RESOLUTION TO LER 92-001-00

EVALUATION OF THE EFFECTS OF USING VARIOUS DAMPING VALUES IN THE SEISMIC ANALYSIS OF PNPS PIPING SYSTEMS

FINAL REPORT

BOSTON EDISON COMPANY
OCTOBER 1993

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BACKGROUND/DISCUSSION

Boston Edison Company (BECo) issued LER 92-001-00 to detail and discuss circumstances related to the use of inappropriate damping values in the seismic analysis of piping systems for Pilgrim Nuclear Power Station (PNPS). For the analysis in question, damping values from Reg. Guide 1.61 or ASME Code Case N-411 were used. Although these damping values are legitimate, the NRC has generally permitted their use only in conjunction with "current spectra", meaning spectra based on the Reg. Guide 1.60 ground response spectra. Since the design basis curves presently in use at PNPS are based on the original Housner curve, PNPS seismic piping analysis which used either the Reg. Guide 1.61 damping or ASME Code Case N-411 are considered to have potentially reduced design margin without explicit NRC approval.

Boston Edison Company reported the affected piping to be **"OPERABLE"**. Although the damping used were inappropriate for Design Basis analysis, usage of these damping values for ***"operability evaluations"*** has been generally accepted by the NRC for "Housner" plants. Additionally, for all affected PNPS analysis, the analysis results have been compared to Design Basis Allowables, since they were, at that time, being considered Design Basis analysis.

To resolve the damping issue, Boston Edison Company, committed to continued evaluations which included the development of new response spectra for both the Housner and R.G. 1.60 ground response spectra (anchored at 0.08g OBE and 0.15g SSE) as well as confirmatory pipe stress analysis. Development of the new spectra utilized state-of-the-art analysis techniques including soil structure interaction and improved curve fitting algorithms to develop the Time History from the ground response input spectra.

DEFINITION OF TERMS

The following terms are defined for usage within this report:

1. **BECo C-114 spectra** - Any of the curves contained in PNPS Specification C-114-ER-Q-E0 "Seismic Response Spectra". In general, these spectra represent what was used in the original design to implement the Housner design basis requirement.

2. **EQE Housner spectra** - Any of the family of curves developed for BECo by EQE Engineering Consultants that are contained in EQE document # 42103-0-010 (Ref. SUDDSRF 93-143). The basis for these curves is the original Housner ground response, coupled with current analysis techniques. These current analysis techniques include the use of Soil Structure Interaction (SSI) in place of the building model's soil springs and the use of a synthetic time history which closely "fits" the required Housner ground input motion, in place of the enveloping Taft time history record.

3. **EQE R.G. 1.60 spectra** - Any of the curves developed for BECo by EQE Engineering Consultants and contained in EQE document # 42103-0-008 (Ref. SUDDSRF 93-141). The basis for these curves is the R.G. 1.60 input response spectra, coupled with the same current analysis techniques used to develop the EQE Housner spectra discussed in item 2.) immediately above. These curves are used in conjunction with either R.G. 1.61 damping or ASME Code Case N-411 damping, as noted.

4. **N-411 damping** - damping values from ASME Code Case N-411.

5. **Original FSAR damping** - OBE damping = 1/2% ; SSE damping = 1%

6. **Case3** - A piping analysis which uses the BECo C-114 design spectra with Code Case N-411 damping. 2-D absolute sum combination is used. *This case is the limiting case of the analyses that used improper damping since it would produce the lowest seismic demand.*

7. **Case4** - A piping analysis which uses the EQE Housner spectra with original FSAR damping. 2-D absolute sum combination is used. *For these LER evaluations, this case is considered to be a legitimate design basis analysis.*

8. **Case5** - A piping analysis which uses EQE R.G. 1.60 spectra with R.G. 1.61 damping applied. 3-D SRSS combination technique is used. *This case is considered to be an upgrade which meets all current regulatory requirements.*

9. **Case6** - A piping analysis which uses EQE R.G. 1.60 spectra with N-411 damping applied. 3-D SRSS combination technique is used. *For these LER evaluations, this case is considered to be a state-of-the-art analysis, having the least seismic demand, yet still in agreement with today's regulatory requirements.*

EVALUATION APPROACH

The assessment of the issues related to resolution of LER 92-001 focused on comparisons of current BECo design basis spectra to new spectra developed for BECo by EQE Engineering Consultants, and also on comparison of the results of several piping analysis performed for BECo by ALTRAN Corporation using these new spectra.

PART 1 - Comparisons of spectra content:

A BECo C-114 Spectra with N-411 damping would theoretically produce the least conservative results. The EQE R.G. 1.60 spectra with N-411 damping would have the lowest acceleration content which still meets today's regulatory requirements. If the BECo C-114 spectra envelopes the EQE R.G. 1.60 spectra, then the results calculated using the BECo C-114 spectra are considered acceptable and no further analysis or modifications would be required.

PART 2 - Comparisons of piping analysis results:

Piping analysis results calculated using the BECo C-114 Spectra (with ASME Code Case N-411 damping) are compared to analysis results calculated using the EQE Housner spectra and the EQE R.G. 1.60 spectra with various damping levels. Three actual PNPS piping models are used.

SUMMARY/CONCLUSIONS for PART 1

Based on comparisons of specific spectra acceleration contents, the following details are noted:

EQE Housner w/1% damping vs. BECo C-114 w/N-411 damping - (Refer to curves 1, 2 and 3 in attachment A) The EQE Housner curve w/1% damping is generally enveloped by the BECo C-114 curve w/N-411 damping in the horizontal directions. At the lowest elevations, there is a small area below 4 Hz where this is not the case. This is not considered significant since most seismically designed piping systems have a fundamental frequency in the range of 5 to 12 Hz. (Piping systems do not respond to seismic inputs which are below their natural frequency and so this small area noted above is not expected to affect any PNPS piping). For the BECo C-114 curves, there were no specific vertical input spectra. Vertical spectra for any location in the plant was taken to be 2/3 of the horizontal ground input, which amounts to about 0.25g input. The EQE Housner curves contain a specific vertical curve for each reactor building node. These new vertical curves have peaks ranging from around .4g to 1.0g. The effect of this minor increase in vertical seismic input is expected to be offset by the more significant reductions seen in the horizontal curves.

EQE R. G. 1.60 w/N-411 damping vs. BECo C-114 w/N-411 damping - (Refer to curves 4, 5, and 6 in attachment A) The EQE R.G. 1.60 curve w/N-411 damping is generally enveloped by the BECo C-114 curve w/N-411 damping in the horizontal directions. At the lowest elevations, there is a small area below 4 Hz where this is not the case. This is not considered significant since most seismically designed piping systems have a fundamental frequency in the range of 5 to 12 Hz. (Piping systems do not respond to seismic inputs which are below their natural frequency and so this small area noted above is not expected to affect any PNPS piping). For the BECo C-114 curves, there were no specific vertical input spectra. Vertical spectra for any location in the plant was taken to be 2/3 of the horizontal ground input, which amounts to about 0.25g input. The EQE R.G. 1.60 curves contain a specific vertical curve for each reactor building node. These new vertical curves have peaks ranging from around .4g to 1.0g. The effect of this minor increase in vertical seismic input is expected to be offset by the more significant reductions seen in the horizontal curves.

PART 1 CONCLUSIONS - The above comparisons indicate that for the EQE Housner 1% damping spectra and for the EQE RG 1.60 N-411 damping spectra there is, in general, a significant reduction in horizontal accelerations compared to the BECo C-114 N-411 damping spectra. The reduction in horizontal acceleration tends to offset minor increases in the vertical accelerations found in the EQE Housner and EQE RG 1.60 curves. In the area of interest, the EQE Housner and the EQE RG 1.60 horizontal curves are both enveloped by the BECo C-114 curve. Based on this evaluation, it is expected that analyses performed using the EQE Housner Spectra (w/1% damping) or the EQE RG 1.60 Spectra (w/N-411 damping) would calculate results which have lower loads and stresses than the results reported in the existing PNPS piping analyses which utilized either RG 1.61 damping or ASME Code Case N-411 damping. Based on these evaluations, the existing PNPS analyses are considered conservative, and, since their results are less than Design Basis allowables, are considered to be valid Design Basis calculations. No systematic re-analysis is required.

SUMMARY/CONCLUSIONS for PART 2

Based on comparisons of specific piping analysis results the following details are noted (Refer also to the charts contained in attachment B):

Main Steam Piping model - A computer analysis was performed using the EQE Housner spectra, with 1/2% OBE and 1% SSE damping. Another computer analysis using EQE RG 1.60 curves with Code Case N-411 damping was run. The results of these two analyses were compared with a run which used the BECo C-114 spectra with Code Case N-411 damping. For the SSE case, pipe stresses, pipe support/equipment loads, and accelerations for the new analyses were found to be, on the average, approximately 40% of the corresponding loads from the analysis which used inappropriate N-411 damping. Comparisons to Code Allowable stresses for all cases gave ratios much less than 1.0.

Reactor Water Level Piping model - Again, a computer analysis was performed using the EQE Housner spectra, with 1/2% OBE and 1% SSE damping. Another analysis using EQE RG 1.60 curves with Code Case N-411 damping was run. The results of these two analyses were compared with a run which used the BECo C-114 spectra with Code Case N-411 damping. For the SSE case, pipe stresses, pipe support/equipment loads, and accelerations for the new analyses were found to be, on the average, approximately 60% of the corresponding loads from the analysis which used inappropriate N-411 damping. Comparisons to Code Allowable stresses for all cases, again gave ratios much less than 1.0

Control Rod Drive Piping model - As above, a computer analysis was performed using the EQE Housner spectra, with 1/2% OBE and 1% SSE damping. Another analysis using EQE RG 1.60 curves with Code Case N-411 damping was run. The results of these two analyses were compared with a run which used the BECo C-114 spectra with Code Case N-411 damping. For the SSE case, pipe stresses, pipe support/equipment loads, and accelerations for the new analyses were found to be, on the average, approximately 55% of the corresponding loads from the analysis which used inappropriate N-411 damping. Comparisons to Code Allowable stresses for the new analyses gave ratios about 60% while the existing analysis had a ratio of about 90%.

PART 2 CONCLUSIONS - Based on the above comparisons, it is concluded that using the new EQE spectra **with appropriate damping values** will produce analytic results which are consistently less than the existing analysis results. From this it is concluded that the existing PNPS analyses are conservative and since their results are less than Design Basis allowables, they are considered to be valid Design Basis calculations and no systematic re-analysis will be required.

RECOMMENDATIONS

Short Term Resolution: Based on the evaluations performed and the conclusions reached in this report, **it is recommended that LER 92-001-00 be closed**. All PNPS piping analyses which have used inappropriate damping as discussed in this report shall be annotated to indicate that they are "Directly Affected by the issues addressed to LER 92-001-00". It will noted that the results contained in those reports are acceptable for use as a design basis. It will further be noted that any future reviews, evaluations, upgrades, or re-analysis are to be conducted in accordance with the final Long Term Resolution to LER 92-001-00.

Long Term Resolution: Although this report concludes that the existing analyses are considered to be valid design basis analyses, any future design basis reviews, evaluations, analyses, or other considerations should be based on the PNPS FSAR.

At this time, the FSAR specifies these damping values: 1/2% for OBE and 1% for SSE, which are the original damping values and the only damping values that have been approved for design basis analysis by the NRC. In order to preclude unnecessary modifications or costly re-evaluations, it may be advantageous to submit to the NRC a **proposal to amend our FSAR to allow the use of the EQE spectra for design basis analysis**. Specifically, we should consider one of the following options:

OPTION 1 - Using the EQE Reg. Guide 1.60 spectra in conjunction with Reg. Guide 1.61 or ASME code case N-411 damping values.

or

OPTION 2 - Using the EQE Housner spectra in conjunction with original FSAR damping values (1/2% for OBE: 1% for SSE)

Option 1 is preferred since it is consistent with today's regulatory requirements, considering both the spectra shape/content and the state-of-the-art technology used to generate the in-structure spectra curves. We should perform additional reviews, relatively minor in scope, to ensure that the potential for out-liers is identified, understood, and accounted for. This is essential so that we can ensure that our proposed commitments will provide us the freedom to maintain acceptable design margins with minimal contingent conditions being self-imposed on us or required of us.

Detailed Evaluations

Part 1

Comparative Evaluation of Specific SSE Spectra.

I. EVALUATION - BECo C-114 N-411 curve vs. EQE Housner 1% curve (SSE case)

Refer to Attachment A, Curves 1, 2, and 3 as well as Attachment A, Table 1

Horizontal (Lowest elevations):

At the lowest elevations of the Reactor Bldg. structure, there is a small area where the EQE Housner curve is not enveloped by the C-114 curve. This occurs at about 4 Hz or less. In this region the peaks of the two curves are the same; however, the peak of EQE Housner curve is shifted slightly to the left. The effect is not very extensive and is not considered to have any significant effect since the large majority of seismically designed piping systems have a fundamental frequency greater than 4 Hz. Piping does not respond to frequency inputs which are less than its natural frequency. (See note 2 below).

Horizontal (Higher elevations):

At the higher elevations, the EQE Housner curve is essentially enveloped by the C-114 curve for all structures. The C-114 peak accelerations are generally 1.5 to 3 times higher than the peak accelerations from the EQE Housner curves. For nodes above elevation 23', peak accelerations for the Reactor Building Structure range from 1.87g at elev. 51' to 6.95g at elev. 164.5' for the Old Housner, and from 0.80g to 1.80g for corresponding points in the EQE Housner curve. Similar dramatic reductions are noted in curves for the other internal structures.

Vertical:

Specific vertical curves do not exist in the BECo C-114 family. The vertical input, for all locations in the plant, was taken to be equal to 2/3 of the horizontal ground motion. The new specific vertical curves are all consistently higher than the old input, but the accelerations are typically small. Differences between the EQE Housner curves and BECo C-114 curves are not considered significant except in upper areas of the Reactor Bldg. where the increased vertical input is more than offset by highly reduced horizontal accelerations.

NOTES:

1. The above comparisons are considered significant because, as noted earlier, the BECo C-114 w/N-411 damping case is considered a worst case of the analysis which used inappropriate damping, while the EQE Housner 1% curve can be reasonably argued to be a potentially legitimate Design Basis spectra.

2. The natural frequencies for the three piping models analyzed in PART 2 of this evaluation have fundamental frequencies as follows:

Reactor Water Level piping:	4.76 Hz
Main Steam piping:	5.32 Hz
Control Rod Drive piping:	7.02 Hz

These three models see significant reductions in horizontal accelerations in going from BECo C-114 N-411 curve to EQE Housner 1% curves.

II. EVALUATION - BECo C-114 N-411 curve versus EQE R.G. 1.60 N-411 curve (SSE case)

Refer to Attachment A, Curves 1, 2, and 3 as well as Attachment A, Table 1

Horizontal:

At the lower elevations of the Reactor Bldg., there is a small area where the EQE R.G. 1.60 curve is not enveloped by the BECo C-114 curve. This occurs at about 4 Hz or less. The peaks of the two curves are the same, the peak of EQE R.G. 1.60 curve is shifted slightly to the left. The effect is not very extensive and is not considered to be significant since the large majority of seismically designed piping systems have a fundamental frequency greater than 5 Hz. Piping does not respond to frequency inputs which are less than its natural frequency. See note 2 below.

Vertical:

Specific vertical curves do not exist in the BECo C-114 family. The vertical input, for all locations in the plant, was taken to be equal to 2/3 of the horizontal ground motion. The new specific vertical curves are all consistently higher than the old input, but the accelerations are typically small. Differences between the EQE R.G. 1.60 curves and BECo C-114 curves are not considered significant except in upper areas of the Reactor Bldg. where the increased vertical input is more than offset by highly reduced horizontal accelerations.

NOTES:

1. The above comparisons are considered significant because, as noted earlier, the BECo C-114 case is considered a worst case of the analysis which used inappropriate damping, while the Reg. Guide 1.60 N-411 curve is considered to be the case with the least conservatism remaining but which still meets current regulatory requirements.

2. The natural frequencies for the three piping models analyzed in PART 2 of this evaluation have fundamental frequencies as follows:

Reactor Water Level piping:	4.76 Hz
Main Steam piping:	5.32 Hz
Control Rod Drive piping:	7.02 Hz

These three models see significant reductions in horizontal accelerations in going from BECo C-114 N-411 curve to Reg. Guide 1.60 N-411 curves.

Detailed Evaluations

Part 2

Comparative Evaluation of Specific Piping Analyses

I. MainSteam "A" model

Curves: **RB 51'**

Pipe size: Large Bore pipe: 24", 10", 6" **Fundamental Frequency:** 5.317 Hz

Pipe Stresses:

- Case4, Case5, and Case6 were all very similar and always produced lower stresses than Case3

- Ratio of Max Calculated to Code Allowable

Case3:	**Upset = 0.72**	**Faulted = 0.70**
Case4:	**Upset = 0.52**	**Faulted = 0.38**
Case6:	**Upset = 0.48**	**Faulted = 0.37**

- Case4 vs. Case3 ratio of stress:

SSE Average	**= 0.342**
OBE Average	**= 0.418**

Pipe Support & Equipment Nozzle Loads:

- Cases4, Case5, and Case6 were all very similar and always produced lower loads than Case3.

- Case4 vs. Case3 ratio of loads:

SSE Average	**= 0.363**
OBE Average	**= 0.489**

Accelerations:

- Case4, Case5 and Case6 accelerations are always less than Case3.

- Even though "Y" accelerations for Case4, Case5, and Case6 are higher than for Case3, the resultant accelerations for Case3 are significantly higher than Case4, Case5, and Case6.

II. RWL model

Curves: RPV 86.75'

Pipe size: Small bore **Fundamental Frequency:** 4.764 Hz

Pipe Stresses:

- Case4 and Case6 stresses are always less than Case3 stresses.
- Case6 generally produced the lowest stresses, but not for all nodes.
- Case4 and Case6 are very similar.
- Ratio of Max Calculated to Code Allowable

Case3:	**Upset = 0.28**	**Faulted = 0.34**
Case4:	**Upset = 0.29**	**Faulted = 0.27**
Case6:	**Upset = 0.27**	**Faulted = 0.30**

- Case4 vs. Case3 ratio of stress:

SSE Average	**= 0.653**
OBE Average	**= 0.940**

Pipe Support Loads:

- Same tendencies as stresses.
- Case4 vs. Case3 ratio of loads:

SSE Average	**= 0.591**
OBE Average	**= 0.855**

Accelerations:

- Case4, Case5, and Case6 are always less than Case3.
- Even though "Y" accelerations for Case4, Case5, and Case6 are higher than for Case3, the resultant accelerations for Case3 are much higher than Case4, Case5, and Case6.

III. CRD model

Curves: RB 51', RB 23'

Pipe size: Small bore **Fundamental Frequency:** 7.021 Hz

Pipe Stresses:

- Case4 generally produced lowest stresses, but not for all nodes. Case3 had some marginally lower stresses at lower stress levels. (Note: Case4 stresses are always higher than Case3 loads when stresses are significant.
- Case4 and Case6 are very similar.
- When Case4 or Case6 stresses are greater than Case3 stresses, they are still much less than original design.
- Case4 vs. Case3 ratio of stress:

  SSE Average = 0.563
  OBE Average = 0.991

- Ratio of Max Calculated to Code Allowable

Case3:	**Upset = 1.00**	**Faulted = 0.92**
Case4:	**Upset = 0.75**	**Faulted = 0.55**
Case6:	**Upset = 0.75**	**Faulted = 0.57**

Pipe Support Loads:

- Same tendencies as stresses.
- When Case4 or Case6 loads are less than Case3, they are still less than original design loads.
- Case4 vs. Case3 ratio of loads:

  SSE Average = 0.526
  OBE Average = 0.574

Accelerations:

- Case4 or Case6 accelerations are always less than Case3.
- Even though "Y" accelerations for Case4, Case5, and Case6 are higher than for Case3, the resultant accelerations for Case3 are much higher than Case4, Case5, and Case6.

REFERENCES

1. Boston Edison Company, "Pilgrim Nuclear Power Station, Final Safety Analysis Report", FSAR.

2. Boston Edison Company, Licensee Event Report (LER) 92-001-00, "Class I Piping Seismic Damping Ratios".

3. PNPS Specification C-114-ER-Q-E0 "Seismic Response Spectra"

4. USNRC Regulatory Guide 1.60 "Design Response Spectra for Seismic Design of Nuclear Power Plants", Revision 1, December 1973

5. USNRC Regulatory Guide 1.61 "Damping Values for Seismic Design of Nuclear Plants", October 1973

6. American Society of Mechanical Engineers (ASME) Code Case N-411-1, "Alternate Damping Values for Response Spectra Analysis of Class 1, 2, and 3 Piping", Section III, Div. 1: ASME 2/20/86, NY.

7. USNRC Regulatory Guide 1.84, "Design and Fabrication Code Case Acceptability - ASME Section III Division 1"

8. EQE Document No. 42103-0-010, PNPS Housner based Spectra Curves, (SUDDSRF 93-143)

9. EQE Document No. 42103-0-008, PNPS R.G 1.60 Spectra Curves, (SUDDSRF 93-141)

10. ALTRAN Report 93163-TR-1, "Stress Analysis Study of Differing In-Structure Response Spectra on the Qualification of Piping at Pilgrim Nuclear Power Station", October 1993

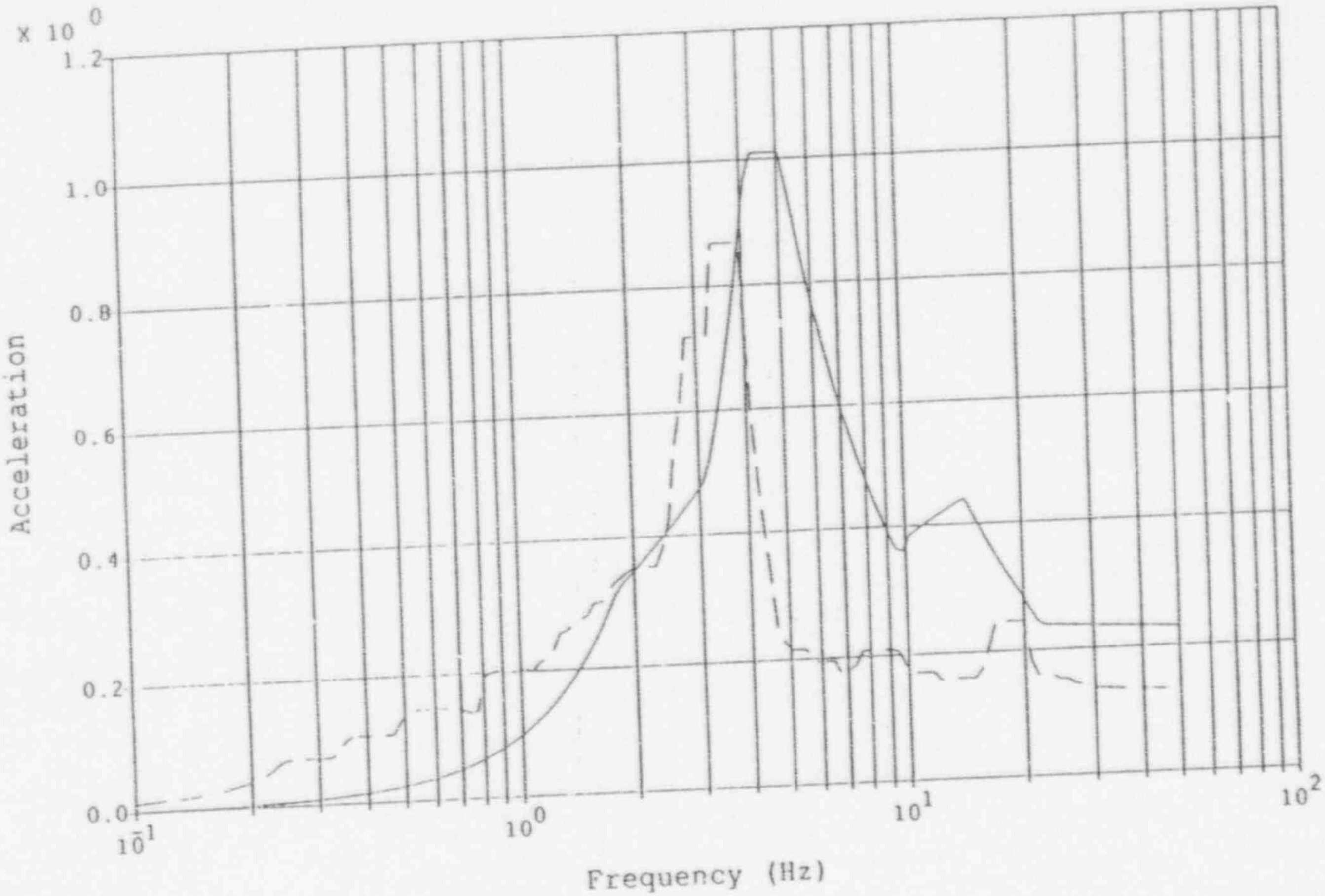
ATTACHMENTS

Attachment A

Seismic Spectra Curve Plots and Table
(Comparisons of various spectra acceleration content)

Attachment B

Charts
(Stress and load ratio comparisons for specific computer analyses)



Legend:

BECO C114 (n411) Hor Design Spectrum ————

EQE Housner (1%) In-Structure Spectrum — — — —

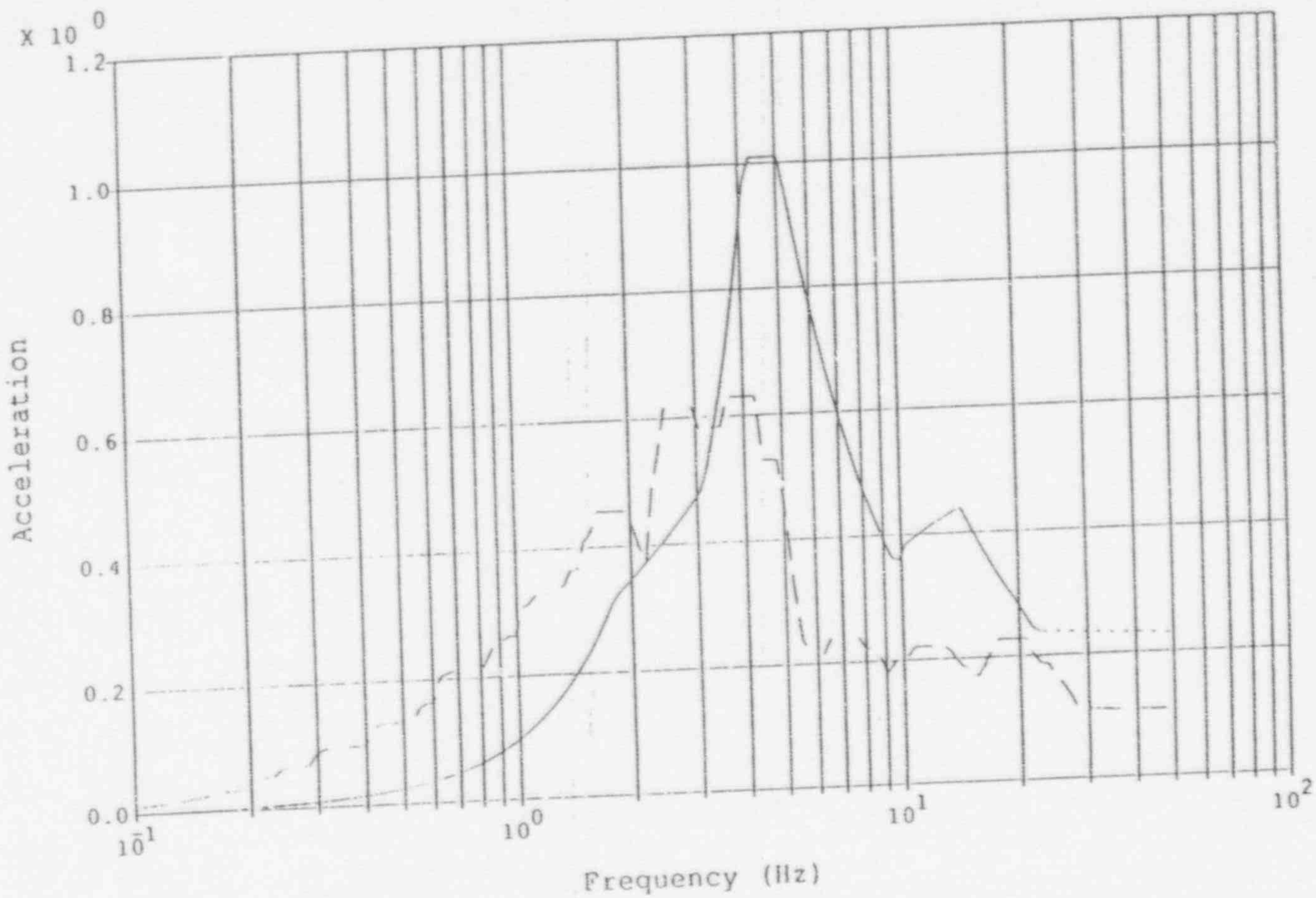
Notes:

North-South Direction
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, Elevation 23.0'
Comparison of Housner Spectra vs. C114 Design Spectrum

Attachment 1 - Curve 1

Attachment 1 - Curve 2



Legend:

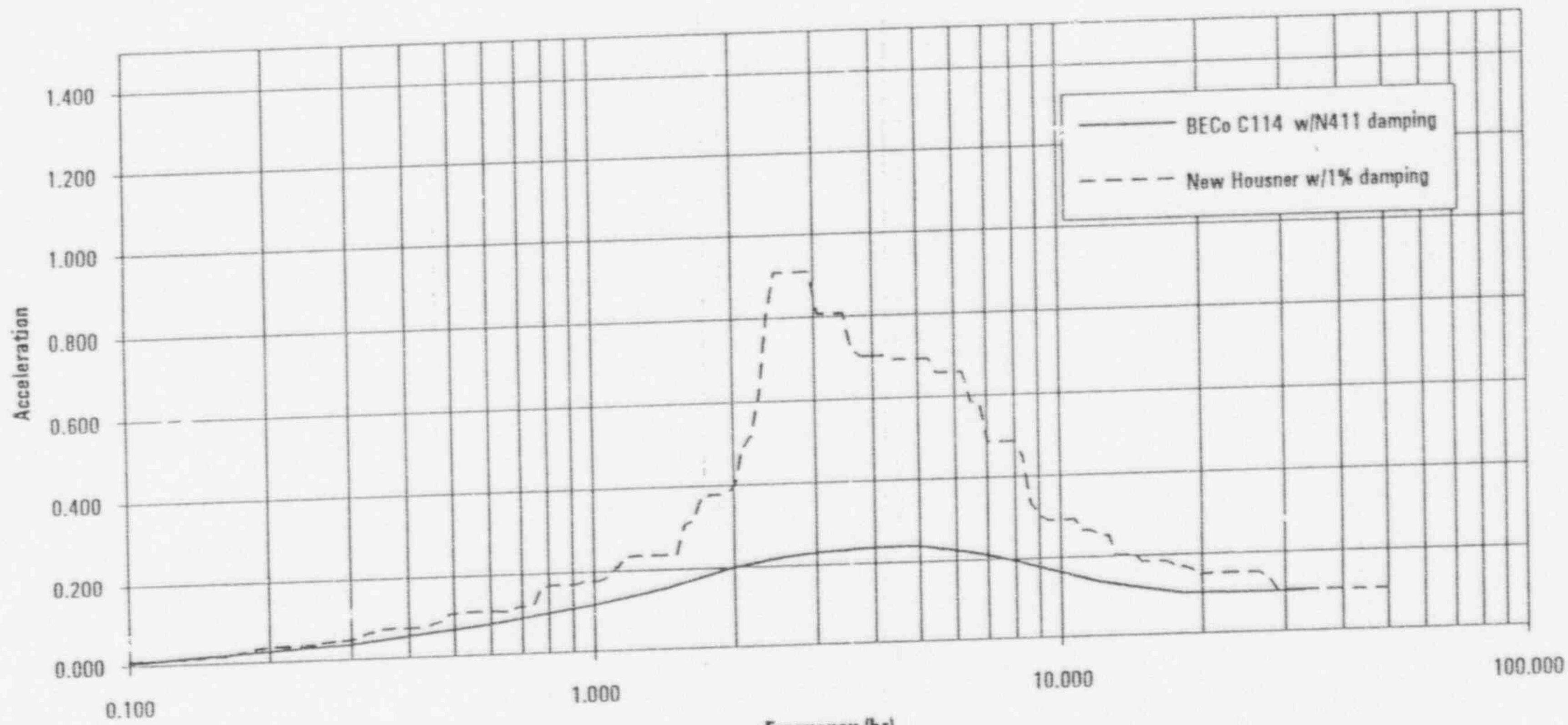
BECO C114 (n411) Hor Design Spectrum ————

EQE Housner (1%) In-Structure Spectrum — — — —

Notes:

East-West Direction
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

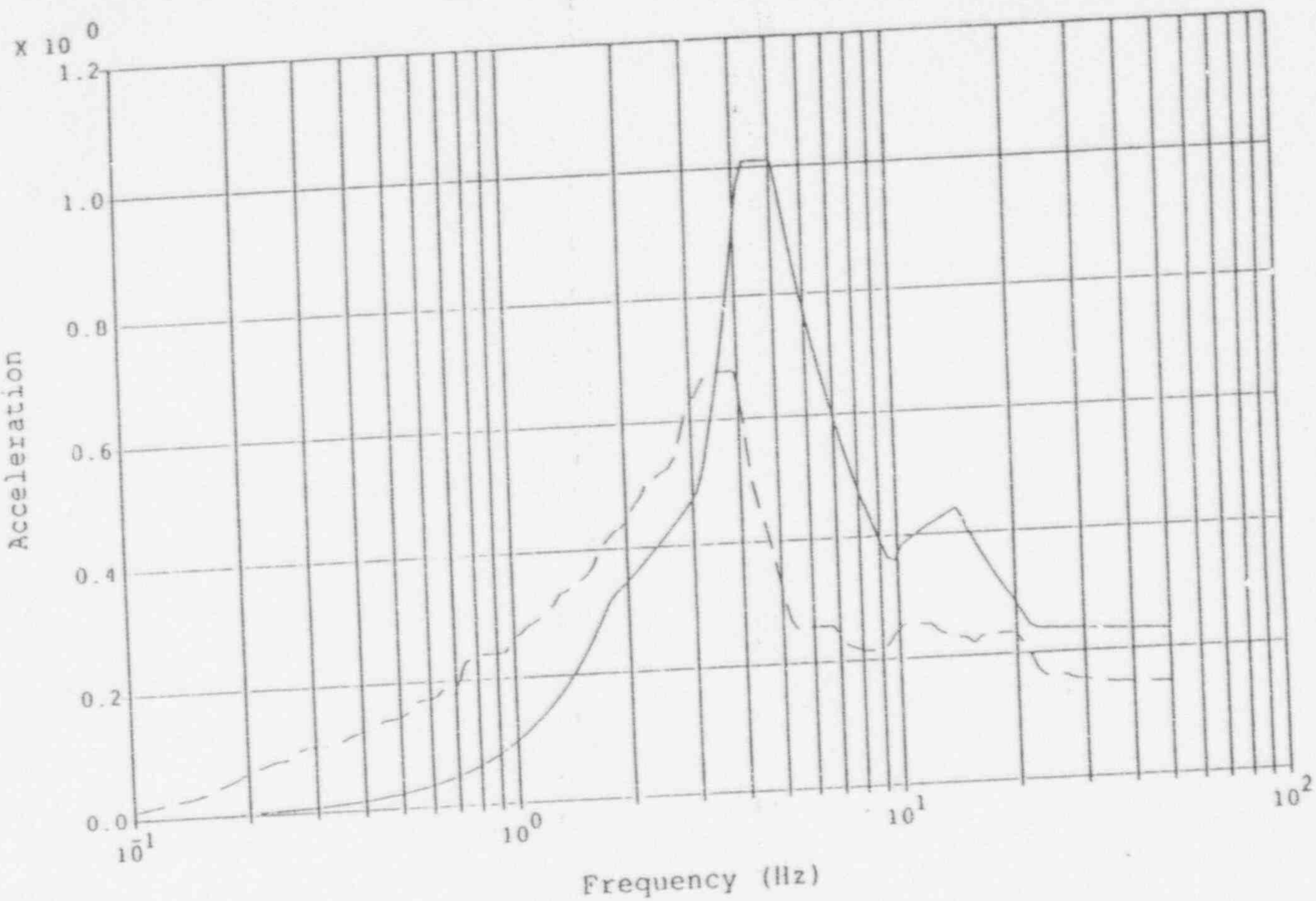
BECO: Pilgrim Reactor Building, Elevation 23.0'
Comparison of Housner Spectra vs. C114 Design Spectrum



BECo PNPS Reactor Building Elevation 23.0' SSE Vertical Direction

Comparison of BECo C-114 Design Spectra vs. New Housner Spectra

Attachment 1 - Curve 3



Legend:
BECO C114 (n411) Hor Design Spectrum ————
EQE RG 1.60 (n411)In -Structure Spectrum — — — — —

Notes:
North-South Direction
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

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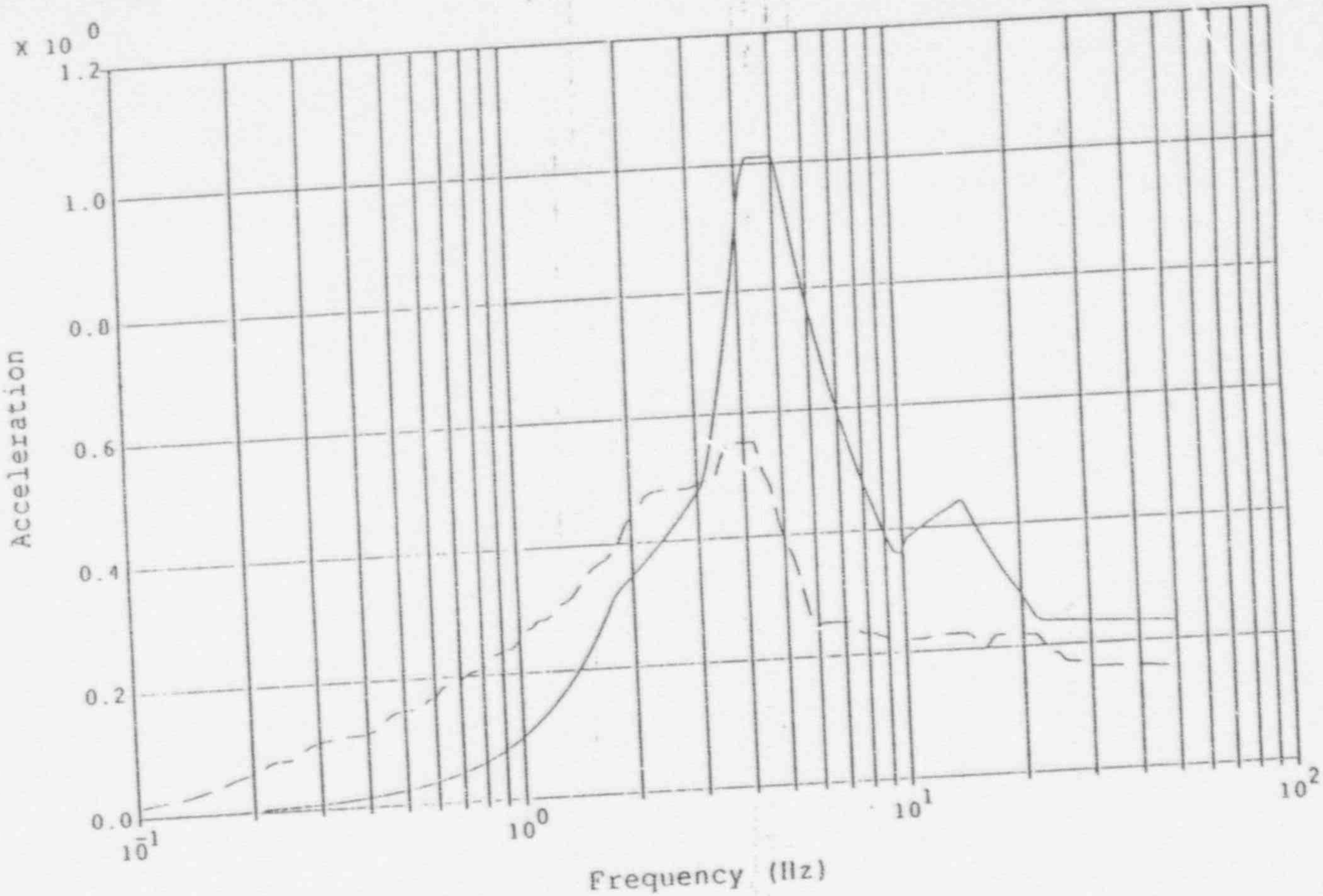
BECO: Pilgrim Reactor Building, Elevation 23.0'
Comparison of RG 1.60 Spectra vs. C114 Design Spectrum

Attachment 1 - Curve 4



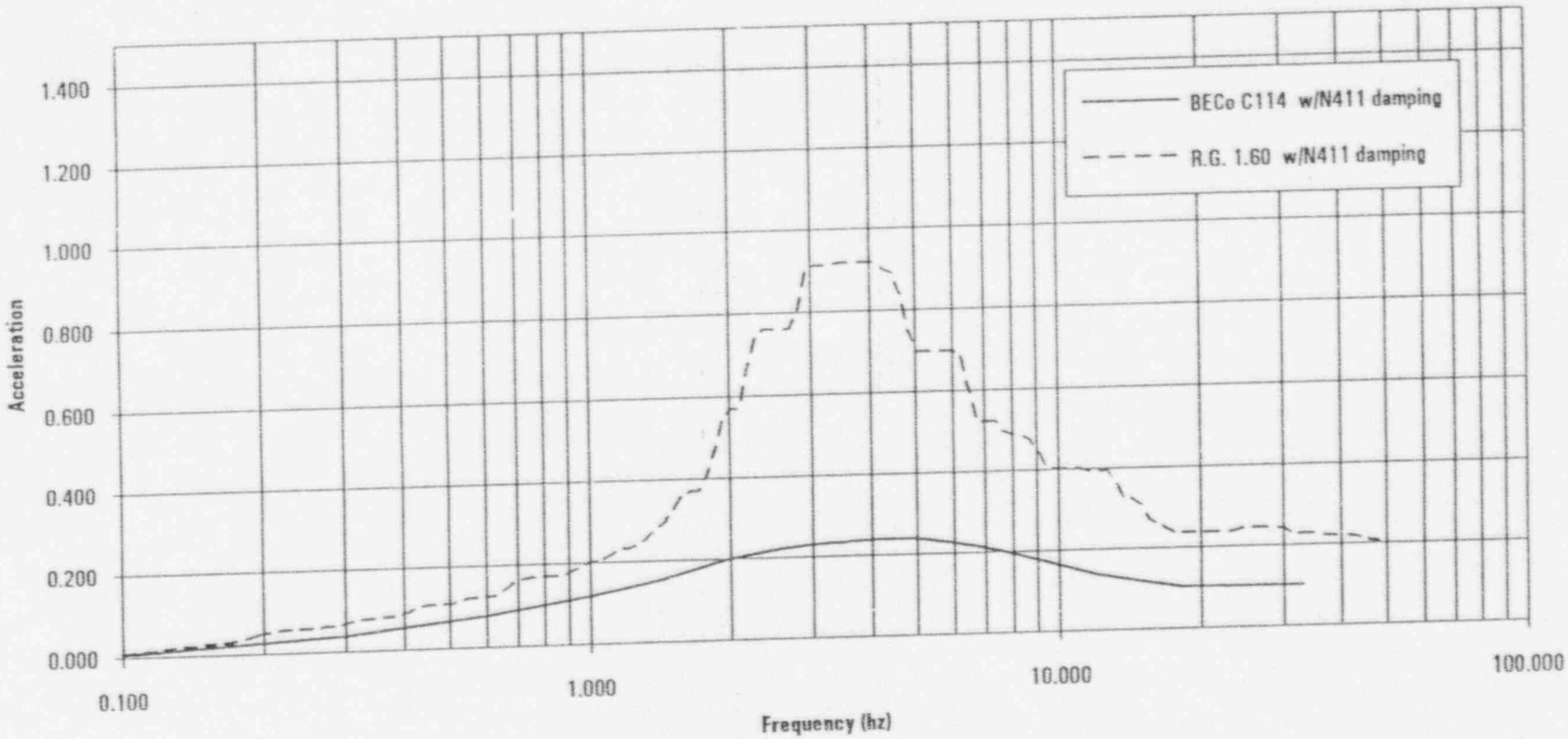
Legend:
BECO C114 (n411) Hor Design Spectrum ————
EQE RG 1.60 (n411) In-Structure Spectrum — — — —

Notes:
East-West Direction
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, Elevation 23.0'
Comparison of RG 1.60 Spectra vs. C114 Design Spectrum

Attachment 1 - Curve 5

SET5-RB2.SSE Chart 1



BECO PNPS Reactor Building Elevation 23.0' SSE Vertical Direction

Comparison of BECo C-114 Design Spectra vs. R.G. 1.60 Spectra

Attachment 1 - Curve 6

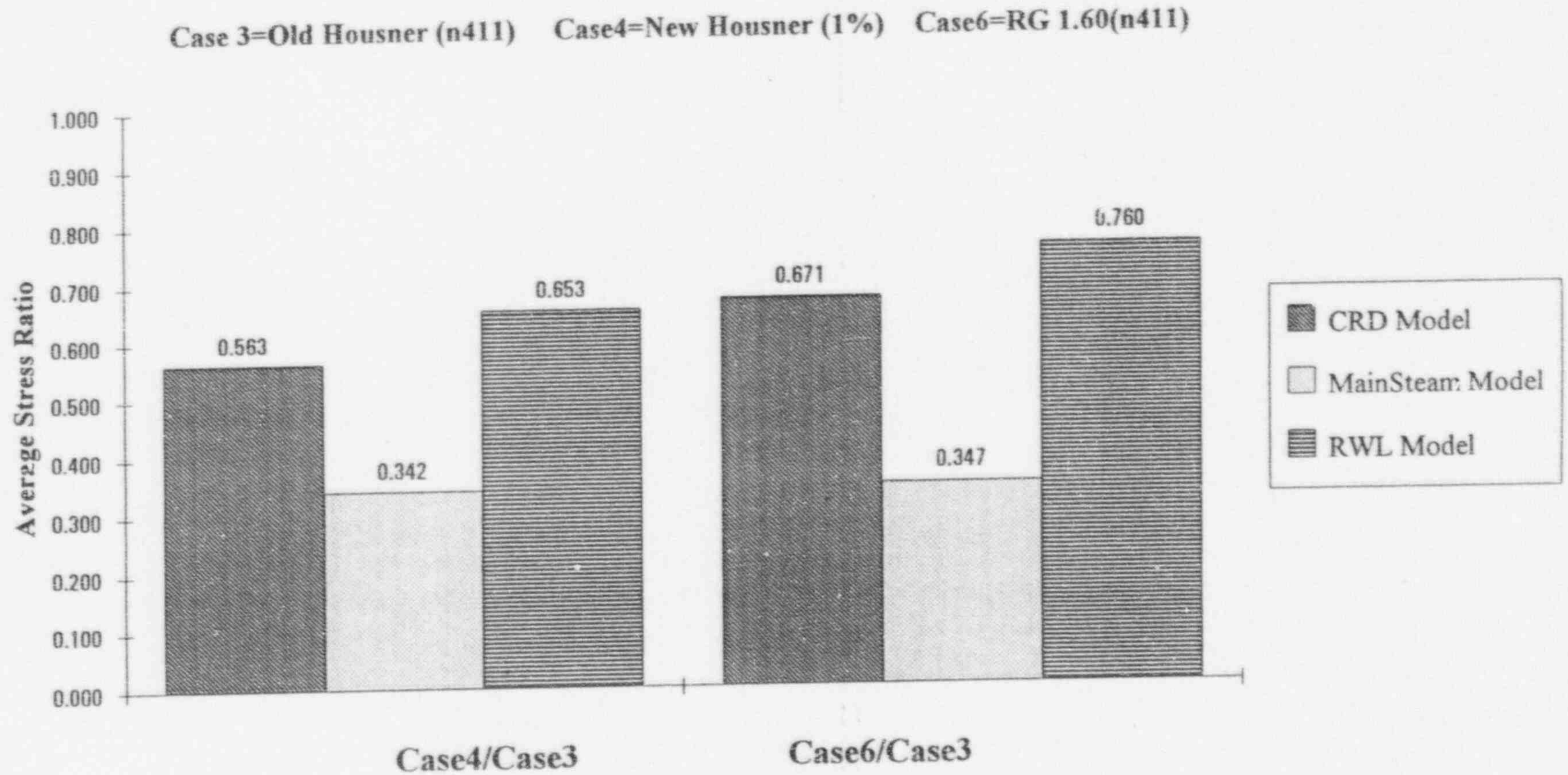
Comparison of Peak Acceleration Values for Various SSE Spectra

C-114 = BECo C-114 Spectra w/N-411 damping
EQE-H = EQE Housner Spectra w/1% damping
EQE-RG = EQE Reg. Guide Spectra w/N-411 damping

Structure	Node	Elev	North-South			Vertical			East-West		
			C-114	EQE-H	EQE-RG	C-114	EQE-H	EQE-RG	C-114	EQE-H	EQE-RG
Reactor Bldg	1	-17.5'	0.49	0.53	0.43	0.22	0.62	0.70	0.49	0.53	0.43
	2	23.0'	1.01	0.87	0.65	0.22	0.90	0.90	1.01	0.63	0.55
	3	51.1'	1.87	1.20	0.80	0.22	0.70	0.90	1.87	0.75	0.70
	4	74.25'	2.04	1.50	1.10	0.22	0.80	0.80	2.04	0.90	0.85
	5	91.25'	2.36	1.70	1.20	0.22	0.82	0.80	2.36	1.10	0.90
	6	117.0'	2.94	1.80	1.40	0.22	0.84	0.80	2.94	1.30	1.10
	7	138.1'	5.90	2.20	1.75	0.22	0.90	0.80	5.90	1.60	1.60
	8	164.5'	6.95	2.40	1.80	0.22	0.90	0.80	6.95	1.80	1.60
Reactor Pedastal	10	15.40'	0.74	0.57	0.48	0.22	0.41	0.44	0.74	0.58	0.45
	11	21.70'	0.86	0.63	0.52	0.22	0.41	0.44	0.86	0.58	0.49
	12	28.00'	1.18	0.70	0.58	0.22	0.41	0.45	1.18	0.62	0.53
	13	35.42'	2.16	0.83	0.65	0.22	0.41	0.50	2.16	0.69	0.59
Bio-Shield Wall	14	47.35'	2.81	1.00	0.70	0.22	0.41	0.50	2.81	0.78	0.66
	15	52.81'	3.00	1.10	0.82	0.22	0.42	0.52	3.00	0.82	0.70
	16	56.64'	3.09	1.20	0.80	0.22	0.42	0.55	3.09	0.80	0.80
	17	71.50'	3.38	1.40	1.00	0.22	0.42	0.55	3.38	1.02	0.84
	18	81.80'	3.62	1.55	1.10	0.22	0.42	0.55	3.62	1.10	0.91
Reactor Vessel	31	47.27'	2.18	1.13	0.83	0.22	0.50	0.90	2.18	0.90	0.75
	32	55.18'	2.70	1.30	0.95	0.22	0.40	0.90	2.70	1.10	0.90
	39	86.75'	4.65	2.00	1.35	0.22	0.40	0.90	4.65	1.80	1.30
Torus		-0.25'	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DryWell Penetr.		21.17'	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Attachment 1 - Table 1

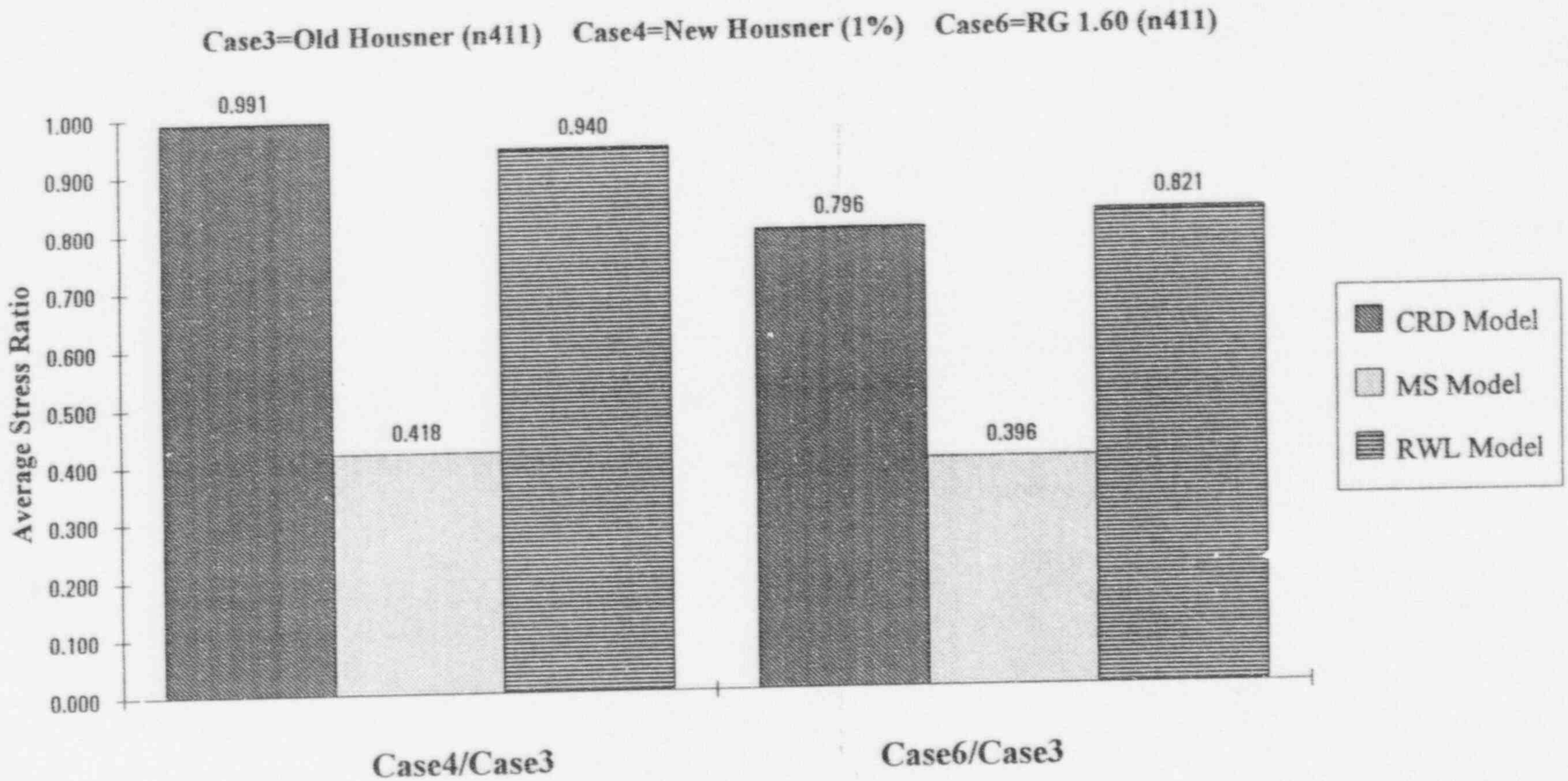
SSE Pipe Stress Level Comparisons



Attachment 2 - Chart 1a

ALL2-1.XLS Chart 1

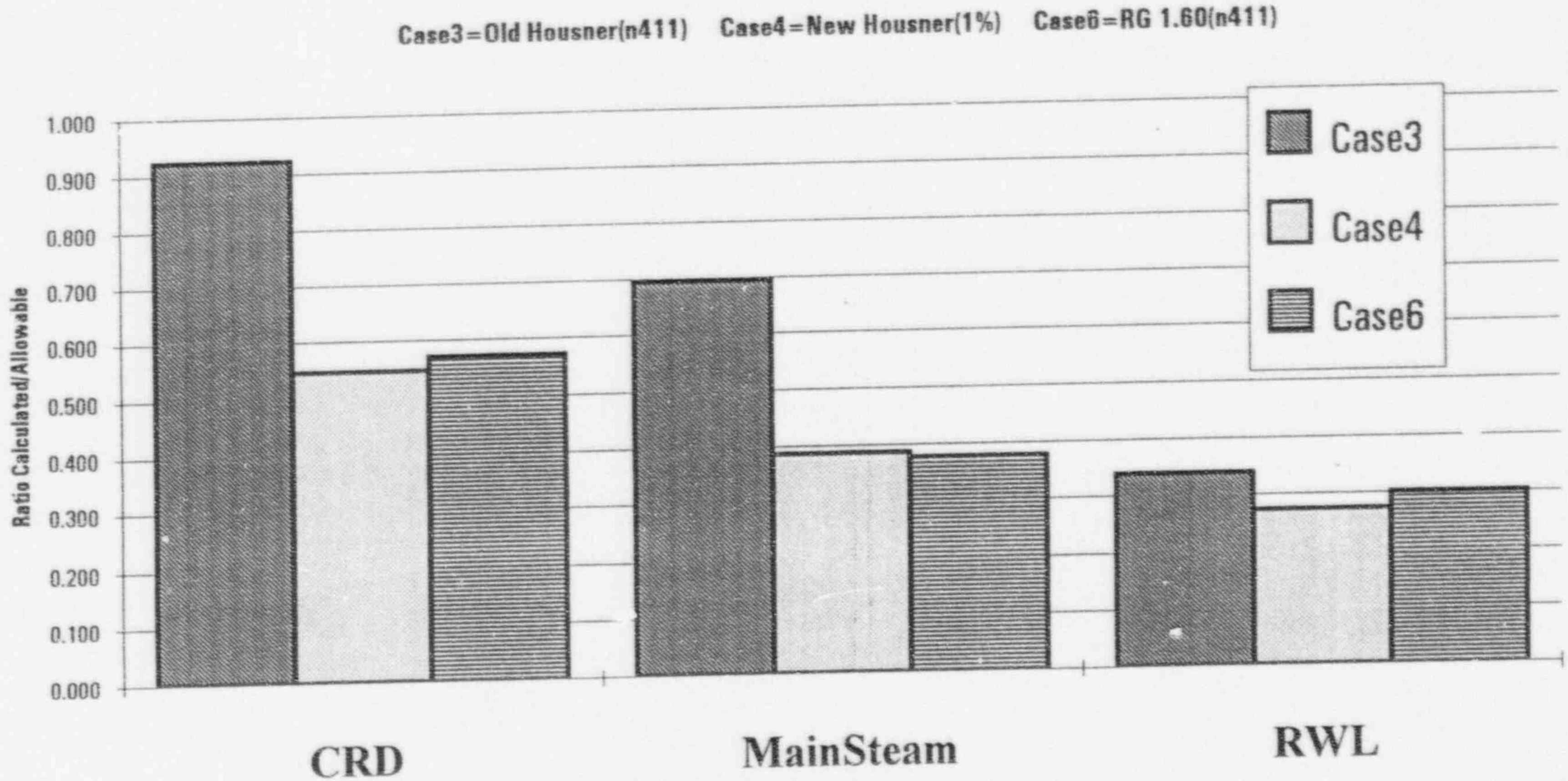
OBE Pipe Stress Level Comparisons



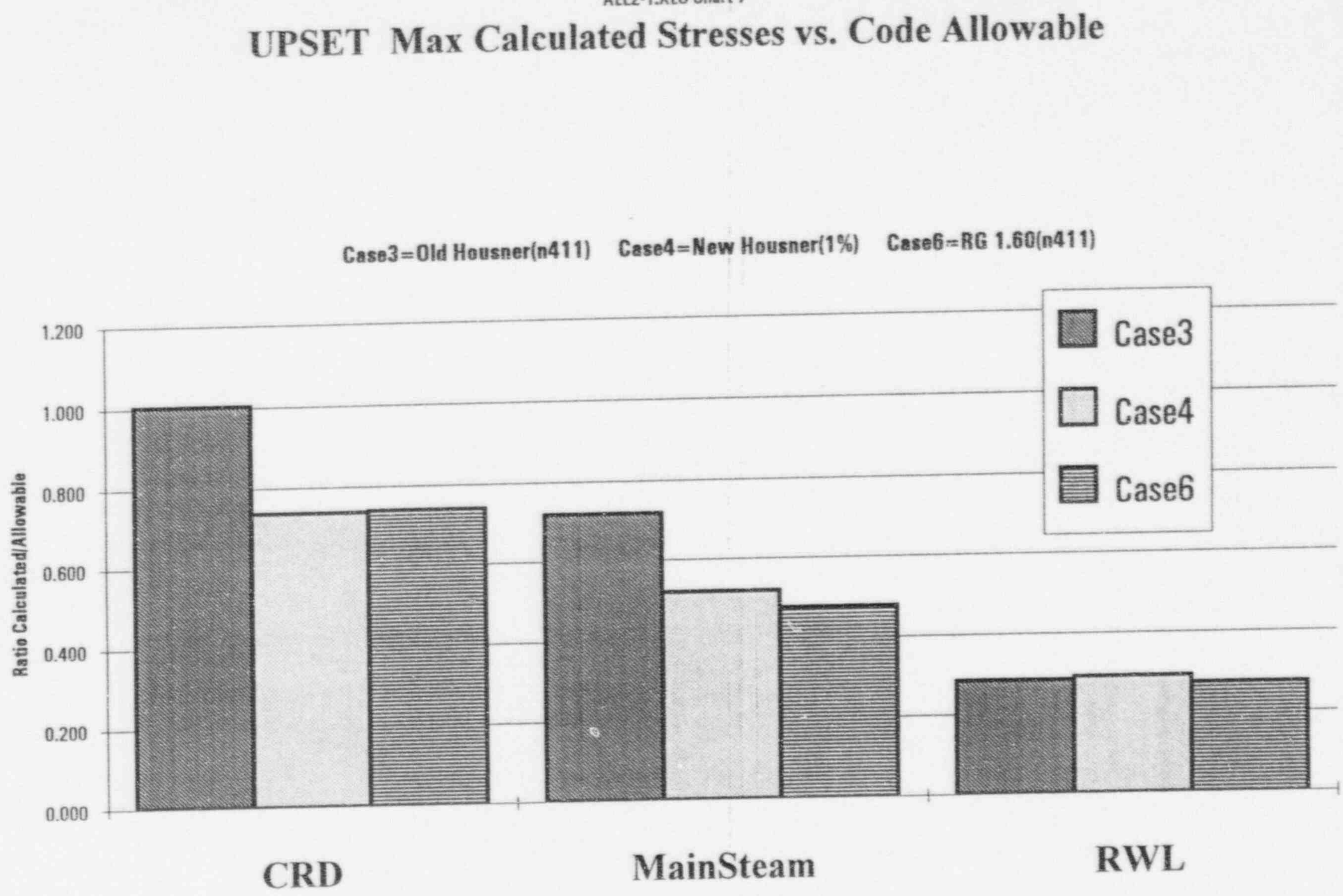
Attachment 2 - Chart 1b

ALL2-1.XLS Chart 8

FAULTED Max Calculated Stresses vs. Code Allowable



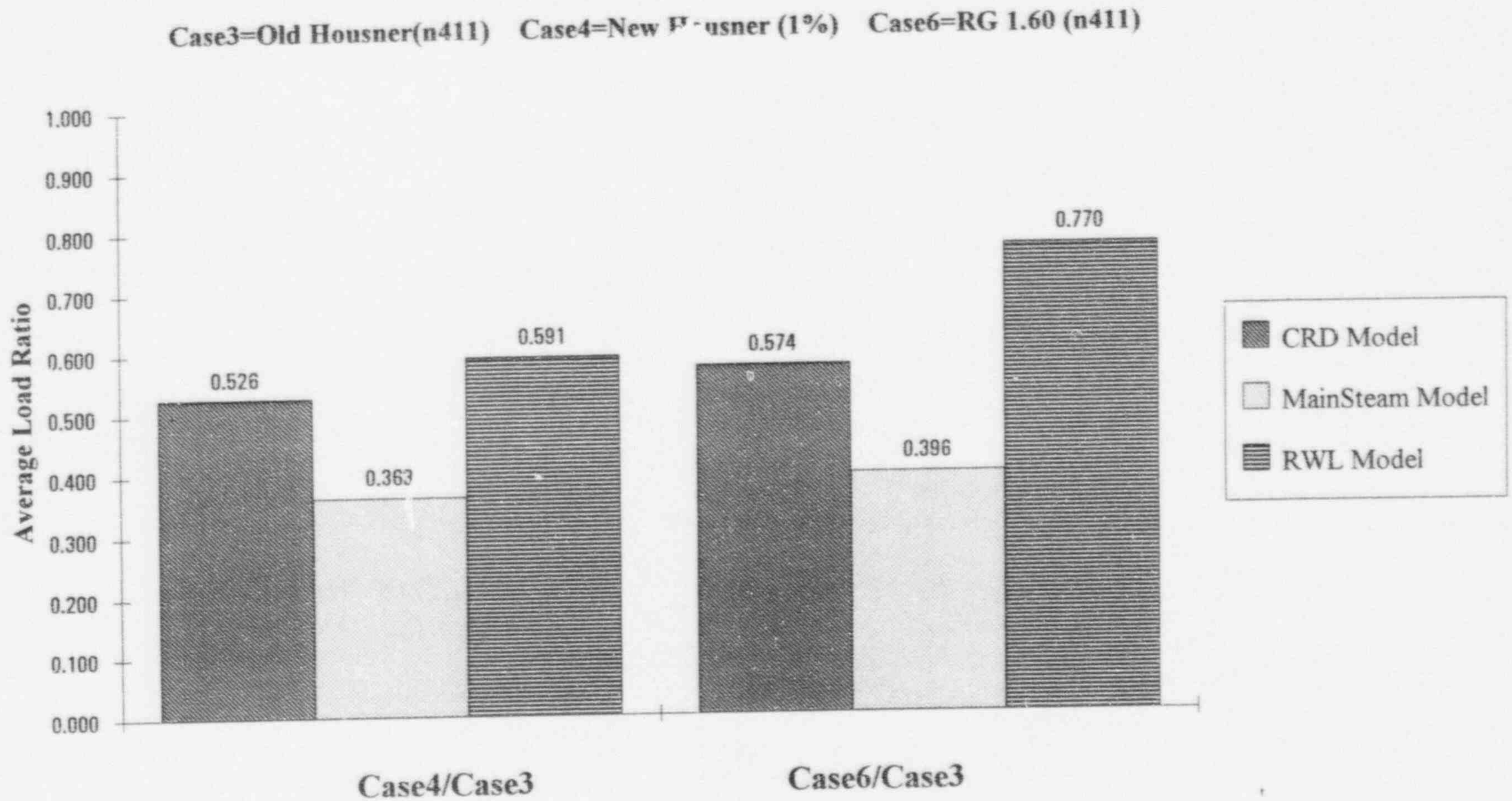
Attachment 2 - Chart 2a



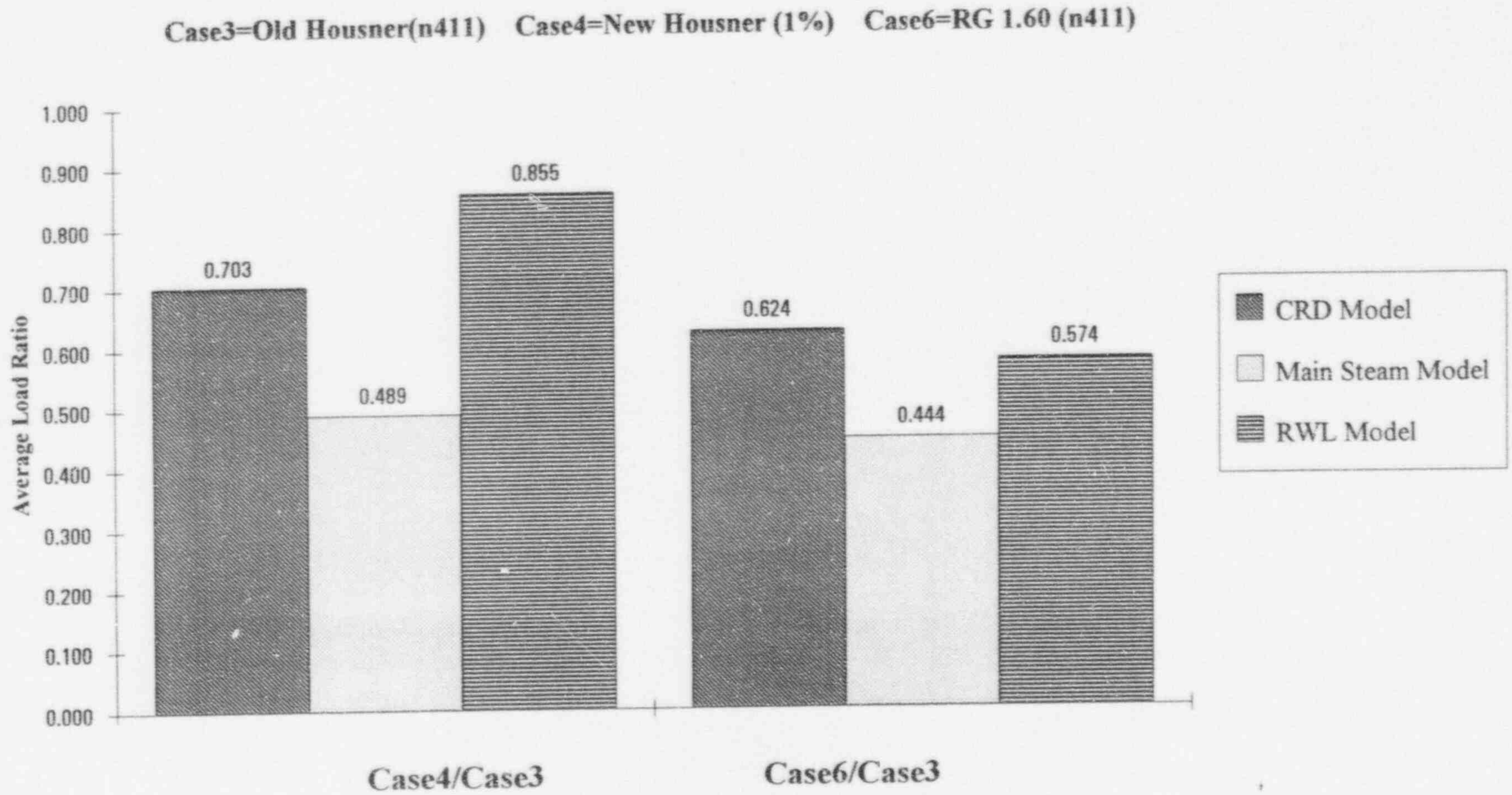
Attachment 2 - Chart 2b

ALL-1.XLS Chart 6

SSE Pipe Support Equipment Nozzle Loads



OBE Pipe Support Equipment Nozzle Loads



Large Bore Pipe Stress Design Basis Calculations Within The LER 92-001 Scope

- **SSW System - Buried Titanium Piping and Aux Bay/Vault Piping**
  Reference. Bechtel Calcs 637 & 638

BECo Calc C15.0.3056	Used RG 1.61 damping
BECo Calc C15.0.3208	Used RG 1.61 damping
BECo Calc C15.0.3019	Used RG 1.61 damping
BECo Calc C15.0.3039	Used RG 1.61 damping

- **RHR/Core Spray System**
  Reference Bechtel Calc 664-665

  BECo Calc M-430 Used RG 1.61 damping

- **RWCU System - Penetration X-14 to E-208A**
  Reference Bechtel Calc 681

  BECo Calc M-474 Used N411 damping

- **Main Steam Blowdown Line "D"**
  Reference GE Analysis 22A2617

  5310SRV-DLD Used N411 damping

Small Bore Pipe Stress Design Basis Calculations Within The LER 92-001 Scope

- **RHR System - Modified Vent Lines**

BECo Calc M-443	Used RG 1.61 or N411 damping

- **Reactor WaterLevel Instrumentation**

CYGNA Calc PI-128	Used N-411 damping
CYGNA Calc PI-129	Used N-411 damping
CYGNA Calc PI-130	Used N-411 damping
CYGNA Calc PI-131	Used N-411 damping

- **Recirculation Flow Xmitter**
  Reference dwg M1001 sht 39

Bechtel Calc 10394-123-2	Used RG 1.61 damping

- **Reactor WaterLevel System**
  Reference dwg M1001 sht 65

CYGNA Calc 85136-3F-PI-59	Used N411 damping

- **Recirculation Instrument piping**
  Reference dwg M1002 Shts 42 & 43

BECo Calc M240	Used RG 1.61 damping

- **Oxygen Analyzer C-19 piping**
  Reference dwg M1002 Shts 115 &116

BECo Calc M-207	Used RG 1.61 damping
BECo Calc M-214	Used RG 1.61 damping

- **Reference Leg to Instrument Racks**
  Reference dwg M1002 Sht 124

CYGNA Calc 85136-SF-V-1	Used RG 1.61 damping

- **Reference Leg to Instrument Racks**
  Reference dwg M1002 Sht 125

CYGNA Calc 85136-SF-V-10	Used RG 1.61 damping

- **RPV Drain**
  Reference dwg M1003 sht 1

S&W Calc 14085.76-NP(B)-021-XS	Used N411 damping

Attachment C

Response to Request for Additional Information Regarding Pilgrim Nuclear Power Station Alternative Reactor Building Response Spectra

Question 1

Item 2 of Attachment 2 which contains the Soil Structure Interaction (SSI) Analysis Soil Properties calculations indicates the following:

(a) the total depth of five soil layers from the grade level to the base of the reactor building (RB) is 45 feet (ft) and the shear wave velocities of these thin soil layers range from 535 feet per second (fps) to 963 fps; and

(b) there are four soil layers between the base of the RB and the bedrock which is situated 35 ft below the base of the RB, and the shear wave velocities of these four layers range from 1215 fps to 1365 fps.

Explain why, for such soil configuration consisting of thin soft layers, the RG 1.60 spectrum-compatible ground motion is input at the grade level and deconvolved to the RB base level. The SRP section 3.7.1 indicates that deconvolving the RG 1.60 spectrum-compatible ground motion from grade level to the base of the RB is not appropriate, for sites composed of one or more thin soil layers overlying a competent material.

Response

The SRP states in paragraph 1.1 of Section 3.7.1 that "The control motion should be defined to be on a free ground surface and should be based on data obtained in the free-field. Two cases are identified depending on the soil characteristics at the site and subject to availability of appropriate recorded ground-motion data. When data are available, for example, for relatively uniform site of soil or rock with smooth variation of properties with depth, the control point (location at which the control motion is applied) should be specified on the soil surface at the top of finished grade. For sites composed of one or more thin soil layers overlying a competent material or in case of insufficient recorded ground-motion data, the control point is specified on an outcrop or a hypothetical outcrop at a location on the top of the competent layer. The control motion specified should be consistent with the properties of the competent material."

The Pilgrim site consists of relatively uniform, smoothly varying properties with depth as described above. It does not consist of nine thin soil layers overlying a competent material as specified in the question. The thicknesses of the soil layers above bedrock, indicated in Item 2, were artificially determined as a means of discretizing the soil profile, which varies smoothly with depth from grade level to bedrock; they do not represent actual physical contrasts between layers, except at depth 45 feet. The attached figure shows a plot of this profile, taken from Item 2.

The intent of the statement in Sec. 3.7.1 of the SRP is two-fold.

(i) If thin soil layers overlying a competent material are present, the frequency characteristics of the free-field surface ground motion should be compatible with the frequency characteristics of the site. The Pilgrim site is one of the smoothly varying properties to bedrock, at a depth of 100 ft., as discussed above. It is unlikely that strong frequency characteristics of the site would be observed. However, if such frequency characteristics were demonstrated, they would occur in the amplified frequency of RG 1.60 (2.5 Hz) or, at lower frequencies (1-2.5 Hz) depending on the high strain soil properties. Hence, even if local site amplification were present, it would be in amplified frequency ranges of RG 1.60 or at frequencies below 2.5 Hz, which are of no affect structurally due to the reactor frequency characteristics and it being embedded.

(ii) Section 3.7.1 of the SRP is, also, intended to preclude situations where unreasonably conservative deconvolution results are predicted at depth in the soil. Such phenomena occur when design response spectra, such as R.G. 1.60, are deconvolved though soft thin layers producing unreasonable large, high frequency content below the layer. This is not the case for Pilgrim, whose low strain shear wave velocities vary from 535 fps to 1465 fps (best estimate high strain velocities vary from 459 fps to 1218 fps).

Question 2

Pages 54/55 of Item 1 of Attachment 2 indicates that impedances and scattering functions for the SSI analyses were calculated for best estimate, upper bound (best estimate times 2.0) and lower bound (best estimate divided by 2.0) soil properties. However, Item 2 of Attachment 2 states that, in the SSI high bound analyses, the shear wave velocities are multiplied by a factor of 1.35, and in the low bound analyses, the shear wave velocities are divided by 1.35. Explain this discrepancy, and confirm that a factor of 2 was in fact used in the upper bound and lower bound analyses as per SRP section 3.7.2.

Response

The discussion on pages 54/55 of Item 1 correctly states that the upper and lower bound soil properties were obtained using a factor of 2.0. This factor was applied to the best estimate soil shear moduli to obtain upper and lower bound shear modulus profiles, per the procedure set forth in Section 3.7.2 of the SRP for design basis analyses. In Item 2, it is stated that a factor of 1.35 was applied to the best estimate shear wave velocities, which corresponds to 82% (1.35 * 1.35 - 1) variation in the shear modulus, which is greater than the minimum 50% required by the ASCE Standard, but lower than the 100% required by the Standard Review Plan" (see sheet 4 of 5 in Item 2). This variation is appropriate for PRA analyses performed in support of IPEEE.

Question 3

Did the recalculated mass and stiffness properties of the RB differ significantly from those used in the original plant design? If so, discuss (a) the principal factors responsible for such difference, and (b) the consequences of such difference?

Response

There are significant differences between the new reactor building model and the model used for original design. These differences include

- The new reactor building model is a three-dimensional model; whereas, the original design used two independent one-dimensional models.

- The new model has separate, interconnected sub-models of the secondary containment, torus, drywell, bioshield wall and reactor vessel; whereas, the original models only included the secondary containment with the internal structures' weight lumped in.

- The new model includes the reactor auxiliary bay.

- The new model more accurately models the secondary containment walls and accounts for the weights and locations of major equipment components.

The overall mass of the new model is 17% higher than the mass of the original model, with the most significant difference, 66%, at Elevation 23' due to the inclusion of the reactor auxiliary bay. Stiffness differences cannot easily be determined because in the new model the secondary containment members are general stiffness matrices rather than beam elements as in the original model. However, there does not appear to be a significant difference in building response. The new model has first mode, fixed base frequencies of 5.0 Hz, N-S, and 6.4 Hz, E-W, versus 5.61 and 5.79 Hz for the original design.

Question 4

List all computer programs that have been used in the various phases of the seismic reanalysis of PNPS, and state whether they were validated for their accuracy in accordance with approved QA procedures.

Response

The following computer programs were used:

- Secondary containment inter-floor stiffness matrices: ANSYS
- Ground motion deconvolution: SHAKE
- Power spectral density function: *FOURIER, THICC*
- Impedances: *SUPELM, P_SUP, IMPLT*
- SSI analysis: *MODSAP, INSSIN, SSIN*
- Response spectra: *RSPEC, BROAD, RSENV, RSPLT.*

All of these computer programs have been validated in accordance with approved QA procedures.

Question 5

Confirm that the voluminous supporting data (attached to BECo's April 1, 1994, submittal) which are marked as "Information Only" are indeed the final documentation of the input and output data meant to be reviewed by the staff before approving the alternative Reactor Building (RB) Response Spectra. This question arises because, in one set of calculations related to the soil properties for the SSI analysis, the acceptance criteria is said to be ASCE Standard 4-86, and no reference has been made to NUREG-0800/SRP 3.7.

Response

The referenced supporting data was marked "Information Only" to identify to the staff that they are not on the controlled distribution list for subsequent document revisions. Nevertheless, none of the seven items identified in Attachment 2 of the April 1, 1994, submittal have been revised since and, thus, represent the final documentation meant to be reviewed by the staff.

The calculation which raised the question is Item #2 of Attachment 2 of the submittal (also discussed in Questions 1 and 2). This calculation was prepared by Stevenson & Associates for the original purpose of developing in-structure response spectra for the IPEEE (seismic) program performed in response to Supplement 4 of Generic Letter No. 88-02. This effort was not subject to NUREG 0800/SRP 3.7 requirements. Subsequently, this calculation was furnished to EQE Engineering for development of alternative Reactor Building (RB) Response Spectra which is the subject of the April 1, 1994, submittal. EQE applied the soil input parameters in a manner consistent with this project as discussed in Item #1 of Attachment 2 to the submittal.

Boston Edison Co. - Pilgrim Nuclear Power Station
Low Strain Shear Wave Velocity Profile