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600 Rocky Hill Road
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U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

USI A-46 Supplementary Information

This letter provides supplementary information on the USI A-46 implementation methodology at Pilgrim Station. In recent Safety Evaluation Reports (SERs) issued by the NRC for Millstone and Ginna, the NRC identified limitations on the use of GIP-2 Method A.1. These limitations are that the safe shutdown equipment (SSE) ground response spectrum (GRS) can be used for comparison to the Bounding Spectrum when:

- The equipment is mounted in the nuclear plant at an elevation below about 40 feet above the effective grade.
- The equipment, including its supports, has a fundamental natural frequency greater than about 8 Hz.
- The amplification factor between the GRS and the in-structure response spectra is not more than about 1.5.

For in-structure response spectra greater than about 1.5 times the GRS, the NRC is requesting licenses to provide additional information justifying the use of Method A.

The structures at PNPS in which Method A was used are typical nuclear plant structures, either reinforced concrete frame and shear wall or heavily braced steel frame, for which the 1.5 amplification factor is applicable. Attachments A and A-1 provide supplementary information on the method of implementation of the GIP-2 rules for Method A use at Pilgrim Station.

We trust this information provides sufficient detail to enable the NRC to perform its evaluation and issuance of a plant specific SER for USI A-46 program implementation at Pilgrim Station.

This letter contains no commitments.

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Attachments: A - Information on Use of GIP-2 Method A
A-1 - Bases for Interpretation and Implementation of GIP-2 Rules for Method A

ATTACHMENT A
Information on use of GIP-2 Method A

References:
1. NRC Letter to Boston Edison Company, "Request for Additional Information (TAC No. M69471)," dated December 16, 1997.
2. Boston Edison Company Letter 2.98.045 to NRC, dated June 15, 1998.
3. Senior Seismic Review and Advisory Panel (SSRAP), "Use of Seismic Experience and Test Data to Show Ruggedness of Equipment in Nuclear Power Plants," Revision 4.0, February 28, 1991.
4. SQUG Letter to NRC, "Generic Issue Included in NRC's Requests for Additional Information on Use of GIP Method A," dated June 30, 1997.

1. NRC Comment: In an April 1, 1999 telecon with NRC and Pilgrim Nuclear Power Station (PNPS) representatives on the use of GIP Method A at PNPS, the NRC noted the procedures used to evaluate the seismic adequacy of PNPS equipment are consistent with the GIP-2 guidelines and the NRC Supplemental Safety Evaluation Report No. 2 (SSER-2), with one exception. PNPS needs to show compliance with a key restriction of the GIP-2 methodology; i.e., the restriction that the amplification factor between the free field response spectra and the in-structure response spectra (ISRS) is not more than about 1.5. Without compliance with this restriction the application of GIP-2 Method A.1 is not appropriate. Since Method A.1 is used to evaluate the seismic adequacy of a portion of the safe shutdown equipment list (SSEL) components, the results of its A-46 effort must be justified.

   PNPS Response: This issue is related to the original NRC RAI of reference 1 in which the NRC requested PNPS, for plant structures containing equipment in the USI A-46 scope, to:

   a) Identify structures which have license-basis in-structure response spectra (5% critical damping) for elevations within 40 feet above the effective grade, which are higher in amplitude than 1.5 times the Seismic Qualification Utility Group (SQUG) Bounding Spectrum.

   b) With respect to the above comparison of equipment seismic capacity and seismic demand, indicate which method in Table 4-1 of GIP-2 was used to evaluate the seismic adequacy for equipment installed on the corresponding floors.

   c) For the structures identified, provide the in-structure response spectra designated according to the height above the effective grade, and provide a comparison of these spectra to 1.5 times the Bounding Spectrum.

In responding to this item, reference 2 provided a technical justification for using Method A where ISRS exceeds 1.5 times the Bounding Spectrum. This issue has been the subject of continuing discussion between the SQUG representatives and NRC staff members on the application of Method A of GIP-2. Based on these discussions, a position was developed which is contained in Reference 4. It is SQUG's belief that the GIP criteria, as presented in the GIP-2 document, and reviewed and accepted by the NRC in SSER-2, does not require the Seismic Review Team (SRT) to justify the 1.5 amplification factor for elevations below about 40 feet above effective grade and frequencies above about 8 Hz.

As explained in Attachment A-1, the sentence on page 4-16 of the GIP-2, "The restrictions .... is based on the conditions that the amplification factor between the free-field response spectra and the in-structure response spectra will not be more than about 1.5, and that the natural frequency of the equipment is not in the high energy range", merely indicates the basis for the development of the criteria associated with the use of Method A (namely, that the component be within approximately 40 feet of effective grade and have a fundamental frequency higher than about 8 Hz), and was not intended to require the SRT to justify the 1.5 amplification factor. As further explained in Attachment A-1, the need for Method A, and the reason licensing basis ISRS frequently exceed 1.5 times the ground response spectrum, is due to the conservatism associated with the analytical procedures used in developing the ISRS. It was only intended that the SRT verify that the building in which Method A was applied was a typical nuclear plant reinforced concrete frame and shear wall or braced steel frame structure.

PNPS endorses the SQUG position. The structures at PNPS in which Method A was used are typical nuclear plant structures, either reinforced concrete frame and shear wall or heavily braced steel frame, for which the 1.5 amplification factor is applicable as per the SSRAP Report (reference 3) and page 4-16 of GIP-2. These structures are the Reactor Building, Turbine Building, Radwaste Building and Diesel Generator Building.

As indicated below, due to the conservatism associated with the licensing basis ISRS curves, all structures at PNPS have original conservative licensing basis ISRS, for elevations within 40 feet above the effective grade, which are higher in amplitude than 1.5 times the licensing basis free field response spectrum.

The following additional information for each of the structures at PNPS is provided to indicate:

a) that the structures housing the SSEL at PNPS are typical of nuclear plant construction, justifying the applicability of the SSRAP estimated amplification factor,

b) the level by which the original conservative licensing basis ISRS exceed 1.5 times the licensing basis free field response spectrum at locations where Method A was applied,

c) that the licensing basis ISRS curves were very conservatively calculated, and

d) that if more realistic median-centered type analyses are performed, the resulting ISRS would not greatly exceed 1.5 times the licensing basis free field response spectrum for frequencies over 8 Hz.

PNPS Site. The PNPS site has approximately 90 feet of soil overlying bedrock. During original plant construction, soil was excavated, and plant structures were founded either directly on the undisturbed glacial till deposits or on a layer of compacted backfill placed over these undisturbed deposits. Final site grade is about elevation 22 feet above mean sea level.

Reactor Building (RB). The RB is an embedded, multi-story reinforced concrete shear wall structure up to the operating floor at elevation 117 feet. SSEL equipment in the RB is located below the operating floor elevation. The foundation consists of an 8-foot thick heavily reinforced concrete mat. The structure is founded on undisturbed soil approximately 42 feet above the bedrock elevation. The elevation of the top of the mat is (–)17.5 feet, which is approximately 40 feet below the site grade. For A-46 implementation, effective grade is specified to be the foundation elevation, so the highest floor using GIP Method A is elevation 23.

The 5% damped ISRS for elevation 23 compared to 1.5 times the Bounding Spectrum and the 5% damped PNPS licensing basis free field response spectrum is shown in Figure 1. It is seen that while the maximum amplification is about 4 at the primary structural frequency of about 4.5 Hz, the amplification is about 3 or less above 8 Hz.

Turbine Building (TB). The TB is an embedded multi-story braced steel frame structure with interior reinforced concrete shear walls up to the turbine deck. All SSEL equipment in the TB is located at or below the turbine deck elevation. The structure is founded on approximately 10 feet of compacted structural backfill over undisturbed soil. The top of the foundation is elevation 6 feet, which is approximately 16 feet below the site grade. For A-46 implementation, effective grade is specified to be the TB foundation elevation, so the highest floor using GIP Method A is elevation 37 feet.

The 5% damped ISRS for elevation 37 compared to 1.5 times the Bounding Spectrum and the 5% damped PNPS licensing basis free field response spectrum is shown in Figure 2. It is seen that while the maximum amplification is about 10 at the primary structural frequency of about 4.5 Hz, for frequencies above 8 Hz the amplification is about 8.5 at 8 Hz, and about 6.5 or less above 9 Hz.

Radwaste Building (RWB). The RWB is an embedded, multi-story reinforced concrete shear wall structure. The structure is founded on compacted backfill over undisturbed soil. The top of the mat is elevation (–)1 feet, which is approximately 23 feet below the site grade. For A-46 implementation, effective grade is specified to be the foundation elevation, so the highest floor using GIP Method A is elevation 37.

The 5% damped ISRS for elevation 37 compared to 1.5 times the Bounding Spectrum and the 5% damped PNPS licensing basis free field response spectrum is shown in Figure 3. It is seen that there is a significant mode at about 12 Hz, and the maximum amplification above 8 Hz is about 5 at 14 Hz.

Diesel Generator Building (DGB). The DGB is a reinforced concrete frame and shear wall structure. The top of the foundation is at plant grade, elevation 23. The highest elevation at which Method A was used is elevation 34.5.

The 5% damped ISRS for elevation 34.5 compared to 1.5 times the Bounding Spectrum and the 5% damped PNPS licensing basis free field response spectrum is shown in Figure 4. It is seen the primary mode is at about 2.5 Hz, and the maximum amplification above 8 Hz is about 2.5 at 12 Hz.

Conservatism in the Licensing Basis ISRS. Attachment A-1 contains a discussion of conservatisms in the calculation of the PNPS licensing basis ISRS. It is judged that the total effect of all these conservatism's results in the PNPS licensing basis ISRS exceeding realistic, median centered ISRS in the frequency range of interest by factors of as much as eight (8).

Conclusions:

- The structures at PNPS in which Method A was used are typical nuclear plant structures, either reinforced concrete frame and shear wall or heavily braced steel frame, for which the 1.5 amplification factor is applicable as per the SSRAP Report and page 4-16 of GIP-2.
- The PNPS licensing basis conservative in-structure response spectra used for A-46 show amplifications of more than 1.5. This is due to conservatisms in the calculation methodology, as discussed in Attachment A-1 to this response. More realistic, median-centered response spectra would result in calculated in-structure response spectra at frequencies above 8 Hz, which would not greatly exceed 1.5 times the licensing basis free field spectrum.

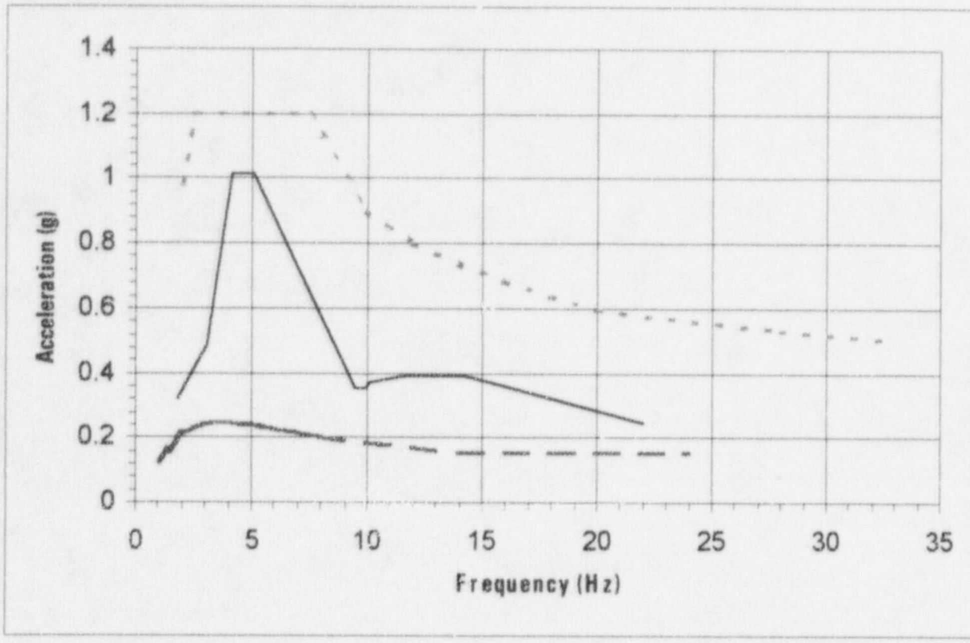

Figure 1. Reactor Building (RB) elevation 23 Licensing Basis ISRS (solid) Compared to Licensing Basis Free Field Response Spectrum (dashed) and 1.5 times Bounding Spectrum (dotted)

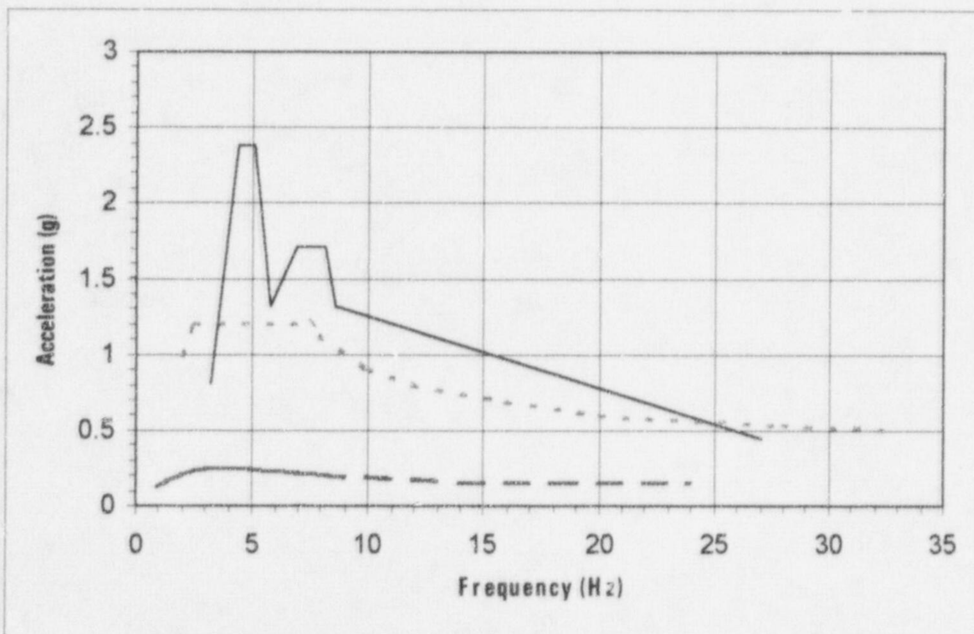

Figure 2. Turbine Building (TB) elevation 37 Licensing Basis ISRS (solid) Compared to Licensing Basis Free Field Response Spectrum (dashed) and 1.5 times Bounding Spectrum (dotted)

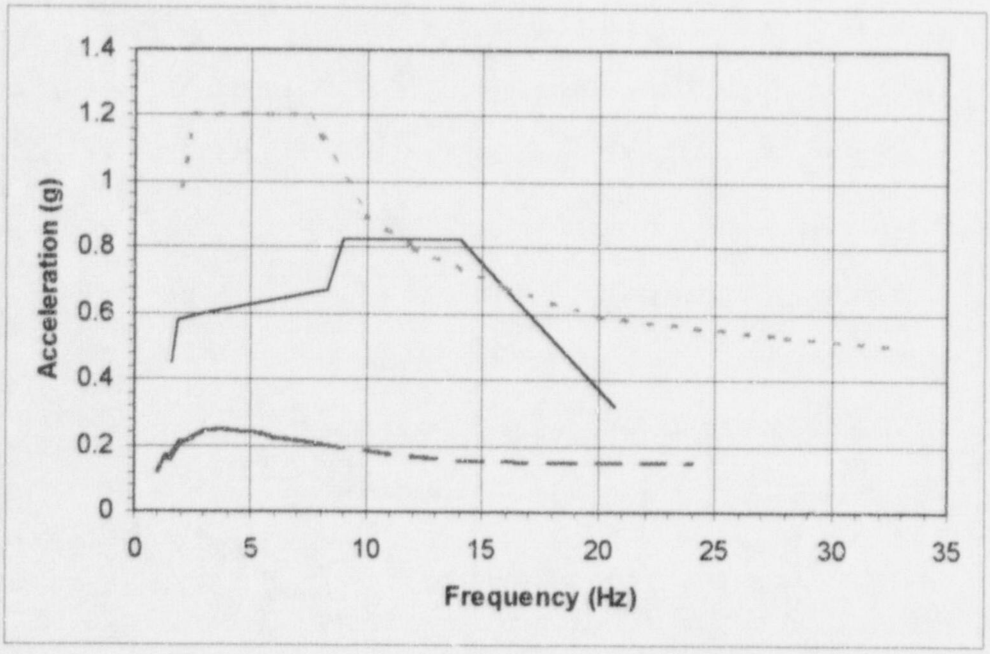

Figure 3. Radwaste Building (RWB) elevation 37 Licensing Basis ISRS (solid) Compared to Licensing Basis Free Field Response Spectrum (dashed) and 1.5 times Bounding Spectrum (dotted)

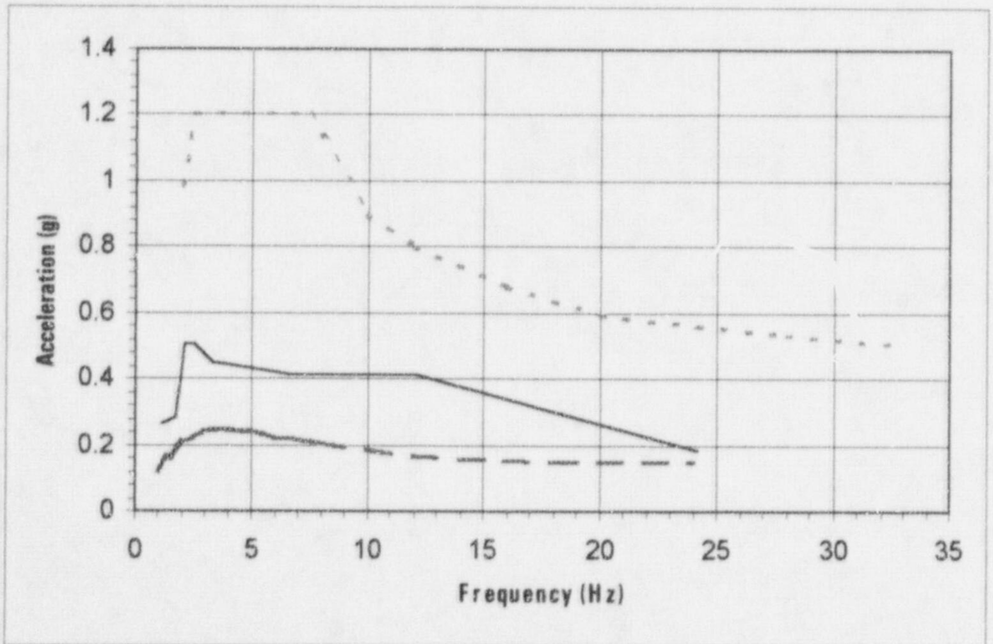

Figure 4. Diesel Generator Building (DGB) elevation 34.5 Licensing Basis ISRS (solid) Compared to Licensing Basis Free Field Response Spectrum (dashed) and 1.5 times Bounding Spectrum (dotted)

ATTACHMENT A-1

Bases for Interpretation and Implementation of GIP-2 Rules for Method A

References:
1. Seismic Qualification Utility Group (SQUG), "Generic Implementation Procedure (GIP) For Seismic Verification of Nuclear Plant Equipment," Revision 2, Corrected February 14, 1992.
2. Senior Seismic Review and Advisory Panel (SSRAP), "Use of Seismic Experience and Test Data to Show Ruggedness of Equipment in Nuclear Power Plants," Revision 4.0, February 28, 1991.
3. Nuclear Regulatory Commission, "Regulatory Analysis for Resolution of Unresolved Safety Issue A-46, Seismic Qualification of Equipment in Operating Plants," NUREG-1211, February 1987.
4. Nuclear Regulatory Commission, "Supplement No.1 to Generic Letter (GL) 87-02 That Transmits Supplemental Safety Evaluation Report No. 2 (SSER No.2) on SQUG Generic Implementation Procedure, Revision 2, As Corrected on February 14, 1992 (GIP-2)," May 22, 1992.
5. "A Methodology for Assessment of Nuclear Power Plant Seismic Margin (Revision 1)," EPRI NP-6041-SL, Rev.1, August 1991.
6. Letter from E.T. Boulette (Boston Edison Company) to NRC, "Request for Approval of Alternative Reactor Building Response Spectra," April 1, 1994.
7. Letter from R.C. McCready (Rochester Gas and Electric) to G. Vissing (NRC), "Additional Information of Use of GIP Method A, R.E. Ginna Nuclear Power Plant, Docket No. 50244," May 25, 1999.

Method A of GIP Table 4-1 (reference 1) provides a methodology to evaluate the seismic adequacy of equipment by comparing equipment capacity based on earthquake experience ground response spectra at database sites with the plant's SSE ground response spectrum (GRS). The composite earthquake experience GRS from the database sites (Reference Spectrum) was reduced by a factor of 1/1.5 to account for possible additional amplification of motion in nuclear plants compared to database plants and is referred to as the "Bounding Spectrum" in the GIP.

The seismic capacity of equipment defined by the Bounding Spectrum is compared to the seismic demand at the effective grade using the plant licensing basis SSE GRS. The GIP Method A conservatively limits use of this approach to equipment which has a fundamental frequency above about 8 Hz and is located lower than about 40 feet above the effective grade of the building. These restrictions prohibit the use of GIP Method A for equipment with low fundamental frequencies and for equipment located at high elevations in buildings where the structure seismic response is known to be typically high.

Additional details justifying the use of GIP Method A may be found in the Senior Seismic Review and Advisory Panel (SSRAP) report (reference 2). This report, included as reference 5 in GIP-2, summarizes SSRAP's judgment on this subject:

> ".... the use of very conservative floor response spectra should be avoided when assessing the seismic ruggedness of floor mounted equipment .... Only for cases of equipment mounted more than 40 feet above grade or equipment with as-anchored frequencies less than about 8 Hz is it necessary to use floor spectra."
>
> [reference 2, pages 102 and 103]

The rules for use of GIP Method A, reviewed and accepted by the NRC in the "Supplementary Safety Evaluation Report (SSER-2)" of Reference 4, have been properly interpreted and implemented at PNPS. Where Method A was used, it is fully justifiable based on the requirements of GIP-2 and its basis documents, such as the SSRAP Report and SQUG's guidelines on the use of Method A. The basis for this position is as follows:

1. **<u>SQUG and PNPS Interpretation of the GIP</u>**

The caution given on page 4-16 of GIP-2 lists two limitations on the use of Method A:

- Equipment should be mounted in the nuclear plant below about 40 feet above the effective grade, and
- Equipment should have a fundamental natural frequency greater than about 8 Hz.

The introductory wording in GIP-2 for these two limitations provides the bases or purposes for imposing them, namely (1) to limit amplification to no more than about 1.5 and (2) to avoid the high-energy frequency range of the earthquake, namely below about 8 Hz. The specific limitations which are intended by the SQUG/NRC expert panel (SSRAP) and SQUG to satisfy these bases are included in the two bullet items listed above. Table 4-1 of GIP-2, which describes the two methods (Method A and Method B) in detail, includes the criteria, which need to be met for each of the two methods. The table includes the above two limitations, but does not include the requirement for checking the amplification between the in-structure response and the free-field.

The statement on page 4-16 that "the amplification will not exceed about 1.5" is the expected result of meeting the above limitations, and not a third condition which is required to be demonstrated.

The caution on page 4-16 of GIP-2 makes it clear that the advantage of Method A is:

> "The advantage of using ground response comparisons is that with the applicable restrictions and limitations [i.e. the two bullet items listed above], all the equipment covered by the Bounding Spectrum or the GERS can be evaluated for seismic adequacy without the need for using in-structure response spectra which are often based on very conservative modeling techniques or may not be available."
>
> [reference 1, page 4-16]

2. <u>The Intent of the GIP</u>

- The GIP cites the SSRAP report (reference 2) as the basis for the Bounding Spectrum development and use in Method A (page 4-11, reference 2). The SSRAP report explains the limitations and conditions, which appear, on page 4-16 of the GIP. SSRAP's report states:

  > "Thus, it is SSRAP's judgment that amplifications greater than a factor of 1.5 are unlikely in stiff structures at elevations less than 40 feet above grade except possibly at the fundamental frequency of the building where higher amplifications occur when such a frequency is less than about 6 Hz. Thus, for equipment with fundamental frequencies greater than about 8 Hz in the as-anchored condition it was judged that floor spectral amplifications within 40 feet of grade would be less than 1.5 when reasonably computed using more median centered approaches."
  >
  > [reference 2, page 102]

- This judgment by the SSRAP was based on numerous studies and actual earthquake measurements which led them to conclude that:

  > "Thus, amplification of the horizontal free-field ground spectra by factors greater than 1.5 are considered to be generally unlikely for elevations less than 40 feet above grade."
  >
  > [reference 2, page 104]

- The SSRAP was aware that many nuclear plants were originally licensed based on very conservative ISRS and that the use of conclusions based on earthquake experience and more median-centered approaches would be more appropriate. A detailed discussion of some of the sources of this conservatism is presented in item 3 below. With reference to this topic, the SSRAP report states:

"It was judged by SSRAP that the use of very conservative floor spectra should be avoided when assessing the seismic ruggedness of floor mounted equipment. It was also the opinion of SSRAP that many of the operating plants may only have these very conservatively computed floor spectra available. To avoid the burden of having to compute more realistic floor spectra, SSRAP decided to anchor its conclusions to ground spectra at the nuclear plant sites in those cases where this was judged to be reasonable."

[reference 2, page 102]

- This was the basis for SSRAP's recommendation (and included in GIP-2 as methods A and B) that:

  "Thus, for the case of equipment with fundamental frequencies greater than about 8 Hz mounted less than 40 feet above grade, SSRAP's conclusions are based upon comparing the bounding spectra with nuclear power plant ground spectra. Only for the case of equipment mounted more than 40 feet above grade or equipment with as-anchored frequencies less than about 8 Hz is it necessary to use floor spectra."

  [reference 2, page 102]

- The SSRAP Chairman and developer of Method A, Dr. Robert Kennedy, was contacted by SQUG and concurs with the interpretation given in item 1 above.

3. Conservatisms Associated with Licensing Basis Calculated ISRS

The following is a detailed description of the typical conservatisms normally found in the analytical methods used for calculating in-structure response spectra (ISRS), at nuclear plants in general and at PNPS in particular. This supplemental information is provided as additional evidence of the validity of Method A as originally developed by the SSRAP.

The process of calculating ISRS is a complicated analytical exercise requiring a significant number of approximations and modeling assumptions, and considerable engineering judgment. As a result, the historical development of ISRS has included a large amount of conservatism, which has typically served two purposes:

1. It has reduced the technical debate as to the correct modeling of the many parameters which are intrinsic to the ISRS calculation methodology, and

2. It has reduced the costs associated with a very detailed, state-of-the-art analysis, (which would attempt to trim out all the unnecessary conservatisms).

As a part of the A-46 program resolution methodology, the SSRAP had developed, and SQUG subsequently endorsed, an alternate ISRS estimation technique (referred to as Method A within GIP-2) which was much more median centered and realistic than the typical design practice. The application of Method A at PNPS was appropriate and technically justified. The fact that design ISRS may show amplifications greater than 1.5 is not surprising, nor does it negate the validity of Method A. In fact, as noted in the SSRAP report it was even expected:

> "Secondly, most unbroadened computed in-structure spectra have very narrow, highly amplified peaks at the resonant frequency of the structure. In most cases these narrow, highly amplified peaks are artificially broadened to account for uncertainty in the structure's natural frequency. This process simply increases the emphasis on these highly amplified peaks.... SSRAP is also of the opinion that these narrow peaks will not be as highly amplified in real structures at high ground motion levels as is predicted by linear elastic mathematical models, nor are such narrow peaked in-structure spectra likely to be as damaging to equipment as is a broad frequency input which is represented by 1.5 times the Bounding Spectrum." [reference 2, pages 19 and 20.]

As described below, three areas are presented to support the application of Method A at U.S. nuclear plants in general, and at PNPS in specific:

A. Measurements of ISRS in actual earthquakes

B. Calculations of overall conservatism in typical ISRS

C. Descriptions of the conservatism's in ISRS in general and PNPS ISRS in particular

A. Measurements of ISRS in Actual Earthquakes

SSRAP developed the Method A response estimation technique based on their research of both actual earthquake measurements and on recent "median centered" analysis. They reference (reference 2, page 102) the measured floor response spectra at elevations less than 40 feet above grade for moderately stiff structures at the Pleasant Valley Pump Station, the Humboldt Bay Nuclear Power Plant, and the Fukushima Nuclear Power Plant, where amplifications over the ground response spectra do not exceed 1.5 for frequencies above about 6 Hz. Other, more recent earthquake data from the Manzanillo Power Plant and SICARTSA Steel Mill in Mexico, as well as several facilities in California and Japan, have been reviewed by SQUG. These data also show that stiff buildings (similar to typical nuclear structures) amplify very little at elevations less than 40 feet above grade and frequencies over 8 Hz. SQUG has informed its members that it knows of no new measured data that challenge GIP Method A.

B. Calculations of Overall Conservatism in Typical ISRS

Calculated ISRS have never been portrayed as representing the realistic expected response during an actual earthquake. As previously stated, ISRS typically contain many conservatisms which make them unrealistically high. The primary reason for the development of Method A was to establish a more median centered method of establishing the structural response without having to embark on costly new analyses of all the site buildings. (It is noted that even the most modern, state-of-the-art ISRS contain significant conservatisms; even those classified as "median-centered" are often very conservative). NUREG/CR-1489, "Best Estimate Method vs. Evaluation Method: A Comparison of Two Techniques in Evaluating Seismic Analysis and Design", stated that typical calculated ISRS contain factors of conservatism of 1.5 to 8. Recent surveys by SQUG show similar levels of conservatism in calculated ISRS.

It was the contention of SSRAP that the ISRS for nuclear structures (considering the 40 foot and 8 Hz conditions) would be within about 1.5 times the ground response spectrum (GRS) if the plant were subjected to an actual earthquake. In deriving the Method A criteria they recognized that due to the variety of ground motions, soil characteristics and structure characteristics there could be occasional exceedances of the 1.5 amplification, but still strongly justified Method A's applicability:

> "It is SSRAP's firm opinion that the issue of potential amplifications greater than 1.5 above about 8 Hz for high frequency input is of no consequence for the classes of equipment considered in this document except possibly for relay chatter[1]."
>
> [reference 2, page 106]

The basis SSRAP gave for drawing this conclusion was that high frequency ground motions do not have much damage potential due to low spectral displacement, low energy content, and short duration. They further noted that the equipment covered does not appear to have a significant sensitivity to high frequencies (except possibly for relay chatter, which is addressed separately in the GIP).

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[1] Because of the SSRAP concern related to possible relay chatter at frequencies above 8 Hz, the SQUG methodology specifically addresses relays which are sensitive to high frequency vibration. Such relays are included on the Low Ruggedness Relays list in Appendix E of EPRI Report NP-7148.

C. Description of Conservatisms in ISRS in General and PNPS ISRS in Particular

The most significant sources of conservatism involved in the development of the ISRS for PNPS include the following:

- Soil-Structure Interaction (soil damping, wave scattering effects)
- Structural Damping
- Ground Motion Incoherence
- Time History Simulation
- Peak Broadening and Enveloping
- Clipping of Narrow Peaks

The degree of conservatism involved in each of these parameters is specific to the building being analyzed, to the floor level being considered, and, often, to the equipment location within the specified floor level. These conservatisms typically cannot be accurately quantified using simplistic calculation techniques since each parameter fits into an overall set of highly nonlinear equations. Thus, it would take a considerable effort to quantify the exact excess conservatisms inherent in the calculated ISRS at PNPS. However, on a qualitative level, it is easy to see the origins and levels of this conservatism. The following parameters are the source of the major portions of the excess conservatism.

<u>Soil Structure Interaction (SSI).</u> Typical design analyses do not account properly for the phenomenon of SSI, including the deamplification with depth that occurs for embedded structures or for the radiation damping effects inherent at soil sites. Fixed-base analyses have been performed for structures founded on rock, and soil-spring analyses, with low damping, for structures founded on soil columns. For soil founded structures, such as at PNPS, the soil spring analyses can vary between conservative and very conservative compared to sophisticated SSI analyses. The simplified analyses that used the frequency-independent soil springs were typically very conservative in that radiation and/or material soil damping were either conservatively eliminated or artificially limited during the analysis. Soil properties were also typically not adjusted to reflect anticipated soil strain levels. Significant reductions have been demonstrated over design type analyses using more modern techniques. These reduction factors are highly dependent on the specific soil conditions and structure configurations, but values of around 2 to 4 have been seen in past studies.

The PNPS structures are founded on soil. The seismic models used to calculate the licensing basis ISRS had frequency-independent soil springs. The damping used in the analyses was specified as 5%. Since the primary modes of response of the major structures are soil response (rocking) modes, and the structures are embedded in the soil, effective modal damping of 20% or more would be expected. If the primary mode of response were realistically assigned 20% damping instead of 5%, then the structure response (and the ISRS) would be reduced by a factor of at least $(.20/.05)^{0.5}$ or 2. Further reductions would result from embedment effects.

Structural Damping. Structural damping is one of the parameters of dynamic analysis to which the seismic analysis results are quite sensitive. It is a physical property of the different materials included in the dynamic model. Values used in current analyses and licensing bases are controlled by Regulatory Guide 1.61 (R.G. 1.61). Values specified in R.G. 1.61 have been shown by several studies to underestimate actual response of steel and concrete structures. Damping values recommended in NP-6041 (reference 5) are more realistic, and are suggested for use in median centered analyses. Damping values specified in PNPS's licensing basis are compared to those in R.G. 1.61 and NP-6041 below:

Structure or Component	*R.G. 1.61 OBE*	*R.G. 1.61 SSE*	*NP-6041 at About 1/2 Yield*	*NP-6041 Just Below Yield*	*PNPS OBE License Basis*	*PNPS SSE License Basis*
Welded Steel	2%	4%	3%	7%	1%	2%
Bolted Steel	4%	7%	7%	10%	2%	5%
Prestressed Concrete	2%	5%	3%	7-10%	N.A.	N.A.
Reinforced Concrete	4%	7%	3-5%	10%	5%	7.5%

As can be seen, the damping values for both the OBE and SSE licensing basis at PNPS are much lower than values allowed by the regulatory guide for steel structures, and lower than NP-6041 for both steel and reinforced concrete structures. These two types of structures encompass the structures at PNPS housing A-46 SSEL components.

A second area of conservatism, which constitutes a larger level of conservatism associated with the generation of the original licensing basis ISRS at PNPS, is that the original plant design curves were only generated for the OBE load case, using 5% structural damping for all structures. For design activities and in the A-46 evaluations, ISRS curves for the SSE were obtained by a linear increase of the OBE curves using the conservative correction factor of 0.15/0.08=1.875. This practice, of linearly increasing the OBE results to obtain the SSE response results in the conservative application of the OBE structural damping values of 5%, for concrete, to the SSE case where values of 7.5% and 10% are allowed by the PNPS licensing basis and recommended by NP-6041, respectively.

If the effective damping of the soil is also considered, then the conservatism associated with damping is even more. As noted in the discussion of SSI, if modal damping of 20% rather than 5% were used for the primary response mode, the ISRS would be reduced by a factor of 2.

Ground Motion Incoherence. As has been documented in the EPRI seismic margin report EPRI NP-6041 (reference 5) there can be a deamplification effect on nuclear type structures due to the incoherence of ground motion. Conservative reduction factors as a function of frequency and building footprint have been documented within NP-6041 to account for the statistical incoherence of the input wave motion. These conservative values range from a factor of 1.1 to around 1.5. More recent studies have documented even greater reduction factors. This ground motion incoherence is applicable to sites like PNPS, and is particularly appropriate in the high frequency range.

Time History Simulation. ISRS at PNPS were generated using the Taft Earthquake time history. This was intended to approximate the licensing basis smooth ground response spectrum with a PGA of 0.08g for the modified Housner shape of the OBE. Figure A-1 shows a plot of the 5% damped response spectrum from the Taft time history and the PNPS licensing basis ground response spectrum. The Taft spectrum conservatively envelops the licensing basis free field spectrum in the frequency range of 1 to 7 Hz. Above 7 Hz, the Taft spectrum is close to the licensing basis free field spectrum. For each structure, the degree of conservatism in the ISRS depends on the structure's response frequency.

The RB and TB have fundamental frequencies at about 4.5 Hz. The Taft time history is seen to over-compute response at 4.5 Hz by a factor of about 1.5. This means the structural response, the resulting floor time histories and the ISRS are over-conservative by a factor of 1.5 due to conservatism in the Taft time history. The DGB primary mode is at about 2.5 Hz. It is seen from Figure A-1 that the Taft time history over-computes the response by about 1.5 for this frequency also. The primary mode for the RWB, however, is at about 12 Hz. The Taft time history does not over-compute response at this frequency.

Peak Broadening and Enveloping. The licensing basis spectra for PNPS are artificially broadened at the resonant frequencies. The GIP recommends using realistic, median-centered, unbroadened ISRS. The broadening and smoothing of the PNPS licensing basis ISRS was conservatively done. If the original unbroadened spectra were compared to the free field spectrum, the apparent amplification at 8 Hz for the RB and TB would be reduced (because the line forming the high frequency side of the resonant range would shift to the left, and in the case of the TB the line be lowered in amplitude as well, to match the unbroadened spectrum.) Since the resonant peak for the RWB is above 8 Hz (it is at 12 Hz), the broadening and smoothing does not add conservatism to the amplification because the amplitude of the peak is not reduced. It is not clear how much the DGB ISRS at frequencies over 8 Hz were affected by peak broadening and smoothing, so it will be assumed that there is no conservatism due to this.

For the RB and TB, the effects of broadening and smoothing are judged to add a factor of conservatism of about 1.2 to the apparent amplification at frequencies over 8 Hz. For the RWB and DGB, this factor is judged to be about 1.0.

Clipping of Narrow Peaks. The SSRAP Report and the GIP recommend procedures for adjusting narrow peaks to reflect two areas of conservatism:

1. Narrow peaks are not as highly amplified in real structures as are predicted by linear elastic models.

2. Narrow peaks in ISRS are not as damaging to equipment as are broad frequency input such as the Reference Spectrum.

The GIP recommends an averaging technique over a frequency range of 10% of the peak frequency (e.g., 1 Hz range for a 10 Hz peak frequency) using the unbroadened ISRS. The PNPS ISRS have narrow peaks and did not utilize the peak reduction methods of the GIP. The conservatism involved has been shown to be in the range of 5% to 20% for typical narrow peaks at several plants.

For the RB, TB and DGB, peak clipping would not affect the ISRS at frequencies above 8 Hz, because the peak frequency is below 8 Hz. For the RWB, peak clipping would reduce the apparent amplification in this range because the peak is at about 12 Hz. The factor of conservatism for the RWB is judged to be at least 1.1.

Overall Conservatism

The total effect of all these conservatism's can result in significant overestimation of the amplification of the ISRS over the GRS for frequencies above 8 Hz. The following table summarizes the factors of conservatism for each building discussed above.

Building	RB	TB	RWB	DGB
SSI and Damping	3.0	3.0	3.0	2.0
GM Incoherence	1.5	1.5	1.2	1.1
Time History	1.5	1.5	1.0	1.5
Peak Broadening	1.2	1.2	1.0	1.0
Peak Clipping	1.0	1.0	1.1	1.0

There are several additional sources of conservatism (e.g., structural modeling, structural/soil nonlinearities, etc.) which add to the overall conservatism in the calculation of ISRS. These additional conservatisms, coupled with those described above, reinforce the overall levels of conservatism in ISRS of between 1.5 and 8 which were referenced by SSRAP (LLNL Report NUREG/CR 1489 "Best Estimate Method vs. Evaluation Method: A Comparison of Two Techniques in Evaluating Seismic Analysis and Design").

<u>Other Information</u>

The following items describe results of ISRS calculations, which confirm the levels of conservatism in the licensing basis ISRS discussed above.

1. SSI analyses of the PNPS Reactor Building

2. Comparison of median centered and design basis analyses at other nuclear plants

1. <u>SSI Analysis of PNPS Reactor Building</u>

In 1993, new SSE ISRS were computed for the Reactor Building. The methodology included soil-structure interaction analysis and time histories whose response spectra closely matched the free field response spectrum. The control point was taken as the soil surface in the free field. The free field spectrum was taken as the Regulatory Guide 1.60 spectrum for soil sites. The soil properties were varied, and the ISRS were peak broadened, in accordance with the Standard Review Plan. The results were reported to the NRC in reference 6.

The SSI analysis was repeated in a follow-up study, but with the control point taken as a theoretical rock outcrop. The input spectrum was taken as the 84th percentile NUREG/CR-0098 ("Development of Criteria for Seismic Review of Selected Nuclear Power Plants") rock spectrum anchored to 0.15g. The soil properties were varied, and the ISRS were peak broadened, in accordance with the Standard Review Plan.

The resulting ISRS at elevation 23 from each analysis are plotted in Figure A-2 along with the input response spectrum. If the control point were to be specified at the foundation elevation in the soil, the resulting ISRS would fall in between the two ISRS shown. It can be seen that the amplification over the free field spectrum for frequencies above 8 Hz is very low.

The results of these analyses confirm the levels of conservatism qualitatively assessed above for the RB. Since the TB is also an embedded structure, and its primary frequency is similar to that of the RB, the results of the SSI analyses confirm the qualitative assessment for it as well.

2. Comparison of median centered and design basis analyses at other nuclear plants

In reference 7, a comparison evaluation of overall seismic margins between median centered and design basis analysis for nuclear power plant structures at various facilities was presented. The information was developed by EQE International, Inc., under the auspices of the Seismic Qualification Utility Group, and was meant to demonstrate that factors of safety in original design basis analysis can be shown to be in the range of 2.5 to 5. Table 1 of reference 7 is attached to this letter.

The structures in the table are reinforced concrete shear wall structures with frequencies in the range of 7 to 13 Hz. Factors of conservatism are seen to range from 2.3 to 5.4. For sites designated as "rock/soil" they range from 3.3 to 5.4.

The PNPS RWB and DGB are fundamentally reinforced concrete shear wall structures, for which the results of Table 1 are applicable. The results of Table 1 are seen to be supportive of the qualitative assessment of factors of conservatism for the RWB and DGB given above.

Summary

Consideration of the above indicates that there are large factors of conservatism in the PNPS licensing basis ISRS. If these factors of conservatism are taken into account, the judgment of the PNPS USI A-46 SRT that the PNPS structures are "typical nuclear plant" structures for which GIP Method A is applicable is seen to be reasonable. If realistic, median centered ISRS were to be calculated for the PNPS RB, TB, RWB and DGB for the elevations at which Method A was used, the amplification of the ISRS over the free field GRS would not greatly exceed 1.5.

4. Not a Significant Safety Issue

The expected differences between calculated ISRS and actual building response do not represent a significant safety question. The lessons learned from review of hundreds of items of equipment at various sites that have experienced earthquakes which were significantly larger than those for Eastern U.S. nuclear plants are that missing anchorage, seismic interaction hazards, and certain equipment-specific weaknesses (incorporated into the GIP caveats) were the seismic vulnerabilities which cause equipment damage. These areas are conservatively addressed in the GIP. The NRC staff acknowledged the seismic ruggedness of nuclear power plant equipment in the backfit analysis for USI A-46 in which they stated the following:

> ". . . subject to certain exceptions and caveats, the staff has concluded that equipment installed in nuclear power plants is inherently rugged and not susceptible to seismic damage."
>
> [reference 3, page 16]

Method A is only applicable to relatively stiff equipment with fundamental frequencies over about 8 Hz. As noted above, SSRAP and SQUG have agreed that excitations over 8 Hz have little damage potential due to low spectral displacements, low energy content and short duration. This judgment is supported by industry and NRC guidance for determining whether an Operating Basis Earthquake (OBE) is exceeded following a seismic event at a nuclear power plant. EPRI Report NP-5930 "A Criteria for Determining Exceedence of the Operating Basis Earthquake", and NRC Regulatory Guide 1.166 "Pre-earthquake and Immediate Nuclear Plant Operator Post-earthquake Actions", recognize that damage potential is significantly reduced for earthquake ground motions above 10 Hz. Thus, the question of what is the precise value of building amplification over 8 Hz has very little safety significance.

5. Conclusions

The discussion above leads to several conclusions:

- The results from actual measured ISRS on "nuclear type" structures support the 1.5 response levels advocated within Method A.

- Qualitative assessments of the conservatism inherent within the methods utilized to calculate ISRS have been provided above. These conservatisms are typically quite significant (as has been independently verified by median/modern assessments such as the LLNL study) and result in ISRS, which show amplifications well beyond the 1.5 factor from Method A. Specific exceedances noted for PNPS (beyond the 1.5 factor) are due to the conservatisms inherent in the ISRS calculation methods, and do not invalidate the application of Method A.

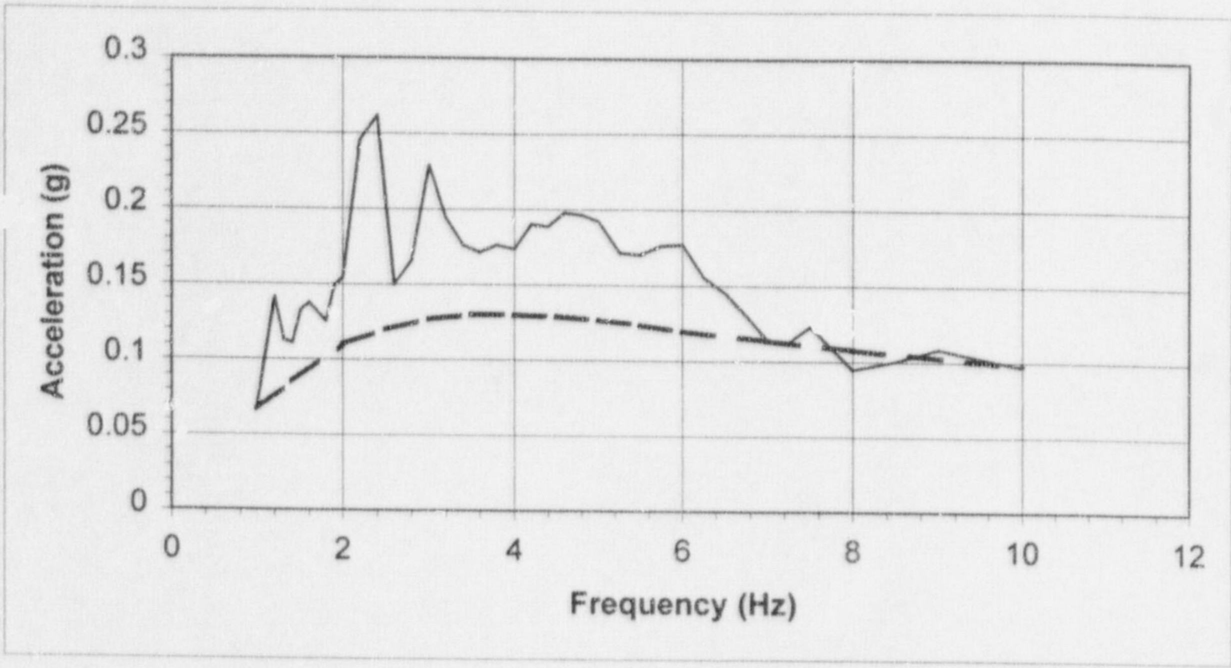

Figure A-1. Taft Time History Spectrum (solid) compared to Licensing Basis Free Field Response Spectrum (dashed)

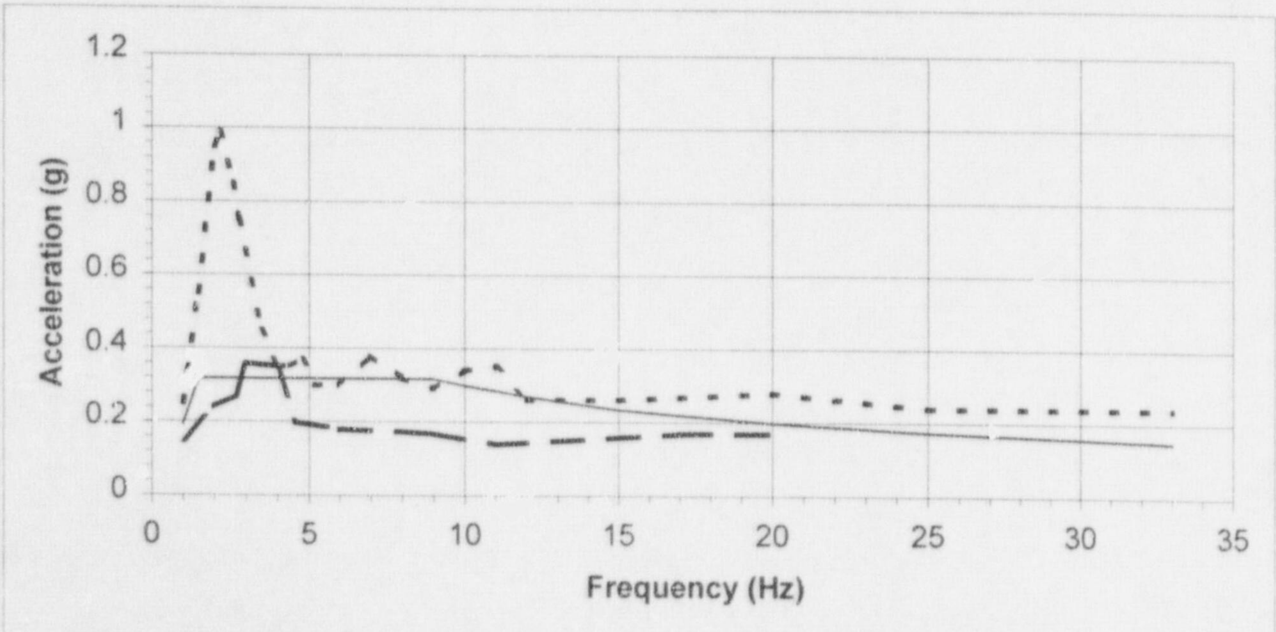

Figure A-2. Reactor Building elevation 23 Recalculated ISRS for control point at surface (dashed) and control point at rock (dotted) versus Free Field Response Spectrum Input (solid)

Table 1
Comparison of Design Basis to Median Centered
(Peak Spectral Response Comparison)

Plant	Building	Construction	Estimated Frequency	Comments	Damping **	Design Basis Analysis Peak S_a	Median Centered Peak S_a	Margin Design/ Median	Ground Spectra
A [1]	Auxiliary Building	5 Story, Reinforced Concrete Shear Wall	7-8 Hz	Rock Site	2%	3.8g (Figure 1)	1.5g (Figure 1)	2.53	0.12g Reg Guide 1.60
B	Reactor Building Interior Structure	Reinforced Concrete Shear Wall	10-13 Hz	Rock/Soil	5%	5.8g* (Figure 2)	1.1g (Figure 3)	5.3	0.12g Site Specific (Figure 4)
B	Reactor Building Exterior Shell	Reinforced Concrete Shear Wall	4 Hz 12 Hz	Rock/Soil	5%	2.2g (Figure 5)	0.67g (Figure 6)	3.3	0.12g Site Specific (Figure 4)
C [2]	Containment Interior Structure	Reinforced Concrete Shear Wall	10 Hz	Rock Site	5%	10.7g (Figure 7)	4.7g (Figure 7)	2.3	0.75g Hosgri (Figure 8)
D	Auxiliary Building	Reinforced Concrete Shear Wall	10 Hz	Soil Site	5%	1.4g (Figure 9)	0.26g [3] (Figure 9)	5.4	0.1g Modified Newmark (Figure 10)

* SSE defined as 2 x OBE for this Plant's Design Basis

** Equipment damping value applies both to design basis ISRS and median centered ISRS.

[1] Plant A is Comanche Peak, information is on the NRC docket.

[2] Plant C is Diablo Canyon, information is on the NRC docket. It should be noted that the reanalysis for the 0.75g Hosgri earthquake was done relatively recently, and had less inherent conservatism in the design basis response analysis than older plants such as Ginna. Thus, the margin of 2.3 (design peak/median peak) is judged to be on the lower end of the margins expected for older plants.

[3] Median Value was scaled to reflect the fact that the median ISRS were generated for a Reg. Guide 1.60 shape (conservative), instead of the Plant D Design SSE.