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AUTH.NAME	AUTHOR AFFILIATION
MECREDY,R.C.	Rochester Gas & Electric Corp.
RECIP.NAME	RECIPIENT AFFILIATION
VISSING,G.S.	

See Reports

SUBJECT: Forwards non-proprietary & proprietary response to 970905 RAI re structural evaluation of proposed mod of plant spent fuel storage pool,dtd 970331.Proprietary response withheld, per 10CFR2.790.

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ROBERT C. MECREDY
Vice President
Nuclear Operations

October 20, 1997

U.S. Nuclear Regulatory Commission
Document Control Desk
Attn: Guy S. Vissing
Project Directorate I-1
Washington, D.C. 20555

Subject: Response to Request for Additional Information - Spent Fuel Pool (SFP) Modifications - Structural Design Considerations (TAC No. M95759)
R.E. Ginna Nuclear Power Plant
Docket No. 50-244

Ref.(1): Letter from G. S. Vissing (NRC) to R. C. Mecredy (RG&E), Subject: Request for Additional Information - Spent Fuel Pool Modifications - Structural Design Considerations (TAC No. M95759), dated September 5, 1997.

Dear Mr. Vissing:

By Reference 1, the NRC staff requested additional information regarding the proposed Modification of the Ginna Spent Fuel Storage Pool dated March 31, 1997. The questions were related to the Structural Evaluation of the proposed Modification.

Enclosed are responses to the questions submitted by the NRC staff which are provided in two separate documents: a Non-Proprietary and a FRAMATOME Proprietary. The Non-Proprietary document contains all the responses but omits the following information which is considered FRAMATOME Proprietary: (a) selected data in response to NRC Question No. 4.b, and (b) electronic files with input data to the ANSYS code as listed in responses to NRC Questions No. 2.e and 10.

The document entitled FRAMATOME Proprietary is a duplicate of Non-Proprietary version except that proprietary data has been added to that document. The FRAMATOME Proprietary data in that document

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is supported by an affidavit signed by FRAMATOME TECHNOLOGIES, INC.. Accordingly, it is respectfully requested that the document entitled "FRAMATOME Proprietary" be withheld from public disclosure in accordance with 10CFR 2.790 of the Commission's regulations.

Very truly yours,

Robert C. Mecredy

Robert C. Mecredy

JPO

c: Mr. Guy S. Vissing (Mail Stop 14B2)
Senior Project Manager
Project Directorate I-1
Washington, D.C. 20555

U.S. Nuclear Regulatory Commission
Region I
475 Allendale Road
King of Prussia, PA 19406

Ginna Senior Resident Inspector

Mr. Paul D. Eddy
State of New York
Department of Public Service
3 Empire State Plaza, Tenth Floor
Albany, NY 12223-1350

AFFIDAVIT OF JAMES H. TAYLOR

A. My name is James H. Taylor. I am Manager of Licensing Services for Framatome Technologies, Inc. (FTI). Framatome Cogema Fuels is administratively responsible to Framatome Technologies, Inc. Therefore, I am authorized to execute this Affidavit.

B. I am familiar with the criteria applied by FTI to determine whether certain information of FTI is proprietary and I am familiar with the procedures established within FTI to ensure the proper application of these criteria.

C. In determining whether an FTI document is to be classified as proprietary information, an initial determination is made by the Unit Manager, who is responsible for originating the document, as to whether it falls within the criteria set forth in Paragraph D hereof. If the information falls within any one of these criteria, it is classified as proprietary by the originating Unit Manager. This initial determination is reviewed by the cognizant Section Manager. If the document is designated as proprietary, it is reviewed again by Licensing personnel and other management within FTI as designated by the Manager of Licensing Services to assure that the regulatory requirements of 10 CFR Section 2.790 are met.

D. The following information is provided to demonstrate that the provisions of 10 CFR Section 2.790 of the Commission's regulations have been considered:

(i) The information has been held in confidence by FTI. Copies of the document are clearly identified as proprietary. In addition, whenever FTI transmits the information to a customer, customer's agent, potential customer or regulatory agency, the transmittal requests the recipient to hold the information as proprietary. Also, in order to strictly limit any potential or actual customer's use of proprietary information, the substance of the following provision is included in all agreements entered into by FTI, and an equivalent version of the proprietary provision is included in all of FTI's proposals:

"Any proprietary information concerning Company's or its Supplier's products or manufacturing processes which is so designated by Company or its Suppliers and disclosed to Purchaser incident to the performance of such contract shall remain the property of Company or its Suppliers and is disclosed in confidence, and Purchaser shall not publish or otherwise disclose it to others without the written approval of Company, and no rights, implied or otherwise, are granted to produce or have produced any products or to practice or cause to be practiced any manufacturing processes covered thereby.

Notwithstanding the above, Purchaser may provide the NRC or any other regulatory agency with any such proprietary information as the NRC or such other agency may require; provided, however, that Purchaser shall first give Company written notice of such proposed disclosure and Company shall have the right to amend such proprietary information so as to make it non-proprietary. In the event that Company cannot amend such proprietary information, Purchaser shall, prior to disclosing such information, use its best efforts to obtain a commitment from NRC or such other agency to have such information withheld from public inspection.

Company shall be given the right to participate in pursuit of such confidential treatment."

(ii) The following criteria are customarily applied by FTI in a rational decision process to determine whether the information should be classified as proprietary. Information may be classified as proprietary if one or more of the following criteria are met:

a. Information reveals cost or price information, commercial strategies, production capabilities, or budget levels of FTI, its customers or suppliers.

b. The information reveals data or material concerning FTI research or development plans or programs of present or potential competitive advantage to FTI.

c. The use of the information by a competitor would decrease his expenditures, in time or resources, in designing, producing or marketing a similar product.

d. The information consists of test data or other similar data concerning a process, method or component, the application of which results in a competitive advantage to FTI.

e. The information reveals special aspects of a process, method, component or the like, the exclusive use of which results in a competitive advantage to FTI.

f. The information contains ideas for which patent protection may be sought.

The document(s) listed on Exhibit "A", which is attached hereto and made a part hereof, has been evaluated in accordance with normal FTI procedures with respect to classification and has been found to contain information which falls within one or more of the criteria enumerated above. Exhibit "B", which is attached hereto and made a part hereof, specifically identifies the criteria applicable to the document(s) listed in Exhibit "A".

(iii) The document(s) listed in Exhibit "A", which has been made available to the United States Nuclear Regulatory Commission was made available in confidence with a request that the document(s) and the information contained therein be withheld from public disclosure.

(iv) The information is not available in the open literature and to the best of our knowledge is not known by Combustion Engineering, EXXON, General Electric, Westinghouse or other current or potential domestic or foreign competitors of Framatome Technologies, Inc.

(v) Specific information with regard to whether public disclosure of the information is likely to cause harm to the competitive position of FTI, taking into account the value of the information to FTI; the amount of effort or money expended by FTI developing the information; and the ease or difficulty with which the information could be properly duplicated by others is given in Exhibit "B".

E. I have personally reviewed the document(s) listed on Exhibit "A" and have found that it is considered proprietary by FTI because it contains information which falls within one or more of thecriteria enumerated in Paragraph D, and it is information which is customarily held in confidence and protected as proprietary information by FTI. This report comprises information

<u>AFFIDAVIT OF JAMES H. TAYLOR</u> (Cont'd.)

utilized by FTI in its business which afford FTI an opportunity to obtain a competitive advantage over those who may wish to know or use the information contained in the document(s).

James H Taylor
JAMES H. TAYLOR

State of Virginia)
) SS. Lynchburg
City of Lynchburg)

James H. Taylor, being duly sworn, on his oath deposes and says that he is the person who subscribed his name to the foregoing statement, and that the matters and facts set forth in the statement are true.

James H Taylor
JAMES H. TAYLOR

Subscribed and sworn before me
this 1st day of Oct. 1997.

Brenda C. Cardona
Notary Public in and for the City
of Lynchburg, State of Virginia.

My Commission Expires July 31, 1999

U. S. NRC
G. S. Vissing

October 20, 1997

Introduction to Responses:

Rochester Gas & Electric Ginna spent fuel storage rerack structural qualification is performed using state of the art techniques. To ease the licensing process, the majority of analytical methods, computer program use and verification are the same as the methods used in the current licensing documents. The individual items are discussed during the response process. The idealization of the rack using beam representation, the consideration of hydrodynamic masses, and the seismic analysis methods are the same as 1985 licensing basis (References 3.23 and 3.24 of the Licensing Report).

The computer program ANSYS, version 5.2, was used for the majority of structural analysis calculations. Since 1970, this program has been used extensively in the nuclear, chemical, building, and electronic industries throughout the world. Extensive use led to a high degree of reliability in obtained computer results, and has been extensively benchmarked by industry. ANSYS has been and continues to be verified by a large volume of users. At Framatome Cogema Fuels, it is benchmarked to hand calculations and to verification problems provided by its developer, Swanson Analysis Systems, Inc. ANSYS has been used in many of 10CFR50 licensing analyses including seismic, time history, and gapped structural analyses.

At Framatome Cogema Fuels the structural analysis personnel has extensive experience in the finite element methods and analysis to solve complex problems. This experience and expertise serves to minimize modeling instabilities typically associated with large non-linear dynamic problems. For the models and analyses reported in the Ginna spent fuel storage rack licensing report, no instabilities existed.

The behavior of spent fuel storage racks is complex, and some simplification of the actual behavior is appropriate when creating a mathematical model for use in a finite element analysis.

Throughout the structural analysis the results are checked against the simplified hand calculation methods. In addition, the results have been compared against recently NRC-licensed spent fuel storage racks to verify the validity of the analysis results and to confirm the design of the racks.

Conservative structural analysis methods are used throughout the structural analysis. Conservatisms include: enveloping seismic time histories, additional safety factors on the seismic time histories, safety factors on loads and displacements, conservative friction factors, and maximum fuel weight and loading in the rack, assumed concurrent impact of all fuel assemblies. The results summarized in Section 3.5.3.3 show large design margins for all rack hardware per ASME, AISC and ACI code allowables. Additional margins exist which are integral to the codes themselves. The resulting margins show the robustness of the Ginna spent fuel storage system design.

References: (continues sequentially the reference numbers in the Licensing Report)

3.44 Application for Amendment to Facility Operating License, Revised Spent Fuel Pool Storage Requirements, Rochester Gas and Electric Corporation, R. E. Ginna Nuclear Power Plant, Docket No. 50-244, Letter dated March 31, 1997, from RG&E to US NRC.

3.45 Scavuzzo-1979, "Dynamic Fluid Structure Coupling of Rectangular Modules in Rectangular Pools," R. J. Scavuzzo, et al., ASME Publication PVP-39, 1979, pp. 77-87.

3.46 Radke-1978, "Experimental Study of Immersed Rectangular Solids in Rectangular Cavities," Edward F. Radke, Project for Master of Science Degree, The University of Akron, Ohio, 1978.

U. S. NRC
G. S. Vissing

October 20, 1997

Question No. 1:

With respect to the single safe shutdown earthquake (SSE) artificial time history used for stress analysis as mentioned on page 75 of the Reference, provide the following:

a) *A comparison between the response spectrum (RS) of the artificial time history and the licensing basis design RS in the final safety analysis report (FSAR).*

b) *Demonstrate the adequacy of the artificial time history including a demonstration of the extent of conformance to a target power spectral density (PSD) function of the artificial time history in accordance with guidance provided in Standard Review Plan (SRP) Section 3.7.1.*

c) *If the RS of the artificial time history does not envelope the licensing basis design RS in the FSAR, what is the basis for using it in the analysis?*

Response:

A total of four sets (X, Y, and Z components) of time histories were generated, such that the average of all four time histories, when multiplied by a factor of 1.10, enveloped the design response spectrum. A single time history set was then chosen (SSE1 for SSE conditions) and an additional factor of 1.20 was applied to the resulting loads and displacements to envelope the loads and displacements from all four time history sets.

a) A comparison of the fuel pool safe shutdown earthquake (SSE) response spectra and the response spectra generated from the SSE1 time history used in the seismic analysis is provided in Figures NRCQ1a.1, NRCQ1a.2 and NRCQ1a.3. NUREG-800, SRP 3.7.1, Section II.1.b states "Each calculated spectrum of the artificial time history is considered to envelop the design response spectrum when no more than five points fall below, and no more than 10 percent below, the design response spectrum." For this comparison, the 10% below curve is also plotted in Figures NRCQ1a.1, NRCQ1a.2 and NRCQ1a.3. The comparison shows:

East-West (X)Spectra	2 frequencies below design RS but within 10% threshold
North-South (Y) Spectra	2 frequencies below design RS but within 10% threshold
Vertical (Z) Spectra	1 frequency below design RS but within 10% threshold

Therefore, this comparison shows that the selected seismic time histories meet the requirements of SRP 3.7.1.

b) The target power spectral density (PSD) of the SSE time history is plotted in Figures NRCQ1b.1, NRCQ1b.2 and NRCQ1b.3. Standard Review Plan SRP 3.7.1, Appendix A, specifies the minimum PSD requirements. Those minima are also plotted on the same figures for comparison. The comparison shows that all of the artificial time histories used in the analysis meet the minimum PSD requirements of the SRP 3.7.1.

c) The artificial time history envelopes the spent fuel pool design response spectra and meets the requirements of SRP 3.7.1.

Figure NRCQ1a.1 Design Vs Input For GINNA SSE1 - Horizontal X

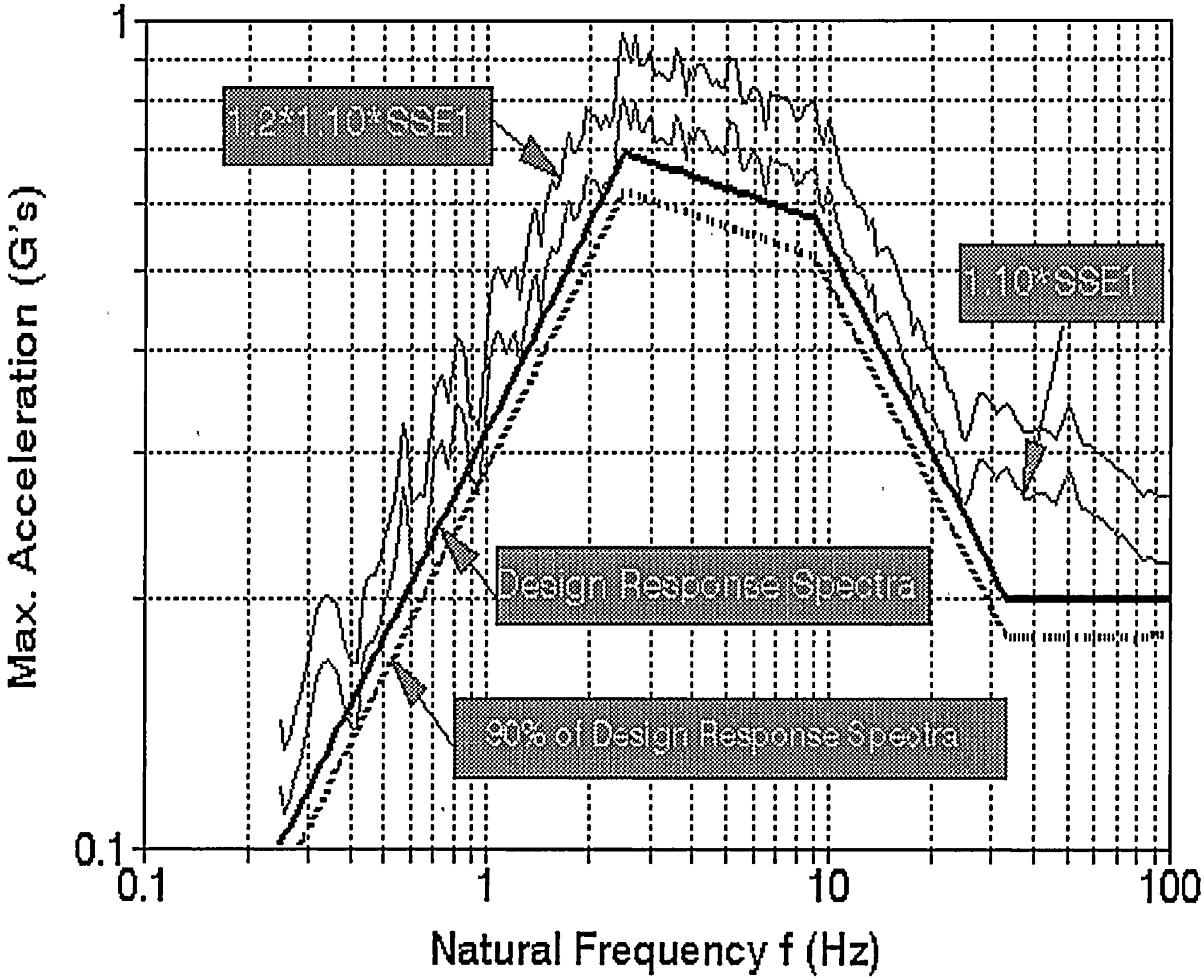

Figure NRCQ1a.2 **Design Vs Input For GINNA SSE1 - Horizontal Y**

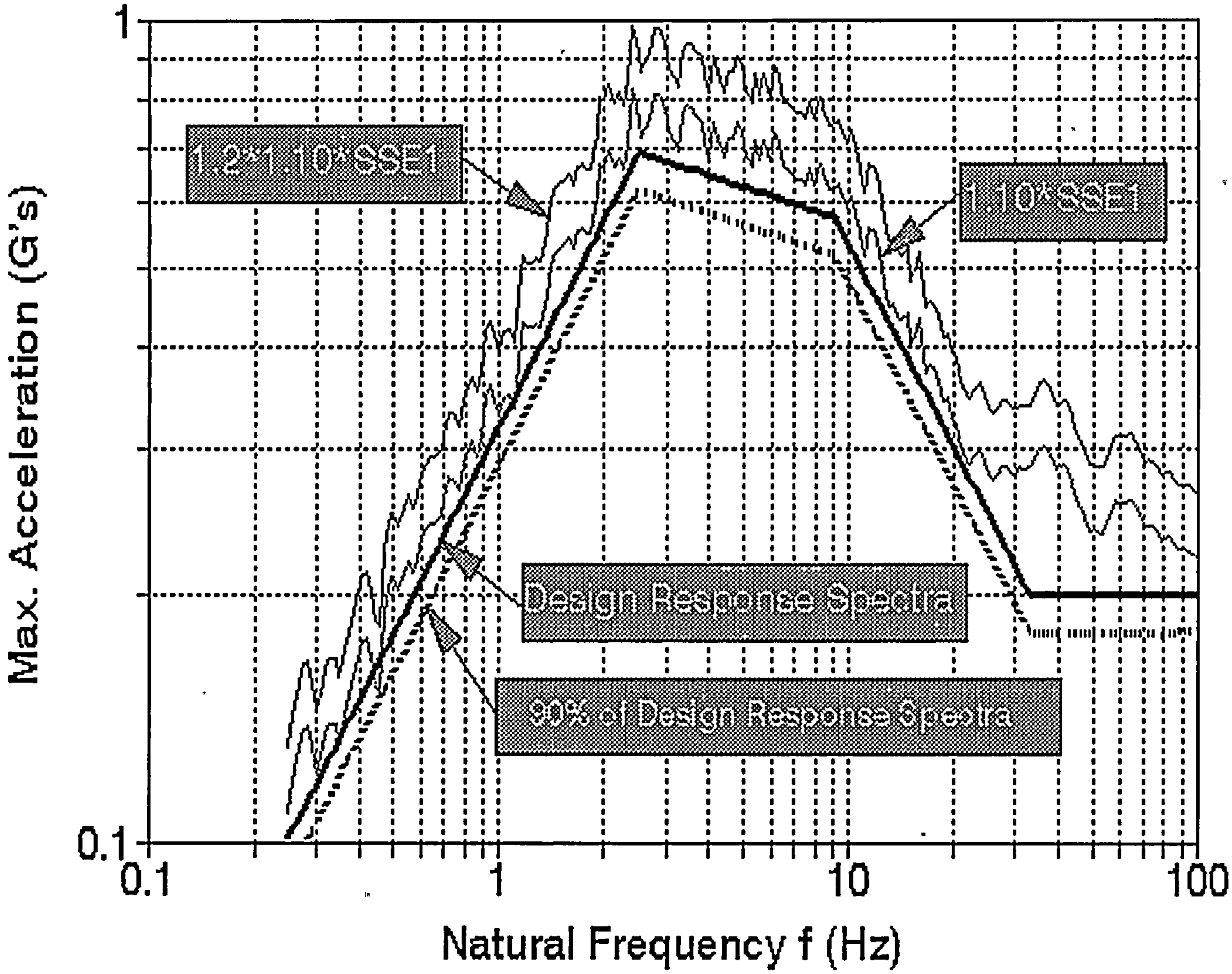

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Figure NRCQ1a.3 **Design Vs Input For GINNA SSE1 - Vertical Z**

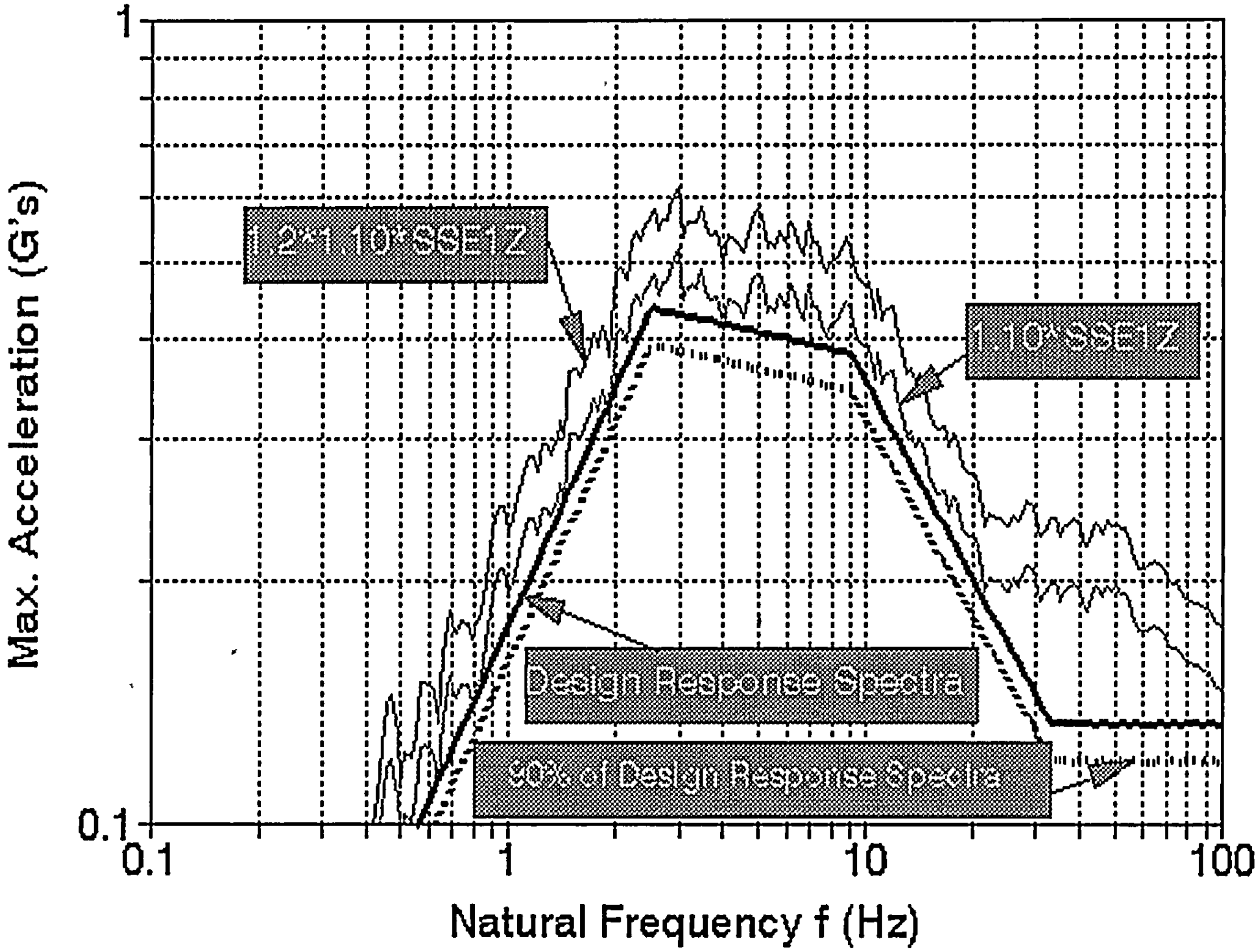

Figure NRCQ1b.1 **PSD Comparison For GINNA SSE1 - Horizontal X**

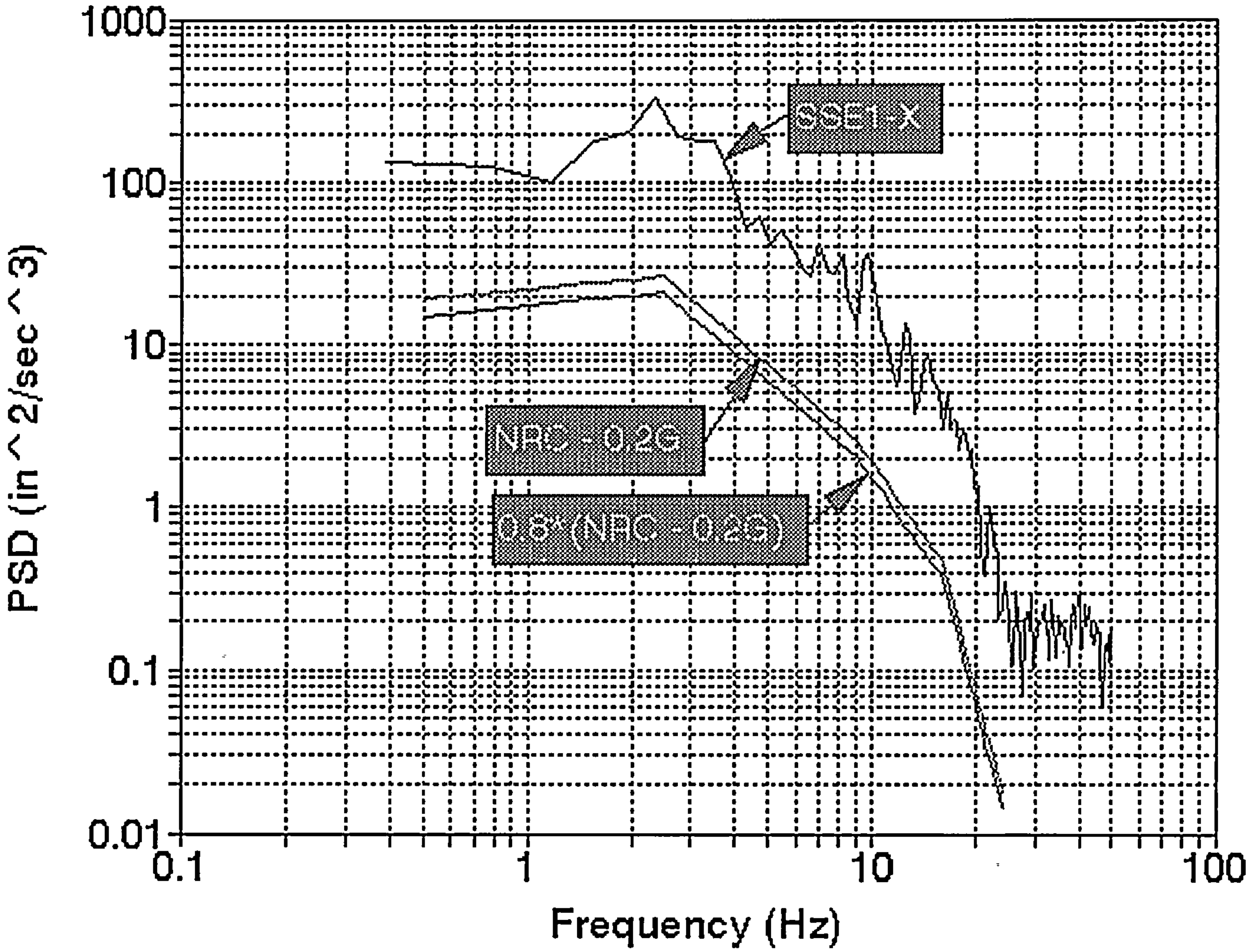

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Figure NRCQ1b.2 **PSD Comparison For GINNA SSE1 - Horizontal Y**

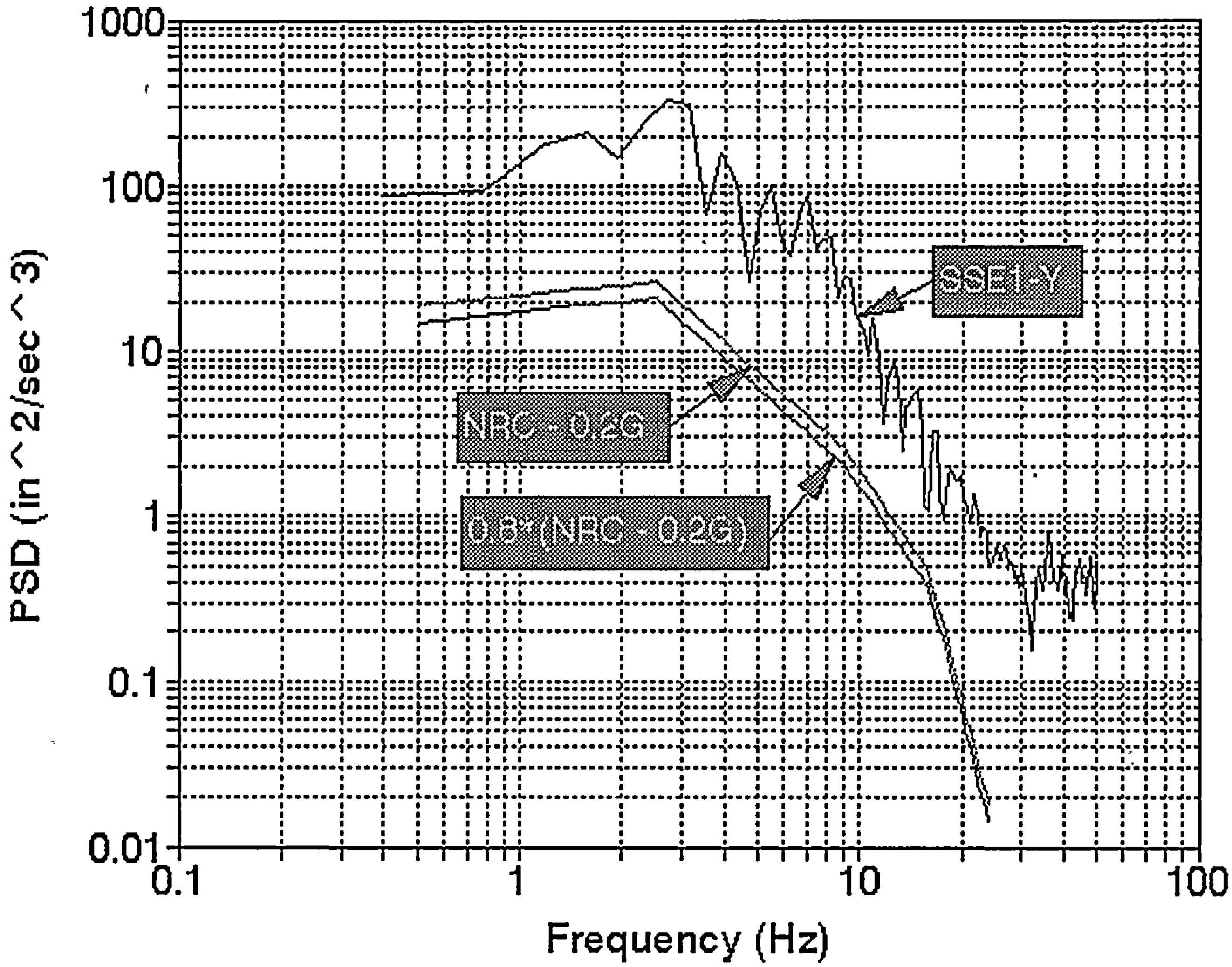

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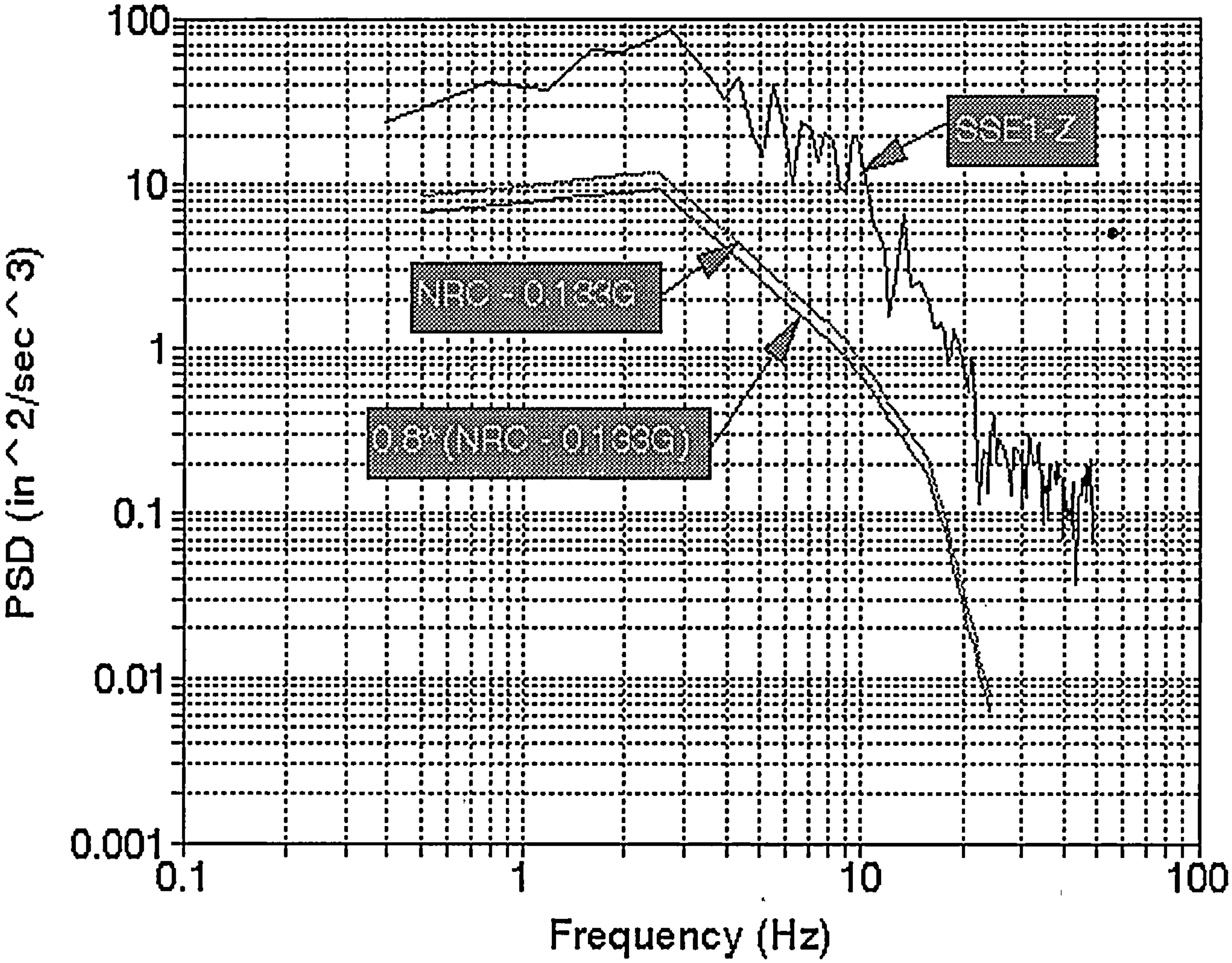
Figure NRCQ1b.3 **PSD Comparison For GINNA SSE1 - Vertical Z**



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G. S. Vissing

October 20, 1997

Question No. 2:

With respect to the dynamic fluid-structure interaction analyses using the computer code, ANSYS, in the Reference:

a) *Explain how the simple stick model used in the dynamic analyses can accurately and realistically represent the actual highly complicated nonlinear hydrodynamic fluid-rack structure interactions and behavior of the fuel assemblies and the box-type rack structure.*

b) *Provide the results of any existing experimental study that verifies the correct or adequate simulation of the fluid coupling utilized in the numeric analyses for the fuel assemblies, racks and walls. If there is no such experimental study available, provide in detail technical justifications on how the current level of the ANSYS code verification is adequate for engineering applications and should be accepted without further experimental verification work.*

c) *Provide in a tabular form the material properties including the stiffness (k) used for the simplified computer structural models shown in Figures 3.5-31 and 3.5-32 on the Reference, and the technical basis for the conclusion that the properties used in the analyses are realistic and equivalent to the properties of the actual rack structure.*

d) *Indicate whether you had any numerical convergency and/or stability problem(s) during the nonlinear, dynamic single- and multi-rack analyses using the ANSYS code. If there were any, how did you overcome the problem?*

e) *Submit the ANSYS input data in ASCII for the Model 1 (3-D Single Rack Plate Model) and the Model 2 (3-D Single Rack Beam Model) analyses with complete information (i.e., artificial time history input motions, loading conditions, boundary conditions, material properties, loading steps, etc.) on a 3.5-inch diskette.*

Response:

a) The behavior of spent fuel storage racks is complex, and some simplification of the actual behavior is appropriate when creating a mathematical model for use in a finite element analysis. One has to assess the aspects of the structural behavior which are important to simulation while considering the end use.

The racks are very rigid structures and their natural frequencies are much greater than the predominant seismic input forcing frequencies. Hence, the rack structure motion can be described by a 3-D beam element (six degrees-of-freedom, three translational and three rotational).

The mathematical models (3-D single rack and whole pool multi-rack) used to perform dynamic analyses of the fuel storage rack structure simulated the three-dimensional characteristics of the rack modules in a comprehensive manner. These models included features to allow for sliding and tipping of the racks and to represent the hydrodynamic coupling which can occur between fuel assemblies and rack cells, between racks, and between the racks and the reinforced concrete walls. The gap elements were incorporated to account for impact between the fuel assembly and the rack. To detect any impact between racks and/or any impact between the racks and the pool wall, additional gap elements were introduced into the 3D-whole pool model of the single rack The support legs were modeled as compression-only gap elements which considered the local vertical flexibility of the rack-support interface. Friction elements were used at the bottom of the support legs.

The spent fuel storage racks are free-standing structures. They are constructed of a simple tube structure assembled in a honeycomb pattern. Under given seismic excitation they behave similar to a very rigid structure. The beam representation gives adequate simulation for seismic loadings. As discussed in the report, for thermal and other conditions, the complete rack was idealized using plate elements.

The spent fuel storage racks seem like a complex structure. However, when compared to other 10CFR50 license applications, like reactor vessel internals, steam generator internals, containment building, which all are analyzed using beam representation, the spent fuel storage rack itself is a very simple assembly of square tube structures.

Also, the beam representation is consistent with the 1985 licensing basis, NRC SER dated November 14, 1984 (Reference 3.24 of the Licensing Report). Also, this approach is concurrent with recently licensed spent fuel storage racks, namely, Zion Station Units 1 and 2, Docket Nos. 50-295 and 50-304; Haddam Neck Plant, Docket 50-213; and Pilgrim Nuclear Power Station, Docket 50-293.

In summary, the methodology used for the mathematical model of the rack structures is consistent with industry practice.

b) The experimental verification of the fluid coupling simulation is provided in Appendix NRCQ2-A to this question. The results show very good agreement between the ANSYS results and the experimental test results.

The validation of the ANSYS Version 5.2 is in conformance with the provision of the Framatome Technologies Inc., Quality Assurance Program, Doc. No. 56-1201212 (Section 7.2 of the Licensing Report). The validation meets the requirements of the subsection II.4.c of SRP Section 3.8.4 and subsection II.4.e of SRP Section 3.8.1. SRP 3.8.1 states computer program validation should meet any of the following procedures or criteria:

(i) The computer program is a recognized program in the public domain, and has had sufficient history of use to justify its applicability and validity without further demonstration.

(ii) The computer program solution to a series of test problems has been demonstrated to be substantially identical to those obtained by a similar and independently written and recognized program in the public domain. The test problems should be demonstrated to be similar to or within the range of applicability of the problems analyzed by the public domain computer program.

(iii) The computer program solution to a series of test problems has been demonstrated to be substantially identical to those obtained from classical solutions or from accepted experimental tests or to analytical results published in technical literature. The test problem should be demonstrated to be similar to or within the range of applicability of the classical problems analyzed to justify acceptance of the program.

ANSYS is a widely used and accepted computer program in the public domain. The validation of the fluid coupling element using classical equations was presented to the NRC Staff during a meeting on August 25, 1997. The experimental verification is provided in Appendix NRCQ2-A to this question. The computer program validation requirements of the SRP 3.8.4 and SRP 3.8.1 are met.

c) The material properties used in the 3-D Single Rack and 3-D Whole Pool Rack model are given in Tables 3.4-2 through 3.4-8 of the Licensing Report. The material properties for the structural material are from the ASME Code, which is referenced in the report. The rack stiffnesses are generated internally in the computer program from cross-section properties and are provided in the following summary. The rack stiffness, in terms of cross-section properties, is provided in Section 3.5.3.1.1.1, starting in page 136 of the Licensing Report. The stiffness properties are developed using classical applied mechanics equations. The seismic analysis results are not sensitive to the rack stiffness, and this is demonstrated in Section 3.5.2.7.

Fuel Cell Impact Stiffness summary:

Type 1 (Existing U.S. Tool & Die Racks):	4,449 lb/in
Type 2 and Type 4 (New ATEA Racks)	7,036 lb/in
Type 3 (New ATEA Racks)	6,595 lb/in

The following axial stiffnesses (AE/L) are calculated internally in ANSYS, but are given for information purposes. All page references are from the Ginna Licensing Report.

Consolidated Fuel Canister Structural Properties:

$E = 27.87$ E6 psi
$A = 3.6681$ in^2
$A_{eff} = 9.3920$ in^2
$L = 159$ in $\quad$ $k_{eff} = 1.65$ E6 lb/in (k for A_{eff})

Fuel Assembly Structural Properties:

E (Zircaloy) = 12.0 E6 psi
$A = 7.1419$ in^2
$L = 159$ in $\quad$ $k = 5.39$ E5 lb/in

Support Pad Structural Properties (k represents individual support pad)

E = 27.87 E6 psi
L = 10.0 in (for Rack Types 1,4), and L = 19.60 in (for Rack Types 2,3)

Legs of Type 1 Rack: k = 3.75 E8 lb/in	A = 134.5 in^2	Ix = 1372.6 in^4	Iy = 1274.6 in^4
Legs of Rack 7 (2A): k = 5.69 E7 lb/in	A = 40.0 in^2	Ix = 211.0 in^4	Iy = 211.0in^4
Legs of Rack 8 (2B): k = 7.54 E7 lb/in	A = 53.0 in^2	Ix = 290.0 in^4	Iy = 290.0 in^4
Legs of Rack 9 (3C): k = 3.84 E7 lb/in	A = 27.0 in^2	Ix = 144.0 in^4	Iy = 144.0 in^4
Legs of Rack 10(3A): k = 5.69 E7 lb/in	A = 40.0 in^2	Ix = 211.0 in^4	Iy = 211.0 in^4
Legs of Rack 11(3E): k = 5.69 E7 lb/in	A = 40.0 in^2	Ix = 217.0 in^4	Iy = 217.0 in^4
Legs of Rack 12(3D): k = 3.84 E7 lb/in	A = 27.0 in^2	Ix = 144.0 in^4	Iy = 144.0 in^4
Legs of Rack 13(3B): k = 5.23 E7 lb/in	A = 36.8 in^2	Ix = 190.0 in^4	Iy = 190.0 in^4
Legs of Type 4 Rack: k = 2.91 E7 lb/in	A = 10.45in^2	Ix = 32.9 in^4	Iy = 86.5 in^4

Type 1 (Existing) Rack Structural Properties:

E = 27.87 E6 psi
A = 420.3 in^2
L = 159 in   k = 7.37 E7 lb/in

Type 2 Rack Structural Properties:

E = 27.87 E6 psi
L = 158.5 in

Rack 7:	A = 113.9 in^2	k = 2.00 E7 lb/in
Rack 8:	A = 129.5 in^2	k = 2.28 E7 lb/in

Type 3 Rack Structural Properties:

E = 27.87 E6 psi
L = 162 in

Rack 9:	A = 66.2 in^2	k = 1.14 E7 lb/in
Rack 10:	A = 92.7 in^2	k = 1.59 E7 lb/in
Rack 11:	A = 84.8 in^2	k = 1.46 E7 lb/in
Rack 12:	A = 66.2 in^2	k = 1.14 E7 lb/in
Rack 13:	A = 82.1 in^2	k = 1.41 E7 lb/in

Type 4 Rack Structural Properties:

E = 27.87E06 psi
L = 158.5 in

Rack Type 4:	A = 25.9 in^2	k = 4.55 E6 lb/in

d) There were no convergency or stability problems for either the single- or multi-rack model runs during the nonlinear, dynamic analyses. All load cases ran for the full time history and obtained a converged solution, using the same basic ANSYS program parameters.

The ANSYS solver uses the implicit integration scheme which, upon convergence, produces a repeatable, stable solution within prescribed (program-chosen defaults) tolerance limits.

e) The ANSYS input data in the ASCII form are provided in the enclosed 3.5-inch computer diskette. Note that these input data are proprietary information and should be used only for the Ginna licensing effort. These data are for use with ANSYS Version 5.2. All data are self-explanatory and an experienced ANSYS user should be able to use it easily. If you encounter any problem, FRAMATOME can assist the NRC Staff at its Lynchburg offices.

Disk Files Include:

Disk ANSYS Input Files,	File S3DR8PL.TXT	3-D Single Rack Plate Model
	File S3DR8SC.TXT	3-D Single Rack Dynamic Model

The 3-D Single Rack Plate Model (Model 1) was used for the static stress, thermal, and the base plate stress analysis, as presented in the detailed descriptions of Model 1 in Section 3.5.2.3 of the report. The model was not used with any time history input.

The loading conditions, boundary conditions, material properties, and loading steps are part of these input files. The time history input (SSE1) is included with the input for Model 2.

Appendix NRCQ2-A

Experimental Verification
of
ANSYS Hydrodynamic Mass Coupling
and
Dynamic Behavior of Immersed Rectangular Solids in Rectangular Cavities

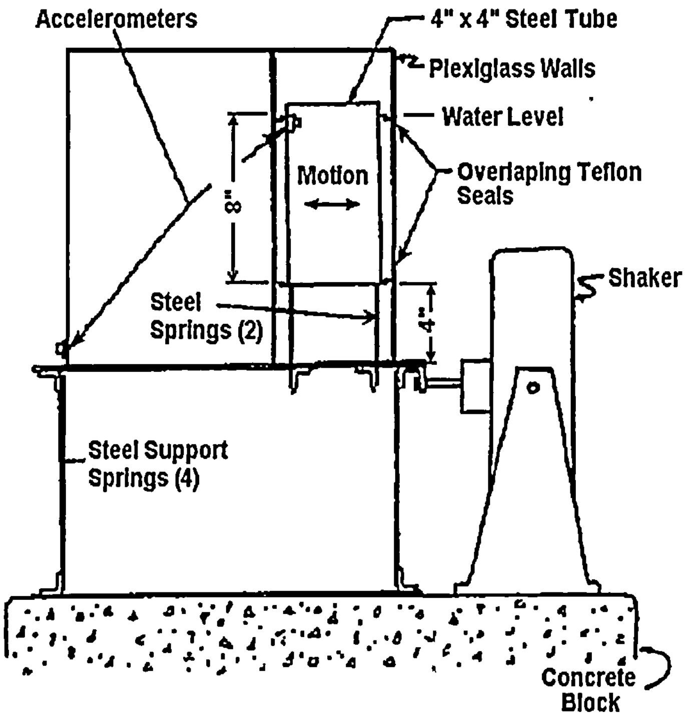
1. Objective

An ANSYS numerical study was made to demonstrate the correlation between an ANSYS model utilizing hydrodynamically coupled rectangular tube contained within a laterally excited rectangular container, or cavity, and the experimental results reported in References 3.45 and 3.46. A single degree-of-freedom (DOF) oscillator model (Ref. 3.45), used for estimating certain system's parameters is also compared to the ANSYS results.

2. Experiment Setup

An experimental set-up, reported in References 3.45 and 3.46, is shown in Figure A1. A rectangular steel tube with a solid bottom is enclosed in a long rectangular plexiglass container rigidly connected to a solid base plate. The base plate is supported with four steel consoles acting as springs for the laterally imposed base plate motion via electromagnetic actuator. The plexiglass container is additionally reinforced with a separate rectangular plexiglass plate fixed to the base plate (Fig.A1, left upper corner).

Figure A1 Experiment Setup



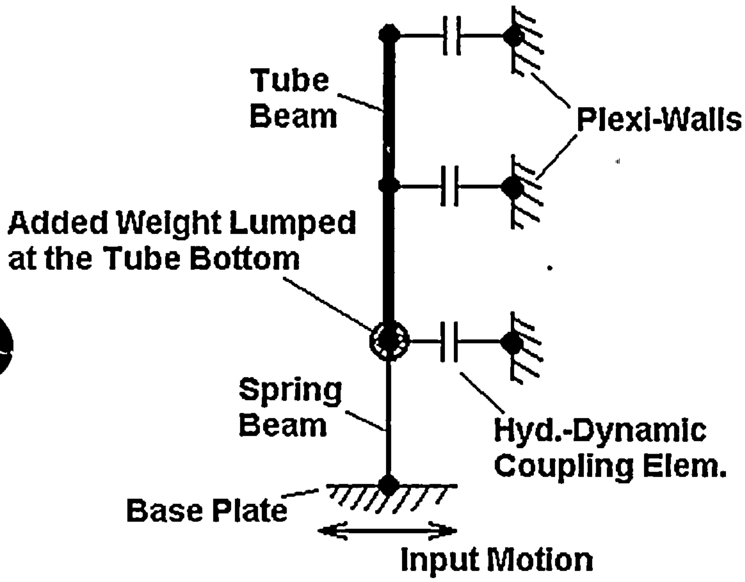
The steel tube bottom plate is connected to the base plate via two elongated steel plates acting as consoles. These vertical steel plates act as springs for the tube's laterally induced motion. At the top and bottom tube elevations, teflon seals are introduced in order to minimize eventual vertical mean flow along tube walls. The seal's locations also define water column height. A pair of accelerometers is used to pick up acceleration time histories for both the tube and the rigid plexiglass container. The shaker's frequency ranged from 5 to 35 Hz, to obtain adequate data points. The amplitude

response ratio is measured for each excitation frequency. The results are plotted for selected points in Figure A4.

3. ANSYS Model Description

The system shown in Fig.A1 is modeled in ANSYS as a series of two vertically connected beams, with the upper one being hydrodynamically coupled to the enveloping plexiglass container, as shown in Figure A2.

Figure A2 ANSYS Model



The bottom beam represents a pair of vertical steel strips, while the upper beam represents the steel tube. ANSYS 3D element "BEAM4" (Ref. 3.40) is used for both beams, while hydrodynamic coupling is modeled with ANSYS "FLUID38" elements at the tube beam top, middle and bottom locations. Additional weight placed in the tube (Ref. 3.46) is lumped at its bottom. Forced input harmonic motion is applied to both spring beam bottom (base plate) and plexiglass container walls.

Model properties are obtained as follows:

Steel Tube

Tube envelope mass: $m_t = V_t\,(\rho_t) = 0.0174$ lb-s^2/in (weight = m_t g = (0.0174)(386.4) = 6.72 lb), where, $V_t = 4(a\ h\ t) = 24$ in^3 (the material tube envelope volume), a = 4.0 in (tube side width), h = 8.0 in (tube height), t = 3/16" = 0.1875 in (tube wall thickness) and $\rho_t = 72.46\text{x}10^{-5}$ lb-s^2/in^4 (tube wall density, steel, room temperature).

From Ref. 3.46, total tube weight is 15 lb, which includes additional weight together with bolts and nuts connecting tube base to steel springs. It is assumed that all additional mass is concentrated at the bottom of the tube; i.e., it is lumped at the bottom tube beam node. This lumped mass includes tube bottom plate.

Lumped mass (tube bottom): m_{bot} = (total weight) / g - (tube envelope mass)
= 15.0/386.4 - 0.0174 = 0.0214 lb-s^2/in
or weight = (0.0214)(386.4) = 8.28 lb

Tube cross section: $A_t = 4(a\,t) = 3$ in^2
Tube cross section moment of inertia: $I_t = 2[a^3 t/12 + (a\,t)(a/2)^2] = 8.0$ in^4

Steel Spring

Equivalent spring beam consists of two vertical steel strips, each 4" long, 1" wide and 3/32" thick. Bending occurs about the weak axis.

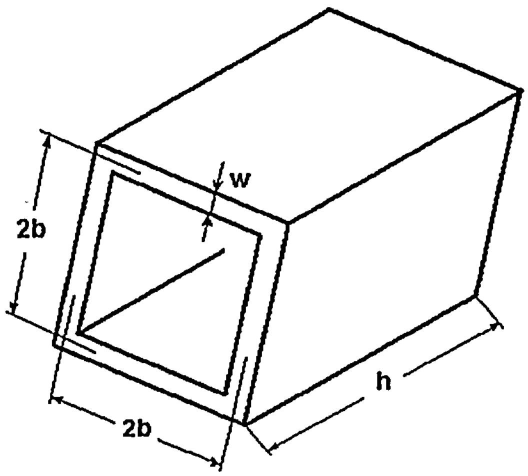
Eqv. Spring cross section: $A_s = 2(c\,t_s)$ = 2(1")(0.0938") = 0.1875 in^2
Eqv. Spring cross sect. moment of inertia: $I_s = 2[t^3c/12]$ = 2[0.0938^3(1")/12] = 1.373x10^{-4} in^4
Eqv. Spring lateral stiffness: $k = 12\,I_sE / L^3$ = 772.3 lb/in, for both beam ends clamped, where: E = 30 MSI (steel elastic modulus @ room temperature) and L = 4" (equivalent spring beam length). It is suggested in Ref. 3.46 that while excited, the tube remains practically parallel to the plexiglass container walls. In the ANSYS model, this effect is achieved by imposing rotational constraint at the common beams node.

Fluid Masses

Hydrodynamic mass, Ref. 3.45: $M_h = (16/3)\,\rho_w\,h\,b^3/\,w$ = 0.0908 lb-s^2/in, where ρ_w = 9.345x10^{-5} lb-s^2/in^4 (water density @ room temperature), b = (a+w)/2 = (4+0.5)/2 = 2.25 in (water column centerline width, (Fig.A3)), and w = 0.5 in (tube-to-wall gap).

Displaced fluid mass, Ref. 3.45: $M_1 = (2b - w)^2\,h\,\rho_w$ = 0.01196 lb-s^2/in
Fluid mass based on container volume, Ref. 3.45: $M_2 = (2b + w)^2\,h\,\rho_w$ = 0.01869 lb-s^2/in

Figure A3 Water Column Dimensions



The effect of hydrodynamic fluid coupling is discretized as 1/2 at the tube beam mid-height and 1/4 at its top and bottom (Fig.A2). ANSYS fluid coupling element "FLUID38" (Ref. 3.40) is used with KEYOPT(3) = 2 for concentric arbitrary cylinders (i.e., rectangular) and KEYOPT(6) = 2 for local element coordinate system's lateral axes oriented in global X and Z directions.

Boundary Conditions

Boundary conditions are shown in Fig.A2. All DOFs of the spring beam bottom node are fixed (clamped condition) except the X-displacement component, which is prescribed as sinusoidal motion. The same also applies for the three wall nodes connecting hydrodynamic elements to the tube beam. Due to the fact that the tube remains practically parallel to the container walls, the tube beam bottom node is prevented from rotation about lateral Z-axis (spring's beam bending axis). To match the measured natural frequency in water, spring beam stiffness is adjusted as $k = (2\pi\ f_1)^2\ [m+M_h] = (2\pi\ 9.2)^2\ [0.0388 + 0.0908] = 433.1$ lb/in.

Structural Damping

A time history analysis approach is used to obtain the system's response amplitude ratio. The system is excited to a sinusoidal excitation at selected nodes and response amplitude, or nodal displacement response as a function of time is obtained for selected points of the system. The connecting node between the spring and the tube beams is chosen, since its motion sufficiently describes behavior of the system and it could also be compared against a single DOF theoretical model. Rayleigh damping is used for comparison purposes. In addition to the stiffness matrix multiplier β, the mass matrix multiplier α is simultaneously used to provide more uniform damping over a desired range of frequencies. These multipliers are obtained as a solution of the system of two simultaneous linear equations:

$$\zeta_i = \alpha / (2\omega_i) + \beta\omega_i / 2, \text{ where } \omega_i = 2\pi f_i \quad [s^{-1}]$$

By choosing known pairs of natural frequencies with their associated damping ratio values (Ref. 3.45), $f_1 = 15.3$ Hz and $\xi_1 = 0.053$, in air; $f_2 = 9.2$ Hz and $\xi_2 = 0.062$ in water, the Rayleigh damping multipliers are $\alpha = 5.456$ and $\beta = 5.122\text{x}10^{-4}$.

4. Results

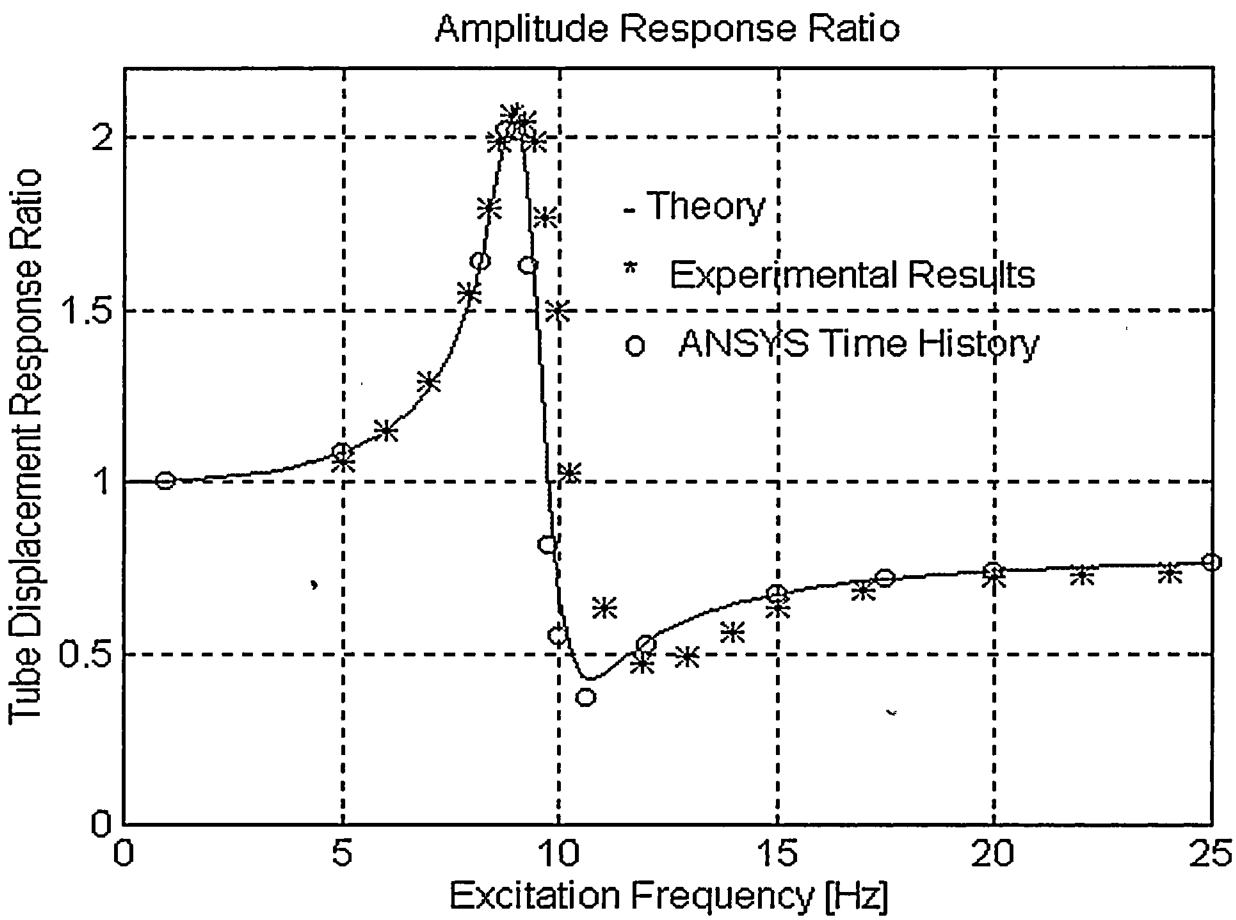
The experiment (in water) data points are obtained from Ref. 3.46. Note that the accuracy of their coordinates in amplitude response plot (Fig.A4) might be insufficient, due to the small scale of the original experiment curve provided in Ref. 3.45. However, their trend is sufficient to validate the ANSYS model's comparison. In the time history method, a 3 second displacement time history is created for each selected excitation frequency, and applied at the selected nodes of the system. The amplitude for all time-histories is unity, i.e., 1.0 in. ANSYS results are also compared against single DOF oscillator model (equation 24 in Ref. 3.45, labeled as "Theory" in Fig. A4), with the total tube mass lumped at the top of the spring beam. Figure A4 shows good comparison between the ANSYS and theoretical response ratio predictions. A minor discrepancy between these models and the experiment is in part due to a sensitivity of measuring equipment, as suggested in Ref. 3.46.

Conclusions

1) It is concluded that ANSYS hydrodynamic element FLUID38 can be used to represent fluid-structure interaction of rectangular prismatic containers with good correlation with both theory and test results. There is a good agreement between ANSYS results and experimental test data for dynamic fluid-structure interaction problems. This verifies the capacity of ANSYS to perform seismic time-history analyses of submerged spent fuel storage racks in pools.

2) Use of beam stick-model and lumped masses is a realistic representation of fuel and rack type structures for use in time-history driven dynamic analyses.

Figure A4 Comparison of Results



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Question No. 3:

With respect to the dynamic fluid coupling element (FLUID38 of the ANSYS code) used in the analysis:

a) *It is our understanding that the element FLUID38 was developed for a fluid flow study in an infinitely long rigid cylindrical pipe. Explain how this element can be applicable for your 3-D fluid-rack (single- and multiple-rack) interaction analysis.*

b) *If the ANSYS input (real constants (R2, R1, L, F, DX, DZ, WX, WZ, M2, M1, MHX, MHZ, CX, CZ) and material properties (DENS)) were used for the FLUID38 element, provide the values and technical basis for the conclusion that those values are realistic.*

c) *One of the assumptions for the FLUID38 element of ANSYS code is that the lumped option is not available with this element. Did you use the lumped option for the fluid mass? If not, how do you treat the fluid mass? Explain.*

Response:

a) The ANSYS FLUID38 element is the dynamic fluid coupling element. This element is a generic element to represent a dynamic coupling between two points of a structure. The points represent the centerline of concentric cylinders. The cylinders might be circular or have an arbitrary cross-section. The default values are for a cylinder vibrating in a cylinder. However, when one uses KEYOPT(3) = 2 it can be an arbitrary cross section. This option is used in the single-rack and multi-rack interaction analysis. The dynamic fluid coupling used is based on a rectangular body vibrating in fluid contained in an annulus created by a rectangular outer body. The fluid coupling values are based on the Singh-1990 (Reference 3.38 of the Licensing Report) paper. The derivation of fluid dynamic values are experimentally verified by Scavuzzo-1979, "Dynamic Fluid Structure Coupling of Rectangular Modules in Rectangular Pools" (Reference 3.45).

b) In the ANSYS FLUID38 element input if KEYOPT(3) = 0 is used, it represents the concentric cylinders, and for that case R2, R1, etc., constants are required. In our case KEYOPT(3) = 2 for arbitrary cross sections was used. M_1, M_2, M_{hx}, and M_{hy} terms of the fluid couple-mass matrix were also input. Tables 3.5-10 and 3.5-11 of the Licensing Report provide the mass matrix terms M_1, M_2, M_{hx}, and M_{hy} used in the fluid structure interaction analysis.

c) The lumped mass option (LUMPM, ON) is not available for ANSYS FLUID38 element. We did not use lump masses for this element. The dynamic fluid coupling is hydrodynamic mass based on potential theory, Singh-1990 (Reference 3.38). Section 3.5.2.5 discusses the use and calculation of hydrodynamic fluid mass.

Question No. 4:

With respect to the analytical simulation of the rattling fuel assembly impacting against the cell:

a) *How did you calculate the magnitude of the largest impact force and the location of the impact in the fuel assembly and the cell wall?*

b) *How did you determine and analyze the fuel assembly and cell wall integrity?*

c) *Discuss the considerations given to the effects of the fluid between the fuel assembly and cell wall during the interactions.*

d) *Provide available experimental studies that verify the reasonableness of the numerical simulation adopted to represent the fuel assembly and the cell wall interaction.*

Response:

a) Impacts between the rack and fuel assembly lumped masses were accounted for by the use of gap elements, as shown in Figure 3.5-41 of the Licensing Report. The impact forces are calculated from the seismic time-history analysis. Gapped spring elements are employed to track the impact forces. The peak forces on these gapped elements represent the impact force.

The impact forces between the fuel assemblies and the cell wall were obtained using the minimum and maximum results summary obtained through the post-processing capability of ANSYS. The post-processing used was POST26, which can extract requested data from a time-history analysis, in order to produce tables of result items versus time. The real-time fuel/rack impact loads were tabulated in POST26 for the sum of both the top and middle rack nodes throughout the entire time-history. The real time maximum impact load was thus obtained for all the fuel assemblies in any particular rack. The assumption that all fuel assemblies act in unison is conservative.

Therefore, the maximum combined fuel/rack impact load was then divided by the number of fuel assemblies in the rack to obtain a maximum fuel/rack impact load per fuel assembly. The summary of the resulting fuel-to-rack impact loads for each rack and for each load case is tabulated in Tables 3.5-46 through 3.5-57 of the Licensing Report.

b) The cell wall integrity is determined by stress analysis. Section 3.5.2.2.2.4 discusses the stress analysis. Table 3.5-58 provides the results of the cell wall stress analysis and shows comparison of actual impact load against the allowable load.

The ANSYS finite element analysis was used to calculate stresses in the fuel rack-cell wall due to impact loading of fuel assemblies. The maximum allowable fuel rack load was defined as one which would reach the maximum stress intensity based on the stress limit specified in the ASME Code Section III, Subsection NF. The calculation gave an allowable load per cell of 2290.0 pounds for the OBE condition and 2900.0 pounds for the SSE condition. These allowable loads are much lower than the load value required to ensure the fuel assembly integrity. The elastic load limits of the fuel assembly spacer grids tested range from [b, c, d]. The fuel assembly structural integrity is assured, if the spacer grid impact loads are lower than the spacer grid elastic load limit. The highest impact load value obtained from the OBE analysis is 908 pounds and from the SSE analysis is 1600 pounds. These calculations confirm the local rack cell wall integrity and the fuel assembly integrity for the maximum fuel to rack cell wall impact loads.

c) The fluid between the fuel assembly and the cell wall was considered in the seismic analysis. The theory of cylinder vibrating in the fluid (Reference 3.38 of the Licensing Report) is utilized in the hydrodynamic mass calculations. The fuel assembly containing 179 individual fuel rods, 16 guide tubes and one instrument tube was utilized in the calculation. Section 3.5.2.5.1 provides the detailed fuel assembly hydrodynamic calculations for W-Standard, W-OFA and Exxon fuel assemblies.

d) Section 3.5.3.1.1.3 discusses the numerical simulation between the fuel assembly and the cell wall. This is a classic engineering mechanics problem. No experimental studies are required for the general structural problem. No known experimental study exists at Framatome Cogema Fuels. All the experiments performed by Babcock & Wilcox are for fuel impacting a rigid surface or impacting other fuel assemblies.

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Question No. 5:

Provide a complete deformation shape with magnitudes of the deformations of the rack from the bottom to the top for the single-rack SSE analysis when the maximum displacement at the rack top corner occurs.

Response:

The single-rack 3-D model was used for parametric studies only. The displacements and loads were obtained from the whole-pool multi-rack model. A summary of all the maximum absolute horizontal displacements is provided in response to NRC Question # 7. A review of those displacements shows that the maximum displacement for any rack, for all loading conditions, occurs at Rack #7, during Load Case #1. The summary of those maximum displacements are provided in the table below. Therefore, the description of the maximum absolute displacements for Rack #7 are provided for the rack bottom, middle, and top four corners.

Table NRCQ5.1 Max. Rack Horizontal Disp. @ Top - LC#1
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #1 - Unconsolidated Fuel - SSE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.25760	0.33280	-0.42080	0.28260
2	-0.28680	0.26240	-0.36870	0.26970
3	-0.29000	0.18640	-0.26200	0.19300
4	-0.25190	0.19140	-0.25300	0.17590
5	-0.38440	0.24140	-0.19250	0.19140
6	-0.35710	0.27190	-0.24400	0.20520
7	-0.59190	0.41610	-0.27550	0.16960
8	-0.55160	0.55660	-0.32230	0.20600
9	-0.58630	0.56700	-0.33660	0.19350
10	-0.53080	0.44060	-0.28250	0.14030
11	-0.52280	0.57350	-0.29340	0.16560
12	-0.49180	0.57140	-0.33350	0.14440
13	-0.50680	0.45750	-0.37800	0.10220

Table NRCQ5.2 **Rack Corner Nodal Displacements at Rack's Top, Middle, and Base for Rack #7 (inches)**

Corner	UX	UY	UZ
Top South-West	-0.52334	-0.17714	-0.07794
South-East	-0.52334	0.01878	0.19580
North-West	-0.66054	-0.17714	-0.07786
North-East	-0.66054	0.01878	0.19588
Rack Center	-0.59194	-0.07918	0.05897

Corner	UX	UY	UZ
Mid South-West	-0.26183	-0.17708	-0.07639
South-East	-0.26183	0.01867	0.19417
North-West	-0.39891	-0.17708	-0.07606
North-East	-0.39891	0.01867	0.19449
Rack Center	-0.33037	-0.07920	0.05905

Corner	UX	UY	UZ
Base South-West	-0.00563	-0.17587	-0.07059
South-East	-0.00589	0.01925	0.18817
North-West	-0.14242	-0.17622	-0.06957
North-East	-0.14266	0.01925	0.18918
Rack Center	-0.07427	-0.07840	0.05930

Question No. 6:

Provide the largest magnitude of the hydrodynamic pressure distribution along the height of the rack during the fluid and rack interaction for each case of the 3-D single- and multi-rack analyses.

Response:

The single 3-D rack model was used for parametric studies. The loads, including the hydrodynamic loads, and displacements were all obtained solely with the multi-rack whole-pool model. Therefore, the requested hydrodynamic pressure distribution is provided for the whole-pool multi-rack model. The hydrodynamic pressure distributions are tabulated for each rack that interfaces with the spent fuel pool walls. The real-time summation of hydrodynamic loads for the bottom, middle, and top of each rack was used to provide an average hydrodynamic pressure for the entire height of the rack. Also, a real-time summation of hydrodynamic loads was obtained for all the racks facing each of the four walls. The real-time averaged wall pressure for each of the four walls was then determined, and is provided in the following tables.

The tables NRCQ6.1 thru NRCQ6.12 are for each of the Load Cases 1 thru 12.

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Table NRCQ6.1 Max. Rack Seismic Hydro Pressures - LC#1
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #1 - Unconsolidated Fuel - SSE - Mu = 0.8

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-2.497	2.853
R2-WW	-2.693	2.956
East Side		
R7-EW	-3.052	3.935
R11-EW	-3.786	5.008
R12-EW	-7.643	10.077
R13-EW	-4.176	4.995
South Side		
R1-SW	-5.418	3.758
R3-SW	-15.162	11.255
R5-SW	-18.334	15.081
R7-SW	-3.322	2.726
R11-SW	-3.220	2.477
North Side		
R2-NW	-5.325	3.671
R4-NW	-18.282	13.105
R6-NW	-10.452	8.595
R10-NW	-5.775	4.522
R13-NW	-2.524	2.001
Sum of Real Time Rack Pressures (psi) Averaged for Each Side		
SUM-WW	-1.397	1.564
SUM-EW	-2.383	3.144
SUM-SW	-8.709	6.782
SUM-NW	-8.023	6.051

Note: The above reported pressures are on the perimeter racks.

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Table NRCQ6.2 Max. Rack Seismic Hydro Pressures - LC#2
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #2 - Unconsolidated Fuel - SSE - Mu = 0.2

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-2.538	2.322
R2-WW	-2.683	2.478
East Side		
R7-EW	-3.399	3.937
R11-EW	-3.514	4.294
R12-EW	-6.801	8.846
R13-EW	-3.808	4.191
South Side		
R1-SW	-3.994	3.166
R3-SW	-11.901	10.363
R5-SW	-16.997	14.018
R7-SW	-3.209	2.633
R11-SW	-3.252	2.489
North Side		
R2-NW	-4.159	3.021
R4-NW	-14.293	12.220
R6-NW	-9.635	7.681
R10-NW	-5.423	4.571
R13-NW	-2.441	2.121
Sum of Real Time Rack Pressures (psi) Averaged for Each Side		
SUM-WW	-1.405	1.288
SUM-EW	-2.316	2.789
SUM-SW	-7.461	6.320
SUM-NW	-6.835	5.746

Note: The above reported pressures are on the perimeter racks.

Table NRCQ6.3 Max. Rack Seismic Hydro Pressures - LC#3
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #3 - Consolidated Fuel - SSE - Mu = 0.8

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-1.076	1.058
R2-WW	-1.136	1.165
East Side		
R7-EW	-3.434	3.065
R11-EW	-8.085	7.052
R13-EW	-4.144	3.297
South Side		
R1-SW	-2.819	3.758
R3-SW	-7.232	9.212
R5-SW	-9.799	11.062
R7-SW	-2.064	2.120
R11-SW	-2.113	2.302
North Side		
R2-NW	-3.087	3.713
R4-NW	-9.412	11.433
R6-NW	-5.921	7.043
R10-NW	-3.287	3.491
R13-NW	-1.539	1.679
Sum of Real Time Rack Pressures (psi) Averaged for Each Side		
SUM-WW	-0.573	0.594
SUM-EW	-2.598	2.140
SUM-SW	-4.441	5.411
SUM-NW	-4.438	5.224

Note: The above reported pressures are on the perimeter racks.

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Table NRCQ6.4 Max. Rack Side Seismic Hydro Pressures - LC#4
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #4 - Unconsolidated Fuel - SSE - Mu = 0.5

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-2.496	2.716
R2-WW	-2.693	3.450
East Side		
R7-EW	-2.833	3.557
R11-EW	-3.635	4.561
R12-EW	-8.232	10.163
R13-EW	-4.412	5.273
South Side		
R1-SW	-4.812	4.002
R3-SW	-13.171	11.270
R5-SW	-18.104	15.125
R7-SW	-3.234	2.738
R11-SW	-3.143	2.562
North Side		
R2-NW	-4.900	3.999
R4-NW	-16.626	13.171
R6-NW	-10.289	8.305
R10-NW	-5.717	4.574
R13-NW	-2.516	2.100
Sum of Real Time Rack Pressures (psi) Averaged for Each Side		
SUM-WW	-1.397	1.649
SUM-EW	-2.444	3.044
SUM-SW	-7.890	6.804
SUM-NW	-7.345	6.082

Note: The above reported pressures are on the perimeter racks.

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Table NRCQ6.5 Max. Rack Seismic Hydro Pressures - LC#5
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #5 - Unconsolidated Fuel - SSE - Mu = 0.8

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-2.472	2.545
R2-WW	-2.886	2.509
East Side		
R7-EW	-3.613	2.986
R11-EW	-3.397	2.998
R12-EW	-8.074	6.885
R13-EW	-4.146	3.585
South Side		
R1-SW	-4.976	4.245
R3-SW	-14.174	11.671
R5-SW	-19.040	15.898
R7-SW	-3.244	2.753
R11-SW	-3.190	2.722
North Side		
R2-NW	-4.206	3.657
R4-NW	-15.838	13.773
R6-NW	-11.010	8.848
R10-NW	-5.730	4.647
R13-NW	-2.598	2.032
Sum of Real Time Rack Pressures (psi) Averaged for Each Side		
SUM-WW	-1.439	1.232
SUM-EW	-2.529	2.120
SUM-SW	-8.327	7.067
SUM-NW	-7.579	6.289

Note: The above reported pressures are on the perimeter racks.

Table NRCQ6.6 Max. Rack Seismic Hydro Pressures - LC#6
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #6 - Consolidated Fuel - SSE - Mu = 0.8

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-1.506	1.348
R2-WW	-1.471	1.416
East Side		
R7-EW	-3.261	2.409
R11-EW	-3.998	3.217
R12-EW	-7.709	6.599
R13-EW	-3.798	3.236
South Side		
R1-SW	-3.140	3.605
R3-SW	-7.733	9.405
R5-SW	-10.036	11.641
R7-SW	-2.006	2.053
R11-SW	-2.166	2.111
North Side		
R2-NW	-3.025	3.625
R4-NW	-9.821	11.752
R6-NW	-6.090	7.459
R10-NW	-3.323	3.438
R13-NW	-1.556	1.628
Sum of Real Time Rack Pressures (psi) Averaged for Each Side		
SUM-WW	-0.798	0.735
SUM-EW	-2.464	2.025
SUM-SW	-4.705	5.519
SUM-NW	-4.472	5.300

Note: The above reported pressures are on the perimeter racks.

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Table NRCQ6.7 Max. Rack Seismic Hydro Pressures - LC#7
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #7 - Unconsolidated Fuel - SSE - Mu = 0.2

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-2.669	3.256
R2-WW	-2.892	2.950
East Side		
R7-EW	-3.089	3.847
R11-EW	-3.311	3.281
R12-EW	-6.694	7.194
R13-EW	-3.281	3.099
South Side		
R1-SW	-4.174	3.541
R3-SW	-12.369	10.802
R5-SW	-17.681	14.806
R7-SW	-3.088	2.660
R11-SW	-2.896	2.522
North Side		
R2-NW	-4.512	3.821
R4-NW	-16.343	13.617
R6-NW	-10.252	8.157
R10-NW	-5.470	4.614
R13-NW	-2.374	2.129
Sum of Real Time Rack Pressures (psi) Averaged for Each Side		
SUM-WW	-1.452	1.661
SUM-EW	-2.157	2.288
SUM-SW	-7.704	6.603
SUM-NW	-7.332	5.982

Note: The above reported pressures are on the perimeter racks.

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Table NRCQ6.8 Max. Rack Seismic Hydro Pressures - LC#8
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #8 - Consolidated Fuel - OBE - Mu = 0.8

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-0.610	0.565
R2-WW	-0.712	0.616
East Side		
R7-EW	-1.122	1.317
R11-EW	-1.710	1.775
R12-EW	-3.812	3.869
R13-EW	-1.701	1.849
South Side		
R1-SW	-1.787	1.756
R3-SW	-4.039	4.728
R5-SW	-4.853	5.393
R7-SW	-0.909	0.928
R11-SW	-0.895	0.895
North Side		
R2-NW	-1.776	1.756
R4-NW	-5.043	5.911
R6-NW	-3.019	3.327
R10-NW	-1.412	1.448
R13-NW	-0.671	0.701

Sum of Real Time Rack Pressures (psi) Averaged for Each Side

SUM-WW	-0.356	0.311
SUM-EW	-1.026	1.149
SUM-SW	-2.389	2.668
SUM-NW	-2.291	2.546

Note: The above reported pressures are on the perimeter racks.

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Table NRCQ6.9 Max. Rack Seismic Hydro Pressures - LC#9
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #9 - Unconsolidated Fuel - OBE - Mu = 0.2

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-1.165	1.201
R2-WW	-1.271	1.198
East Side		
R7-EW	-1.176	1.344
R11-EW	-1.073	1.364
R12-EW	-2.231	2.632
R13-EW	-1.349	1.243
South Side		
R1-SW	-1.987	1.989
R3-SW	-5.749	5.831
R5-SW	-7.889	7.210
R7-SW	-1.247	1.405
R11-SW	-1.241	1.072
North Side		
R2-NW	-2.070	1.676
R4-NW	-7.087	6.834
R6-NW	-4.472	3.717
R10-NW	-2.099	1.453
R13-NW	-0.983	0.986
Sum of Real Time Rack Pressures (psi) Averaged for Each Side		
SUM-WW	-0.656	0.636
SUM-EW	-0.724	0.871
SUM-SW	-3.463	3.296
SUM-NW	-3.206	2.817

Note: The above reported pressures are on the perimeter racks.

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Table NRCQ6.10 Max. Rack Seismic Hydro Pressures - LC#10
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #10 - Unconsolidated Fuel - OBE - Mu = 0.2

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-0.919	0.908
R2-WW	-1.149	0.950
East Side		
R7-EW	-1.108	1.294
R11-EW	-1.163	1.449
R12-EW	-2.398	2.540
R13-EW	-1.237	1.369
South Side		
R1-SW	-1.854	1.911
R3-SW	-5.474	5.362
R5-SW	-7.407	6.794
R7-SW	-1.344	0.962
R11-SW	-1.251	0.997
North Side		
R2-NW	-1.957	1.522
R4-NW	-6.723	6.387
R6-NW	-4.172	3.581
R10-NW	-2.265	2.203
R13-NW	-1.021	1.169
Sum of Real Time Rack Pressures (psi) Averaged for Each Side		
SUM-WW	-0.550	0.500
SUM-EW	-0.740	0.828
SUM-SW	-3.312	3.047
SUM-NW	-3.064	2.681

Note: The above reported pressures are on the perimeter racks.

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Table NRCQ6.11 Max. Rack Seismic Hydro Pressures - LC#11
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #11 - Mixed Fuel - SSE - Mu = Mixed

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-1.595	2.038
R2-WW	-1.649	2.091
East Side		
R7-EW	-1.773	1.560
R11-EW	-2.573	2.054
R12-EW	-6.048	5.603
R13-EW	-3.290	2.499
South Side		
R1-SW	-3.179	2.417
R3-SW	-8.105	6.179
R5-SW	-6.950	6.892
R7-SW	-1.458	1.411
R11-SW	-2.096	1.857
North Side		
R2-NW	-3.344	2.535
R4-NW	-11.218	8.439
R6-NW	-5.235	4.926
R10-NW	-2.636	2.160
R13-NW	-1.841	1.375

Sum of Real Time Rack Pressures (psi) Averaged for Each Side

SUM-WW	-0.859	1.110
SUM-EW	-1.770	1.435
SUM-SW	-4.227	3.473
SUM-NW	-4.561	3.617

Note: The above reported pressures are on the perimeter racks.

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Table NRCQ6.12 Max. Rack Seismic Hydro Pressures - LC#12
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #12 - Mixed Fuel - OBE - Mu = Mixed

Maximum Rack Pressures Due to Seismic Loading

Rack	Min. Press. (psi)	Max. Press. (psi)
West Side		
R1-WW	-0.427	0.453
R2-WW	-0.329	0.385
East Side		
R7-EW	-0.727	0.683
R11-EW	-1.437	1.378
R12-EW	-2.964	2.354
R13-EW	-1.343	1.223
South Side		
R1-SW	-0.884	0.845
R3-SW	-4.968	3.847
R5-SW	-6.250	4.785
R7-SW	-0.876	0.801
R11-SW	-0.883	1.030
North Side		
R2-NW	-0.737	0.608
R4-NW	-3.948	3.091
R6-NW	-3.349	2.345
R10-NW	-1.220	1.017
R13-NW	-0.497	0.517
Sum of Real Time Rack Pressures (psi) Averaged for Each Side		
SUM-WW	-0.203	0.225
SUM-EW	-0.836	0.736
SUM-SW	-2.679	1.955
SUM-NW	-1.893	1.369

Note: The above reported pressures are on the perimeter racks.

Question No. 7:

Provide a summary of the peak response results (i.e., maximum absolute displacements at the top and bottom of the rack, magnitudes of the bending, shear and axial stresses with their locations, maximum pedestal horizontal and vertical loads, impact loads, etc.) of the single- and multi-rack SSE analyses in a tabular form.

Response:

The 3-D single-rack dynamic model and the 3-D whole pool multi-rack dynamic analysis models, and their intended uses, are described in Sections 3.5 (page 73 of the Licensing Report) and Section 3.5.2.3 (pages 107 to 109 of the Licensing Report). As presented, the 3-D single-rack dynamic model was used for various sensitivity studies. The displacements, loads, and associated stresses are obtained from the 3-D whole pool multi-rack dynamic mathematical model. Therefore, the following results are presented for the multi-rack model only.

The displacements provided in the Licensing Report were relative displacements - between the racks and surrounding racks, or between the perimeter racks and the spent fuel pool wall. The maximum absolute displacements at the top and bottom of the racks are tabulated in the attached Tables NRCQ7.1 through NRCQ7.24, for all load cases.

The rack maximum forces (bending and shear), moments (bending and torsion) are reported in Section 3.5.3.1.8.1, Tables 3.5-67 through 3.5-90 in a tabular form.

The rack maximum bending, axial and shear stresses are reported in Section 3.5.3.1.2.7.

The maximum pedestal horizontal and vertical loads are reported in Section 3.5.3.1.5, Tables 3.5-22 through 3.5-45 in a tabular form.

The maximum fuel to rack impact loads are reported in Section 3.5.3.1.6, Tables 3.5-46 through 3.5-57 in a tabular form.

Table NRCQ7.1 Max. Rack Horizontal Disp. @ Top - LC#1
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #1 - Unconsolidated Fuel - SSE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.25760	0.33280	-0.42080	0.28260
2	-0.28680	0.26240	-0.36870	0.26970
3	-0.29000	0.18640	-0.26200	0.19300
4	-0.25190	0.19140	-0.25300	0.17590
5	-0.38440	0.24140	-0.19250	0.19140
6	-0.35710	0.27190	-0.24400	0.20520
7	-0.59190	0.41610	-0.27550	0.16960
8	-0.55160	0.55660	-0.32230	0.20600
9	-0.58630	0.56700	-0.33660	0.19350
10	-0.53080	0.44060	-0.28250	0.14030
11	-0.52280	0.57350	-0.29340	0.16560
12	-0.49180	0.57140	-0.33350	0.14440
13	-0.50680	0.45750	-0.37800	0.10220

Table NRCQ7.2 Max. Rack Horizontal Disp. @ Base - LC#1
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #1 - Unconsolidated Fuel - SSE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.03724	0.06038	-0.07127	0.04580
2	-0.08373	0.04358	-0.05174	0.05001
3	-0.04396	0.02711	-0.05670	0.03254
4	-0.04533	0.02433	-0.05314	0.03130
5	-0.04523	0.02999	-0.03317	0.03733
6	-0.05074	0.02506	-0.04841	0.03996
7	-0.08194	0.03318	-0.11520	0.01411
8	-0.06622	0.06787	-0.13520	0.01375
9	-0.04845	0.07066	-0.13020	0.00962
10	-0.07122	0.03151	-0.09588	0.00988
11	-0.06686	0.06603	-0.15610	0.00744
12	-0.07009	0.05713	-0.13950	0.01199
13	-0.04091	0.08492	-0.13190	0.00621

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Table NRCQ7.3 Max. Rack Horizontal Disp. @ Top - LC#2
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #2 - Unconsolidated Fuel - SSE - Mu = 0.2

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.20310	0.24260	-0.23770	0.26350
2	-0.20330	0.20100	-0.19230	0.26430
3	-0.17020	0.14690	-0.24880	0.14400
4	-0.16100	0.16980	-0.25310	0.14120
5	-0.16430	0.13740	-0.28210	0.15670
6	-0.17680	0.17760	-0.30480	0.17370
7	-0.36910	0.14020	-0.35310	0.13700
8	-0.31460	0.17830	-0.37400	0.17430
9	-0.39740	0.18650	-0.38660	0.13990
10	-0.22680	0.24660	-0.30850	0.13140
11	-0.46800	0.13850	-0.28450	0.11700
12	-0.47080	0.11450	-0.26690	0.15710
13	-0.27060	0.15340	-0.34380	0.09970

Table NRCQ7.4 Max. Rack Horizontal Disp. @ Base - LC#2
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #2 - Unconsolidated Fuel - SSE - Mu = 0.2

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.07600	0.06355	-0.16120	0.17780
2	-0.09061	0.06818	-0.10310	0.19000
3	-0.03990	0.03548	-0.17800	0.06131
4	-0.05535	0.07545	-0.18220	0.06546
5	-0.05633	0.02840	-0.20670	0.05355
6	-0.07367	0.08071	-0.23090	0.07678
7	-0.26450	0.07782	-0.23310	0.01380
8	-0.23370	0.09739	-0.23790	0.01596
9	-0.31630	0.10490	-0.23890	0.00823
10	-0.14470	0.17440	-0.17410	0.00730
11	-0.40710	0.07303	-0.16430	0.03825
12	-0.41700	0.05288	-0.12700	0.05833
13	-0.18190	0.08832	-0.21120	0.02261

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Table NRCQ7.5 Max. Rack Horizontal Disp. @ Top - LC#3
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #3 - Consolidated Fuel - SSE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.28250	0.34740	-0.34790	0.33030
2	-0.24240	0.28350	-0.30640	0.29540
3	-0.15660	0.16630	-0.22950	0.18970
4	-0.19240	0.19310	-0.21630	0.19670
5	-0.18440	0.17210	-0.21540	0.21510
6	-0.19730	0.19930	-0.24260	0.26420
7	-0.27200	0.29190	-0.21980	0.24110
8	-0.32720	0.35680	-0.29730	0.24860
9	-0.39270	0.36180	-0.31500	0.23560
10	-0.25340	0.25620	-0.23730	0.20660
11	-0.40990	0.47120	-0.28000	0.16950
12	-0.43600	0.44050	-0.25880	0.19930
13	-0.32440	0.30230	-0.32240	0.15130

Table NRCQ7.6 Max. Rack Horizontal Disp. @ Base - LC#3
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #3 - Consolidated Fuel - SSE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.02963	0.08100	-0.06999	0.05401
2	-0.03071	0.02842	-0.06237	0.04588
3	-0.02215	0.02441	-0.04722	0.02990
4	-0.02593	0.02377	-0.04187	0.03227
5	-0.02152	0.02363	-0.03840	0.03303
6	-0.02460	0.02322	-0.03077	0.04759
7	-0.04509	0.05602	-0.04370	0.02714
8	-0.04295	0.06551	-0.08174	0.03714
9	-0.07166	0.03030	-0.09566	0.02131
10	-0.03239	0.05243	-0.04473	0.02635
11	-0.09444	0.02620	-0.08570	0.01601
12	-0.06613	0.04315	-0.06909	0.03757
13	-0.04723	0.05821	-0.07137	0.02015

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Table NRCQ7.7 Max. Rack Horizontal Disp. @ Top - LC#4
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #4 - Unconsolidated Fuel - SSE - Mu = 0.5

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.29140	0.29570	-0.40560	0.27690
2	-0.24370	0.25830	-0.35330	0.25780
3	-0.28440	0.17620	-0.24460	0.16400
4	-0.24970	0.19300	-0.24040	0.16420
5	-0.37750	0.25800	-0.18660	0.17500
6	-0.34400	0.28940	-0.22980	0.20010
7	-0.57590	0.44130	-0.25950	0.16410
8	-0.53350	0.59220	-0.30110	0.20690
9	-0.57660	0.58020	-0.31510	0.19580
10	-0.52700	0.44280	-0.27800	0.13920
11	-0.52520	0.58540	-0.29130	0.14680
12	-0.49170	0.58170	-0.31280	0.14290
13	-0.49680	0.48470	-0.30700	0.14850

Table NRCQ7.8 Max. Rack Horizontal Disp. @ Base - LC#4
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #4 - Unconsolidated Fuel - SSE - Mu = 0.5

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.06448	0.03943	-0.08053	0.03250
2	-0.04869	0.04497	-0.05841	0.05560
3	-0.03082	0.02787	-0.05235	0.03424
4	-0.02337	0.02694	-0.04774	0.03357
5	-0.05038	0.02519	-0.03337	0.03860
6	-0.03523	0.04108	-0.06152	0.04440
7	-0.06854	0.04104	-0.10440	0.01376
8	-0.05219	0.08899	-0.11510	0.01568
9	-0.03128	0.09148	-0.09633	0.00852
10	-0.07351	0.03912	-0.10520	0.00869
11	-0.04714	0.07810	-0.10090	0.01362
12	-0.05441	0.06937	-0.10640	0.00840
13	-0.04132	0.11050	-0.06561	0.01893

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Table NRCQ7.9 Max. Rack Horizontal Disp. @ Top - LC#5
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #5 - Unconsolidated Fuel - SSE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.18990	0.17380	-0.31140	0.32050
2	-0.20260	0.23700	-0.25600	0.33370
3	-0.21380	0.17460	-0.20670	0.22220
4	-0.17870	0.20350	-0.20880	0.21170
5	-0.29270	0.20990	-0.19080	0.18430
6	-0.25300	0.23450	-0.22940	0.21310
7	-0.56010	0.32340	-0.24590	0.17240
8	-0.51250	0.47370	-0.29380	0.22330
9	-0.52430	0.48480	-0.31760	0.22230
10	-0.46080	0.38520	-0.28720	0.16000
11	-0.52940	0.46670	-0.30500	0.13070
12	-0.48790	0.47870	-0.33800	0.13440
13	-0.48880	0.40670	-0.33210	0.15320

Table NRCQ7.10 Max. Rack Horizontal Disp. @ Base - LC#5
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #5 - Unconsolidated Fuel - SSE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.03580	0.04627	-0.07851	0.08393
2	-0.03048	0.03778	-0.03985	0.08068
3	-0.03755	0.02401	-0.03321	0.04379
4	-0.02851	0.02860	-0.03982	0.03519
5	-0.03759	0.02726	-0.03663	0.04251
6	-0.02547	0.04116	-0.04466	0.05161
7	-0.06249	0.05345	-0.06886	0.01393
8	-0.07255	0.07396	-0.07892	0.01529
9	-0.04499	0.06142	-0.11320	0.02185
10	-0.04656	0.04498	-0.09735	0.00944
11	-0.05161	0.07697	-0.12170	0.00730
12	-0.05549	0.08894	-0.12510	0.00820
13	-0.04446	0.08146	-0.10460	0.00609

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Table NRCQ7.11 Max. Rack Horizontal Disp. @ Top - LC#6
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #6 - Consolidated Fuel - SSE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.23050	0.32670	-0.31260	0.35880
2	-0.25070	0.29760	-0.27540	0.32310
3	-0.16650	0.24240	-0.22420	0.19550
4	-0.18690	0.20970	-0.21230	0.18510
5	-0.14570	0.19100	-0.21370	0.20160
6	-0.16020	0.18780	-0.23410	0.24650
7	-0.28190	0.29620	-0.21080	0.23420
8	-0.36950	0.36500	-0.28280	0.24120
9	-0.39160	0.36150	-0.30990	0.23780
10	-0.29210	0.27430	-0.24680	0.19220
11	-0.38140	0.48770	-0.28570	0.15630
12	-0.35640	0.42070	-0.29250	0.18600
13	-0.37140	0.30730	-0.33660	0.14670

Table NRCQ7.12 Max. Rack Horizontal Disp. @ Base - LC#6
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #6 - Consolidated Fuel - SSE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.02900	0.04717	-0.05076	0.10330
2	-0.03887	0.03377	-0.04990	0.07382
3	-0.02250	0.03253	-0.04870	0.03116
4	-0.02394	0.02860	-0.04665	0.03141
5	-0.01934	0.02418	-0.04324	0.03416
6	-0.01997	0.02465	-0.03789	0.04483
7	-0.03452	0.05312	-0.03707	0.02709
8	-0.03769	0.08631	-0.07240	0.03487
9	-0.06204	0.05149	-0.06606	0.02612
10	-0.02691	0.06189	-0.04530	0.02590
11	-0.08069	0.04502	-0.07084	0.00969
12	-0.06606	0.04247	-0.05413	0.01296
13	-0.04278	0.05559	-0.07601	0.01875

Table NRCQ7.13 Max. Rack Horizontal Disp. @ Top - LC#7
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #7 - Unconsolidated Fuel - SSE - Mu = 0.2

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.16800	0.14430	-0.20100	0.31790
2	-0.19030	0.19600	-0.13870	0.29530
3	-0.14140	0.15520	-0.15140	0.19160
4	-0.15330	0.14850	-0.17600	0.16990
5	-0.13170	0.15470	-0.19070	0.15910
6	-0.13850	0.13650	-0.24190	0.19320
7	-0.20840	0.26540	-0.33540	0.13150
8	-0.25400	0.26810	-0.37390	0.17870
9	-0.28070	0.22720	-0.41170	0.14390
10	-0.19430	0.23080	-0.29410	0.14100
11	-0.38570	0.20760	-0.32050	0.11840
12	-0.54530	0.13120	-0.30840	0.14560
13	-0.24120	0.19910	-0.31250	0.13130

Table NRCQ7.14 Max. Rack Horizontal Disp. @ Base - LC#7
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #7 - Unconsolidated Fuel - SSE - Mu = 0.2

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.05906	0.05380	-0.11980	0.24900
2	-0.06482	0.08367	-0.05676	0.21150
3	-0.03077	0.03802	-0.06922	0.11760
4	-0.04402	0.03961	-0.09945	0.09140
5	-0.03820	0.05111	-0.12820	0.07477
6	-0.05557	0.04126	-0.18950	0.10770
7	-0.09401	0.20160	-0.21490	0.01396
8	-0.14690	0.19920	-0.24550	0.02873
9	-0.17890	0.15780	-0.24740	0.00780
10	-0.11120	0.16080	-0.15860	0.01001
11	-0.29860	0.12690	-0.22860	0.01035
12	-0.47840	0.07696	-0.21290	0.02105
13	-0.15870	0.13330	-0.20260	0.03134

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Table NRCQ7.15 Max. Rack Horizontal Disp. @ Top - LC#8
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #8 - Consolidated Fuel - OBE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.11370	0.12630	-0.18140	0.19330
2	-0.11330	0.12120	-0.16620	0.16670
3	-0.07782	0.09454	-0.10110	0.09726
4	-0.07965	0.08075	-0.09862	0.09388
5	-0.06691	0.07764	-0.10910	0.10090
6	-0.07055	0.06913	-0.13020	0.12030
7	-0.13950	0.11230	-0.13890	0.11900
8	-0.14260	0.12930	-0.18670	0.13040
9	-0.17750	0.15580	-0.17680	0.13740
10	-0.11340	0.11080	-0.16160	0.09546
11	-0.21430	0.21500	-0.17720	0.08728
12	-0.23460	0.21000	-0.16030	0.10050
13	-0.17900	0.14510	-0.20540	0.07412

Table NRCQ7.16 Max. Rack Horizontal Disp. @ Base - LC#8
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #8 - Consolidated Fuel - OBE - Mu = 0.8

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.01840	0.01274	-0.02858	0.03217
2	-0.01355	0.01180	-0.02813	0.02744
3	-0.01043	0.00924	-0.01734	0.01667
4	-0.01016	0.01054	-0.01771	0.01487
5	-0.00727	0.00980	-0.02037	0.01845
6	-0.00716	0.01015	-0.02334	0.02099
7	-0.02067	0.01675	-0.01500	0.01485
8	-0.02089	0.01944	-0.02212	0.01655
9	-0.02940	0.01972	-0.01614	0.01291
10	-0.01621	0.01572	-0.01618	0.01084
11	-0.03166	0.03701	-0.02075	0.00847
12	-0.03222	0.03183	-0.02836	0.00446
13	-0.02951	0.01986	-0.02110	0.00904

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Table NRCQ7.17 Max. Rack Horizontal Disp. @ Top - LC#9
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #9 - Unconsolidated Fuel - OBE - Mu = 0.2

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.10670	0.10160	-0.19560	0.13740
2	-0.09604	0.09986	-0.16950	0.16200
3	-0.08225	0.07480	-0.10910	0.07603
4	-0.07036	0.07243	-0.10590	0.07939
5	-0.07050	0.07250	-0.08731	0.08764
6	-0.06763	0.07034	-0.10830	0.09834
7	-0.10050	0.15700	-0.10310	0.08977
8	-0.12450	0.14890	-0.11810	0.09964
9	-0.16780	0.13950	-0.09962	0.11460
10	-0.10710	0.10240	-0.08660	0.08530
11	-0.14200	0.12880	-0.11780	0.07094
12	-0.15780	0.10660	-0.09529	0.09744
13	-0.19130	0.07786	-0.12740	0.05970

Table NRCQ7.18 Max. Rack Horizontal Disp. @ Base - LC#9
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #9 - Unconsolidated Fuel - OBE - Mu = 0.2

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.02387	0.01397	-0.11270	0.05502
2	-0.01530	0.02630	-0.07639	0.09551
3	-0.01889	0.00689	-0.03814	0.01685
4	-0.00885	0.01303	-0.03253	0.01629
5	-0.00655	0.01352	-0.01651	0.02084
6	-0.00820	0.02331	-0.03289	0.02285
7	-0.00659	0.07038	-0.01164	0.01420
8	-0.03091	0.05374	-0.03022	0.01279
9	-0.09305	0.05786	-0.01004	0.03093
10	-0.02025	0.03915	-0.00683	0.02048
11	-0.07416	0.06133	-0.04825	0.00655
12	-0.11550	0.04983	-0.01237	0.02229
13	-0.11360	0.02916	-0.02082	0.00730

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Table NRCQ7.19 Max. Rack Horizontal Disp. @ Top - LC#10
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #10 - Unconsolidated Fuel - OBE - Mu = 0.2

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.14200	0.13680	-0.17300	0.09902
2	-0.11540	0.13340	-0.17490	0.11270
3	-0.07823	0.09438	-0.11040	0.08676
4	-0.08496	0.10960	-0.10800	0.08037
5	-0.08016	0.08358	-0.10670	0.09304
6	-0.08274	0.09461	-0.10430	0.11000
7	-0.11070	0.16890	-0.10380	0.09089
8	-0.11620	0.16780	-0.13110	0.10390
9	-0.17870	0.15250	-0.14890	0.10430
10	-0.14480	0.09360	-0.10690	0.08482
11	-0.11900	0.17610	-0.10420	0.07383
12	-0.20090	0.09320	-0.12120	0.09207
13	-0.20950	0.07103	-0.13520	0.07252

Table NRCQ7.20 Max. Rack Horizontal Disp. @ Base - LC#10
GINNA 3D Whole Pool Model - Without Perimeter Racks
Load Case #10 - Unconsolidated Fuel - OBE - Mu = 0.2

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.03095	0.03006	-0.09498	0.02311
2	-0.02385	0.03886	-0.07780	0.02193
3	-0.01250	0.01011	-0.02894	0.01621
4	-0.01344	0.01401	-0.02704	0.01555
5	-0.01303	0.01195	-0.03653	0.01636
6	-0.00979	0.01194	-0.01566	0.03323
7	-0.00921	0.07850	-0.02239	0.01061
8	-0.00983	0.07407	-0.03278	0.01321
9	-0.08851	0.07162	-0.02074	0.01459
10	-0.06550	0.02948	-0.02159	0.01749
11	-0.03869	0.09176	-0.03615	0.00760
12	-0.15990	0.04029	-0.02132	0.01312
13	-0.14080	0.01560	-0.02246	0.01026

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Table NRCQ7.21 Max. Rack Horizontal Disp. @ Top - LC#11
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #11 - Mixed Fuel - SSE - Mu = Mixed

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.05948	0.19390	-0.27610	0.17710
2	-0.07477	0.20290	-0.20820	0.21940
3	-0.19750	0.02548	-0.11660	0.15300
4	-0.11830	0.15000	-0.14470	0.12360
5	-0.04267	0.22040	-0.17710	0.06950
6	-0.13300	0.18390	-0.16050	0.15850
7	-0.37730	0.14160	-0.07047	0.21700
8	-0.31710	0.21120	-0.18530	0.14650
9	-0.43740	0.34140	-0.25770	0.14450
10	-0.24290	0.20000	-0.15430	0.12330
11	-0.38210	0.37110	-0.20210	0.12490
12	-0.45110	0.37320	-0.25110	0.12960
13	-0.37550	0.32950	-0.28790	0.11450

Table NRCQ7.22 Max. Rack Horizontal Disp. @ Base - LC#11
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #11 - Mixed Fuel - SSE - Mu = Mixed

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.01445	0.05982	-0.15590	0.01150
2	-0.01573	0.04529	-0.10070	0.03121
3	-0.03814	0.00370	-0.03602	0.03054
4	-0.01484	0.01815	-0.03315	0.02177
5	-0.01465	0.02287	-0.03013	0.02401
6	-0.01800	0.02262	-0.03820	0.03220
7	-0.03193	0.05243	-0.01931	0.03262
8	-0.11330	0.00274	-0.09398	0.03485
9	-0.03733	0.05549	-0.10420	0.02030
10	-0.03297	0.08081	-0.06981	0.04140
11	-0.06541	0.02504	-0.06771	0.01611
12	-0.08157	0.03135	-0.06574	0.00541
13	-0.03724	0.06029	-0.08769	0.01894

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Table NRCQ7.23 Max. Rack Horizontal Disp. @ Top - LC#12
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #12 - Mixed Fuel - OBE - Mu = Mixed

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.12800	-0.05099	-0.13840	0.03572
2	-0.02762	0.02608	-0.09272	0.02421
3	-0.03787	0.03915	-0.05966	0.04653
4	-0.03407	0.03728	-0.04433	0.04576
5	-0.10000	-0.00996	-0.02910	0.08573
6	-0.10610	-0.00685	-0.04246	0.09343
7	-0.07496	0.10240	-0.04333	0.07983
8	-0.12220	0.12010	-0.10590	0.07594
9	-0.13640	0.16730	-0.11620	0.07165
10	-0.07718	0.09392	-0.10030	0.04885
11	-0.18440	0.18660	-0.12090	0.06964
12	-0.22110	0.15880	-0.22060	-0.01558
13	-0.14960	0.11520	-0.16270	0.06942

Table NRCQ7.24 Max. Rack Horizontal Disp. @ Base - LC#12
GINNA 3D Whole Pool Model - With Perimeter Racks
Load Case #12 - Mixed Fuel - OBE - Mu = Mixed

Maximum Rack Horizontal Displacements (X and Y - (in))

Rack	Min X	Max X	Min Y	Max Y
1	-0.01067	0.00032	-0.02250	0.01146
2	-0.01613	0.01311	-0.08309	0.01242
3	-0.00473	0.00567	-0.01409	0.00958
4	-0.00827	0.00950	-0.01946	0.01329
5	-0.01120	0.00375	-0.00882	0.01935
6	-0.01198	0.00319	-0.01166	0.01812
7	-0.00469	0.07092	-0.00503	0.03917
8	-0.02037	0.01650	-0.01667	0.01072
9	-0.02629	0.01897	-0.02377	0.00620
10	-0.00686	0.04084	-0.04963	0.00555
11	-0.03173	0.01917	-0.01639	0.00689
12	-0.02413	0.03670	-0.06873	-0.00189
13	-0.02462	0.01230	-0.01833	0.00719

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Question No. 8:

If there is an impact between a rack and a reinforced concrete spent fuel pool (SFP) wall:

a) *Provide the magnitude of the hydrodynamic pressure used in the SFP concrete wall analysis.*

b) *Provide the temperature profiles with magnitudes used for the SFP slab and walls analyses.*

c) *Provide the calculated safety margins for the four walls and the slab with respect to the bending and shear strength evaluations.*

d) *If the ANSYS code was used for the analyses of the SFP walls and slab, provide a technical explanation on how the effects of reinforcement and concrete cracking is reflected in the computer modeling simulations. Submit the complete input including the ANSYS model with all boundary and loading conditions used for the SFP analyses of the walls and slab on a 3.5-inch diskette.*

Response:

The gaps between the racks and between the racks and the walls are designed such that for any of the seismic (OBE and SSE) events, the racks do not impact the spent fuel pool wall. This is true for both resident U.S. Tool and Die racks and also for the new ATEA racks. This is discussed in Section 3.1, "Scope," Section 3.2.2, "Acceptance Criteria," and Section 3.5.3.5, "Conclusion," of the Licensing Report.

The results of all the 3-D whole-pool multi-rack model runs demonstrated that there were not any rack-to-pool wall impacts (nor any rack-to-rack impacts) from any of the analyses. Further, as stated in Section 3.5.3.1.14 on page 279 of the Licensing Report, there were no impacts after the cumulative effects of 5 OBE's plus 1 SSE.

The minimum rack to pool wall gaps existing after the cumulative effects of 5 OBE's plus 1 SSE were as follows:

West Wall:	9.434 in
East Wall:	2.686 in
South Wall:	4.516 in
North Wall:	1.184 in

The above numbers were taken directly from Tables 3.5-137 and 3.5-138 on page 282 of the Licensing Report.

Question No. 9:

Indicate whether there were rack-to-pool wall and/or rack-to-rack impacts from the multi-rack analysis.

Response:

The gaps between the racks and between the racks and the walls are designed such that for all of the seismic (OBE and SSE) events, the racks do not impact the spent fuel wall nor the racks impact any other racks. This is true for both resident U.S. Tool and Die racks and also for the new ATEA racks. This is discussed in Section 3.1, "Scope," Section 3.2.2, "Acceptance Criteria," and Section 3.5.3.5, "Conclusion," of the Licensing Report.

In summary, there were neither any rack-to-rack nor any rack-to-pool wall impacts from any of the analyses. Further, as stated in Section 3.5.3.1.14 on page 279 of the Licensing Report, there were no impacts after the cumulative effects of 5 OBE's plus 1 SSE.

Question No. 10:

Submit the ANSYS input data on a 3.5-inch diskette for the weld analysis, the fuel/rack impact analysis and the rack thermal stress analysis as mentioned in the Reference.

Response:

The listing of the computer input data is provided on a 3.5-inch computer diskette in ASCII format. These input are for the ANSYS Version 5.2. These data are proprietary.

The weld stress analysis is discussed in Section 3.5.3.1.3. The weld stress analysis was performed using classical equations. The computer program ANSYS was not used.

The Disk Files Include:

Disk ANSYS Input Files,	File FUELLOAD.TXT	Fuel Rack Impact Model
	File S3DPR8TO.TXT	Rack Thermal Stress Model

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Question No. 11:

Discuss the quality assurance and inspection programs to preclude installation of any irregular or distorted rack structure and to confirm the actual fuel rack gap configurations with respect to the gaps assumed in the ANSYS analyses after installation of the racks.

Response:

The Quality Assurance procedures are discussed in Section 7.0 of the Licensing Report. Section 7.2.13 discusses the procedures for the Handling, Storage, and Shipping. Section 7.2.14 discusses the procedures for Inspection, Tests, and Operating Status. This section also discusses installation and testing.

The following QA/QC actions will assure that the fuel racks are properly fabricated and installed:

1. Dimensional inspections of the racks, by ATEA Quality personnel, will occur during the rack fabrication. A Source Inspection will be performed by FTI QC on the fuel storage racks prior to shipment from ATEA in accordance with an inspection plan prepared by FTI. This inspection will verify that the racks meet drawing requirements, and will check for warpage and distortion.

   a) The results of the inspections will be documented on an inspection report.

   b) Non-conforming conditions will be presented to ATEA for corrective action, in accordance with the ATEA QA Program. FTI will follow-up on the disposition of the ATEA non-conformance reports and, if required, reinspect the fuel rack assemblies.

   RG&E QA will perform surveillance of the inspection and preparation for shipment activities to provide additional assurance that the racks are fabricated as required.

2. Following shipment to Ginna and prior to installing the fuel racks, a receipt inspection will be performed to check for shipping damage.

3. The installation of the fuel racks will be in accordance with the RG&E-approved FTI Safety-Related QA Program.

4. A Traveler/Installation Procedure and installation drawings will be used to install the racks. The Traveler/Procedure will provide detailed instruction to sequence the installation and provide documentation (measurements, verifications, sign-offs for step completion, etc.) to show that the racks are properly installed. The Traveler/Procedure will include in-process QC HOLD points to verify critical installation steps and measurements and allow for RG&E HOLD points. These procedures will be prepared by the cognizant FTI Engineering organization, in accordance with the FTI QA Program, approved by FTI QA, and provided to RGE for concurrence.

5. Personnel will be trained and certified, as required by the FTI QA Program. The

5. Personnel will be trained and certified, as required by the FTI QA Program. The installation crew will receive mock-up training, pre-job briefings, and other task-specific training, as required to support the task.

6. FTI QA/QC will perform a final inspection and detailed review of the installation procedure and supporting documentation at the completion of the task to verify that the work was done in accordance with the applicable procedure(s) and the FTI QA Program.

7. In-process and final inspection will be performed in accordance with approved installation procedures and drawings. Lack of distortion and gap configuration will be a requirement of the installation process. Specific details that address distortion, irregularities, and gap configuration in accordance with the Structural Evaluation in the Licensing Report will be developed and approved prior to installation of the racks.

8. All installation activities will be subject to oversight and assessment by RG&E QA, in addition to FTI oversight activity.

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Question No. 12:

Provide the locations of the leak chase systems with respect to the locations of the racks and pedestals.

Response:

The ATEA Drawing described below provides the location of leak chases and also the location of rack support pads. The reference drawing provides support pad locations for both the resident spent fuel storage racks and the new ATEA racks.

ATEA Drawing No. SA20.001.00000, Sheet 2 of 2, Revision D (Framatome Technology Drawing No. 02-1186074F-03). Title, "Rochester Gas & Electric Co., R.E. Ginna Nuclear Power Station No 1, General Arrangement Support Pads Location."

Question No. 13:

Describe the method of leak detection in the SFP pool structure. How are leaks monitored? Is there any existing leakage?

Response:

The leak detection system consists of a grid of rectangular indentations in the concrete behind the steel liner, located in the floor of the spent fuel pit and refueling canal. They were formed during the initial construction of the pit. The grid is arranged such that any leakage is channeled to a collection chamber, which is periodically checked and drained of any collected borated water, which undergoes treatment.

There has been a history of leakage from the spent fuel pit/refueling canal area, and RG&E believes it has been determined that the source of the leakage is in the refueling canal. RG&E is taking measures to stop this leakage and will monitor the leakage again at our next scheduled refueling outage (the refueling canal is normally empty during normal plant operations.)

<u>Question No. 14</u>:

Indicate whether or not you are planning to place an overhead platform on the racks permanently or as temporary storage during the installation of the racks.

<u>Response</u>:

There is no plan to place an overhead platform on the racks either permanently or as temporary storage during rack installation.

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Question No. 15:

Was the rack design controlled mainly by the results of the single-rack analysis? If yes, was there any physical rack design change necessitated by the results of the multi-rack analysis? As applicable, describe the change(s).

Response:

The 3-D single-rack dynamic analysis model and 3-D whole-pool multi-rack dynamic analysis models and their intended use are described in Section 3.5 (page 72 of the Licensing Report) and Section 3.5.2.3 (pages 106 to 109 of the Licensing Report). As described, the 3-D single-rack dynamic mathematical model is used for various sensitivity studies. The loads, displacements, and associated stresses are obtained from the 3-D whole-pool multi-rack dynamic mathematical model. The length and location of tabs, the weld size, the weld size of support legs, etc., are designed from the loadings and stresses from the 3-D whole-pool multi-rack dynamic analysis. The gaps between the racks and the gaps between the rack and the wall are designed to preclude any impact from the results of the 3-D whole-pool multi-rack dynamic analysis.

The single-rack model was used for parametric studies. The whole-pool multi-rack model was used for the loads and displacements. Therefore, the rack design was not controlled by the results of the single-rack analysis. There were several items that were modified based on the results of the multi-rack analysis. Those items are as follows:

a) Rack base plate welds were adjusted to ensure adequate design margins.

b) Rack inter-connecting tabs and associated welds were adjusted to ensure adequate design margins.

Question No. 16:

Describe the plan and procedure for the post-operating basis earthquake inspection of fuel rack gap configurations.

Response:

RG&E has seismic instrumentation located in the sub-basement of the Intermediate Building. That instrumentation will activate and record various data of the event, the purpose of which is to determine if an Operating Basis Earthquake has occurred. That data is processed by way of the Technical Engineering Guidelines TEG 2.0, "Response Spectrum Calculation," and TEG 2.1, "SSE and OBE Exceedance Determination". Upon processing of the data, and if an Operating Base Earthquake had occurred, a detailed structural engineering inspection would be conducted to determine if any structural damage did occur. Although inspection of the gaps is not specifically identified as a requirement of this inspection, the spent fuel pit and the condition of the spent fuel racks/fuel assemblies would receive close scrutiny. These inspections would be performed by Professional Engineers experienced in seismic analyses/design and also trained as Seismic Capability Engineers, per requirements of the Seismic Qualification User's Group (SQUG) Generic Implementation Program.