than 4,000 psi. FENOC has confirmed from actual compressive test results that 28-day minimum compressive strength of the concrete utilized in the fuel pool foundation mat is greater than 4,000 psi. Therefore, utilizing the actual concrete strength of 4,000 psi is acceptable when performing the mechanical accident calculations on the spent fuel pool concrete foundation mat. The concrete properties utilized in the proposed reracking LAR are in compliance with the BVPS-2 licensing basis for a minimum concrete strength of 3,000 psi.

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:

This request for additional information will be resolved in future correspondence.

21. **Section 7.2 of Enclosure C in Reference 1 indicated that the resistance of the rack to deformation at the peripheral surfaces is much less than the interior panels which make up the replacement racks. Please provide justification for concluding that the outer panels are the most limiting locations for the shallow drop FHA scenario given that the welded interior panels may be more susceptible to the crushing forces due to a dropped fuel assembly, due to a lower failure strain value of the weld material (Type 308 Stainless Steel) as compared to the base material (Type 304 Stainless Steel).**

Response:

The outer panels (or filler panels) are most limiting because they are secured to the adjacent storage cells via 8 inch long intermittent stitch welds on 35 inch centers over the height of the rack. Meanwhile, every interior panel is part of a contiguous four-sided storage cell (as shown in Figure 2.6.2 in Enclosure C of Reference 1). Since the weld material has a lower failure strain than the base material, and the outer panels and the interior panels are the same thickness, the outer panels are more susceptible to the crushing forces due to a dropped fuel assembly.

22. **Reference h.18 in Section 2.3 of Enclosure C in Reference 1 indicated that guidance from Revision 1 of Regulatory Guide (RG) 1.124, "Service Limits and Loading Combinations for Class 1 Linear-Type Supports" was utilized in the development of the LAR submitted in support of the proposed spent fuel pool rerack at BVPS-2. However, Section 1.0 of Reference 1 makes no mention of the use of RG 1.124 as it relates to the structural acceptance criteria utilized in the design of the proposed racks for BVPS-2. Please confirm that the guidance on the use of Subsection NF of Section III of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code found in RG 1.124 was considered in Reference 1.**

Response:

The guidance on the use of Subsection NF of Section III of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code found in RG 1.124

was considered in Reference 1. Specifically, Table 1 of SRP 3.8.4, Appendix D (Reference 11) states the following:

> The provisions of ASME Code, Section III, Division 1, Subsection NF 3231.1 shall be amended by the requirements of paragraphs c. 2, 3, and 4 of RG 1.124.

RG 1.124 (Reference 16) contains a typographical error. Subsection NF 3231.1 does not exist in Section III of the ASME Code. RG 1.124 should refer instead to Subsection NF 3321.1. The seismic analysis of the BVPS-2 spent fuel racks meets the requirements of paragraphs c. 2, 3, and 4 of RG 1.124 (Reference 16) based on the following:

i) The values of ultimate strength (Su) as a function of temperature are obtained directly from ASME, Section II, Part D. Note that the material property tables were transferred from Section III to Section II of the ASME Code starting with the 1992 edition.

ii) The value of yield strength (Sy) at temperature is less than 5/6 Su for all structural materials specified for the BVPS-2 spent fuel racks.

iii) For operating basis earthquake (OBE) load combinations, the calculated stresses in the spent fuel racks are compared with level A service limits in accordance with NF-3321.1(a).

iv) For safe shutdown earthquake (SSE) load combinations, the calculated stresses in the spent fuel racks are compared with level D service limits in accordance with NF-3321.1(a) and F-1334. It is noted that Reference 16 refers to F-1370(a). However, in the 1998 edition of the ASME Code, F-1370(a) has been replaced by F-1334.

v) The compressive stress in the rack cell structure is demonstrated to be less than 2/3 of the critical buckling limit.

vi) There are no bolted connections anywhere in the spent fuel racks.

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23. In Section 7.5.5, "Fuel to Fuel Drop Event," of Reference 1, Enclosure B, it is stated that the Fuel-to-Fuel Drop Event is bounded by the existing FHA analysis. Please provide additional information regarding how many feet of water coverage there will be above the damaged fuel during the postulated

Fuel-to-Fuel Drop event, and the associated decontamination factor, compared to that of the design-basis FHA analysis.

Response:

A fuel handling accident (FHA) bounding analysis was performed in support of the license amendment request (LAR) number 73 dated March 19, 2001 that resulted in issuance of BVPS-2 Amendment 121 (Accession No. ML012330496). This design-basis analysis demonstrated that the maximum expected fuel rod damage is from a FHA occurring in the reactor containment building. Therefore, the FHA in the reactor containment building enveloped the FHA in the fuel building.

A new mechanical drop analysis in the fuel building was performed for the rerack LAR (Reference 1). The analysis results show that the design-basis FHA, as discussed above, continues to bound the results of the new mechanical drop analysis.

In the new mechanical drop analysis presented in Holtec report HI-2084175 (Enclosure C of Reference 1), 10 rods are predicted to fail in the target assembly due to dropping one assembly on top of another stored in the fuel building storage racks. No fuel rods are predicted to fail in the dropped assembly.

Based on the new mechanical drop analysis for the fuel building, there will be a minimum coverage of 23 feet of water above the damaged fuel during the postulated Fuel-to-Fuel Drop event. Based on the depth of water above the damaged fuel being 23 feet or greater, the decontamination factors for the elemental and organic iodine species are 500 and 1, respectively. This results in an overall effective decontamination factor (DF) of 200, which equals the DF in the design-basis FHA analysis.

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. Letter from B. K. Grimes, Nuclear Regulatory Commission, Position Paper: "Review and Acceptance of Spent Fuel Storage and Handling Applications," dated April 14, 1978.

4. Not Used

5. Roark's Formula for Stress and Strain, 6th Edition

6. Timoshenko and Gere, Theory of Elastic Stability, 2nd Edition

7. ACI 318-71, titled "Building Code Requirements for Reinforced Concrete"

8. Not Used

9. Not Used

10. Not Used

11. NUREG-0800, SRP 3.8.4, Revision 2, titled "Other Seismic Category I Structures"

12. Holtec Report HI-2084010, "Mechanical Drop Accident Analyses Supporting Beaver Valley Unit 2 Reracking Project," Revision 1.

13. Holtec Report HI-2084131, "Fuel Pool Structural Evaluation of Beaver Valley Unit 2," Revision 3.

14. **Not Used**

15. **Not Used**

16. **RG 1.124 Rev. 1 titled: "Service Limits and Loading Combinations for Class 1 Linear-Type Component Supports, Revision 1."**

17. **Holtec Drawing 5606, Revision 6.**

18. **ASME Code, Section II, Part D, 2001.**

19. **British Nuclear Fuels Limited (BNFL) Commercial R3 Procedure, October 2005**

20. **LS-DYNA User's Manual, Version 971, p. 71 (MAT) – p. 75 (MAT) "*MAT_JOHNSON_COOK"**

21. **Journal of Mechanics and Physics of Solids, 1976, Volume 24, pages 147 to 169, Pergamon Press**