MAINE YANKEE ATOMIC POWER COMPANY •

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JHG 81-165

EDISON DRIVE
AUGUSTA, MAINE 04336
(207) 623-3521

July 28, 1981
FMY 81-112

United States Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Office of Nuclear Reactor Regulation
Division of Licensing
Mr. Robert A. Clark, Chief
Operating Reactors, Branch No. 3

Reference: (a) License No. DPR-36 (Docket No. 50-309)
(b) Letter Maine Yankee Atomic Power Co. to USNRC dated June 3, 1981 (FMY 81-87)
(c) USNRC Letter to MYAPCo dated March 12, 1981
(d) UNSRC Letter to MYAPCo dated April 29, 1981

Subject: Maine Yankee Fuel Storage Modification

Dear Sir:

Enclosed herewith are responses to the vendor design specific questions which were not available at the time of our letter, Reference (b). This information completes our obligations in response to your letters References (c) and (d).

As discussed in our letter, Reference (b), MY intends to assemble in the form of a complete report all the aspects of the spent fuel storage concepts for your convenience.

NRC mandated action items have forced us to reschedule this complete report several times. We believe about two more weeks will be required to complete our submittal.

As we have indicated informally to your staff, the final spent fuel rack design will utilize 10.25 inch center to center spacing rather than the 10.50 inch center to center spacing previously described. This is a fine tuning of the rack design which will allow us to more closely approach the upper limit of 1500 permanent storage locations assumed in previous analyses. This design refinement will be fully reflected in the complete report described above.

Sincerely,

MAINE YANKEE ATOMIC POWER COMPANY

John H. Garrity

John H. Garrity, Director
Nuclear Engineer & Licensing

JHG/plb

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Maine Yankee Atomic Power Company

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14. Question

Provide sufficient details (discussion, sketches and schematics) of the racks, rack base supporting structures, racks arrangement in the pool, the spent fuel pool, and all gaps (clearance and expansion) of the rack structure and fuel bundles.

Response

See Attachment I, Section 3.0, 3.1 and 3.2; and Drawing No. P-31146-D, sheets 1 and 2.

7/28/81

19. Question

Provide the load combinations, the acceptable criteria and the reference standards or papers used in the design of the spent fuel racks. Also, provide a discussion on the fabrication techniques (including welding) that will be used during the construction of the racks.

Response

See Attachment I, Section 3.0, Section 4.1.1, Section 4.1.2, and Section 6.0.

7/28/81

21. <u>Question</u>

Provide step by step detailed discussion on how the seismic effects on the racks have been considered. Provide, also, a discussion on the sliding and stability of the racks, the friction forces due to the sliding, the floor response spectra or time history, the damping values and applicability of Regulatory Guide 1.92.

<u>Response</u>

See Attachment I, Section 4.0 and Section 5.0.

7/28/81

22. Question

Due to the gaps between assemblies and the wall of the guide tubes, additional loads will be generated by the impact of the fuel assemblies during a postulated seismic excitation and sliding. Provide the justifications and the numerical values of these dynamic magnification factors due to the impact. Provide, also, sufficient details describing the gaps, the guide tubes and the boundary conditions of the fuel bundle inside the guide tubes.

Response

See Attachment I, Section 4.0, Section 5.0, and Figure 3.1.

7/28/71

23. Question

With regard to the issue of heavy drop accident (straight, through, and inclined) over the spent fuel racks, provide the following:

a. Sketches, schematics and discussions regarding the shape of the impact area.

b. Detail justification on why there will be no geometric distortion of the racks and how the structural criteria established for this case can be met.

Response

See Attachment 1, Sections 4.3 and 4.4.

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25. Question

Provide a detailed discussion of the analysis used to calculate the stresses due to the fuel handling uplift accident, thermal loads, dead loads and friction loads. The model used and the assumptions made should also be provided.

Response

See Attachment I, Section 4.0.

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26. Question

Due to thermal or seismic movement, friction forces will be present between the racks and the fuel pool liner. Discuss how these friction forces have been incorporated in the analysis. Provide also the numerical values with justifications of the coefficient of friction used in the analysis.

Response

See Attachment I, Section 4.0 and Section 5.0.

27. Question

Provide design details to allow us to evaluate the compatibility of the materials of construction and the poison material in the redesigned racks with respect to galvanic and other corrosion processes.

Response

See Attachment I, Section 3.0.

7/28/81

28. Question

If venting of the "containment pocket" for the poison material is not provided, explain the method used to mitigate the effects of gas buildup.

Response

The design includes boral in sealed cans. Sealed boral has been used extensively in high density storage racks for several years, most recently in the stainless steel racks at the Segouyah generating station which are very similar to the proposed Maine Yankee racks.

Leakage of water into the stainless cavity due to a weld failure or the presence of extensive moisture on the boral during assembly can be eliminated by proper manufacturing controls. Visual examinations will be conducted on the seam welds in accordance with ASME Codes and also leak check tests will be performed on the storage cavities to verify the seam weld integrity. Without the presence of water in the cavity, hydrogen gas which results from the corrosion of aluminum in contact with stainless steel, cannot be generated.

In addition, the Maine Yankee design utilizes the inner wall can as the structural member, so in the unlikely occurrance of leakage and subsequent gas generation, the outer skin would slightly bow. In this case, the fuel bundle would not become wedged into the can and the boral would not be mislocated.

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IV. MECHANICAL AND STRUCTURAL CONSIDERATIONS

1.0 Introduction

This section contains the description and structural evaluation of new spent fuel storage racks.

Section 2.0 of this document is a summary. Section 3.0 includes a physical description of the racks and a description of Quality Assurance Program for the rack fabrication. Section 4.0 describes the design basis analytical models and the results for the structural analysis for the spent fuel storage racks at the Sequoyah Generating Station. Section 5.0 is a justification of the spent fuel storage rack design for Maine Yankee based on the analysis done on the Sequoyah racks with the different design conditions between the two taken into account.

TABLE OF CONTENTS

2.0 SUMMARY

The high density fuel racks are of a welded stainless steel construction containing a neutron absorbing medium of natural Boron Carbide (B_4C) in an aluminum matrix core clad with 1100 series aluminum. This neutron absorber is marketed under the trade name of boral. The boral is sealed within two concentric square stainless steel tubes hereinafter called "Poison Cans". The B-10 areal density of the boral is .0256 G/CM^2.

Applicable Federal Regulations, Nuclear Regulatory Commission

(NRC) Regulations and the latest industry standards were used as design basis for the structural seismic design of the racks.

The racks shall be designed and fabricated to meet the requirements of Yankee specifications and applicable portions of the NRC Regulatory Guides and Published Standards such as, but not limited to, the following references of Section 6.0.

3.0 DESCRIPTION OF PROPOSED HIGH-DENSITY SPENT FUEL RACKS

The proposed rack modules will be free standing and are thus free to slide or rock on the floor during a seismic event. Since the modules are not tied together, they could also interact during a seismic event. The sliding, rocking, and interaction analyses are discussed further in Para. 4.0.

The advantages of this type of restraint system are:

1) Uplift loads are eliminated on any pool floor embedments.
2) Horizontal forces are reduced relative to a vertically restrained rack.
3) All modules are designed to be independently self-supporting.
4) Individual modules can be removed and installed with a minimum of effort.

3.1 Module Construction (Drawing No. P-31146-D, Sheets 1,2)

The proposed spent fuel storage racks are a poisoned design. The rack module is composed of poison canisters and a bottom grid. Except for the neutron absorber, and the 17-4 pH alloy feet, all rack materials are fabricated from 300 series stainless steel. (See pg. 3-4)

Poison canisters are die-formed at the top and welded together at the top to form the top grid. These canisters also provide lead-in surfaces for the fuel.

The poison canisters are also welded to the bottom grid. The fuel support surfaces and fuel rack support feet are integral to the bottom grid. The feet can be adjusted to facilitate leveling at installation.

The nominal interior square width dimension of the fuel canister will be 8.75 ± .06 inches to accomodate the fuel.

Each poison canister prior to shipment will be checked by a full length dummy fuel assembly 8.500 x 8.500 -0 +.03 inches which will account for the combined cross-sectional tolerance, straightness, twist, and opening squareness.

The poison canister consists of two concentric stainless steel tubes with Boral in the annulus. The outside tube is welded to the inside canister at the top and bottom.

Note that only the inside canister tube is used as a structural element. The outer tube will be 0.036 inches thick.

3.2 RACK FABRICATION

The storage racks will be fabricated in accordance with the detail drawings and specifications established during the design phase.

All structural welding on the racks will be either gas metal-arc welding {GTAW (MIG)} or gas tungsten arc welding {GTAW (TIG)}. These weld processes give clean spatter-free welds with good penetration and no slag formation.

The outer tube will be MIG-welded to the inner canister.

The individual cavities will be welded on special fixtures to maintain required squareness and dimensional tolerances. The module structures will then be welded together using a special fixture to assure that the assembly is square and properly aligned.

The racks will be cleaned and completely wrapped with reinforced plastic and skid-mounted. The racks will be covered with tarp and shipped by motor freight.

All materials used in the rack construction are of U.S. origin. The following charts present materials, alloys, and material specifications used in the spent fuel module assembly.

Description	ASTM Standard	Alloy
Bottom Grid	A240 or A276	304L SS
Poison Can		
Inner Tube	A-666-72 Grade B	304 SS
Outer Tube	A-666-72 Grade B	304 SS
Boral		1100 Alum. and B_4C
Threaded Foot	A-564-66	17-4-PH H-1100

The clear space under the rack is at least 4.25 to allow for coolant flow under the racks.

Module weights and dimensions -

Module Size	Width (in)	Length (in)	Dry Wt (lb) Empty)
6 x 9	61.5	92.25	16,200
6 x 8	61.5	82	14,400
7 x 8	71.75	82	16,800
6 x 6	61.5	61.5	10,800
7 x 9	71.75	92.25	18,900
8 x 9	82.0	92.25	21,600

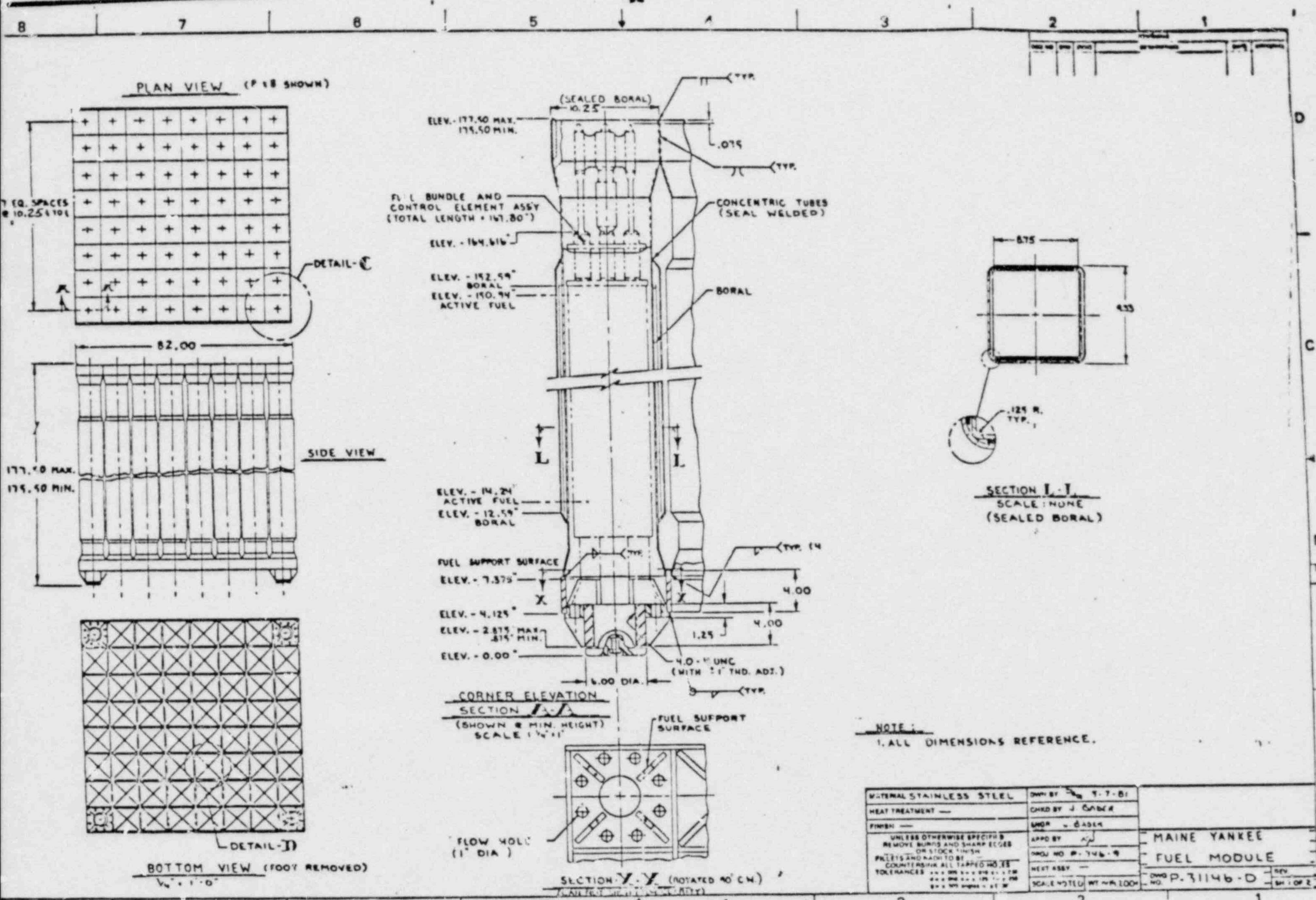
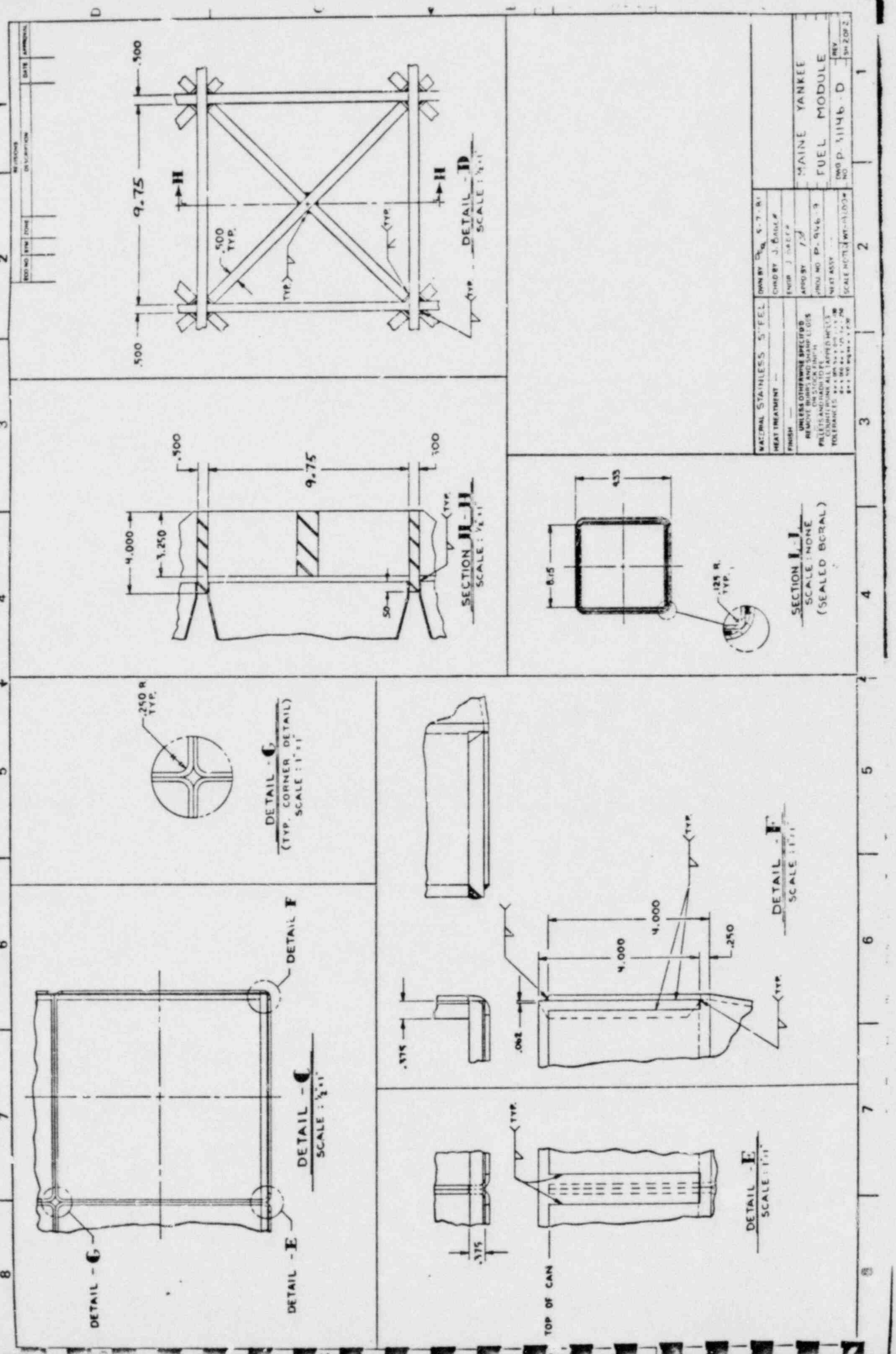
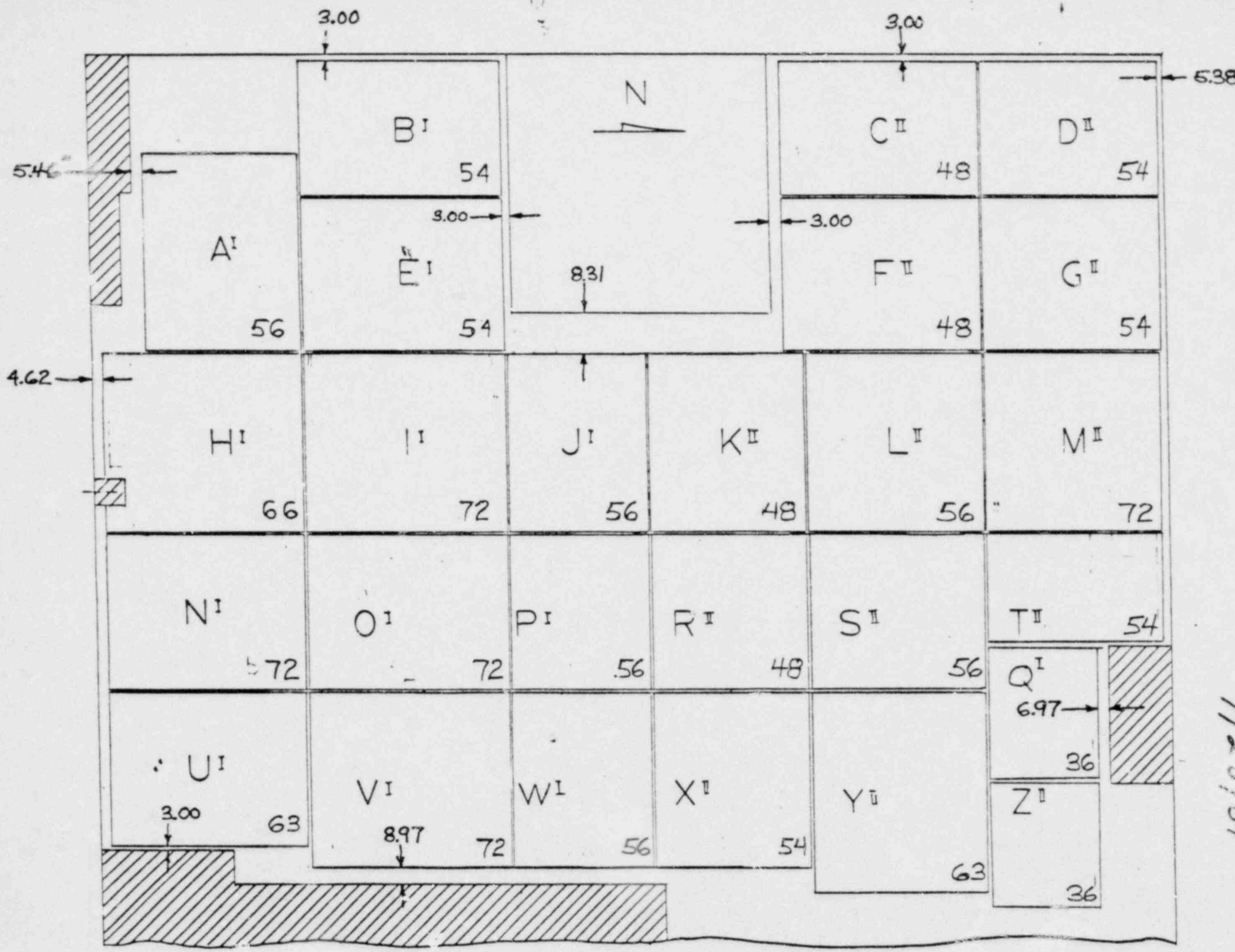

PLAN VIEW (P 18 SHOWN)
DETAIL-C
82.00
SIDE VIEW
177.50 MAX.
175.50 MIN.
DETAIL-D
BOTTOM VIEW (FOOT REMOVED)
(SEALED BORAL)
10.25
ELEV. - 177.50 MAX.
175.50 MIN.
.075
CONCENTRIC TUBES
(SEAL WELDED)
ELEV. - 164.616"
ELEV. - 152.59"
BORAL
ELEV. - 150.94"
ACTIVE FUEL
BORAL
ELEV. - 14.24"
ACTIVE FUEL
ELEV. - 12.59"
BORAL
FUEL SUPPORT SURFACE
ELEV. - 7.375"
ELEV. - 4.125"
ELEV. - 0.00"
4.00
4.00
1.25
6.00 DIA.
CORNER ELEVATION
SECTION A-A
(SHOWN @ MIN. HEIGHT)
FUEL SUPPORT
SURFACE
FLOW HOLE
(1" DIA)
SECTION Y-Y (ROTATED 45° C.W.)
.875
.125 R.
TYP.
SECTION L-L
SCALE: NONE
(SEALED BORAL)
NOTE:
1. ALL DIMENSIONS REFERENCE.
MATERIAL STAINLESS STEEL
HEAT TREATMENT —
FINISH —
CHKD BY J. GABER
MAINE YANKEE
FUEL MODULE
P.31146-D

FIGURE 3.1

FIGURE 3.2


DETAIL - D
SCALE : ½:1
9.75
.500
SECTION H-H
4.000
3.250
DETAIL - G
(TYP. CORNER DETAIL)
SCALE : 1:1
.250 R TYP.
DETAIL - C
DETAIL - G
DETAIL - E
DETAIL F
DETAIL - F
SCALE : 1:1
DETAIL - E
SCALE : 1:1
TOP OF CAN
SECTION I-I
SCALE : NONE
(SEALED BORAL)
.125 R. TYP.
MATERIAL STAINLESS STEEL
MAINE YANKEE
FUEL MODULE



① 1" NOMINAL SPACING BETWEEN RACKS

FIGURE 3.3

7/28/81

4.0 STRUCTURAL ANALYSES

4.1 Basis for Analyses

The high density spent fuel storage racks are Seismic Category I equipment as defined in Nuclear Regulatory Commission (NRC) Regulatory Guide 1.13. These racks are designed to withstand the effects of a Design Basis Earthquake (DBE) and remain functional, in accordance with NRC Regulatory Guide 1.29 and the Code of Federal Regulations, Title 10, Part 50.

The structure of the racks is designed to remain functional and to maintain the required spacing between stored fuel assemblies in the event of impact of a fuel bundle dropped on the racks from an elevation of 18 inches (maximum). In this case, local plastic deformation is allowed at the point of impact. The structure of the racks is also analyzed for effects of the impact of a fuel bundle dropped through an empty storage cavity. Failure of a vertical fuel support is allowed in this case. A comparative analyses with the impact conditions, as stated above is also conducted on a rack due to maximum uplift (5,000 lb.) of the refueling crane on a fuel bundle which is stuck. No permanent deformation is allowed in this case.

All member and plate stresses for the above conditions are within the factored combination stress limits of Table 4-1.

4.1.1 Load Combinations and Allowable Stresses

The following load combinations result in rack stresses that are within the following stress limits:

TABLE 4-1

Load Combinations	Stress Limits
1. D + L + T + P	F_s
2. D + L + T + H	F_s
3. D + L + T + E	F_s
4. D + L + T + I	
Condition 1	1.6 F_s
Condition 2	1.6 F_s
Condition 3 (See Note 1)	1.6 F_s
Condition 4	1.6 F_s
Condition 5	1.6 F_s
5. D + L + T' + E'	1.6 F_s

NOTE

(1) Local failure of fuel support is allowed, however, overall member stress shall be limited to 1.6 F_s.

Where:

F_s = Normal allowable stress according to paragraph 4.1.2.

D = Dead load of racks including the support framing

L = Live load due to the weight of fuel assemblies which shall be considered as varying from zero to full load, and loadings corresponding to varying placement of the fuel assemblies in the rack shall be considered so that the most critical loads are obtained.

T = Thermal loads for water temperature equal to 150°F The minimum water temperature is 40°F.

P = Lifting force of 5,000 pounds applied to the top of rack at any fuel bundle location.

H = Horizontal force of 1000 pounds applied to the top of rack at any fuel bundle location and at a varying angle from 0° to 45° from the horizontal.

E = Loads and resulting forces and moments generated by the Operating Basis Earthquake, (OBE) resulting from ground surface horizontal acceleration and vertical ground surface acceleration acting simultaneously.

E' = Loads and resulting forces and moments generated by the Design Basis Earthquake (DBE) resulting from ground surface horizontal acceleration and vertical ground surface acceleration acting simultaneously.

T' = Thermal loads for loss of coolant condition corresponding to pool surface temperature equal to 212°F.

I = Impact load resulting from the following conditions:

Condition 1- 18" fuel bundle drop above the rack impacting on middle of the welded cavities.

Condition 2- 18" fuel bundle drop above the rack impacting on the corner of the top portion of the cavities.

Condition 3- 18" fuel bundle drop above the racks free falling through an empty cavity and impacting the bottom grid

Condition 4- The inclined fuel drop assumes that the fuel bundle strikes the top of the rack with a maximum horizontal velocity of the crane

Condition 5 - After the fuel bundle has dropped vertically on to the top of the rack the fuel will roll over and hit the top of the rack

4.1.2 Allowable Stresses (For Stainless)

The allowable stresses shall be in accordance with ASME Boiler and Pressure Vessel Code Section III, Appendix XVII. This is interpreted as being identical to the AISC Steel Construction Manual, (Section 5).

The 1/3 increase in allowable stress for emergency condition is not allowed. The increase in allowable stress is defined by paragraph 4.1.1.

4.2 Seismic Analyses

A time history analysis is performed by using the computer program ANSYS (Engineering Analysis System). ANSYS is documented by a User's Manual, published by Swanson Analyses Systems, Inc., Elizabeth, PA. A static seismic analysis is performed by using the computer program SAPIV. The development and documentation of SAPIV was sponsored by the National Science Foundation and is available as Report EERG 73-11 from the Earthquake Engineering Center at the Univeristy of California.

4.2.1 ANSYS Seismic Model

To consider the effects of module rocking, interaction and fuel rattling, the double rack ANSYS model is used and is shown on Figure 4-1. Section No. 1 of this model represents the mass and stiffness of all the fuel assemblies and extends the height of the rack. It is pinned at the bottom of the rack and is allowed to impact at the top and middle third points. Gap elements are located at these impact points which represent the fuel assembly clearance. The section properties of the fuel assembly are used for this element. Note, this model conservatively assumes that all fuel assemblies are in phase and move toghether at all times.

Section No.2 and 3 represent the composite rack stiffness. The section properties and constraints of these members will be sized so that the primary frequencies correspond to the detail model when the fuel gap goes to zero. The bottom grid legs are represented by section No. 4. The vertical spring under each leg is known as a "gap spring". The gap spring element represents two plane surfaces which may maintain or break physical contact. At each time step, the program checks for leg tensile forces; if they exist, the program releases the leg vertical restraint, allowing top uplift and rocking.

A single vertical degree of freedom spring represents the pool floor vertical stiffness. The spring rate is rigid at 33 HZ and using the mass of both racks. A horizontal spring at the floor represent the rack seismic support grid stiffness.

A structural damping of 2% (SSE) and 1% (OBE) for welded steel structures was used. No increase in damping will be included for water submergence.

The external hydrodynamic water mass determination is based upon a paper by R.J. Fritz entitled "The Effects of Liquids On The Dynamic Motion of Immersed Solids" Journal of Engineering for Industry, February 1972. All internal water entrapped within the rack envelope is added to the horizontal mass.

The double rack model includes module interaction or potential for banging with other racks in the pool. Gap springs are located at the top rack elevation and initially have the maximum rack to rack clearance. This model assumes that the largest interaction occurs for a pair of racks because their rocking motion away from each other is unconfined by adjacent modules.

The digitized time histories are generated artificailly utilizing computer program, SIMQKE, developed under the auspices of the National Science Foundation.

The following four time histories were generated using the design response spectrums.

1) 1.0% OBE Horizontal
2) 2.0% SSE Horizontal
3) 1.0% OBE Vertical
4) 2.0% SSE Vertical

The horizontal response spectrums 1 and 2 above were based on the E-W spectrum since it is the worst of the N-S and E-W directions.

The generated time histories have a duration of 15 seconds digitized at an interval of 0.01 seconds.

Complete nodal force sets at time increments when critical nodal maximums occur, are tabulated from this time history analysis and used in the static analysis as described in paragraph 4.2.2. These equivalent nodal loads are calculated from the ANSYS internal stress information. In doing so these equivalent nodal loads when applied to the structure will produce the same internal forces and moments as generated during particular times of the time history analysis.

4.2.2 SAPIV Finite Element Model

Figure 4.2 is an isometric drawing of the SAPIV finite element computer nodal. Maximum equivalent nodal forces for the seismic analysis are determined from the ANSYS time history analysis, para. 4.2.1. These horizontal and vertical static forces are applied to the SAPIV model in the same manner as in the ANSYS time history model. An equal load set is applied in an orthogonal plane and an SRSS is computed for these two load sets.

4.2.3 ROCAN T.H. Model Description

In this program, the rack is idealized as a non-linear torsional system as shown on Figure 4.2.1.The model accounts for an unsymmetrical fuel configuration as shown on Figure 4.2.2. Based on the fuel and rack weights and the rack dimensions, the overall C.G. is located. For this configuration the maximum righting moment about either the right (MRR) or left legs (MRL) is determined.

The horizontal flexibility of the rack is accounted for by a non-linear torsional spring (KT) whose equivalent spring rate is delineated on Figure 4.2.3. As shown, a cut-off value in righting moment is applied for uplift about each rack foot. Therefore, the righting moment, MR, is equal to KT (torsional spring rate) times the angular displacement for MRR $\leq$ MR $\leq$ MRL. (MRL and MRR are the righting moments about the left and right legs respectively. After uplift, they are equal to the rack weight times the horizontal C.G. distance.)

Horizontal and vertical acceleration time histories can be inputted into the model simultaneously. Both of these accelerations are used in determining the total overturning moment, "MO".

The rack angular accelerations are then determined from a torque balance, which is then integrated to determine velocities and displacements. However, in the integration the following non-linear characteristics are included:

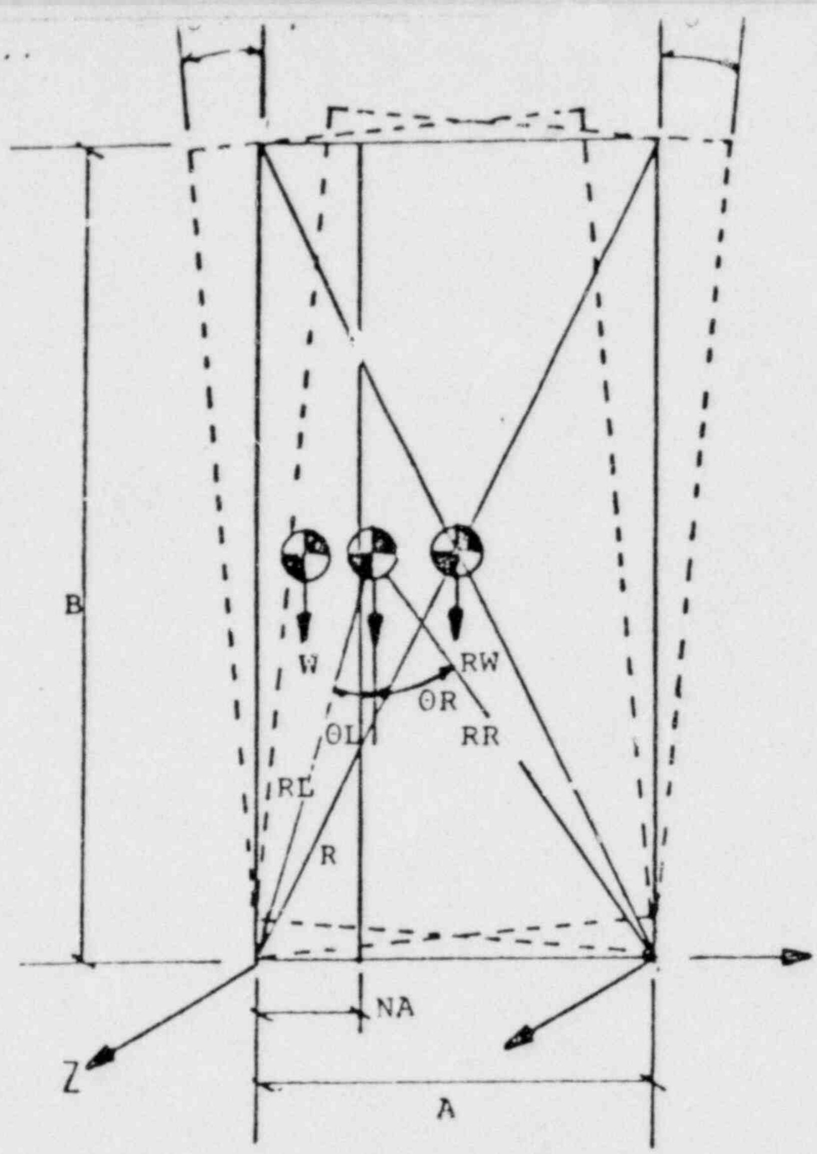
1) Changes in righting and overturning moments due to changes in displacement.
2) Changes in righting moment due to uplift.
3) Changes in moment of inertia based on which foot the rack is uplifting on.
4) Changes in torsional damping; after uplift, the damping is set equal to zero.

In addition the model accounts for horizontal sliding. At each time step the base reactions are calculated and compared against the maximum friction force. If sliding occurs, the overturning moment is corrected and new values of angular accelerations and base reactions are computed. This iteration process is continued until convergence is achieved.

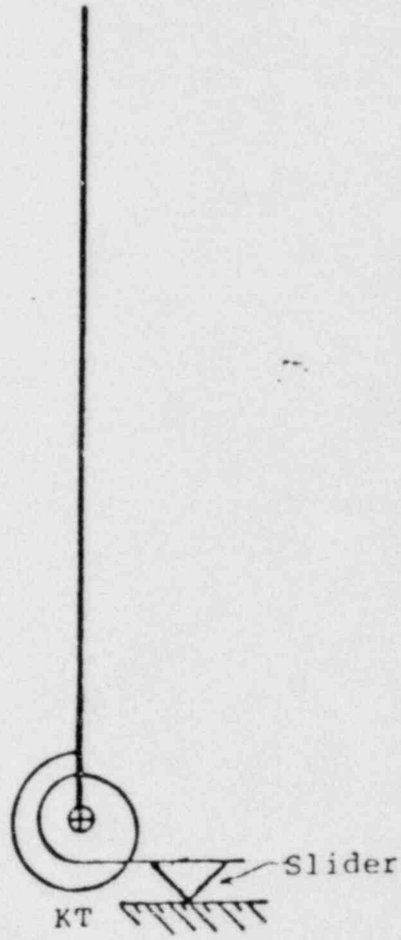
Since uplift will result in local foot impact, impact loads are approximated based on the maximum energy resulting from the peak maximum and minimum angular velocity computed during the response. The loads are summarized at the completion of the response.

The program is applicable for submerged racks where the fluid motion is either in phase or out of phase with the support motion. For out of phase fluid motion, the program will use a forcing function proportional to the weight[1].

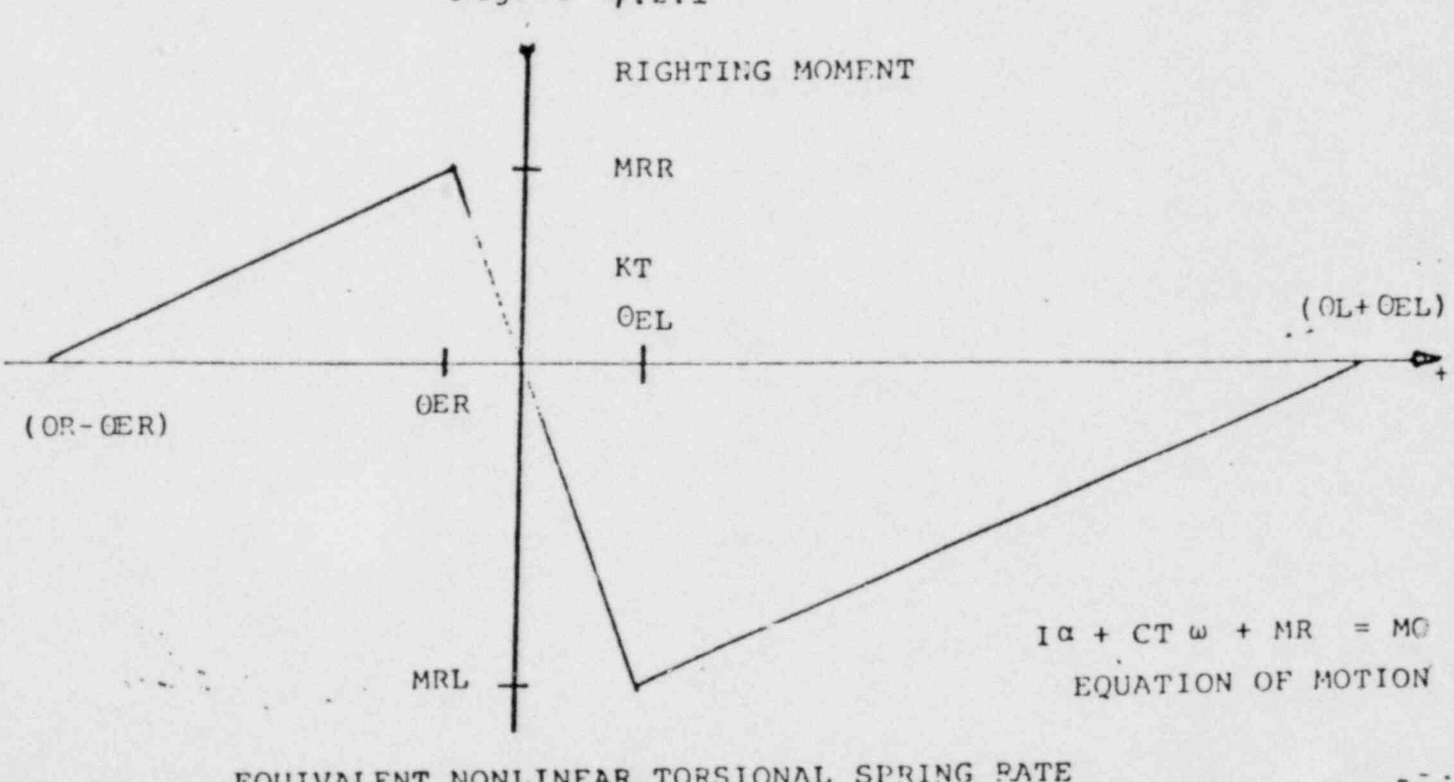
1) Reference - See The Effects of Submergence on Structural Response In Confined Pools by A. J. Sturm and C. S. Song, June 1979.



SPENT FUEL RACK
Figure 4.2.1



TORSIONAL MODEL
FIGURE 4.2.2



$I\alpha + CT\,\omega + MR = MO$

EQUATION OF MOTION

EQUIVALENT NONLINEAR TORSIONAL SPRING RATE

FIGURE 4.2.3

4.3 Dropped Fuel Bundle Analyses

Analyses were performed to define the equivalent static load for dropped bundle accident conditions 1,2,3,4, and 5 (see para. 4.1.1).

The following method is used in defining the impact loads: for conditions 1 and 2 the net impacting energy was determined to be the potential energy for the fuel bundle minus energy absorbed by collapsing the bottom tripod fitting on the fuel bundle. Using the SAPIV model, spring rates were determined at various impact locations on the rack. A static impact load was then determined for each of these locations by equating the elastic structural strain energy with the net impact energy.

For condition 3, an unimpeded fuel assembly drop through an empty cavity, an equivalent static load was determined to shear out the bottom fuel support. The following presents the equivalent static loads for the three drop conditions.

For condition 4, it is assumed that the bundle strikes the top of the rack moving at the maximum horizontal velocity that the crane can produce. The equivalent horizontal static load was determined based on this horizontal velocity.

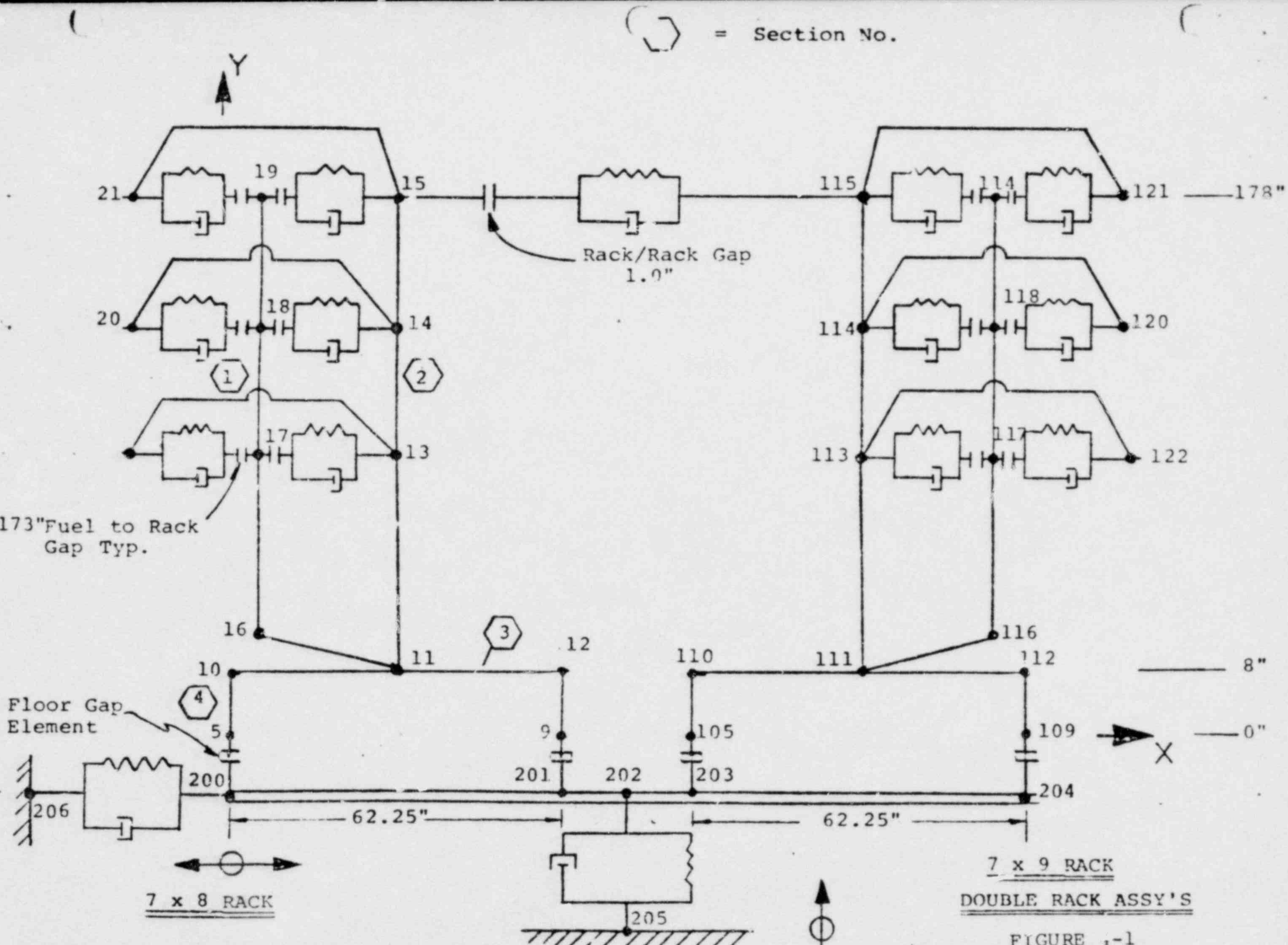
For condition 5, the fuel rolls over and hits the top of the rack after it has been dropped vertically onto the top of the rack. The equivalent static load was determined to be a triangular distributed load determined by the angular velocity at impact.

Condition	Description	Load
1	18 inch drop, middle of rack	178,400 lbs.
2	18 inch drop, corner of rack	139,600 lbs.
3	Drop through empty cavity of rack	51,670 lbs.
4	Inclined fuel drop	4,520 lbs.
5	Fuel roll over	187,400 lbs.

Condition 1 and 2 are the loads due to vertical impact. The subsequent roll over impact load of condition 5 was shown to be less than the above stated vertical impact values. Equivalent static loads for different dropped fuel bundle cases were then applied at proper locations to the SAPIV finite element model of the rack and combined with the dead weight vertical load (rack full of fuel). Stresses for each member were such that the ductility ratio was less than 10 and that no deformation will result in an increase in criticality.

4.4 Summary

All the member stresses satisfy the stress combination limits and factored allowable stresses of the stress limits in Table 4-1. The dropped fuel bundle cases have ductility ratios of less than 10 and result in no deformation that will increase criticality.



7 x 8 RACK

7 x 9 RACK

DOUBLE RACK ASSY'S

FIGURE .-1

NOTE: Nodes 5-200, 9-201, 105-203, 109-204, are coupled in the horizontal direction.

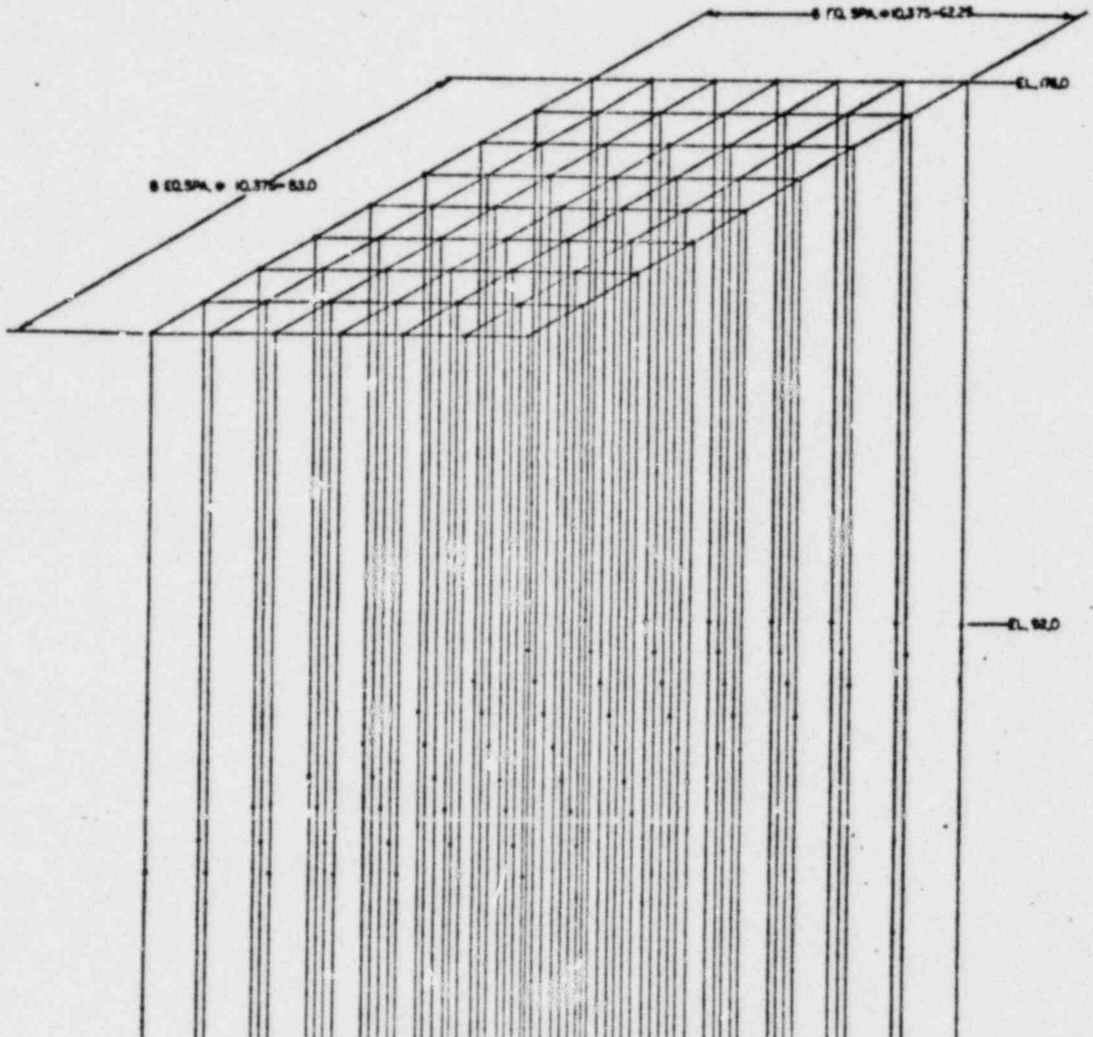


FIGURE 4.2

SAP IV RACK FINITE ELEMENT MODEL

5.0 MAINE YANKEE JUSTIFICATION

5.1 Design Condition Differences

The Sequoyah racks and the Maine Yankee racks a : structurally the same. There are four differences in the design conditions between the Sequoyah racks and the Maine Yankee racks. These four design conditions are:

1. Seismic Response Spectrum
2. Fuel Weight
3. Free Standing (Maine Yankee)-vs-grid(Sequoyah)
4. Dropped Fuel Bundle

To show that the racks are good for the design conditions for Maine Yankee the stresses determined from the Sequoyah rack analysis were factored up or down to take the design condition changes into account.

5.2 Fuel Weight

The fuel weight for Sequoyah is 1650 lbs. and for Maine Yankee is 1280 lbs. Maine Yankee is going to pin storage enabling 1.64 density factor for a total of 1.64 (1280) = 2099 lbs. The dead and live load stresses are factored up by the ratio of the fuel weights which is

$$\frac{2099}{1650} = 1.2722.$$

This is shown in Table 5.4 which is stress interactions instead of stresses.

5.3 Seismic Response Spectrum

The response spectrums for Maine Yankee is less than that which was used for Sequoyah. Figures 5.1 and 5.2 show the Maine Yankee response spectrum and the Sequoyah spectrum that was used and the target spectrum. The seismic stresses in the Sequoyah rack were determined from a time history analysis. A spectral analysis was done only for information on the Sequoyah racks; however, the results of this analysis will be used to compute seismic comparison factors between the Maine Yankee and Sequoyah racks. This is justifiable because stresses in the Maine Yankee racks occur with a .8 coefficient of friction which causes no sliding so the rack behaves like it is attached to the floor. The aforementioned comparison factors will be used to relate rack stresses as determined from the Sequoyah time history analysis for similar Maine Yankee racks.

The spectral analysis of the Sequoyah racks was done on the computer program ANSYS. The spectral analysis gives the frequencies, participation factor, and the mode coefficients. The mode coefficient is defined as:

EQ. 5.1 $$M.C. = \frac{S_{vi} \quad \gamma_i}{W_i}$$ Ref: ANSYS User Information Manual P. 2.11.4-2.11.5

Where S_{vi} = The spectral modal velocity for the i th mode

γ_i = The participation factor for the i th mode

W_i = The circular natural frequency of mode i

So That

$$\{d\}_i = MC_i \{\psi\}_i$$

Where $\{d\}_i$ = The maximum absolute modal displacement vector

$\{\psi\}_i$ = The square matrix containing all mode shape vectors such that the i th column is the mode shape vector for the i th mode.

This means that the mode coefficient indicates which modes are dominate because they have the largest deflections and therefore stresses.

The mode coefficient ratio (M.C. ratio) is the mode coefficients normalized, the mode coefficient divided by the maximum mode coefficient, see ANSYS User Information Manual, page 2.11.5.

To find stresses in the Maine Yankee Racks due to a lower seismic response spectrum the reduction in mode coefficient (and therefore stresses) from Sequoyah must be found. The Sequoyah spectrum analysis has the frequencies, participation factors, and mode coefficients for the first 57 modes for the N-S, E-W, and vertical directions.

To find the frequencies for the Maine Yankee racks, The Sequoyah frequencies were reduced by the square root of the ratios of the fuel weight, which is $\left\{\frac{1650}{1.64(1280)}\right\}^{\frac{1}{2}}$ for the significant frequencies up through 30 HZ. Significant frequencies are defined as a M.C. ratio of .005 or over, which is a ½% of the maximum. A new participation factor was determined for the Maine Yankee racks by increasing Sequoyah's by the ratio of the fuel weights which is $\frac{1.64(1280)}{1650}$. From the Maine Yankee response spectrums on Figures 5.1 and 5.2, the velocities for each of the new frequencies were found. Using the new frequencies, the new participation factor, and the velocity the Maine Yankee mode coefficients were calculated using equation 5.1 this is shown in Tables 5.1 through 5.3. Since the mode coefficient is proportional to the maximum displacement of that mode the absolute summation of the mode coefficients will be proportional to the total displacement in that direction. The SRSS of the mode coefficients for each direction will be proportional to the displacement for that response spectrum. The seismic comparison factor will then be the ratio of the SRSS of the absolute sum of the mode ceofficients of each direction of Maine Yankee to Sequoyah. This ratio is computed as

$$\frac{\{.1343^2 + 4.0943^2 + 5.1482^2\}^{1/2}}{\{.2185^2 + 7.4377^2 + 8.887^2\}^{1/2}} = .568$$

The seismic comparison factor is the amount of the Sequoyah modal response that are equivalent to Maine Yankee's modal response. The seismic comparison factor is used to ratio down Sequoyah's seismic stresses to obtain Maine Yankee seismic stresses. This is shown in Table 5.5. The dead + live + seismic load is shown in Table 5.6 for Maine Yankee.

5.4 Dropped Fuel Bundle

The Maine Yankee dropped fuel bundle height is 18 inches and the fuel weight is 2099 lbs. (See Section 5.2). The Sequoyah dropped fuel bundle height is 18 inches and the fuel weight is 1650 lbs. The stresses caused by the dropped bundle for Sequoyah were factored by the ratio of the equivalent static forces to get the Maine Yankee rack stresses. The equivalent static force is $F \propto \sqrt{\varepsilon}$

Where ε is the impacting energy

ε = drop distance times the weight

The ratio is $\dfrac{\sqrt{12(2099)}}{\sqrt{18(1650)}} = .9209$ and

The stress interactions for the Maine Yankee racks dropped fuel case is in Table 5.7.

5.5 Free Standing Racks

The Maine Yankee racks are free standing while the Sequoyah racks are on a floor grid. Since the Maine Yankee racks are free the rack sliding and rocking was analysed via the computer program ROCAN. ROCAN is a proprietary computer program of PaR Systems Corp. of St. Paul, Minnesota and is a interactive nonlinear rocking analysis for submerged, unsymmetrical, single degree of freedom systems subjected to various inputs, e.g., initial displacement, sinusoidal, and time history. This program has been benchmarked against public programs such as ANSYS. Both a 7 x 9 rack and 5 x 8 rack was used with a fuel weight of 2099 lb. and a coefficient of .2 with the rack empty, 25%, 50%, 75% and 100% full of fuel using the Sequoyah E-W and vertical response spectrums. The results are shown in Table 5.8 for the 7 x 9 rack. The largest displacement at the top of a 7 x 9 rack computed was .531". This displacement is much less than the rack installation clearance in the pool.

Because the Sequoyah racks are restrained against sliding and the Maine Yankee racks are not, the seismic stresses would be lower than what was calculated based on the Sequoyah racks. The interactions in Table 5.8 are therefore conservative.

5.6 The stress interactions from the dead load, live load, and seismic load are all less than 1.0. The stresses caused by the dropped fuel bundle are above yield but the ductility ratio is less than 10 and the deformation does not result in an increase in criticality, therefore, the stresses are acceptable.

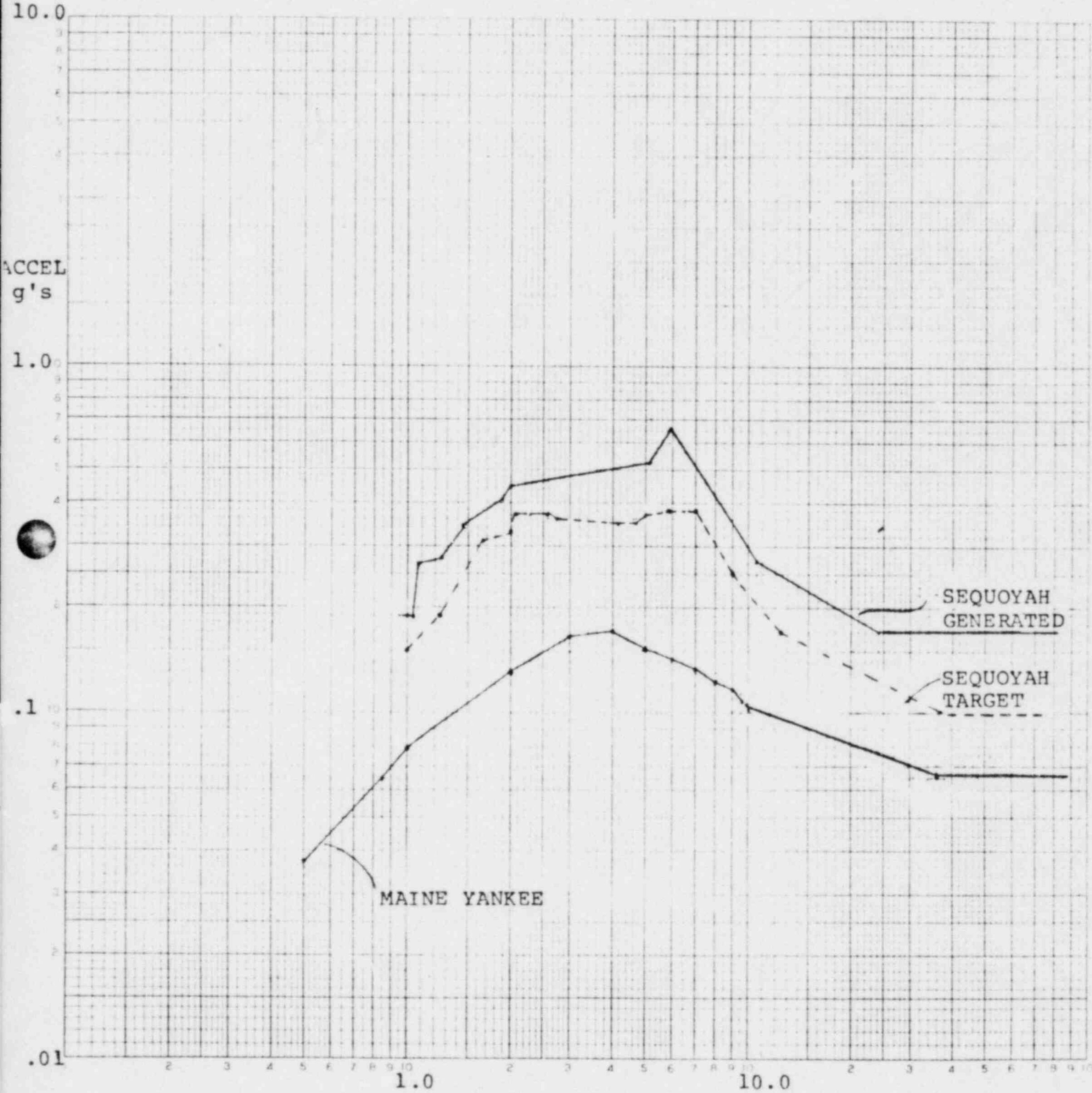


FIGURE 5.1

2% SSE VERTICAL

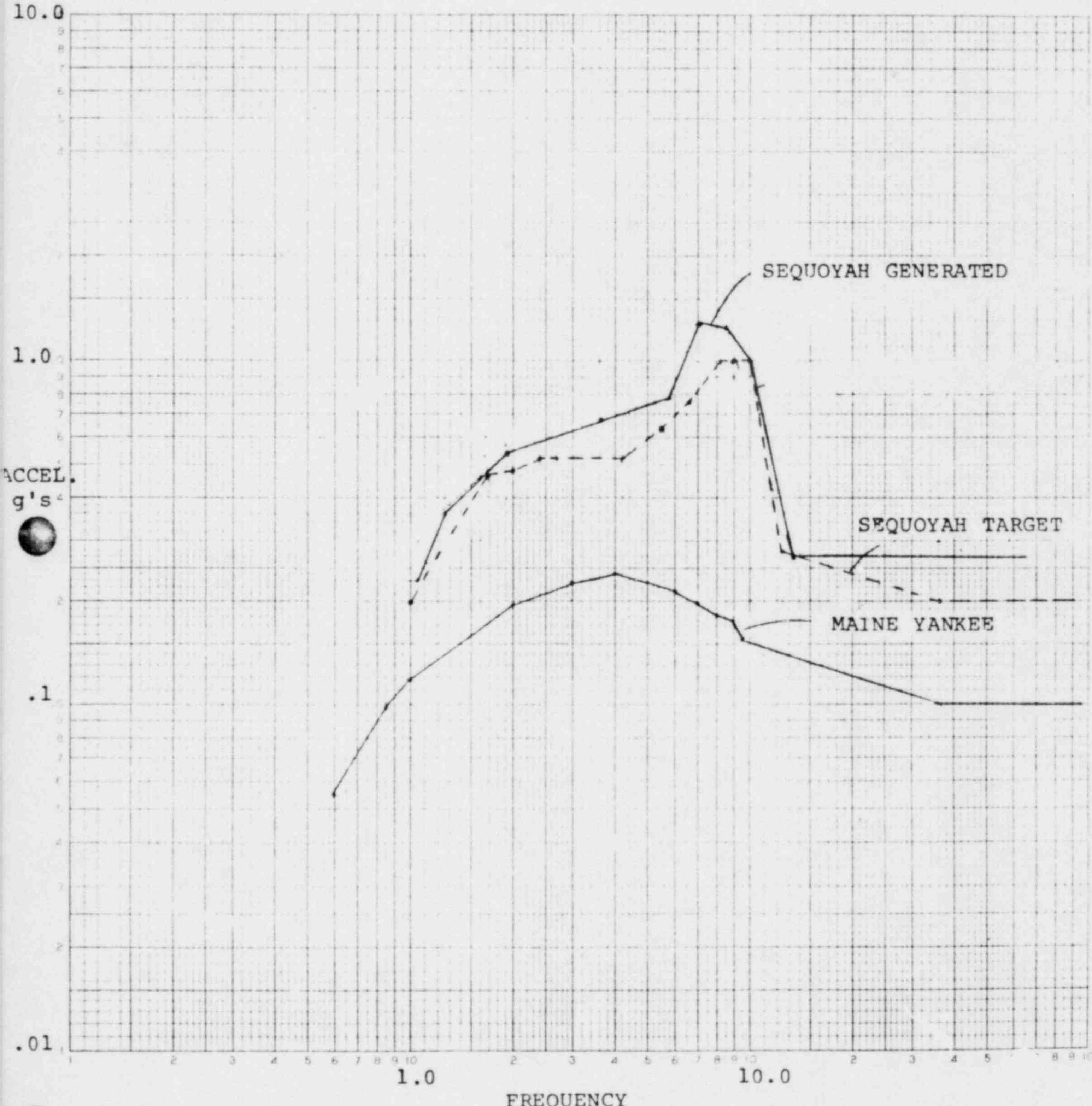


FIGURE 5.2

2% SSE HORIZONTAL

TABLE 5.1.A

SEQUOYAH N-S RESPONSE SPECTRUM

MODE	FREQUENCY	PARTICIPATION FACTOR	MODE COEF.	M.C. RATIO
1	3.557	16.63	8.491	1.0
2	4.048	.6388	.2652	.030405
3	6.316	.2855	.0680	.008163
6	16.73	6.746	.0637	.005465

Absolute sum of the MC. = 8.887

TABLE 5.1.B

MAINE YANKEE N-S RESPONSE SPECTRUM

MODE	FREQUENCY	PARTICIPATION FACTOR	MODE COEF.	M.C. RATIO
1	3.154	21.157	4.911	1.00
2	3.589	.8127	.1449	.0295
3	5.600	.3632	.0417	.00849
6	14.832	8.5825	.0506	.01030

Absolute sum of the M.C.=5.1482

TABLE 5.2.A

SEQUOYAH E-W RESPONSE SPECTRUM

MODE	FREQUENCY	PARTICIPATION FACTOR	MODE COEF.	M.C. RATIO
1	3.557	-.7075	.3612	.052850
2	4.048	16.68	6.924	1.00
3	6.316	-.3977	.09464	.014808
7	17.49	6.695	.05784	.006318

Absolute sum of the MC. = 7.43768

TABLE 5.2.B

MAINE YANKEE E-W RESPONSE SPECTRUM

MODE	FREQUENCY	PARTICIPATION FACTOR	MODE COEF.	M.C. RATIO
1	3.154	-.9001	.2089	.0552
2	3.589	21.21	3.783	1.00
3	5.600	-.5060	.0575	.0152
7	15.506	8.5177	.0449	.0119

Absolute sum of the M.C.= 4.0943

TABLE 5.3.A

SEQUOYAH VERTICAL RESPONSE SPECTRUM

MODE	FREQUENCY	PARTICIPATION FACTOR	MODE COEF.	M.C. RATIO
1	3.557	-.0689	.02308	.546844
2	4.048	-.1442	.04306	1.00
3	6.316	.00219	.0003493	.006642
4	14.19	.02308	.000292	.005571
5	16.34	1.158	.009762	.187022
6	16.73	-1.714	.01312	.261663
7	17.49	-3.908	.02563	.536843
10	18.06	-.1676	.001006	.021316
13	18.18	.1219	.007218	.015237
14	18.20	-.2074	.001226	.02587
16	18.21	.0426	.0002515	.005305
18	[illegible].25	-.07487	.00044	.009281
20	19.66	-.283	.001678	.029227
21	19.73	-8.741	.04175	.894782
22	20.16	.3712	.001699	.036023
23	22.02	3.784	.01375	.294178
24	22.27	9.628	.03420	.727108

Absolute sum of the MC. = .2185

TABLE 5.3.B

MAINE YANKEE VERTICAL RESPONSE SPECTRUM

MODE	FREQUENCY	PARTICIPATION FACTOR	MODE COEF.	M.C. RATIO
1	3.154	-.07747	.01200	.4089
2	3.589	-.18346	.021803	.7430
3	5.600	.002785	.0002114	.0072
4	12.580	.02936	.000171	.00523
5	14.487	1.4733	.006312	.2151
6	14.532	-2.1806	.008658	.2951
7	15.506	-4.9719	.01735	.59128
10	16.012	-.21323	.0006994	.02384
13	16.118	.15509	.0005054	.01722
14	16.136	-.26386	.0001083	.00369
16	16.145	.05420	.0001763	.00601
18	16.180	-.09525	.0003092	.0105
20	17.430	-.36004	.0009534	.0325
21	17.492	-11.1207	.029343	1.00
22	17.873	.47226	.0012196	.0416
23	19.522	4.8142	.0098121	.3344
24	19.744	12.2492	.024685	.8413

Absolute sum of the M.C. .1343

TABLE 5.4
7 x 9 Rack Dead + Live Load Interaction

Section	Sequoyah Interaction	Maine Yankee Factored Interaction
Top Casting Inner	.044	.056
Top Casting Outer	.043	.055
Poison Can	.492	.626
Bottom Casting Inner	.243	.309
Bottom Casting Outer	.079	.101
Bottom Casting Cruciform	.330	.420
Bottom Casting Outside Corner	.509	.648
Bottom Foot	.076	.097

Note: The Sequoyah interaction was factored by the ratio of the fuel weights $\frac{1.64\ (1280)}{1650} = 1.2722$

TABLE 5.5
7 x 9 SSE Seismic Interaction

Section	Sequoyah Interaction	Maine Yankee Factored Interaction
Top Casting Inner	.097	.055
Top Casting Outer	.095	.054
Poison Can	.563	.320
Bottom Casting Inner	.462	.262
Bottom Casting Outer	.461	.261
Bottom Casting Cruciform	.434	.247
Bottom Casting Outside Corner	.355	.202
Bottom Foot	.339	.193

TABLE 5.6

7 x 9 D+L + SSE Interaction

Section	Maine Yankee* Factored D+L Int.	Maine Yankee Factored SSE Int.	Maine Yankee Interaction
Top Casting Inner	.056	.055	.111
Top Casting Outer	.055	.054	.109
Poison Can	.626	.320	.946
Bottom Casting Inner	.309	.262	.571
Bottom Casting Outer	.101	.261	.362
Bottom Casting Cruciform	.420	.247	.667
Bottom Casting Outside Corner	.648	.202	.850
Bottom Foot	.097	.193	.290

TABLE 5.7

7 x 9 D + L + I Interaction

Section	Maine Yankee Factored* D + L Int.	Sequoyah I Int.	Factored I Int.	**Factored D+L+I Int.
Top Casting Inner	.056	.221	.204	.260
Top Casting Outer	.055	.242	.223	.228
Poison Can	.626	.375	.345	.971
Bottom Casting Inner	.309	.618	.569	.878
Bottom Casting Outer	.101	.177	.163	.264
Bottom Casting Cruciform	.420	.817	.752	1.172
Bottom Casting Outside Corner	.648	1.264	1.164	1.812
Bottom Foot	.097	.188	.173	.270

* See Table 5.4

** Factored By $\left[\frac{12\ (2099)}{18\ (1650)}\right]^{1/2} = .9209$

TABLE 5.8

7 x 9 RACK SLIDING AND ROCKING DISPLACEMENT

EARTH-QUAKE	FRACTION FULL	MAX.TOP HORIZ. DISP.	MIN.TOP HORIZ. DISP.	MAXIMUM SLIDING DISP.	MINIMUM SLIDING DISP.
	1	.381	-.343	.07215	-.04145
2%	.75	.277	-.366	.02567	-.07068
E-W	.5	.531	-.483	.161	-.0005763
SSE	.25	.318	-.271	.115	-.007293
	0	.138	-.125	.01621	-4.964E-6

TABLE 5.9

5 x 8 RACK SLIDING AND ROCKING DISPLACEMENT

EARTH-QUAKE	FRACTION FULL	MAX.TOP HORIZ. DISP.	MIN.TOP HORIZ. DISP.	MAXIMUM SLIDING DISP.	MINIMUM SLIDING DISP.
	1	1.32	-1.04	.08889	-.01487
2%	.75	1.12	-1.57	.05538	-.06032
E-W	.5	.614	-.959	.07675	-.02827
SSE	.25	.665	-1.45	.04638	-.07288
	0	.549	-.547	0	0

6.0	Reference ABBV	Description
1.	United States Nuclear Regulator Commission (USNRC)	
	a. NRC Reg. Guide 1.13	Spent Fuel Storage Facility Design Basis, Rev.1,Dec. 1975
	b. NRC Reg. Guide 1.29	Seismic Design Class Rev. 2, Feb. 1976
	c. NRC Reg. Guide 1.92	Combination of Modes in Seismic Analysis, Rev. 1, Feb. 1976
	d. NRC Reg. Guide 1.70	"Validation of Calculational Methods for Nuclear Criticality Safety"
	e. NRC SRP 3.8.4	Seismic Category I Structures, 1975
	f. NRC SRP 9.1.2	Spent Fuel Storage Review Responsibility, 1975
	g. NRC SRP 9.2.5	Ultimate Heat Sink, Pages 9.2.5-8 thru 9.2.5-14, 1975

2. Industry Codes and Standards

a. ASME	Boiler & Pressure Vessel Code Section III Subsection NA Appendix i, XVII, and subarticle NF-4000, 1974 Edition (American Society of Mechanical Engrs.)
b. AISC	Steel Construction Manual AISC (7th Edition). June, 1973 (American Institute of Steel Constr.)
c. ACI 318-71	Building Code Requirements for Reinforced Concrete. (American Concrete Institute.)
d. AA	"Aluminum Standards and Data" published by Aluminum Association 5th Edition, Jan., 1976 Aluminum Association.
e. ASTM	ASTM Standards: A240-72b, A276-71, A312-72a, B209-73, B26-74, B211-74.
f. ANSI N45.2	"Quality Assurance Requirements of Nuclear Power Plants", 1971
g. ANSI N45.2.2	"Packaging and Shipping, Receiving Storage and Handling of Items for Nuclear Power Plants", 1972
h. ANSI N45.2.10	"Quality Assurance Terms and Definitions", 1973
i. ANSI N18.2	Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactors Plants, 1973
j. AWS	Specification D1.1, Rev. 2-77 Structural Welding Code

3. Federal Specifications

10 CFR 50, Appendix B 1975	Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants
10 CFR 73.55	Requirements for physical protection of licensing activities in nuclear power reactors against industrial sabotage.
10 CFR 20	Standards for protection against radiation

4. Computer Programs

SAP IV	Computer Program, Static and Dynamic Analysis of Linear Structures
ANSYS	Computer Program"Engineering Analysis System" Swanson Analysis Systems, Inc.
SAGS	Static Analysis of General Structures SDRC Version III, 3/77
DAGS	Synamic Analysis of General Structures SDRC Verion III, 5/77
SIMQKE	Computer program which digitized time histories are generated artificially.
ROCAN	Computer program for considering nonlinear rocking and sliding motion of submerged eccentrically loaded fuel racks.