MITSUBISHI HEAVY INDUSTRIES, LTD.
16-5, KONAN 2-CHOME, MINATO-KU
TOKYO, JAPAN

January 28, 2010

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffery A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-10019

Subject: MHI's Responses to US-APWR DCD RAI No. 493-3983

Reference: 1) "Request for Additional Information No. 493-3983 Revision 1, SRP Section: 03.07.03 - Subsystem Analysis," dated 12/1/2009.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Responses to Request for Additional Information No. 493-3983, Revision 1."

Enclosed are the responses to 4 RAIs contained within Reference 1. This transmittal completes the response to this RAI.

Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of this submittal. His contact information is provided below.

Sincerely,

Y. Ogata

Yoshiki Ogata,
General Manager- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosure:

1. Response to Request for Additional Information No. 493-3983, Revision 1

CC: J. A. Ciocco
C. K. Paulson

Contact Information
C. Keith Paulson, Senior Technical Manager
Mitsubishi Nuclear Energy Systems, Inc.
300 Oxford Drive, Suite 301
Monroeville, PA 15146
E-mail: ck_paulson@mnes-us.com
Telephone: (412) 373-6466

D081
NRO

Docket No. 52-021
MHI Ref: UAP-HF-10019

Enclosure 1

UAP-HF-10019
Docket No. 52-021

Response to Request for Additional Information No. 493-3983,
Revision 1

January, 2010

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

1/28/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 493-3983 REVISION 1**
SRP SECTION:	**03.07.03 - Seismic Subsystem Analysis**
APPLICATION SECTION:	**3.7.3**
DATE OF RAI ISSUE:	**12/01/2009**

QUESTION NO. RAI 03.07.03-2:

Section 3.7.3.II.8 of the SRP stated that if it is not feasible or practical to isolate a seismic category I system, then adjacent non-seismic category I systems should be analyzed according to the same seismic criteria applicable to the seismic category I system. In response to RAI 3.7.3-11, the applicant proposes that a new paragraph be inserted in Section 3.7.3 of the DCD that states that adjacent non-seismic category I systems be analyzed to the same seismic input as seismic category I systems and components.

In DCD Section 3.8.4.4.4, the applicant states that the seismic category II structures and subsystems are designed and analyzed using the same methods and stress limits as for seismic category I structures except structural steel in-plane stress limits are permitted to reach 1.0 Fy. Explain why the allowable for the in-plane stress limit has been relaxed relative to that for seismic category I systems and components, and explain how the proposed change meets the guidelines of the SRP, or how the proposed change otherwise meets the intent of 10 CFR Part 50 Appendix A, General Design Criterion 2.

Reference: MHI response to RAI 213-1951, MHI Ref: UAP-HF-09114, ML090910119, dated 3/27/2009.

ANSWER:

Seismic category II structures and subsystems are designed and analyzed to ensure that, under SSE effect, they do not fall or displace to the point that they could damage seismic Category I SSCs. In order to avoid any permanent deformation/displacement of the seismic Category II structures and subsystems under seismic effect, the maximum stress under the critical load combinations has to be limited to yield stress or 1.0 F_y. This approach has been used historically at many nuclear power plants. See MHI's previous response to RAI 223-1996 question 3.8.1-14 item 3 for additional discussions on loads, load combinations, and acceptance criteria (including limiting maximum allowable stress to yield stress or 1.0 F_y). MHI's commitment, as stated in DCD Subsection 3.8.4.4.4, is to use "the same methods and stress limits specified for seismic Category I structures and subsystems" in the analysis and design of seismic Category II structures and subsystems. The stress limit coefficients used for all load combinations in DCD

Table 3.8.4-4 for seismic Category II structures and subsystems are the same as for seismic Category I structures and subsystems in order to assure the same margin of safety as for seismic Category I structures and subsystems in accordance with SRP Section 3.7.2 Subsection II.8.C acceptance criteria requirements. The DCD will be revised to provide clarifications as described below.

Impact on DCD

See Attachment 1 for the mark-up of the DCD Tier 2, Section 3.8, changes to be incorporated.

- Change the 2nd paragraph in Subsection 3.8.4.4.4 by deleting the phrase "except where noted therein" to state: "Seismic Category II structures and subsystems are analyzed and designed using the same methods and stress limits specified for seismic Category I structures and subsystems and the same load combinations and stress coefficients given in Table 3.8.4-4."

- Change the 2nd sentence of Note 11 of Table 3.8.4-4 to state: "For load combinations 7 through 11, the allowable stress shall not exceed 1.0 F_y.

See Attachment 2 for the mark-up of the DCD Tier 2, Appendix 3.A, changes to be incorporated.

- Change the 3rd sentence in the paragraph by deleting the phrase "except where noted" in Appendix 3A, Subsection 3A.1.2, to state: "Seismic category II ductwork and supports, including support anchorages, are therefore analyzed and designed using the same methods and stress limits specified for seismic category I structures and subsystems, in Table 3.8.4-4."

See Attachment 3 for the mark-up of the DCD Tier 2, Appendix 3.F, changes to be incorporated.

- Change the 3rd sentence in the paragraph by deleting the phrase "except where noted" in Appendix 3F, Subsection 3F.1.2, to state: "Seismic category II conduit systems, including support anchorages, are therefore analyzed and designed using the same methods and stress limits specified for seismic category I structures and subsystems, in Table 3.8.4-4."

See Attachment 4 for the mark-up of the DCD Tier 2, Appendix 3.G, changes to be incorporated.

- Change the 2nd sentence in the paragraph by deleting the phrase "except where noted" in Appendix 3G, Subsection 3G.1.2, to state: "Seismic category II cable tray systems including support anchorages are, therefore, analyzed and designed for the applicable SSE, such as in-structure response spectra developed from the CSDRS within the standard plant Reactor Building and the East and West Power Source Buildings using the same methods and stress limits specified for seismic category I cable tray systems in Table 3.8.4-4."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

1/28/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 493-3983 REVISION 1**
SRP SECTION:	**03.07.03 - Seismic Subsystem Analysis**
APPLICATION SECTION:	**3.7.3**
DATE OF RAI ISSUE:	**12/01/2009**

QUESTION NO. RAI 03.07.03-3:

In response to RAI 3.7.3-14, the applicant refers to a verified standardized modeling methodology to confirm the adequacy of the number of discrete mass degrees of freedom for the reactor coolant loop subsystem model. Describe this methodology, describe what key features of the methodology were incorporated in the analysis and design of standard plant and discuss how the modeling methodology compares with the modeling guidelines of the SRP.

Reference: MHI response to RAI 213-1951, MHI Ref: UAP-HF-09189, ML091180437, dated 4/24/2009.

ANSWER:

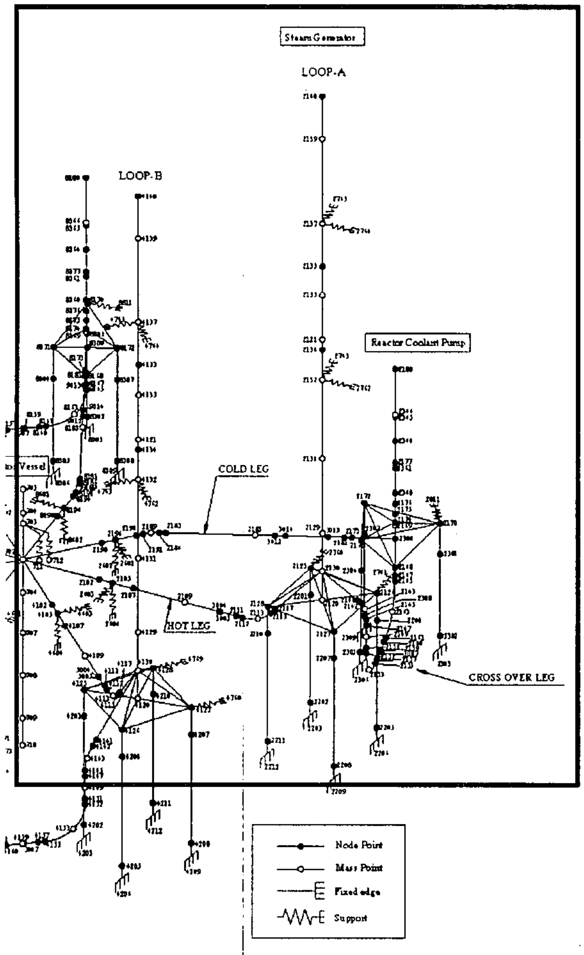
The general methodology for the lumped-mass stick model of the reactor coolant loop subsystem is as follows;

a. It is requested to provide sufficient number of degrees of freedom in order to evaluate the vibrational characteristics and seismic responses including high-frequency modes for the RCL subsystem.

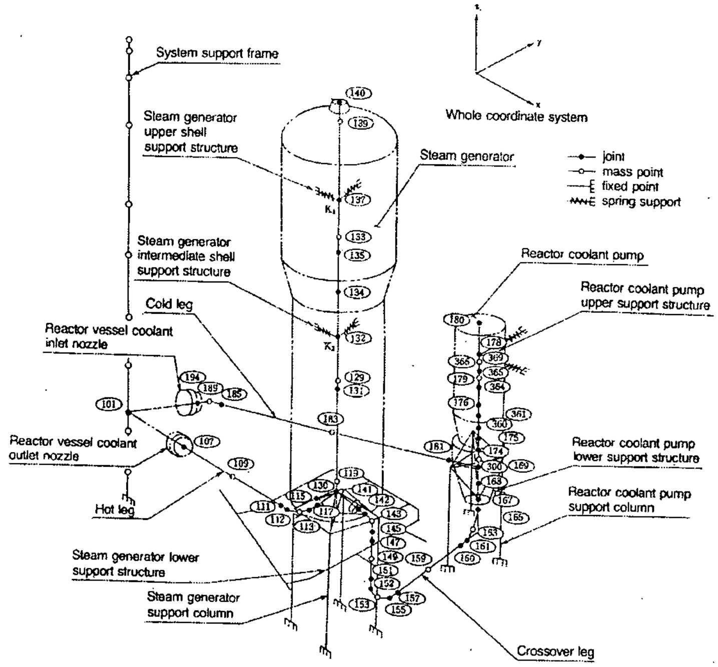
b. It is important to provide the nodal point, where the section properties of the element member of equipment or piping changes, in the center line of each element.

c. It is necessary to provide the six components of mass in the lumped mass node, which are, three translational masses and three rotational inertias along the global X,Y,Z coordinate system.

The part of the Loop-A model of the US-APWR RCL extracted from the technical report MUAP-08005 Rev. 0 [1] is presented in the left-side figure, while the standardized loop model of the Japan PWR plant is in the right-side figure. These loop models are constructed under the common modeling methodology described above. The appropriateness of the standardized loop modeling and response analysis method was proved by the seismic proving test of NUPEC PWR Primary Coolant Loop System [2), 3)].



Loop-A model of US-APWR RCL
(Reference 1)



Typical loop model of domestic PWR RCL
(Reference 2)

Figure 1 Comparison of RCL Model

Reference:

1) "Dynamic Analysis of the Coupled RCL-R/B-PCCV-CIS Lumped Mass Stick Model", MUAP-08005 Rev. 0, Mitsubishi Heavy Industries, April 2008, ML081210249

2) "Proving test on the seismic reliability for the PWR Primary Coolant Loop System", K.Fujita et al., ASME PVP, Vol.182, pp303-308, 1989

3) "Proving test on the seismic reliability for the PWR Primary Coolant Loop System", H.Akiyama et al., 11th SMiRT, Vol.K, 1991

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

1/28/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 493-3983 REVISION 1**
SRP SECTION:	**03.07.03 - Seismic Subsystem Analysis**
APPLICATION SECTION:	**3.7.3**
DATE OF RAI ISSUE:	**12/01/2009**

QUESTION NO. RAI 03.07.03-4:

Regarding the response to RAI 3.7.3-14, describe the relevance of the benchmarking data presented in the 1989 ASME PVP proceedings to the modeling of the US-APWR. Is the benchmark data intended to demonstrate the validity of the general MITI methodology? Is it because the configuration of the PWR RCL is similar to the USAPWR design that the benchmarking validates the modeling of the US-APWR RCL?

Reference: MHI response to RAI 213-1951, MHI Ref: UAP-HF-09189, ML091180437, dated 4/24/2009.

ANSWER:

The US-APWR is a four loop plant. Each RCL consists of the reactor vessel (RV), the steam generator (SG), the reactor coolant pump (RCP), and the loop piping. The loop piping consists of hot leg, cross over leg, and cold leg piping. These basic configurations are common for the Japan PWR RCL. Although the length, the size or the weight of each component or piping are different, the methodology to develop the lumped-mass stick model of the RCL subsystem is thought to be common to the Japan PWR RCL, as presented in Figure 1 of the answer to RAI 03.07.03-3. For example, the comparison of the number of the nodes between US-APWR RCL model and the Japan PWR RCL model is presented in the following table.

Table 1 Comparison of the number of nodes in a loop model between US-APWR RCL and domestic PWR RCL

	US-APWR (for one loop)	Japan PWR RCL (for one loop)
Steam generator	27	25
Reactor Coolant Pump	23	22
Loop Piping	36	21

*The lumped-mass stick models are referred to Figure 1 of the answer of RAI 03.07.03-3.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

1/28/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 493-3983 REVISION 1**
SRP SECTION:	**03.07.03 - Seismic Subsystem Analysis**
APPLICATION SECTION:	**3.7.3**
DATE OF RAI ISSUE:	**12/01/2009**

QUESTION NO. RAI 03.07.03-5:

The response to RAI 3.7.3-15 raises questions regarding the determination of the appropriate acceleration levels or ISRS to be used for analysis of SSCs. The applicant states in their response that if a piece of in-line safety-related equipment is rigid, then the equivalent static load can be taken as 1.5 times the peak of the ISRS applicable to the subsystem, or else it can be taken to be the acceleration at the mounting point of the equipment. The applicant further states that if the equipment is not rigid, then the ISRS at the mounting point of the equipment is required.

In the case of rigid equipment, for the equivalent static load to be defined by 1.5 times the peak of the ISRS applicable to the subsystem, the ISRS must be taken at the mounting point of the subsystem to the subsystem support, not the mounting point of the subsystem support to the underlying system unless it can be demonstrated that the subsystem supports are rigid. Accordingly, how does the applicant propose to determine the ISRS that includes potential flexibility of subsystem supports, or does the applicant propose to design rigid supports?

Also, if the response spectrum method is used and some components of the subsystem are rigid, how does the applicant intend to demonstrate that the "rigid mode acceleration" will be accounted for in the response spectrum analysis when determining the proper equivalent acceleration to be used in analyzing the equipment?

Reference: MHI response to RAI 213-1951, MHI Ref: UAP-HF-09189, ML091180437, dated 4/24/2009.

ANSWER:

The applicant is fully aware of the fact that the flexibility of the intervening structural element has to be considered in order to utilize the remote ISRS which is normally generated at a location where the intervening structural element is supported. Or alternatively, the remote ISRS can be modified with the inclusion of the flexibility of the intervening structural element and be transferred up to the proper interface location for use in the seismic dynamic analysis of the equipment or subsystem. Depending on the degree of the flexibility of the intervening structural element, the following two approaches are adopted:

a) When the intervening structural element (e. g., consisting of both the subsystem and its supports for line-mounted equipment) is judged to be rigid (i.e., frequency > 50 Hz), the remote ISRS can be transferred to the desired location by properly incorporating the rigid body motion effect of the intervening structural element. The new translational ISRS at the equipment mounting interface shall be taken to be the absolute sum of the translational ISRS at the remote location and the contributions arising from the structural rocking and torsional effects between the two locations.

b) When the intervening structural element is judged to be flexible (i.e., frequency < 50 Hz), a new ISRS at the equipment mounting interface shall be generated and the flexibility of the intervening structural element has to be included. Or alternatively, the seismic dynamic analysis of the equipment is expanded to include the intervening structural element.

When response spectrum method is used, the mass and stiffness of the intervening structure are all included into the model for dynamic analysis. The response generated via the modal superposition coupled with the missing mass correction shall ensure that all rigid mode effect is included.

Impact on DCD

See Attachment 5 for the mark-up of the DCD Tier 2, Section 3.8, changes to be incorporated.

- Add the following as the 4th paragraph in Subsection 3.7.3.1:

  "The time history or response spectra generated at the support point of the subsystem are utilized as the input motion for performing the seismic dynamic analysis of the subsystem. However, where these data are not readily available, the data generated for a distance away from the structural support point may be used. To account for the structural linkage (i.e., intervening structural element) between these two locations, the additional amplification of the response due to the presence of the intervening structural element can be calculated and the remote input motion can be transformed. For cases where the intervening structure is rigid (i.e., frequency > 50 Hz), the transformation can be achieved by adding the effect due to the rigid body motion of the intervening structure to the existing input motion at the remote location. The new translational time history at the interface location is generated by algebraic summation of the translational acceleration time history at the reference location and the time-history contribution arising from the rocking and torsional effects of the intervening structural element. The new translational response spectra are obtained by absolute sum of the translational response spectra at the reference location and the contributions arising from the rocking and torsional effects of the intervening structural element. For places where the intervening structural element is judged to be flexible, the new ISRS are generated by incorporating the flexibility of the intervening structural element. Or alternatively, the seismic dynamic analysis of the subsystem shall be expanded to include the flexibility of the intervening structural element."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

This completes MHI's responses to the NRC's questions.

The COL Applicant is to provide design and analysis procedures for the ESWPT, UHSRS, and PSFSVs.

3.8.4.4.4 Seismic Category II Structures

Seismic category II structures need not remain functional during and after an SSE. However, such structures must not fall or displace to the point they could damage seismic category I SSCs.

Seismic Category II structures and subsystems are analyzed and designed using the same methods and stress limits specified for seismic Category I structures and subsystems, and the same load combinations and stress coefficients given in Table 3.8.4-4~~, except where noted therein~~.

3.8.4.5 Structural Acceptance Criteria

Structural acceptance criteria are listed in Table 3.8.4-3 for concrete structures and in Table 3.8.4-4 for steel structures, and are in accordance with ACI-349 (Reference 3.8-8) and AISC N690 (Reference 3.8-9), except as provided in the table notes.

The deflection of the structural members is limited to the maximum values as specified in ACI-349 (Reference 3.8-8) and AISC N690 (Reference 3.8-9), as applicable.

Subsection 3.8.5.5 identifies acceptance criteria applicable to additional basemat load combinations.

3.8.4.6 Materials, Quality Control, and Special Construction Techniques

The following information pertains to the materials, quality control programs, and any special construction techniques utilized in the construction of the seismic category I structures for the US-APWR.

3.8.4.6.1 Materials

The major materials of construction in seismic category I structures are concrete, grout, steel reinforcement bars, splices of steel reinforcing bars, structural steel shapes, and anchors.

3.8.4.6.1.1 Concrete

Concrete utilized in standard plant seismic category I structures, other than PCCV and upper part of the tendon gallery in the basemat, has a compressive strength of f'_c = 4,000 psi. Concrete utilized in the PCCV and upper part of the tendon gallery in the basemat has a compressive strength of f'_c = 7,000 psi and is subject to the PCCV material requirements in Subsection 3.8.1.6, including the requirements of ASME III, Division 2 (Reference 3.8-2), as shown in Figure 3.8.5-4. The COL Applicant is to specify concrete strength utilized in non-standard plant seismic category I structures. A test age of 28 days is used for normal concrete. Batching and placement of concrete is performed in accordance with ACI 349 (Reference 3.8-8), ACI 304R (Reference 3.8-38), and ASTM C 94 (Reference 3.8-42). During construction, volume changes in mass concrete are controlled where necessary by applying measures and provisions outlined

ATTACHMENT 1

to RAI 493-3983

Table 3.8.4-4 Load Combinations and Load Factors for Seismic Category I Steel Structures (Sheet 2 of 2)

Notes:

1. Coefficients are applicable to primary stress limits given in ANSI/AISC N690-1994 Sections Q1.5.1, Q1.5.2, Q1.5.3, Q1.5.4, Q1.5.5, Q1.6, Q1.10, and Q1.11. Calculated stresses shall not exceed allowable stresses for each of the load combinations shown in this table.
2. In no instance shall the allowable stress exceed $0.7F_u$ in axial tension nor $0.7F_u$ times the ratio Z/S for tension plus bending.
3. For primary plus secondary stress, the allowable limits are increased by a factor of 1.5.
4. The maximum values of P_a, T_a, R_a, Y_j, Y_r, and Y_m, including an appropriate dynamic load factor, is used in load combinations 9 through 11, unless an appropriate time history analysis is performed to justify otherwise.
5. In combining loads from a postulated high-energy pipe break accident and a seismic event, the SRSS may be used, provided that the responses are calculated on a linear basis.
6. All load combinations is checked for a no-live-load condition
7. In load combinations 7 through 11, the stress limit coefficient in shear shall not exceed 1.4 in members and bolts.
8. Secondary stresses which are used to limit primary stresses are treated as primary stresses.
9. Consideration is also given to snow and other loads as defined in ASCE 7.
10. This load combination is to be used when the global (non-transient) sustained effects of T_a are considered.
11. The stress limit coefficient where axial compression exceeds 20% of normal allowable, is 1.5 for load combinations 7, 8, 9, 9a, and 10, and 1.6 for load combination 11. For ~~seismic category II members the stress limit coefficient applicable to axial and bending stresses for~~ load combinations 7 through 11 ~~is 1.7, however~~ the allowable stress shall not exceed 1.0 F_y.
12. Load combinations and stress limit coefficients are applicable for AISI design of cold-formed steel structural members used in subsystem supports. Allowable strengths per AISI may be increased by the stress limit coefficients shown, subject to the limits noted in this table. The allowable strength shall equal or exceed the required strength calculated, in accordance with AISI, for each of the load combinations shown in this table.

Typically stress criteria for ductwork and supports results in selection of standard member sizes and maximum span lengths. Those HVAC systems that do not satisfy the parameters qualified for standard member sizes and maximum span lengths are designed to satisfy their specific load and operating conditions. Pressures due to flow velocity are based on the operability requirements of each HVAC system.

3A.1.2 Seismic Category II Ductwork

Seismic category II ductwork is not essential for the safe shutdown of the plant and need not remain functional during, and after, a SSE. However, such ductwork and supports must not fall or displace excessively where it could damage any seismic category I structures, systems, and components (SSCs). Seismic category II ductwork and supports, including support anchorages, are therefore analyzed and designed using the same methods and stress limits specified for seismic category I structures and subsystems~~, except where noted~~ in Table 3.8.4-4.

3A.2 Applicable Codes, Standards and Specifications

The design and construction of seismic category I HVAC systems conform to AG-1-2003, Code on Nuclear Air and Gas Treatment, including Addendum AG-1a and AG-1b (Reference 3A-8). Sheet metal ducts are constructed in accordance with the American National Standards Institute (ANSI)/Sheet Metal and Air Conditioning Contractors National Association (SMACNA), HVAC Duct Construction Standards – Metal and Flexible (Reference 3A-1). The American Iron and Steel Institute (AISI), Specification for the Design of Cold-Formed Steel Members (Reference 3A-2), provides the methodology for evaluating the effects of shear lag and plate buckling appropriate for this type of duct construction. Structural steel duct supports are designed and constructed in accordance with the American Institute of Steel Construction (AISC) Specification for the Design, Fabrication and Erection of Steel Safety Related Structures for Nuclear Facilities (Reference 3A-3) or AISI as applicable.

Schedule round pipe used as ductwork is not discussed within this Appendix. Codes, standards, and specifications applicable to schedule pipe is in accordance with piping and pipe support criteria in Sections 3.9 and 3.12.

3A.3 Loads and Load Combinations

3A.3.1 Loads

Supports are designed for dead, seismic, thermal loads, and airflow forces at duct elbows, as applicable. Ducts are also designed for the operational and accident pressure loads. Construction live load is considered, however, it is not present during design seismic events. In addition, any accessory loads to the duct or supports are included in the qualification of the duct and duct supports.

The following loads are applicable for the ductwork load combinations:

ADL Additional dynamic loads resulting from system excitations due to structural motion, such as that caused by safety relief valve actuation and other hydrodynamic loads due to the design basis accident (DBA), small pipe break accident (SBA), and intermediate pipe break accident (IBA).

analyzed and designed using the same methods and stress limits specified for seismic category I structures and subsystems, except where noted in Table 3.8.4-4.

3F.2 Applicable Codes, Standards, and Specifications

Conduits are manufactured to satisfy the American National Standard Institute (ANSI) C80.1 American Standard for Electrical Rigid Steel Conduit (ERSC), (Reference 3F-1) or ANSI C80.5, American Standard for Electrical Rigid Aluminum Conduit (ERAC), (Reference 3F-2), as applicable. Junction boxes are manufactured to satisfy the National Electrical Manufacturer Association (NEMA) Standards Publication 250 Enclosures for Electrical Equipment (1000 Volts Maximum) (Reference 3F-3). Installation of the conduit system conforms to the requirements of the National Fire Protection Associations (NFPA) 70, National Electric Code (NEC), (Reference 3F-4).

The American Iron and Steel Institute (AISI) Specification for the Design of Cold-Formed Steel Members (Reference 3F-5) provides the methodology for structurally evaluating cold formed steel shapes, as applicable. Structural steel shapes used for supports are designed and constructed in accordance with the American Institute of Steel Construction (AISC) Specification for the Design, Fabrication, and Erection of Steel Safety Related Structures for Nuclear Facilities (Reference 3F-6). Welding is evaluated and performed in accordance with the American Welding Society (AWS) Standard D1.1 Structural Welding Code, (Reference 3F-7).

3F.3 Loads and Load Combinations

3F.3.1 Loads

Conduit systems are designed for dead, seismic, and thermal loads, as applicable. Design dead load includes the working load (weight) of cables permitted in the conduit. In addition, any accessory loads to the conduit and conduit supports are included in the qualification of the conduit and conduit supports.

3F.3.2 Load Combinations

Refer to Subsection 3.8.4.3 for various load combinations applicable to seismic category I SSCs.

Seismic category II conduit and conduit supports are qualified for the applicable SSE to assure they do not damage any seismic category I SSCs by falling or displacing excessively under any seismic loads. Seismic category II conduit supports are, therefore, qualified for maximum seismic load combinations and associated allowable stresses as discussed in Subsection 3.8.4.3.

3F.4 Design and Analysis Procedures

Refer to Section 3.7 for seismic system analysis and qualification requirements of seismic category I and seismic category II SSCs and their supports.

ATTACHMENT 4
to RAI 493-3983

3G Seismic Qualification of Cable Trays and Supports

3G.1 Description

This appendix provides the methodology used to qualify the structural integrity of seismic category I and seismic category II electrical cable trays and cable tray supports (hereafter referred to as "cable tray systems"). Cable tray systems containing non-Class 1E cable in non-seismic structures are not required to be qualified to the requirements of this appendix.

In general, the design of cable trays and cable tray supports is accomplished through the following steps:

- Determine applicable load combinations and corresponding allowable stresses for trays and supports
- Limit spacing of tray supports to maintain tray stresses within allowable stresses corresponding to the applicable load combination
- Assure that the maximum stresses of tray supports are within allowable stressescorresponding to the applicable load combination
- Provide system bracing to control seismic movement and interaction with other seismic category I structures, systems, or components (SSCs).

3G.1.1 Seismic Category I Cable Tray Systems

Seismic category I cable tray systems are designed for all applicable load combinations to maintain structural integrity within stress limits. This is achieved by analyzing the cable tray system (tray, fittings, connectors, fasteners, supports, etc.) and limiting the support spacing to maintain critical stresses to acceptably low levels. The seismic qualification of cable tray systems is to satisfy the safe-shutdown earthquake (SSE) requirements of the structure in which they are contained. Seismic category I cable tray systems, including support anchorages, in US-APWR standard plant seismic category I structures are analyzed and designed for a SSE which is equivalent to the in-structure response spectra developed from the certified seismic design response spectra (CSDRS). Site-specific seismic category I structures are analyzed and designed using as a minimum the site-specific SSE developed from the site-specific ground motion response spectra (GMRS) and foundation input response spectra (FIRS).

3G.1.2 Seismic Category II Cable Tray Systems

Seismic category II cable tray systems are designed to verify that the items will not fall or displace excessively where it could damage any seismic category I SSCs during, and after, a SSE. Seismic category II cable tray systems including support anchorages are, therefore, analyzed and designed for the applicable SSE, such as in-structure response spectra developed from the CSDRS within the standard plant Reactor Building and the East and West Power Source Buildings using the same methods and stress limits specified for seismic category I cable tray systems~~, except where noted~~ in Table 3.8.4-4.

Time history analysis of seismic systems is discussed in Subsection 3.7.2. The time history seismic analysis of a subsystem can be performed by simultaneously applying the displacements and rotations at the interface point(s) between the subsystem and the system. These displacements and rotations are the results obtained from a model of a larger subsystem or a system that includes a simplified representation of the subsystem.

The choice of applied seismic analysis method depends on the desired level of precision and the level of complexity of the particular subsystem being designed. The equivalent static load method of analysis is predominantly used for civil structure-related seismic subsystems and is generally the preferred method because it is relatively simple and at least as conservative as the other more detailed methods. For example, the equivalent static load analysis method is generally used for miscellaneous steel platforms, stairs, and walkways, reinforced masonry block walls and enclosures, HVAC ducts and duct supports, electrical tray and tray supports, and conduits and conduit supports.

The time history or response spectra generated at the support point of the subsystem are utilized as the input motion for performing the seismic dynamic analysis of the subsystem. However, where these data are not readily available, the data generated for a distance away from the structural support point may be used. To account for the structural linkage (i.e., intervening structural element) between these two locations, the additional amplification of the response due to the presence of the intervening structural element can be calculated and the remote input motion can be transformed. For cases where the intervening structure is rigid (i.e., frequency > 50 Hz), the transformation can be achieved by adding the effect due to the rigid body motion of the intervening structure to the existing input motion at the remote location. The new translational time history at the interface location is generated by algebraic summation of the translational acceleration time history at the reference location and the time-history contribution arising from the rocking and torsional effects of the intervening structural element. The new translational response spectra are obtained by absolute sum of the translational response spectra at the reference location and the contributions arising from the rocking and torsional effects of the intervening structural element. For places where the intervening structural element is judged to be flexible, the new ISRS are generated by incorporating the flexibility of the intervening structural element. Or alternatively, the seismic dynamic analysis of the subsystem shall be expanded to include the flexibility of the intervening structural element.

Torsional effects due to the significant effect of eccentric masses connected to a subsystem are included in the subsystem analysis. For rigid components (i.e., those with natural frequencies greater than the ZPA cutoff frequency of 50 Hz), the lumped mass is modeled at the center of gravity of the component with a rigid link to the appropriate point in the subsystem. For flexible components having frequency less than the ZPA, the subsystem model is expanded to include an appropriate model of the component.

Regardless of the method chosen, to avoid resonance, the fundamental frequencies of components and equipment are preferably selected to be less than one half or more than twice the dominant frequencies of the support structure. If this is not practical, equipment and components with fundamental frequencies within this range are designed for any associated resonance effects in conjunction with all other applicable loads.

The equivalent static load method of analysis and the various modal response spectra analysis methods are described in the following subsections.