

January 2, 2007

L-MT-06-087 10 CFR 50.90

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

Monticello Nuclear Generating Plant Docket 50-263 License No. DPR-22

Response to Request for Additional Seismic Information for a License Amendment Request for Contingent Installation of a Temporary Fuel Storage Rack in the Spent Fuel Pool (TAC No. MD0302)

- References: 1) NMC letter to U.S. NRC, "License Amendment Request for Contingent Installation of a Temporary Spent Fuel Storage Rack," (L-MT-06-013), dated March 7, 2006.
 - 2) NMC letter to U.S. NRC, "Supplement to a License Amendment Request for Contingent Installation of a Temporary Fuel Storage Rack in the Spent Fuel Pool (TAC No. MD0302)," (L-MT-06-044), dated May 30, 2006.
 - NMC letter to U.S. NRC, "Response to Request for Additional Information for a License Amendment Request for Contingent Installation of a Temporary Fuel Storage Rack in the Spent Fuel Pool (TAC No. MD0302)," (L-MT-06-058), dated September 7, 2006.

On March 7, 2006, as supplemented on May 30, 2006, the Nuclear Management Company, LLC (NMC) submitted a license amendment request for the Monticello Nuclear Generating Plant (References 1 and 2) to revise the licensing basis to allow temporary installation of a Programmed and Remote (PaR) Systems Corporation 8x8 (64 cell) high-density fuel storage rack in the spent fuel pool to maintain full core off-load capability.

On September 7, 2006, (Reference 3) the NMC provided additional information on the structural, seismic and thermal hydraulic design of the proposed temporary high-density fuel storage rack. On December 8, 2006, the U.S. Nuclear Regulatory Commission (NRC) during a teleconference with the NMC requested additional information pertaining to the seismic design of the fuel storage rack. Enclosure 1 provides the response to this request. Enclosure 2 provides a copy of a calculation performed by Stevenson & Associates on behalf of NMC to independently determine the natural frequencies of the PaR 8x8 fuel storage rack.

USNRC Page 2

This letter makes no new commitments or changes to any existing commitments.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on January _____, 2007.

phint. Com

John T. Conway Site Vice President, Monticello Nuclear Generating Plant Nuclear Management Company, LLC

Enclosures: (2)

cc: Administrator, Region III, USNRC Project Manager, Monticello, USNRC Resident Inspector, Monticello, USNRC Minnesota Department of Commerce

SEISMIC RAI RESPONSE

Background

On March 7, 2006, as supplemented on May 30, 2006, (References 1 and 2) the Nuclear Management Company, LLC (NMC) submitted a license amendment request (LAR) for the Monticello Nuclear Generating Plant (MNGP) to revise the licensing basis to allow for the temporary installation of a Programmed and Remote (PaR) Systems Corporation 8x8 (64 cell) high-density fuel storage rack in the spent fuel pool (SFP) to maintain full core off-load capability.

On September 7, 2006, (Reference 3) NMC provided additional information on the structural, seismic and thermal hydraulic design of the proposed temporary high-density fuel storage rack. On December 8, 2006, the U.S. Nuclear Regulatory Commission (NRC) during a teleconference with the NMC requested additional information (RAI) pertaining to the seismic design of the fuel storage rack. The RAIs are shown in bold and the NMC responses are provided immediately thereafter in standard type.

NRC Request for Additional Information

NMC provided results of seismic analyses performed in 1977 for the following spent fuel storage rack configurations: 8x10, 8x11, 9x12, and 10x11 cells, using an lowa plant site response spectrum. NMC utilized the above analyses to qualify the PaR (8x8) spent fuel storage rack at Monticello plant.

The NRC staff reviewed the NMC submittals and has the following comments:

(1) The frequency ranges at which the maximum spectral acceleration amplitude appears differ significantly between Iowa, Monticello response spectra and that from an artificial time history, as tabulated below (based on Figure AA and BB of Enclosure 1 of the 9/7/06 submittal):

Specification Site	Frequency Corresponding to Maximum Horizontal Spectral Acceleration	Frequency Corresponding to Maximum Vertical Spectral Acceleration		
lowa	3.6 - 4.5 Hz	3.3 - 6.2 Hz		
Monticello	1.6 - 2.6 Hz	3.3 - 4.3 Hz		
Artificial Time History	4.5 - 5.5 Hz	3.3 - 4.3 Hz		

The Figure AA and BB and the above table indicate that the two response spectra (lowa and Monticello sites) are significantly different, especially for the horizontal component of the ground motion. More important, contrary to the assertion made by NMC (Section 3.0 (3) of Enclosure 1 to the 9/7/06 letter), the time history spectrum used in the seismic response analysis does

SEISMIC RAI RESPONSE

not envelop the specific spectrum (Monticello plant site) as required by RG 1.60.

The site design response spectrum for the fuel storage racks analysis at the MNGP was generated in compliance with the requirements of Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Revision 1, dated December 1973. This site design response spectrum was used to generate the horizontal and vertical floor response spectra at the spent fuel pool elevation. These are the MNGP response spectra shown on Figures AA and BB.

While it is true that both the vertical and horizontal artificial time history response spectrums shown on Figures AA and BB do not envelope the MNGP floor response spectrum over the entire frequency range, the fundamental frequencies used in the PaR analysis are 14.0 Hz vertical and 8.0 Hz horizontal. In the range of fundamental frequencies for the PaR 8x8 fuel storage rack (23 Hz vertical, 9 Hz horizontal, Enclosure 2) to zero period (∞ Hz) the artificial time history response spectrum does bound the MNGP response spectrum by a wide margin. Thus the seismic loading used in the 1977 PaR Systems Report will bound loads from a seismic evaluation using the MNGP response spectrum.

It should be noted that the MNGP does not have a 6 percent damping response spectra. The 5 percent MNGP response spectra is plotted on Figures AA and BB to compare to the artificial time history response spectrum which was for a 6 percent damping. A 6 percent damping response spectra for the MNGP would be lower than the 5 percent shown.

(2) The submittals are lacking structural and seismic analyses for the proposed 8x8 spent fuel storage rack. The seismic analysis results provided by NMC were all for the existing fuel rack configurations at a different plant site, and those rack configurations do not envelop the proposed rack configuration. In addition, only two components (1 horizontal and 1 vertical) of ground motion were considered in the seismic analyses; this is not in compliance with the guidelines of RG 1.60.

The 1977 PaR Systems Report provided structural and seismic analyses for the various fuel storage rack sizes listed therein, which encompasses the 8x8 fuel storage rack to be installed at the MNGP in the event of a full-core offload was required. Although the PaR Systems Report did not specifically analyze all sizes and configurations of the fuel storage racks qualified in the report, the analyses performed on the fuel storage rack configurations bound the fuel storage racks listed within the report. Two response spectrums were generated, a horizontal and a vertical. The last paragraph on page 9 in Section 5.3 of the PaR Systems Report indicates that an equal load set was applied in an orthogonal plane and that the results were combined using the square-root-sum-of-the-squares (SRSS) method. This substantiates that the load and stress results are based on 3 components of

SEISMIC RAI RESPONSE

seismic motion, two simultaneous horizontal directions combined with the vertical direction.

During a teleconference with the NRC staff on December 8, 2006, the staff indicated that the PaR Systems Report (Reference 1) did not clearly identify that the frequencies for the evaluated fuel storage racks enveloped the 8x8 fuel storage rack proposed to be used, if necessary, at the MNGP. To resolve this issue, NMC directed Stevenson & Associates to perform a calculation to independently determine the natural frequencies of the PaR Systems 8x8 fuel storage rack. Enclosure 2 provides a copy of this calculation. The results of this calculation confirm the statements made by NMC in our September 7, 2006, RAI response (Reference 3). A summary of the analysis is presented below.

The simplified 2-dimensional dynamic model presented in the PaR Systems qualification report was recreated and validated by comparing the results to a SAP2000 computer program (Reference 4) run using the same fuel storage rack model (8x11) as given in the 1977 PaR Systems Report. The results for the recreated model indicate a horizontal first mode frequency of 8.2 Hz and a vertical frequency 17.2 Hz. These results are within three (3) percent of the PaR Systems Report values, thus validating that this modeling technique is capable of adequately capturing the dynamic properties of the PaR 8x8 fuel storage rack.

The PaR 8x8 fuel storage rack was then modeled by amending the input properties of the SAP2000 model. The properties were computed following the same methodology presented in the 1977 PaR Systems Report. The 8x8 fuel storage rack model yielded the following results: a first mode horizontal natural frequency of 9.0 Hz and a vertical frequency of 23.0 Hz. Since these values are bounded by (are higher than) the PaR Systems Report values and the response spectra used by PaR bounds the MNGP spectra for the frequency ranges of interest, these results confirm that the PaR Systems Report is conservative for the 8x8 fuel storage rack, that is proposed for use at the MNGP in the event that an emergency full-core offload is necessary.

SEISMIC RAI RESPONSE

REFERENCES

- 1. NMC letter to U.S. NRC, "License Amendment Request for Contingent Installation of a Temporary Spent Fuel Storage Rack," (L-MT-06-013), dated March 7, 2006.
- 2. NMC letter to U.S. NRC, "Supplement to a License Amendment Request for Contingent Installation of a Temporary Fuel Storage Rack in the Spent Fuel Pool," (TAC No. MD0302) (L-MT-06-044), dated May 30, 2006.
- 3. NMC letter to U.S. NRC, "Response to Request for Additional Information for a License Amendment Request for Contingent Installation of a Temporary Fuel Storage Rack in the Spent Fuel Pool (TAC No. MD0302)," (L-MT-06-058), dated September 7, 2006.
- 4. CSI, SAP2000, Integrated Software for Structural Analysis and Design, Version 10.0.2.

EVALUATION OF THE 8X8 SPENT FUEL STORAGE RACK TO DETERMINE THE NATURAL FREQUENCIES

BY

STEVENSON & ASSOCIATES

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Calculation Signature Sheet

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Major Revisions

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Description of Revision:Initial		
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Associated Equipment or System References:

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1	Monticello	1	FPC	Spent fuel storage rack	
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Superseded Calculations

Facility	Calc Document Number	Title

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Associated Reference(s): EC 9757

Does this calculation:	YES	NO	Calc No(s), Rev(s), Add(s)]
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Augment (credited by) another calculation?				
Affect the Fire Protection Program per Form 3765?			If Yes, attach Form 3765	
Affect piping or supports?		\boxtimes	If Yes, attach Form 3544	
Affect IST Program Valve or Pump Reference Values, and/or Acceptance Criteria?			If Yes, inform IST Coordinator and provide copy of calculation	

What systems are affected?

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External Design Document Suitability Review Checklist

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Design Review Comment Form

Sheet ____ of ____

DOCUMENT NUMBER/ TITLE: CA-06-114/ Evaluation of the 8X8 spent fuel storage rack to determine the natural frequencies

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STEVENSON & ASSOCIATES a structural-mechanical consulting engineering firm	determine the natural frequencies	By: SJK Check: VMA

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STEVENSON & ASSOCIATES a structural-mechanical	JOB NO.: 06Q4646Calculation: C-001Client: Monticello Nuclear Generating Plant (MNGP)SUBJECT: Evaluation of the 8X8 spent fuel storage rack to determine the natural frequencies	Sheet 3 of 12 Date: 12/11/2006 Revision: 0 By: SJK Check: VMA
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Figure 1: Single Rack Attached Fuel Model (Fig. 2 [1]).....6



1. OBJECTIVE

The existing 8x8 spent fuel storage rack was obtained from Duane Arnold which procured the rack from PAR Systems in 1977 with a qualification. The seismic evaluation portion of the referenced report evaluates an 8x12, 9x12, 8x11 and 10x11 rack configuration, and determines the lateral and vertical fundamental frequencies to be 8 Hz and 14 Hz.

The objective of this calculation is to determine the natural frequency of the 8x8 spent fuel storage rack and show that the dynamic characteristics of the 8x8 fuel rack are within the range of the PAR Systems qualification.

2. EXECUTIVE SUMMARY

The objective of this calculation is to determine the natural frequency of the 8x8 spent fuel storage rack, which was obtained from Duane Arnold which procured the rack from PAR Systems in 1977 with a qualification. The simplified 2D dynamic model presented in the PAR Systems qualification report [1], was recreated and validated by comparing the results of a current run using the same rack model (8x11 fuel rack) as given in the aforementioned report [1].

The 8x8 fuel rack was then modeled by amending the input properties of the SAP2000 model. The properties were computed following the same methodology presented in referenced report [1]. The 1st horizontal natural frequency is found to be at 9.0 Hz. The "*Casting Bottom*" vertical mode is approximately 23 Hz.

Comparison between the Iowa Spec. M-303 response spectrum and the MNGP time history response spectrum at 5% damping shows that the Iowa Spec. M-303 envelopes the MNGP response spectrum both vertically and horizontally in frequency ranges that are approximately higher than 5 Hz and 2.5 Hz, respectively. Since the 8x8 fuel rack natural frequency lies within this range, it can be concluded that the Iowa Spec. M-303 Ioads shall always be larger than MNGP. Thus, the original qualification report [1] should insure the 8x8 fuel rack configuration as well.

3. REFERENCES

- 1. PAR Systems Report Sect. 5.3., "Model Description, Formulation and Assumptions for the Seismic Analysis of BWR Spent Fuel Racks at DAEC, JAF and Peach Bottom", Rev. 3, March 27,1978
- Roark's Formulas for Stress and Strain, Warren C. Young, 6th Edition, McGraw-Hill International Editions, 1989
- 3. CSI, SAP2000, Integrated Software for Structural Analysis and Design, Version 10.0.2.

CA	JOB NO.: 06Q4646 Calculation: C-001	Sheet 5 of 12
	Client: Monticello Nuclear Generating Plant (MNGP)	Date: 12/11/2006 Revision: 0
	SUBJECT: Evaluation of the 8X8 spent fuel storage rack to	
SIEVENSUN &	determine the natural frequencies	By: SJK
a structural-mechanical consulting engineering firm		Check: VMA

4. METHODOLOGY

The rack structure is a large rectangular tube enveloped by the side panels with no structural stiffness added for either the poison cans or fuel assemblies. Dynamic analysis of a detailed SAP IV model have determined a lower bound horizontal frequency for the 4 fuel rack configurations to be approximately at 8 Hz. A vertical diaphragm frequency of the bottom casting to be at 14 Hz [1].

A simplified ANSYS model (see Fig. 2 of [1]), consisting of a cantilever beam extending the height of the racks, attached to a horizontal beam at the base bottom casting elevation with leg beams connecting the ends of this member to the floor, show that the fundamental frequencies of this idealized system agree quite closely with the detailed model. Thus, this simplified model will be used to determine the natural frequency of the 8x8 rack.

The methodology consists of the steps outlined below. The detailed calculations, organized according to these steps, are provided in Sect. 6. The coordinate system used in the calculations follows the right hand rule, where the XY plane = floor plane and Z = Vertical.

- 1. Recreate and match the dynamic characteristics of the simplified dynamic ANSYS model (Fig. 2 of [1]) with the new SAP2000
- 2. Model a 8x8 fuel rack by amending the properties of the SAP2000 model; follow the same procedures presented in [1] for consistency
- 3. Perform a modal analysis in order to obtain the natural frequencies of the 8x8 fuel rack

Note that the 8x11 fuel rack was chosen for comparison since it was determined to have the lowest 1st horizontal frequency mode of all 4 fuel rack configurations.

5. DESIGN INPUTS

Metal Plate Properties [1]

Young's Modulus: Shear Modulus:	E = 10300 ksi G = 3800 ksi		
Cavity Loads [1]			
Dry Module Mass Dry Fuel & Channel Mass Entrapped Water Mass	136 lbf 745 lbf 181 lbf	Wet Module Weight Wet Fuel & Channel	78 lbf 672 lbf
Total Horizontal Mass	1062 lbf/cavity	Total Wet Wt.	750 lbf/cavity

Client: Monticello Nuclear Generating Plant (MNGP) STEVENSION & SESOCIATES activating engineering firm SUBJECT: Evaluation of the 8X8 spent fuel storage rack to By: SJK Check: VMA By: SJK Check: VMA S. CALCULATION S. CALCULATION S. 1 SAP2000 Model – 8x11 Fuel Rack S.1.1 Properties and Input First recreate the original 8x11 fuel rack model in SAP2000. The following properties are presented in Reference [1]. Module size = 8 x 11 Rack height = 167 in No. Cavity = 88 M2 = 32280 lbf M1 = 22374 lbf X1 = 232.1 in A2s = 66520 in ⁴ 4 A3 = 167 in ⁴ 2 A3s = 167 in ⁴ 2 A4 = 38 lin ⁴ 2 A5s = 78.5 lin ⁴ 2 Figure 1: Single Rack Attached Fuel Model (Fig. 2 [1]) Total weight of Section 2 is recomputed accordingly (include weight of Sect. 1), Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 1 W1 = 65560 fbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total weight for Sect. 2 W2 = 27596 lbf [1] Total W2 = 232 <u>1 0</u> $\frac{1}{9} - 232 2 0$ $\frac{1}{9} - 232 2 0$ $\frac{1}{9} - 232 2 0$ $\frac{1}{9} - 232 2 0$ $\frac{1}$			JOB NO.: 06Q4646	C	alculation: C-001	Sheet 6 of 12
STEVENSOR & SUBJECT: Evaluation of the 8X8 spent fuel storage rack to determine the natural frequencies $g_{Y,S,K}$ (hed: VMA) a structural-indechanical $g_{Y,S,K}$ (hed: VMA) 5. CALCULATION 5. CALCULATION 5. CALCULATION 5. CALCULATION 5. SAP2000 Model - 8x11 Fuel Rack 5.1.1 Properties and Input First recreate the original 8x11 fuel rack model in SAP2000. The following properties are presented in Reference [1]. Module size = 8x 11 Reck height = 167 in No. Cavity = 888 W2 = 32780 lbf M1 = 22374 lbf X1 = 232 ln in 2 A3 = 167 in 2 (use total area, [1]) A4 = 280 in ⁴ A5 = 163 in ⁴ 2 A5 = 163 in ⁴ 2 Total weight of Section 2 is recomputed accordingly (include weight of Sect. 1). Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight of Sect. 1 W1 = 65560 lbf [1] Total weight of Sect. 1 W1 = 65560 lbf [1] Total weight of Sect. 1 W1 = 65560 lbf [1] Total weight of Sect. 2 W2 = 27398 lbf [1] Total weight for Sect. 2 W2 = 27398 lbf [1] Total weight of Sect. 2 W2 = 27398 lbf [1] Total weight if $S = 93456$ lbf = W1 + W2 6.1.2 Joint Coordinates $\frac{100 + 10 + 232 + 0 + 0}{8 + 232 + 0 + 0} = 0$			Client: Monticello	Nuclear Gen	erating Plant (MNGP)	Date: 12/11/2006 Revision: 0
STEVENSON 8 ASSOCIATES a structural-intechanical consulting engineering firm 6. CALCULATION 8.1 SAP2000 Model – 8x11 Fuel Rack 5.1.1 Properties and Input First recreate the original 8x11 fuel rack model in SAP2000. The following properties are presented in Reference [1]. Wo Cavity = 88 W2 = 23.21n 12 = 66520 in ⁴ 4 A3 = 167 in ² A23 = 63 in ² 13 = 388000 in ⁴ 4 A3 = 167 in ² A33 = 167 in ² A44 = 38 in ² A55 = 76.5 in ² 2 Total weight of Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 2 W2 = 27898 lbf [1] Total weight of Sect. 1 W1 = 65560 lbf [1] Total weight W8 = 93456 lbf = W1 + W2 6.1.2 Joint Coordinates $\frac{1}{p_1 + p_2} = \frac{1}{p_2} + $			SUBJECT: Evalua	tion of the 8X8	spent fuel storage rack t	to
AssociatesCheck: VMACheck: VMACheck: VMASocialing engineering fromCheck: VMASocialing engineering fromSocialing engineering engineering fromSocialing eng	STEVENSO	ON &	determine the natu	ral frequencies	spent her storage fack i	By: SJK
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$\begin{array}{cccccccccccccccccccccccccccccccccccc$	XI 12	= 23.2 in	n^4			¹ 2
$\begin{array}{cccc} & & = 120 \text{ in } 2 \\ A2s & = 63 \text{ in } 2 \\ B3 & = 388000 \text{ in } ^4 \\ A3 & = 167 \text{ in } ^2 \\ A3s & = 167 \text{ in } ^2 \\ A3s & = 167 \text{ in } ^2 \\ 43s & = 167 \text{ in } ^2 \\ 44s & = 280 \text{ in } ^4 \\ A4 & = 38 \text{ in } ^2 \\ A4s & = 19 \text{ in } ^2 \\ 15 & = 211 \text{ in } ^4 \\ A5 & = 153 \text{ in } ^2 \\ A5s & = 76.5 \text{ in } ^2 \\ A5s & = 76.5 \text{ in } ^2 \\ A5s & = 76.5 \text{ in } ^2 \\ Total weight of Section 2 is recomputed accordingly (include weight of Sect. 1), \\ Total weight for Sect. 1 W1 & = 65560 \text{ lbf [1]} \\ Total weight for Sect. 2 W2 & = 27896 \text{ lbf [1]} \\ Total weight Ws & = 93456 \text{ lbf } = W1 + W2 \\ 6.1.2 \text{ Joint Coordinates} \\ \hline \begin{array}{c} \hline 1 & 0 & 0 & 11133 \\ \hline 3 & 0 & 0 & 5567 \\ \hline 4 & 0 & 0 & 0 & 567 \\ \hline 4 & 0 & 0 & 0 & 567 \\ \hline 5 & -2322 & 0 & -10 \\ \hline 9 & 2322 & 0 & -10 \\ \hline 9 & 2322 & 0 & -10 \\ \hline 9 & 2322 & 0 & -10 \\ \hline 10 & 2322 & 1 & 0 \\ \hline 10 & 2322 & 1 & 0 \\ \hline 11 & 0 & 0 & 1 & 0 \\ \hline \end{array}$	1∠ Δ2	- 00520 = 126 in^	11° 4 2		< <u></u> →2 , '	¹⁴ 2
$\begin{array}{cccc} & & & & & & & & & \\ 3 & & & & & & & & &$	A2 A2s	$= 63 \text{ in}^2$	2			A _{2s}
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A4s = 19 in ⁴ 2 15 = 211 in ⁴ 4 A5 = 153 in ⁴ 2 A5s = 76.5 in ⁴ 2 Figure 1: Single Rack Attached Fuel Model (Fig. 2 [1]) Total weight of Section 2 is recomputed accordingly (include weight of Sect. 1), Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 2 W2 = 27896 lbf [1] Total weight for Sect. 2 W2 = 27896 lbf [1] Total weight Ws = 93456 lbf = W1 + W2 6.1.2 Joint Coordinates Joint 1D X (in) 1 0 1 0 Signe 1: Single Rack Attached Fuel Model (Fig. 2 [1]) Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight Ws = 93456 lbf = W1 + W2 6.1.2 Joint Coordinates 0 0 0 0 0 0 0 0 <td>A4</td> <td>= 38 in^2</td> <td></td> <td>I4, A4, A</td> <td>_{4s} M1↑ \ / / ↑ M1</td> <td>1</td>	A4	= 38 in^2		I4, A4, A	_{4s} M1↑ \ / / ↑ M1	1
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	A4s	$= 19 \ln^2 2$		-	5 6	→X
$\begin{array}{rcl} \hline Joint 12 \\ A5s &= 76.5 \text{ in}^{2} \\ \hline Figure 1: Single Rack Attached Fuel Model (Fig. 2 [1]) \\ \hline Total weight of Section 2 is recomputed accordingly (include weight of Sect. 1), \\ \hline Total weight for Sect. 1 W1 &= 65560 lbf [1] \\ \hline Total weight for Sect. 2 W2 &= 27896 lbf [1] \\ \hline Total weight & Ws &= 93456 lbf = W1 + W2 \\ \hline 6.1.2 & Joint Coordinates \\ \hline \hline \frac{Joint ID}{2} & X (in) & Y (in) & Z (in) \\ \hline \frac{1}{2} & 0 & 0 & 111.33 \\ \hline 3 & 0 & 0 & 55.67 \\ \hline 4 & 0 & 0 & 0 \\ \hline 5 & -23.2 & 0 & 0 \\ \hline 6 & 23.2 & 0 & 0 \\ \hline 7 & -23.2 & 1 & 0 \\ \hline 8 & -23.2 & 0 & -10 \\ \hline 9 & 23.2 & 0 & -10 \\ \hline 10 & 23.2 & 1 & 0 \\ \hline 11 & 0 & 0 & 1 \\ \hline \end{array}$	10	- 211 III" - 153 in^	4 ว		877. M2 77.9	
Joint ID Figure 1: Single Rack Attached Fuel Model (Fig. 2 [1]) Total weight of Section 2 is recomputed accordingly (include weight of Sect. 1), Total weight for Sect. 1 W1 = 65560 lbf [1] Total weight for Sect. 2 W2 = 27896 lbf [1] Total weight for Sect. 2 W2 = 27896 lbf [1] Total weight Ws = 93456 lbf = W1 + W2 6.1.2 Joint Coordinates Joint ID X (in) Y (in) Z (in) 1 0 0 111.33 3 0 0 55.67 4 0 0 0 5 -23.2 0 0 6 23.2 0 -10 9 23.2 0 -10 10 23.2 1 0	A5s	= 76.5 in	2 N2			
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5.1.2 Joint Coordinates Joint ID X (in) Y (in) Z (in) 1 0 0 167 2 0 0 111.33 3 0 0 55.67 4 0 0 0 5 -23.2 0 0 6 23.2 0 0 7 -23.2 1 0 9 23.2 0 -10 10 23.2 1 0	Total weight	١	Vs = 93456 lbf	= W1 + W2		
Joint IDX (in)Y (in)Z (in)100167200111.3330055.6740005-23.200623.2007-23.2108-23.20-10923.20-101023.210	6.1.2 Joint C	Coordinates	3			
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Joint ID	X (ir	i) Y (in)	Z (in)		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	<u>}</u> −−− <u></u> }			10/		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\frac{2}{3}$		0 0	55.67		
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	4		0 0	0		
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	5	-23	2 0	0		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	6	23.	2 0	0		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	<u>β</u>	-23	$\frac{2}{2}$ 1	0		
	<u>0</u>	-23.	2 0	-10		
	1 9 1			0		
	10	23	2] []			

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Per Reference 1, Section 5, which represents the vertical diaphragm of the "bottom casting", is located at the same elevation as Section 3 but is not attached to it. However, SAP2000 does not allow two different nodes to be assigned at the same location, therefore Section 5 is offset 1" in the Y – direction. Joints 5 & 7 and 6 & 10 are assigned *rigid body* constraints.

6.1.3 Distributed Mass

Concentrated fuel, racks and water mass at	=	40.33 lbf-s^2/in	= Ws / g / 6
nodes 1 and 4 in X-direction only			

Concentrated fuel, racks and water mass at = 80.66 lbf-s²/in = Ws / g / 3 nodes 2 and 3 in X-direction only

Concentrated fuel mass at node 11 = 84.9 lbf-s^2/in = M2 / g In Z-direction only

Concentrated masses at nodes 5 and 6 = 57.9 lbf-s²/in = M1 / g In Z-direction only

6.1.4 Model Validation

The results of the SAP2000 model for the 8x11 rack is presented in the following. The 1st and 2nd horizontal natural frequencies are given at 8.2 Hz and 33.7 Hz, respectively. The "Casting Bottom" vertical mode is approximately 17.2 Hz.

Mode	Frequency	Description
1	8.2	1 st horizontal mode
2	17.2	"Casting Bottom" vertical mode
3	33.7	2 nd horizontal mode
4	61.4	3 rd horizontal mode

Reference [1] determined the lower bound for the fuel rack configurations to be approximately 8 Hz. The results of the SAP200 model validates the reports statement. Also, the vertical diaphragm frequency of the bottom casting was computed to be at 17.7 Hz [1] (for the 8x11 fuel rack), which is also close to the recreated model 17.2 Hz (~ 3% difference).

Thus, the SAP2000 model is validated. It is concluded that the SAP2000 model is capable of capturing the dynamic properties of the 8x8 rack.

6.2 8x8 Rack Model

6.2.1 Properties and Inputs

The methodology in computing the following properties closely follow those that are presented in Reference [1]. This will ensure consistency between the models.

Module 8x8 fuel rack

<u>Properties</u>				
elastic modulus	E =	10300000	psi	given

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the facultion in V direc	tion No.			sives	
# of cavilies in X direc	tion NX	- c))	given	
# of cavilies in Y direc	uon ivy	- 0)	given	
between fuel channel	c.c	= 6.625	5 in	for types simila	ir to those in IOV
outside length of fuel	channei lout	= 5.494	1 in	given	
inside length of fuel cl	nannel lin	= 5.273	3 in	given	
rack height	L	.= 167	7 in	given	
weight / cavity	Wt/cav	ity 74	5 lbf	given	
area of fuel channel	A	.= 2.38	3 in^2	= lout^2 - lin^2	2
moment of inertia of c	hannel	= 11.50) in^4	= (lout^4 - lin^	4) / 12
shear area	As	= 1.19	9 in2	= A / 2	-
Module Section Properti	<u>es</u>				
total # of cavities	N	= 64	4	= Nx x Ny	
distance between sup	ports X1	= 23.2	2 in	= (Nx - 1) x c.	c/2
Section 2					
rack depth	Ł) = 53.0) in	= Ny x c.c.	
rack width	r	i = 53.0) in	= Nx x c.c.	
area	A2	! = 106.0	0 in^2	= (2/2) x b + (2	2/2) x h
moment of inertia	12	2 = 51762	2 in^4	= h^3/12 + b >	(h/2 + 0.75)^2
shear area	A2s	;= 5:	3 in^2	= A2 / 2	
Section 3					
moment of inertia	K	38800	0 in^4	given	
area	A	s= 16	7 in^2	given	
Section_4					
moment of inertia	[4	= 28	0 in^4	given	
area	A	i= 3	8 in^2	given	
shear area	A4:	;= 1	9 in^2	= A4 / 2	
Section 5	Δ.		0 1-02	aivon	
design area	A] =	ษ เ∩ ^2	given = 1.36 x (10^-!	5) x Nx x Nv x (Nx -
mid span deflection [2] 2	<u>\</u> = 0.02	1 in	1)^2 x (Ny - 1)^ 1)^2)	2 / ((Nx - 1)^2 + (N
moment of inertia	l _e	_{ff} = 28	2 in^4	= 5 x Wt/cavity x c.c^3 / (384 x	x Nx x Ny x (Nx - ΄ Ε x Δ)
frequency of bottom	casting fv	v = 24.11	8 Hz	= π / (2 x (Nx - I _{eff} x g / (N x Wt c.c.))	1) x c.c.) x SQRT(l /cavity x (Nx - 1) x
	Δ.	F - 40	e inAg	= ((N x - 1) + ((Ny - 1)) x Ad
area	A	⊃ −	0 11 2	. – (()), – () – ($11y = 177 \times 700$

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consuling engineering min	L <u></u>					
6.2.2 Joint Coordinates	3					
The same coordinates ar	e used as in the previo	ous 8x11 model.				
6.2.3 Distributed Mass						
Total weight for Sect. 1	N1 = 47680 lbf	= N x 745 lbf				
Total weight for Sect. 2	N2 = 20288 lbf	= N x (181 lbf + 136 lbf)				
Total weight	<i>N</i> s = 67968 lbf = \	W1 + W2				
Concentrated fuel, racks nodes 1 and 4 in X-direct	and water mass at tion only	= 29.33 lbf-s^2/in = Ws / g / 6				
Concentrated fuel, racks nodes 2 and 3 in X-direct	and water mass at tion only	= 58.65 lbf-s^2/in = Ws / g / 3				
Concentrated fuel mass a Z-direction only,	Concentrated fuel mass at node 11 InM2 = 23840 lbf = $\frac{1}{2} \times 64745$ lbfZ-direction only,m2 = 61.7 lbf-s^2/in = M2 / g					
Concentrated masses at nodes 5 and 6M1 = 16272 lbf = $\frac{1}{2} \times 64 \times 136 \text{ lbf}$ + $\frac{1}{4} \times 64 \times 745 \text{ lbf}$ In Z-direction onlym1 = $42.144 \text{ lbf-s}^2/\text{in}$ = M1 / g						
6.2.4 Modal Analysis						
The results of the SAP20 horizontal natural frequer vertical mode is approxin	100 model for the 8x8 ra ncies are given at 9.0 H nately 23 Hz.	ack is presented in the following. The 1 st Hz and 36.3 Hz, respectively. The "Castin	and 2 nd ng Bottom"			
ModeFrequencyDescription19.01st horizontal mode223.0"Casting Bottom" vertical mode336.32nd horizontal mode465.93rd horizontal mode						
7. CONCLUSION						
The simplified 2D dynamic model presented in PAR Systems qualification report [1], was recreated in SAP2000. Comparison of the results of a current run using the same rack model (8x11 fuel rack) as given in the aforementioned report [1] showed that the models matched well; the 1 st horizontal mode is above 8 Hz, and the " <i>Casting Bottom</i> " vertical mode only differentiates from the hand computed frequency by 3% (see Sect. 6.1.4).						
The 8x8 fuel rack was then modeled by amending the input properties of the SAP2000 model. The properties were computed following the same methodology presented in referenced report [1]. The 1 st horizontal frequency and the " <i>Casting Bottom</i> " vertical mode are found to be at 9.0 Hz and 23 Hz, respectively.						
The artificial vertical and horizontal time history response spectrum at 6% damping compared to lowa Spec. M-303 response spectrum overlaid with the MNGP time history response spectrum at 5% damping						

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is presented in Attachment A. The comparison shows that the Iowa Spec. M-303 envelopes the MNGP response spectrum both vertically and horizontally in frequency ranges that are higher than 5 Hz and 2.5 Hz, respectively. Since the 8x8 fuel rack natural frequency lies within this range, it can be concluded that the Iowa Spec. M-303 loads shall always be larger than MNGP. Thus, the original qualification report [1] should insure the 8x8 fuel rack configuration as well.



