Quad Cities Units 1 & 2

Shroud Repair Seismic Analysis

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EXECUTIVE SUMMARY

Seismic analyses of Quad Cities Units 1 and 2 have been performed to obtain seismic loads in the NSSS components to support the shroud repair project. The seismic model includes the NSSS components and supporting structures. Prior to inclusion of the shroud repair, the model was benchmarked against the design basis model used in the original seismic analysis. The nuclear core in the seismic model was then updated to the projected Cycle 14 core configuration. The shroud repair hardware was included in the model in the form of three horizontal and one rotational springs. The horizontal springs are located at the elevation of the core support plate, jet pump riser braces and top guide, and the rotational spring represents the tie rod assembly.

The seismic analyses were based on the time history method of analysis. The input motions included the S80E component of the 1957 Golden Gate Park earthquake record and a synthetic time history matching the Housner spectrum curve. Bounding Design Basis Earthquake (DBE) loads were obtained for use in load combinations for the Emergency and Faulted conditions, and bounding Operating Basis Earthquake (OBE) loads for the Upset condition. Vertical seismic loads were obtained based on the static coefficient method used in the original design basis. The resulting seismic loads were used as input to the design of the shroud repair hardware and to validate the continued structural integrity of the core support structure and RPV internals.

Table of Contents

1.0 INTRODUCTION

A seismic analysis of Quad Cities Units 1 and 2 has been performed to obtain seismic loads in the NSSS components to support the shroud repair project. The resulting loads were used as input to the design of the shroud repair hardware and to validate the continued structural integrity of the core support structure and RPV internals. Analyses were done for the complete range of postulated shroud welded joint cracks as well as for a fully uncracked configuration with shroud retraint hardware installed.

With the exception of the nuclear core, the North-South (N-S) and East-West (E-W) seismic models used were identical to those originally used in References 1 and 2. Except for updating the stiffness of the RPV stabilizer, the seismic models used in Reference 2 were the same as those used in Reference 1. The analysis of Reference 2 was done for the Operating Basis Earthquake (OBE) only and the input ground motion was the S80E component of the the 1957 Golden Gate Park earthquake record with the peak ground acceleration normalized to 0.12g. The nuclear core portion of this original seismic model was updated to reflect the projected Cycle 14 core configuration at both Units 1 and 2.

The original seismic model input geometries from References 1 and 2 were converted to the Reference 3 GE Engineering Computer Program (ECP) format for the current evaluation. The details of the construction of the current seismic models are documented in Reference 6. Eigen analyses and OBE time history analayses were completed for the reconstructed seismic models in order to benchmark the current results against those obtained in Reference 2. Reference 7 (Section 1.0) summarizes the results of the benchmarking. The seismic input for this OBE time history analysis was the S80E component of the 1957 Golden Gate Park earthquake record with the peak ground acceleration normalized to 0.12g. Good agreement was obtained in both the frequencies and the OBE seismic loads in the RPV internals.

The nuclear core in the seismic model was then updated to the projected Cycle 14 core configuration. The projected Cycle 14 core configuration differs slightly between Unit 1 and 2, but the difference is so small that one averaged core configuration is representive of both units and, for each horizontal direction, one seismic model may also be used for both units. Seismic analyses were then carried out for a series of bounding cases assuming a wide range of postulated crack conditions, with the repair hardware included. Material damping ratios (corresponding to percent of critical damping) used in the current analysis were taken from Sections 3.7.2.1.6 and 3.9.5.3.4 and Table 3.7.1 of the Quad Cities UFSAR and from References 2 and 4. Damping ratios for the reactor vessel support system were taken directly from Table 3.7.1 and Section 3.7.2.1.6 of the UFSAR. Damping ratios for RPV internals given in Reference 2 and in Section 3.9.5.3.4 of the UFSAR are identical. Reference 2 was issued in January, 1970, and GE has updated damping values, based on actual test data, for the shroud, guide tubes and other internal components. The recommended updated damping values are given in Table 5.8.1-1 of

Reference 4. In the current analysis, damping ratio for the RPV was taken from Table 3.7.1 of the UFSAR , and damping ratios for the shroud and guide tubes were taken from Reference 4. The material damping ratios used in the current analyses are summarized in Section 2.0 below.

The material damping ratios were used to calculate the standard, strain-energy weighted modal damping ratios. The procedure is described in details on p. VIII.L-4 of Reference 3.

According to the UFSAR, the damping ratios for the structures and RPV internals are the same for both the OBE and Design Basis Earthquake (DBE) condition. Thus the seismic analyses were performed for the DBE condition only, and the OBE seismic loadings were taken to be one half of the correspsonding DBE loadings. The DBE seismic input at the structural mat foundation consisted of two different motions, each of which has a normalized peak ground acceleration of 0.24g. The first input motion is the S80E component of the 1957 Golden Gate Park earthquake record. The second input motion is a synthetic time history having a response spectrum closely enveloping the Housner spectrum shown in Figure 3.7-2 of the UFSAR. As discussed in Section 3.0, the synthetic Housner time history complies with the guidelines in Section 3.7.2 of the USNRC Standard Review Plan.

Consistent with the original methods discussed in the UFSAR, vertical seismic loads were included at the stress analysis level by applying the vertical ground acceleration to the weight of the structure under investigation . The vertical ground accelerations were 0.08g and 0.16g for the OBE and DBE condition, respectively, as specified in Section 3.7.1 of the UFSAR.

2.0 SEISMIC MODEL

Two separate models are used for the principal building axes, the N-S and E-W, to reflect the difference in properties of the building structures in the two directions. The NSSS model remains the same in both directions. A detailed discription of the seismic model is given in Reference 6. Figure 1 shows the seismic model including the shroud restraint hardware. The model includes the building, shield wall and pedestal, RPV and internals on a rigid foundation. Figure 2 shows a closeup view of the portion of the model representing the RPV and shroud including the locations of the seven horizontal welds, H1 through H7, along the shroud. The weld H8 need not be modeled because, should it crack, the moment load path through the shroud support legs is maintained and the shear load path through the shroud support plate is also maintained. Thus, a postulated crack in weld H8 will not significantly alter the load paths or the seismic response. Mass properties of the seismic model are represented by lumped masses. Stiffness properties are typically represented by beam elements. A rotational spring (K1) is used to represent the bending stiffness of the shroud support plate. Lateral translational springs are used to

represent the stabilizer (K2) between the RPV and shield wall, the star truss (K3) between the shield wall and reactor building, the upper portions of the reactor and turbine building, and the lateral structural coupling between the two buildings. Horizontal and rotational degrees of freedom in a single plane in each of the E-W and N-S direction are included. All the model branches are located on the same one single centerline in the model. The mass and stiffness properties of the nuclear core in the model reflect the projected Cycle 14 core configuration. The shroud restraint hardware stiffness properties were added to the model as three equivalent horizontal translational springs, K4, K22 and K5, and one equivalent rotational spring, K6. The locations and properties of the horizontal equivalent springs are as follows:

Horizontal Spring	Location	Nodal Connection in Model		Spring Stiffness (kips/inch)
		Shroud Node	RPV Node	
Upper Spring K4	Top Guide	16	75	50
Middle Spring K22	Jet Pump Riser Braces	77	78	35 to 60, Depending on Postulated Cracks (Reference 5)
Lower Spring K5	Core Plate	19	76	200

The stiffness values used for the horizontal springs reflect the combined stiffness of the restraint hardware and shroud based on the results of finite element analysis of each component. Local flexibility of the RPV was ignored in view of its rigidity with respect to those of the restraint hardware and shroud.

The stiffness of the equivalent rotational spring representing the tie rods, K6, was calculated based on the four tie rods rotating about the shroud neutral axis or, as an extreme, about one of the tie rods. The rotational spring is connected at Nodes 14 and 9 on the shroud and RPV model branch, respectively. The tie rods were assumed to rotate about the shroud neutral axis until the maximum tension force induced by seismic plus pressure in the tie rods substantially exceeds the tie rod preload. This assumption gives rise to a lower bound value of 1.342E6 ft-kips/rad. for the stiffness of the equivalent rotational spring, based on an axial stiffness of 608 kips/inch per tie rod. When the maximum tension force induced by seismic plus pressure in the tie rods, calculated on the basis that the tie rods rotate about the shroud neutral axis, substantially exceeds the tie rod preload, the tie rods were assumed to rotate about the edge of the shroud coincident with the location of one of the tie rods. In this case, the stiffness of the equivalent rotational spring has an upper bound value equal to 3 x 1.342E6 ft-kip/rad. = 4.03E6 ft-kip/rad.

3.0 SEISMIC INPUT

The two input ground motions used in the DBE seismic analyses are the S80E component of the 1957 Golden Gate Park earthquake and a synthetic time history having response spectra enveloping the corresponding Housner spectrum. Both input ground motions have a peak acceleration normalized to 0.24g.

Figure 3 shows the 2% and 5% damping response spectra of the Golden Gate Park earthquake normalized to the OBE ground acceleration of 0.12g. The 5% damping spectrum matches the corresponding spectrum of the Golden Gate Park earthquake as shown in the UFSAR, Figure 3.7-2.

The Housner synthetic time history was generated from a simultaneous set of smoothed Housner spectrum curves corresponding to damping ratios of 0.5%, 2% and 5%. The

frequency range for each smoothed spectrum curve in the set was from 0.03 Hz to 55 Hz. The resulting Housner synthetic time history has a strong motion duration in the range of 25 to 30 seconds and a total duration equal to 40 seconds. The response spectra generated from the synthetic time history closely envelop the corresponding smoothed Housner spectrum curves throughout the entire frequency range. For 0.5% and 5% damping, the response spectra from the synthetic time history envelop the corresponding target spectrum curves for all frequencies. Only three points of the 2% damping spectrum from the synthetic time history fell below the corresponding target spectrum curve and were less than 10% below. This complies with the guidelines in Section 3.7.2 of the Standard Review Plan that no more than five points on the resposnse spectrum of the synthetic time history fall below the target spectrum and, where points fall below the target spectrum, they are no more than 10% below. Figure 4 compares the 5% damping spectrum of the OBE synthetic time history to the 5% damping Housner spectrum shown in the UFSAR, Figure 3.7-2.

4.0 SEISMIC ANALYSIS RESULTS

The resulting DBE seismic loads in the RPV stabilizer, RPV skirt and internals, with the restraint hardware installed on an integral, uncracked shroud, are closely comparable to the DBE loads (i.e., two times the OBE loads) from the original seismic analysis of Reference 2. With the restraint hardware installed on a cracked shroud, the DBE seismic loads exceeded those from both the original seismic analysis of Reference 2 and the analysis of an uncracked shroud. Table 1 shows the bounding seismic loads in the RPV stabilizer, RPV skirt, and internals.

The analysis results show that the Housner time history governs the seismic loads in the horizontal restraint hardware while the Golden Gate Park earthquake governs the seismic loads in the tie rods and RPV and internals. Tables 1 and 2 identify the crack cases giving rise to the bounding seimic loads in the individual elements, as summarized in the following.

- o Horizontal restraint hardware and RPV and internals: For Upset and Emergency conditions, the governing case for horizontal restraint hardware and RPV and internal components (except for shroud shear at shroud support plate and moment in shroud support plate) is all welds cracked as hinges. The Upset condition OBE loads are equal to one half of the corresponding Emergency condition DBE loads. For Faulted condition, the governing case is weld H1 cracked as a roller and all other welds cracked as hinges, and the bounding DBE loads are essentially the same as the correponding Emergency condition DBE loads.

- o Tie rods, shroud support plate moment and shroud shear at support plate: For Upset and Emergency conditions, the governing case for the tie rod force and shroud support plate moment is weld H4 cracked as a hinge, and the governing case for shroud shear at support plate is weld H3 cracked as a hinge. The tie rods were assumed to rotate about the center of shroud for the Upset condition, giving a tie rod OBE force of 95 kips, and about the edge of shroud for the Emergency condition, giving a tie rod DBE force of 306 kips. For Faulted condition, the governing case for bounding seismic loads in all three elements is weld H3 cracked as a roller. The tie rods were assusmed to rotate about the edge of shroud in this case, giving a tie rod DBE force of 126 kips which is considerably smaller than the tie rod DBE force of 306 kips for Emergency condition. Comparison in shroud support plate seismic moment between the Upset, Emergency and Faulted conditions is similar to that in the tie rod seismic force.

5.0 REFERENCES

1. GE Document 257HA925, Rev. 1, Seismic Response of Quad Cities Reactor Pressure Vessel and Internals, January 30, 1970.

2. GE Document RA199, Quad Cities Seismic Analysis - Stiff Stabilizer, January 20, 1970.

3. SAP4G07 Users Manual, NEDO-10909, Rev. 7, December 1979.

4. GE Document 386HA596, Rev. 0, Dynamic Load Methods & Criteria - NSSS Equipment, Piping, RPV & Internals, October 21, 1985. (Table 5.8.1-1).

5. GE Document GENE-771-68-1094, Rev. 1, Quad Cities Units 1 & 2 - Shroud and Repair Hardware Stress Analysis.

6. GE Document GENE-523-A169-1194, Quad Cities Units 1 & 2 - Primary Structure Seismic Models, November 16, 1994.

7. GE Document GENE-771-72-1094, Rev. 1, Quad Cities Units 1 & 2 Shroud Repair Seismic Analysis Backup Calculations (GENE-771-71-1094), January 5, 1995.

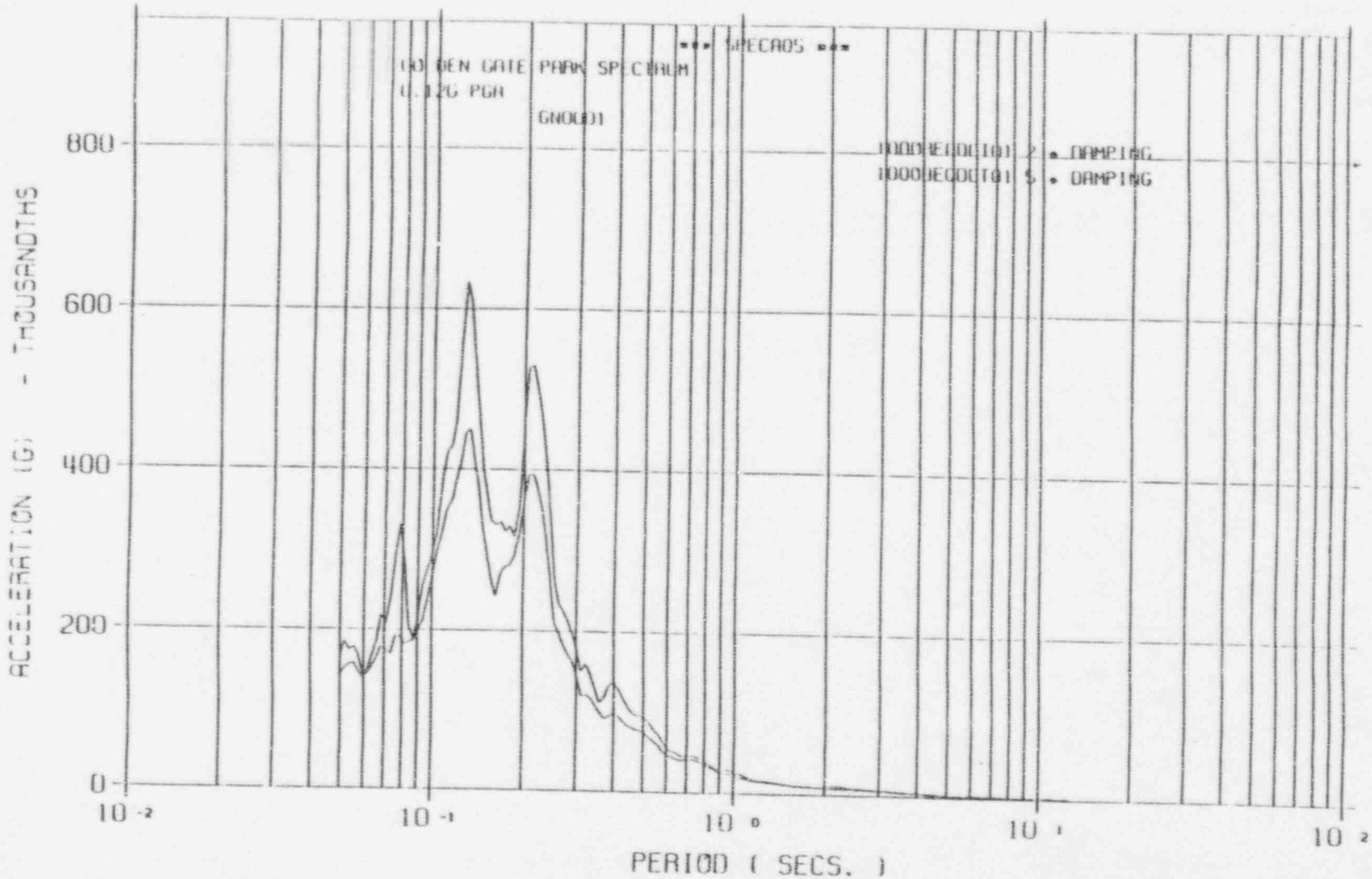

FIGURE 3

RESPONSE SPECTRA OF GOLDEN GATE PARK EARTHQUAKE
WITH A NORMALIZED PEAK ACCELERATION OF 0.12G

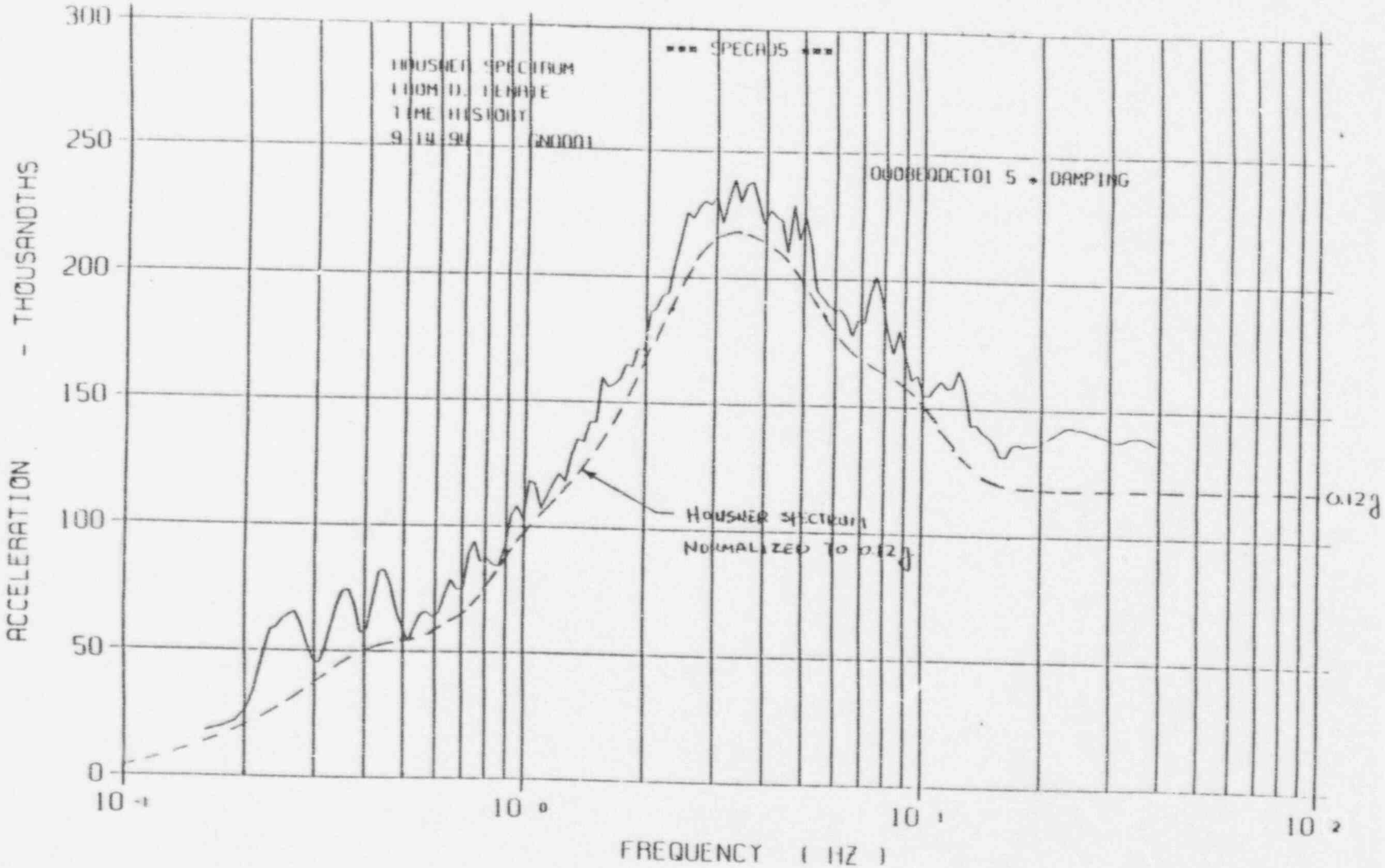

FIGURE 4

HOUSNER SPECTRUM AND SYNTHETIC TIME HISTORY
WITH A NORMALIZED PEAK ACCELERATION OF 0.12G

Enclosure 8
Color Picture of Computer Model of Core Shroud Repair at Quad Cities Station
Non-Proprietary Version

GENE Proprietary Information
Attachment 1 of
107E5487 sh.2 of 3

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