GENERAL ELECTRIC

NUCLEAR ENERGY

PROJECTS DIVISION

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MFN #182-79
RLG #096-79

July 6, 1979

U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. Darrell G. Eisenhut, Deputy Director
Division of Operating Reactors

Gentlemen:

SUBJECT: PISYS ANALYSIS OF NRC BENCHMARK PROBLEMS

Reference: 1) Letter, M. Hartzman (MEB, DSS) to R. O. Brugge (GE), Computer Code Verification, dated May 12, 1979

This letter provides a status report on the progress of our analysis of the five NRC benchmark problems (Reference 1) using the PISYS computer code. The status of this work, as of June 30, 1979, is as follows:

1. The PISYS solution of four problems (NRC Problems No. 5, No. 6, No. 323A and No. 101) have been obtained. The solution of the fifth problem (NRC Problem No. 803) is in progress.

2. The ASME stresses for two problems (NRC Problems No. 323A and No. 101) have been calculated. Calculations for the other three problems will start shortly.

3. The PISYS solutions show good agreements with the frequency and nodal participation factor values given with the problem definitions.

4. An internal design review of the calculational results for all five problems is being scheduled. The benchmark analysis are expected to be completed and transmitted to you by July 31, 1979.

The information which we will provide for each of the five benchmark problems has been agreed to with Dr. M. Hartzman of your staff, and is given in the attachment to this letter.

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Questions or comments regarding this matter should be directed to Dr. L. M. Zull of my staff at (408) 925-5599.

Very truly yours,

R. L. Gridley, Manager
Operating Plant Licensing
Safety and Licensing Operation

RLG:pes/933-934

Attachment

cc: L. S. Gifford

ATTACHMENT

DETAILS OF INFORMATION TO BE
PROVIDED BY GENERAL ELECTRIC
ON THE PISYS ANALYSIS
OF NRC BENCHMARK PROBLEMS

A. General

1. Computer code name - PISYS

2. Version and machine - PISYS02 on Honeywell 6600 (GE/NED)

3. Date of Acquisition - Feb. 17, 1978 (GE/NED approved production status.

4. Method of intramodal and intermodal combination for response spectrum analysis.

For Brunswick-Pilgrim piping re-analysis as well as for GE normal piping analysis, no intramodal combination of x, y and z earthquake results is carried out. The results of x, y, z earthquakes remains separate until intermodal combination is complete.

For Brunswick and Pilgrim re-analysis, the modal responses for each earthquake direction are summed by SRSS method, then these combined results for the different earthquake directions are added to give the final results for the earthquake load. For current GE normal piping analysis, the modal responses for each earthquake direction, however, are summed by the "absolute-sum" closely-spaced-mode SRSS method, and the combined results for the different earthquake directions are added with the SRSS method.

The analysis of the NRC piping benchmark problem will be similar to GE normal piping analysis. The seismic analysis will be carried out using the response spectrum analysis of the PISYS computer program. The x, y and z earthquakes will be input as 3 separate spectra and in 3 separate load cases (although NRC's SAP input specifies, in some cases, the x, y and z earthquakes as fractions of the same spectrum) Combination Method V in PISYS will be used for intermodal combination and inter-earthquake-direction combination. Specifically, the following calculation will be carried out by PISYS for the NRC problem.

4.1 Modal amplitude calculation

$$A_x^n = \left| \frac{S_x}{\omega_n^2} P_x^n \right|$$

$$A_y^n = \left| \frac{S_y}{\omega_n^2} P_y^n \right|$$

$$A_z^n = \left| \frac{S_z}{\omega_n^2} P_y^n \right|$$

Where S_x, S_y, S_z are values at ω_n of the input acceleration spectra in the x, y and z directions, respectively. ω_n is the circular frequency of the nth mode; P_x^n, P_y^n, and P_z^n are the nth modal participation factor in the x, y and z directions respectively. A_x^n, A_y^n, and A_z^n are the nth modal amplitude (generalized modal displacement) for the x, y and z earthquakes, respectively.

4.2 Modal responses

$$q_x^n = A_x^n T_n$$

$$q_y^n = A_y^n T_n$$

$$q_z^n = A_z^n T_n$$

Where q_x^n, q_y^n and q_z^n are nth modal responses to x, y and z earthquakes, respectively. T_n is the transformation vector relating modal amplitude to specific response variables such as displacement, force, moment, etc. In the case of displacement T_n is simply the nth mode shape.

4.3 Intermodal Combination (Method V)

$$Q_x = \left\{ \sum_{n=1}^{NF} (q_x^n)^2 + 2 \left[\sum_{n=1}^{NF} \sum_{m=n+1}^{NF} \left| (q_x^n)\ (q_x^m) \right| \varepsilon_{nm} \right] \right\}^{1/2} \text{ (SRSS)}$$

$$Q_y = \left\{ \sum_{n=1}^{NF} (q_y^n)^2 + 2 \left[\sum_{n=1}^{NF} \sum_{m=n+1}^{NF} \left| (q_y^n)\ (q_y^m) \right| \varepsilon_{nm} \right] \right\}^{1/2}$$

$$Q_z = \left\{ \sum_{n=1}^{NF} (q_z^n)^2 + 2 \left[\sum_{n=1}^{NF} \sum_{m=n+1}^{NF} \left| (q_y^n)\ (q_y^m) \right| \varepsilon_{nm} \right] \right\}^{1/2}$$

Where n and m are two closely-spaced modes and the quantity ε_{nm} is a function of the nth and mth modal frequencies, ω_n and ω_m, and of the modal damping coefficient β_n which is assumed to have the same (default) value of 0.02 for all modes;

$$\varepsilon_{nm} = \frac{1}{1 + \left[\dfrac{\omega_n - \omega_m}{\beta_n (\omega_n + \omega_m)} \right]^2} \qquad \text{if } \varepsilon_{nm} > 0.1$$

$$\varepsilon_{nm} = 0 \qquad \text{if } \varepsilon_{nm} \leq 0.1$$

Final combined results for the load case with x, y and z earthquakes

$$Q = \left(Q_x^2 + Q_y^2 + Q_z^2 \right)^{1/2}$$

464 301

5. Listing of portion of PISYS where modal combinations are performed. A listing of the response spectrum analysis option of PISYS02 has already been given to Dr. M. Hartzman.

B. Output

1. Isometric Drawing

Isometric drawing by a post-processor, PSPLT01, will be provided.

2. Input Echo

Input echo and entire PISYS output will be provided.

3. Frequencies

Same number of frequencies as specified in NRC SAP input for the benchmark problem will be provided.

4. Mode Shapes

Mode shapes corresponding to the above frequencies will be given. The mode shapes are given as mass-normalized eigenvector divided by its amplitude value (i.e., the maximum displacement and rotation values of the mode shape are equal to unity).

5. Participation Factors

They are given for each of the x, y and z global directions.

6. Total modal displacement and rotations.

7. Total element end forces and moments.

Information for both items 6 and 7 are given as combined results of x, y and z earthquakes (the quantities Q_x, Q_y, Q_z and Q in foregoing item A4.3).

8. Total ASME Stresses

Total ASME stresses are hand calculated for selected locations from the total moment given in Item 7 (i.e., seismic results only, no thermal, dead weight, and other loads), using the formula:

$$\sigma = B_I \frac{Mc}{I}$$

Where σ is pipe stress, B_I appropriate stress index for Class I piping, M total pipe moment, c pipe outer radius and I pipe moment of inertia.

464 302