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NORTHERN STATES POWER COMPANY

MINNEAPOLIS, MINNESOTA 55401

January 30, 1978

Director of Nuclear Reactor Regulation
U S Nuclear Regulatory Commission
Washington, DC 20555

MONTICELLO NUCLEAR GENERATING PLANT
Docket No. 50-263 License No. DPR-22

Response to 12/16/77 Request for
Information on HDFSS

On December 16, 1977 the NRC Project Manager for Monticello verbally requested additional information related to the proposed High Density Fuel Storage System (HDFSS). The NRC questions are repeated along with their respective responses. Certain information requested is considered confidential to the HDFSS vendor and has been handled accordingly. This submittal consists of four parts as follows:

1. Response to Request for Additional Information on Monticello HDFSS Submittal (Non-proprietary)

2. Affidavit of Lyle L Zahn, Jr. (Proprietary)

3. Response to Request for Additional Information; Attachment 1 (Proprietary)

4. Supplement 3, January 1978, to Design Report and Safety Evaluation for Replacement of Spent Fuel Pool Storage Racks, August 17, 1977 (Non-proprietary)

L O Mayer, PE
Manager of Nuclear Support Services

LOM/MHV/deh

cc: J G Keppler
G Charnoff

RESPONSE TO REQUEST FOR ADDITIONAL

INFORMATION ON MONTICELLO HDFSS SUBMITTAL

Q-1. Provide drawings which show details of the rack assemblies including connections of the fuel storage tubes to the module, module to base support, and the modifications necessary to the fuel pool base slab and walls to accommodate the new rack assemblies.

A-1. Response to Q-1 is provided in a proprietary supplement (Attachment 1) to this document. A non-proprietary narrative of the same subject matter is included in the, "Design Report and Safety Evaluation for Replacement of Spent Fuel Pool Storage Racks," transmitted by Northern States Power Company to the U.S. Nuclear Regulatory Commission on August 17, 1977.

Q-2 Provide sketches and details of the mathematical model used to analyze the rack assembly and fuel pool.

A-2 The HDFSS module has been analyzed seismically under both OBE and DBE conditions. The seismic analysis was performed in several steps. First, the hydrodynamic effect, which represents the inertial properties of the fluid surrounding the submerged modules, was calculated to obtain the hydrodynamic virtual mass terms based on the module and pool configuration. GE's computer program WATERMASS was used for this purpose.

Figure 1 shows the plan view of the two-dimensional model of the modules and pool used in the hydrodynamic virtual mass analysis. The model consisted of two rigid bodies: the modules and the pool walls. Water finite elements fill the spaces in between the walls and the modules. The diagonal hydrodynamic added-mass values were corrected for three-dimensional end effects and for leakage between the modules using factors which were computed based on the model properties.

Both finite-element and lumped-mass models of a module were then developed in order to provide a basis for selecting simplified module models to be used in the module and support system analysis and module sliding analysis. The finite-element model also was used to obtain the distribution of shear forces in the module plate elements.

An eleven-node lumped-mass model was then developed by lumping the tributary module mass to the corresponding node point and initially selecting the stiffness properties based on beam theory. The stiffness properties of this model were based on matching the natural frequencies of the lumped-mass model. The natural frequencies of the first seven modes are given in Table 1. The sectional properties are given in Figure 2.

Finally, in order to simplify the subsequent analyses, a less complex model was developed. Since the response of the module and column support system was shown to be primarily a rigid body motion, it was found that a two-node lumped mass model can be used to adequately represent the module and column support system analyses. Both the first mode and rigid body dynamic properties were simulated by this model. The lumped mass at the top of the two-mass model was selected so that the base shear force of the first mode was preserved. The height of the model was selected to preserve the overturning moment at the base of the module for both the first mode response and rigid body motion. The mass of the bottom of the model was set equal to the difference between the t^tal module mass and the mass at the top. This ensured that the shear force at the base was preserved for rigid body motion. Finally, the stiffness of the structural element was selected

to preserve the fundamental frequency of the module. The properties of the two-node lumped-mass model are shown in Figures 2 and 3.

The two-node lumped mass model was used in the analysis for the entire system. The finite-element model was used to calculate forces in the model.

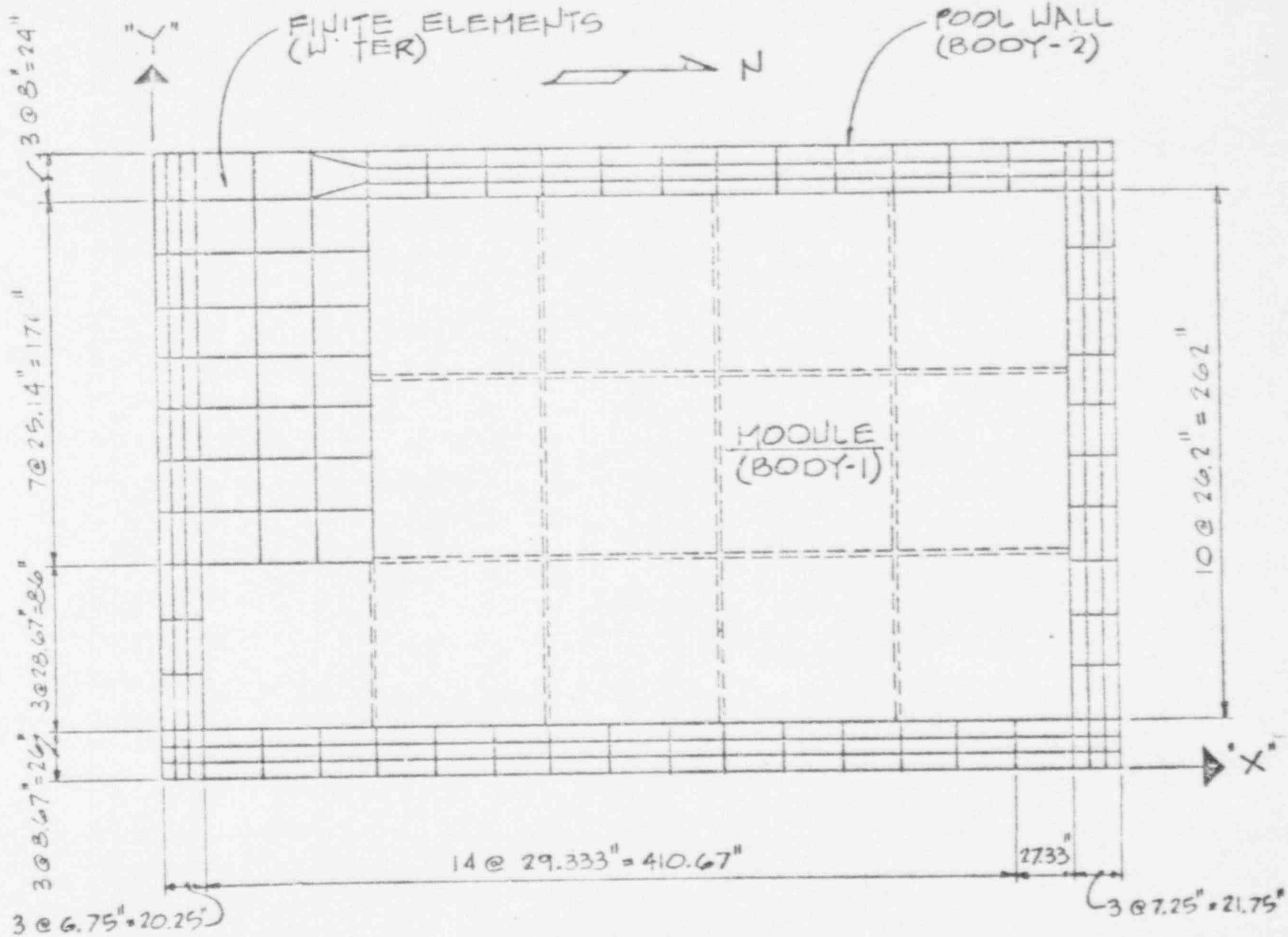


FIGURE 1 MODULES AND POOL MODEL FOR HYDRODYNAMIC VIRTUAL MASS ANALYSIS

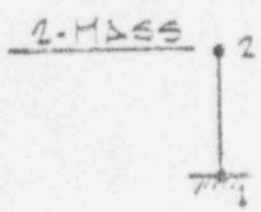
TABLE 1

DYNAMIC PROPERTIES OF FIXED-BASE LUMPED-MASS MODULE MODELS

(Fixed Base in Water)

Model	Mode	(Hz)
Eleven-Node	1	12.5 (H)
	2	42.7 (V)
	3	44.5 (H)
	4	88.4 (H)
	5	126.5 (H)
	6	127.7 (V)
	7	161.5 (H)

Node	Elev. (in.)	Area: Axial (in.²)	Area: Shear (in.²)	Moment of Inertia (in.⁴)	Total Mass* (lb sec²/in.): Diagonal	Total Mass* (lb sec²/in.): Off Diagonal
11-MASS						
21	167.88				42.86	-25.28
		96.29	83.25	102,780		
19	149.92				84.64	-50.56
		96.29	83.25	102,780		
17	131.96				84.64	-50.56
		96.29	83.25	102,780		
15	114.03				84.64	-50.56
		96.29	83.25	102,780		
13	96.04				84.64	-50.56
		96.29	83.25	102,780		
11	78.09				84.64	-50.56
		96.29	83.25	102,780		
9	60.13				84.64	-50.56
		96.29	83.25	102,780		
7	42.17				84.64	-50.56
		96.29	83.25	102,780		
5	24.21				84.64	-50.56
		96.29	83.25	102,780		
3	6.25				51.12	-34.71
		61.75	53.39	114,940		
1	0.00				8.79	- 8.80
1-MASS						
2	114.2				577.15	-351.13
		104.87	60.92	157,400		
1	0.00				203.74	-122.09



* Noted: Total Mass = Structure mass plus hydrodynamic mass.
Masses given here are for N-S direction.

FIGURE 2 FIXED-BASE LUMPED-MASS MODULE MODELS IN POOL

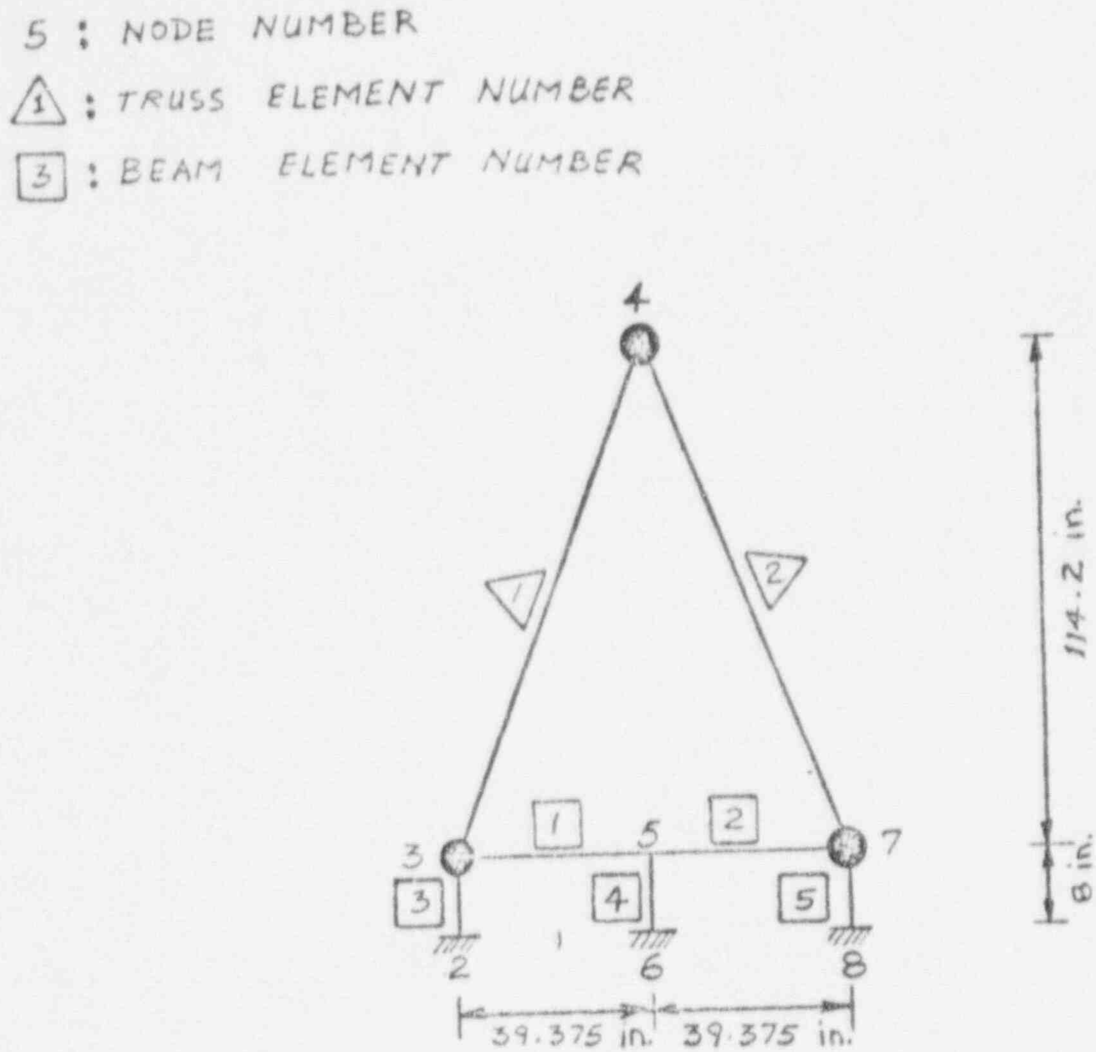


FIGURE -3 MODULE AND SUPPORT COLUMNS MODEL

Q-3. Discuss the integrity of the rack assembly and fuel pool in the event of a postulated fuel handling accident. Include a discussion of the maximum drop height considered, the mass involved, the kinetic energy at the point of impact, and the ductility ratios utilized to absorb the kinetic energy.

A-3. The maximum credible distance which the nose of a fuel assembly can drop at Monticello before striking the top of the HDFSS or stored fuel is 25 in. (Table 4.1-3 in submittal of 8/17/77 stated that the drop height considered was 18"; subsequent design changes require that Table 4.1-3 be revised to reflect a maximum drop height of 25"; revised Table 4.1-3 is attached for reference).

The mass of the dropped fuel assembly is taken as 735 lb. The kinetic energy associated with a straight vertical drop (neglecting drag effects) onto the top of a module is 1530 ft-lb.

Energy absorption is assumed to take place only in the stainless steel material involved, whose ductility can be expressed in terms of a specified minimum elongation of 40% over a 2" gage length. The work involved in bending, buckling, crushing, shearing or tearing was investigated as appropriate to generate the results summarized in Table 4.1-3. In no case could an event be postulated which caused k_{eff} to exceed 0.90.

Structural integrity of the module is maintained because significant damage is limited to portions of only one or two walls of a single fuel space, or a single fuel support plate.

Table 4.1-3 can be found in the last section of this submittal entitled, "Supplement 3, January, 1978, to Design Report and Safety Evaluation for Replacement of Spent Fuel Pool Storage Racks, August 1977, as page 14.

Q-4. Provide a more detailed discussion of the building floor loading which was re-analyzed by the plant architect-engineer.

A-4. The fuel pool floor slab and the perimeter walls were evaluated as one way slabs using the Strength Design Method and the load combinations consistent with present-day methods and NRC criteria and regulations.

In addition, the walls were also checked as deep girders in the longitudinal direction assuming the height of the wall as the overall depth of the girder. This evaluation was in accordance with ACI 318-71, Section 8.10 "Alternate Design Method" and PCA paper ST66, which is based on an elastic analysis. The load combinations used for the Working Strength Design method are consistent with NRC Standard Review Plan.

The applicable design loads used in evaluating the fuel pool structure include the following:

(1) Dead load of the structure - weight of the slabs, walls, and other components permanently affixed thereon.

(2) Hydrostatic load of fuel pool - The water level was assumed to extend to the top of the walls.

(3) Fuel elements and racks - A design load of 2.7 ksf was assumed over the full floor area.

(4) Cask weight - 150 kips.

(5) Live load - Tributary floor live load of 0.2 ksf was used where applicable.

(6) Thermal loads

(a) T_o is due to temperature gradient of 50° through slab and walls under operating conditions.
(b) T_A is due to temperature gradient of 125°F through slab and walls under accident conditions.

(7) Seismic loads

	OBE	SSE
Lateral direction	0.12g	0.26g
Vertical direction	0.045g	0.092g

The minimum yield stress of reinforcing steel was taken as F_y = 60 ksi and the nominal concrete design strength was f_c'= 6.4 ksi. Since this is an existing structure, an increase in strength due to

A-4 (Cont'd)

aging was recognized as specified in Bureau of Reclamation Concrete Manual 8th Edition page 45. For concrete made from Type II Portland Cement, the 5-year strength was estimated as f_c' = 6.4 ksi for a design strength of 4.0 ksi. In addition, the laboratory tests of the 90 day design strength indicated values from 6.57 ksi to 7.12 ksi indicating that the present concrete in the fuel pool structure exceeds the minimum 28-day strength of 4000 psi called for in the original contract documents.

The results of the evaluation show that the moment capacities of the structural components are well above the design moments. However, in order to meet the shear criteria, it was necessary to recognize the increased concrete strength due to aging. When analyzing the pool slab for an actual concrete strength of f_c'=6.4 ksi, the bending capacity was adequate and the shear capacity was reached at the two ends in the short span direction. When the walls were analyzed as one way slabs, both the bending and shear capacities were adequate. When the walls were considered as deep girders, the calculated bending and shear stresses were adequate for f_c' = 6.4 ksi.

In conclusion, the structural analysis of the fuel pool structure shows that in accordance with the established design criteria and aging strength of concrete, the fuel load in the pool structure may be increased from the original 2.0 ksf to a load not to exceed 2.7 ksf.

Supplement 3

January 1978

to

Design Report and Safety Evaluation for
Replacement of Spent Fuel Pool Storage Racks, August 1977

Instructions for Filing Supplement 3

1. Remove the cover sheet and Page 14 of the report which should now be filed with Supplement 2 incorporated.

2. Insert the attached cover sheet and Page 14 which are identified as Supplement 3, January 1978.

3. Pages removed in step 1 above should either be discarded or attached to the end of the updated report for future reference. If the latter option is exercised, mark each of the obsolete pages conspicuously with the words, "SUPERSEDED-JANUARY 30, 1978".

MONTICELLO NUCLEAR GENERATING PLANT

Docket No. 50-263 License No. DPR-22

August 1977

DESIGN REPORT AND SAFETY EVALUATION

FOR

REPLACEMENT OF SPENT FUEL POOL STORAGE RACKS

Incorporating:

Supplement 3
January 1978

TABLE 4.1-3

High Density Spent Fuel Storage System

Assembly Drop Accident

Case Summary

<table>
<tr><th>No.</th><th>Case Description</th><th>Effect on Reactivity</th></tr>
<tr><td>1</td><td>A fuel assembly drops 25 inches vertically and impacts the top of a fully loaded HDFSS module. The dropped assembly comes to rest horizontally on top of the HDFSS.</td><td>Analysis indicates that localized tube damage or fuel support member damage will occur, but neutron absorber material will not be removed from its position between adjacent fuel assemblies. A fuel assembly resting horizontally atop the HDFSS does not increase the system k_{eff} because the model assumes an infinite vertical length of fuel (no neutron leakage in the vertical dimension). ∴ $k_{eff} < 0.90$.</td></tr>
<tr><td>2.</td><td>A fuel assembly drops from 25 inches above the HDFSS, enters an empty storage position and falls to the bottom of the storage position.</td><td rowspan="2">Structural analysis indicates that localized tube damage will occur and one neutron absorber plate may be damaged. An analysis of this case with the neutron absorber plate between two fuel assemblies totally missing, shows that k_{eff} remains less than 0.90.</td></tr>
<tr><td>3.</td><td>A fuel assembly drops from 25 inches above the HDFSS and strikes a tube wall at an oblique angle.</td></tr>
<tr><td>4.</td><td>A fuel assembly drops from 25 inches above the top of a fully loaded module and strikes the upper tie plates of 2, 3 or 4 fuel assemblies in storage.</td><td>It is not possible for a fuel assembly drop of 25 inches to drive four stored assemblies through the bottom of the module Even so, the effect of this event was evaluated as a limiting value. A 25 inch section of fuel in four bundles in an unpoisoned square array was found to have a k_{eff} approximately equal to that of the system. There would be no increase in the k_{eff} of the system.</td></tr>
<tr><td>5.</td><td>A fuel assembly drops from 25 inches above the HDFSS falls outside of the loaded HDFSS and lodges adjacent and parallel to an unpoisoned, occupied fuel storage position.</td><td>This case was analyzed for normal handling conditions. ∴ $k_{eff} < 0.90$.</td></tr>
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