LIC-92-016R

ENCLOSURE 1

ASCM CRITERIA METHODOLOGIES

ALTERNATE SEISMIC CRITERIA & METHODOLOGIES FOR FORT CALHOUN STATION

Prepared for

U. S. Nuclear Regulatory Commission

Prepared By

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1.0 INTRODUCTION

On December 2, 1988, Omaha Public Power District (OPPD) submitted the Alternate Seismic Criteria and Methodologies document for the Fort Calhoun Station, Unit 1 (FCS) to the NRC for review and approval [2]. This criteria document proposed alternate seismic criteria and methodologies for design and analysis of several categories of structures, systems and components which differ from or do not exist in the criteria delineated in the FCS Updated Safety Analysis Report (USAR) [1]. In conjunction with the criteria document, refined seismic response spectra were generated and submitted to the NRC on February 21, 1989 [3].

During the following years, the NRC and OPPD exchanged correspondence and held several meetings and phone calls in an effort to resolve the NRC's comments on the criteria document and associated response spectra. The licensing chronology of the FCS Alternate Seismic Criteria and Methodologies is summarized in Table 1-1.

Subsequent to the development of the FCS Alternate Seismic Criteria and Methodologies in 1988, there were activities on various seismic related issues at FCS and within the nuclear industry. Examples of pertinent activities at FCS were the requalifications of several critical piping systems to address NRC SSOMI and IE Bulletin 79-14 concerns using the USAR design basis criteria, and the development of design basis documents per the Safety Enhancement Program. Examples of pertinent activities within the nuclear industry were the development of SQUG procedures for seismic verification of equipment (USI-46) and the NRC/EPRI sponsored Piping and Fitting Dynamic Reliability Research Program (PFDRRP). The products of these activities have eliminated the need for some of the elements in the original criteria document. In the July 6, 1990 submittal to the NRC [6], OPPD decided to concentrate the licensing efforts in three areas for which significant needs existed and for which significant benefits could be obtained. These three areas are as follows:

- Refined seismic response spectra.
- Seismic analysis methods for piping.
- Heating, ventilation, and air conditioning (HVAC).

This submittal incorporates the resolutions to all NRC's comments pertaining to the three areas above and is intended for the final NRC's review and approval. Once approved by the NRC, OPPD will apply these criteria and associated spectra on an as-needed basis to structures, systems and components. The application will not be mixed with the design basis criteria from the FCS USAR [1] and will be tracked via design basis documents.

Table 1-1

Licensing Chronology of the FCS Alternate Seismic Criteria and Methodologies

During 1988	OPPD developed FCS Alternate Seismic Criteria and Methodologies document and associated refined seismic response spectra.
12/2/88	OPPD submitted the Alternate Seismic Criteria and Methodologies document to the NRC [2]
2/21/89	OPPD submitted the refined seismic response spectra document to the NRC [3].
12/6/89	OPPD received NRC's comments on the criteria document [4].
5/23/90	OPPD submitted referenced documents for the refined seismic response spectra to the NRC [5].
7/6/90	OPPD submitted the response to NRC's comments on the criteria document to the NRC and decided to concentrate the licensing efforts in three areas [6].
8/7/90	OPPD received NRC's comments on the refined spectra document [7].
10/29/90	OPPD submitted the response to NRC's comments on the refined seismic spectra document to the NRC [8].
6/3/91	OPPD received NRC's further comments on the criteria document [9].
6/17/91	OPPD received NRC's Safety Evaluation Report on the criteria and refined spectra documents. Several open items required resolutions [10].
9/5/91	NRC/OPPD meeting.
1/31/92	OPPD submitted a letter to the NRC, outlining the plan to resolve the remaining open items [11].
4/23/92	NRC/OPPD meeting.

2.0 SCOPE

This document provides Alternate Seismic Criteria and Methodologies to the FCS USAR Appendix F, "Classification of Structures and Equipment and Seismic Criteria," [1] in the following three areas:

- Refined Seismic Response Spectra (Section 3.0 of this document). The refined seismic response spectra were generated for the Reactor Building, Auxiliary Building and Intake Structure.
- Seismic Analysis Methods for Piping (Section 4.0 of this document). The seismic analysis methods for piping include the response spectra method, the equivalent static coefficient method, and the linear time history method.
- Heating, Ventilation, and Air Conditioning (Section 5.0 of this document). The attributes for HVAC systems and components include ducts, supports and miscellaneous hardware. The seismic criteria for these attributes include the qualifications by analysis, test, experience data, and using manufacturers' allowables (for HVAC miscellaneous hardware only). Seismic analysis methods for HVAC systems include the equivalent static coefficient method and the response spectra method.

The refined seismic response spectra can be applied to all FCS Seismic Category I structures, systems and components. The seismic analysis methods for piping and the seismic criteria and analysis methods for HVAC can be applied to Category I piping and HVAC systems and components. For FCS, Seismic Category I structures, systems and components are divided into two subcategories: Critical Quality Elements (CQE) and Limited CQE, as defined in the FCS USAR [1].

3.0 REFINED SEISMIC RESPONSE SPECTRA

3.1 CONTROL MOTION

The control motion that was used in the FCS soil-structure interaction analysis is the licensed design motion of the plant, which is contained in USAR Appendix F, Section F.2.1 [1]. The Maximum Hypothetical Earthquake (called Safe Shutdown Earthquake or SSE, herein) has a peak ground acceleration of 0.17g in the two horizontal directions of motion. The Design Earthquake (called Operating Basis Earthquake or OBE, herein) has a peak ground acceleration of 0.08g in the two horizontal directions of motion. For the vertical direction, the peak ground acceleration is 2/3 of the value for the horizontal directions for both OBE and SSE. The control motion was applied in the free field at the foundation level of the plant.

A set of three statistically independent artificial time histories was developed, one for each of the three mutually orthogonal earthquake directions. These time histories envelop the design ground motion in accordance with the procedures in the NRC Standard Review Plan, Section 3.7.1 [12]. The criteria for statistical independence are met since the correlation coefficient between any two time histories is less than +0.16 [13].

3.2 SOIL-STRUCTURE INTERACTION

The design basis FCS soil-structure interaction (SSI) analyses were based on the lumped parameter method, using frequency-independent soil springs. These analyses were performed in 1970. Since then, more refined SSI techniques have been developed.

Refined SSI analyses were performed using the SASSI/CLASSI methodologies to generate updated floor response spectra for the Reactor Building (Containment and Internal Structure), Auxiliary Building and Intake Structure. The SASSI program was used to develop complex and frequency-dependent impedance functions for the soil/pile foundation system. The real term of the complex impedance function represents the stiffness of the soil/pile foundation system. The imaginary part represents the damping or energy dissipation of the soil/pile foundation system. The CLASSI program was used to calculate the structural responses in terms of response spectra at each major elevation of the structures. Input to CLASSI were the SASSI-generated impedance functions, the dynamic properties of the structures and the free-field artificial time histories. For the SSI analyses, the ground motion time histories were applied at the level of the foundation in the free-field. Uncertainties in soil material properties were addressed by performing upper and lower bound soil variation analyses with shear modulus variation factor of ±30% of the best estimate soil shear modulus. The final broadened floor response spectra were the envelope of the upper bound (+30%), lower bound (-30%) and the best estimate case (broadened by ±15% to account for other uncertainties in the analyses).

A detailed description of the refined seismic response spectra generation performed for FCS as part of the development of the Alternate Seismic Criteria and Methodologies is provided in [3] [20].

4.0 SEISMIC ANALYSIS METHODS FOR PIPING

Three linear elastic analysis methods shall be used for seismic loading on piping systems. They are the response spectra method, the equivalent static coefficient method, and the linear time history method. Their application and associated constraints are provided in Subsection 4.1, 4.2 and 4.3, respectively.

4.1 RESPONSE SPECTRA METHOD

The response spectra analysis shall be performed by either the single level (also called enveloped) or multiple level (also called independent support motion or ISM) response spectra techniques.

Single Level Response Spectra Analysis

The single level response spectra analysis method determines the seismic response from the envelope of all spectra applicable to the piping system support points. The following constraints apply:

(1) Modal combination per NRC Regulatory Guide 1.92.

(2) Critical damping per NRC Regulatory Guide 1.61. ITEMS 1 & 5

(3) Missing mass correction to be applied. The "missing mass" for high frequency modes in the rigid range shall be combined with the low frequency modes by the Square-Root-of-the-Sum-of-Square (SRSS) method [14]. The rigid range is defined to be at frequencies above the floor cut-off frequency or 33 Hz, whichever is lower.

(4) Directional response combination per NRC Regulatory Guide 1.92. The seismic spectra for the three translational directions shall be applied simultaneously, and their responses shall be combined by the SRSS method.

Multiple Level Response Spectra Analysis

When response spectra magnitudes at the piping system support points vary significantly, the application of multiple level (independent support motion) response spectra analysis method may be of benefit. This method shall only be applied to piping systems between separate buildings, floor levels, and/or individual structures. The number of support levels shall be kept to a minimum and spectra within a support level shall be enveloped and used for all supports within that group. The following constraints apply:

(1) through (4): Same as above for single level response spectra analysis.

(5) Support level combination by absolute summation.

The seismic inertial response from the response spectra analysis (either single level or multiple level) shall be combined with seismic anchor motion and other dynamic event responses as follows:

Seismic Anchor Motions (SAM)

The SAM effects on piping systems shall be evaluated if the resultant SAM displacement at any anchor or support location exceeds 1/16 inch. On a case-by-case basis, higher SAM displacements may be ignored if justifications are provided. The SAM stresses and reactions shall be combined with seismic inertial stresses and reactions by the SRSS method [14].

Other Dynamic Events

The stresses and reactions from LOCA or water hammer/steam hammer loading (e.g. rapid valve closure or opening) shall be combined with seismic inertial stresses and reactions by the SRSS method [14] [15].

4.2 EQUIVALENT STATIC COEFFICIENT METHOD

The equivalent static coefficient method may be used for determination of the seismic response of small bore piping and tubing. This method is based on multiplying the system mass by the applicable spectral acceleration and by a static coefficient, thus estimating the equivalent dynamic response of the piping system. The static coefficient is used to take into account the effects of both multi-frequency excitation and multi-mode response for non-rigid system excitation. The static coefficient shall be conservatively assumed to be 1.5 per NRC Regulatory Guide 1.100, Revision 2. This method is limited by the following constraints:

(1) Single level (enveloped) response spectra shall be used.

(2) Critical damping per NRC Regulatory Guide 1.61. ITEMS 1 & 5

(3) Directional response combination per NRC Regulatory Guide 1.92. The response of each translational direction shall be calculated separately, then combined by the SRSS method.

For the equivalent static coefficient analysis, piping systems shall be categorized into one of two groups: rigid systems and non-rigid systems. The rigid group is comprised by those systems whose fundamental natural frequency is equal to or above the floor cut-off frequency or 33 Hz, whichever is less. Likewise, the non-rigid group is comprised by those systems whose natural frequency is below the floor cut-off frequency or 33 Hz, whichever is less.

The seismic response of the piping system can be calculated in accordance with the critical parameters defined in Table 4-1. The general equation for the seismic response is:

$$U = KMS_a$$

Where
- U = Seismic system response
- K = Equivalent static coefficient
- M = Total span and support mass
- S_a = Response spectra acceleration, based on system fundamental natural frequency.

In calculating piping system fundamental natural frequency, a piping system, defined herein as piping between two anchor points, can be broken down into simple configurations. Different types of one-dimensional beam models can then be obtained. Examples of beam models are simply-supported beam, multi-span simply-supported beam, cantilever beam, fixed-end beam, etc. The fundamental natural frequency can then be calculated based on these one-dimensional beam models using cook-book formulas. In the process of simplifying a piping system, concentrated masses representing valve weights and/or weights from the projection of an axial pipe run shall be included in the one-dimensional beam models. However, if the design margin of the piping system is expected to be large or the piping system configuration is complex, the fundamental natural frequency need not be calculated. In this case, the peak acceleration of the floor response spectra shall be used as the acceleration response of the piping system. Also, the peak acceleration of the floor response spectra shall be used if the calculated piping fundamental frequency is equal to or below the frequency of the response spectra peak.

Similar to the response spectra method, the seismic inertial response from the equivalent static coefficient analysis shall be combined with the response from SAM and other dynamic event loading by the SRSS method.

4.3 LINEAR TIME HISTORY METHOD

In lieu of the response spectra analysis method, linear time history analysis using time histories of pipe support point motions as excitation to the piping system may be used. The time history analysis shall be performed using the multiple level (independent) support excitation. The following constraints apply:

(1) Critical damping per NRC Regulatory Guide 1.61. | ITEMS 1 & 5

(2) Support levels shall be combined by algebraic summation at each time step. To substantiate the basis for this technique, the input acceleration and displacement records at different support levels shall | ITEM 6

be from the same ground time history earthquake input to the building structures and shall be applied simultaneously. With this approach, the proper phasing for the inputs is retained. ITEM 6

(3) Directional response combination per NRC Regulatory Guide 1.92. The three translational directions of seismic time history motions shall be applied either:

(i) separately, with their responses combined by the SRSS method, or

(ii) simultaneously, with their responses combined algebraically at each time step. Proper phasing for the inputs shall be retained.

The seismic inertial response shall be combined with seismic anchor motion and other dynamic event responses as follows:

Seismic Anchor Motions (SAM)

The SAM effects on piping systems shall be evaluated if resultant SAM displacement at any anchor or support location exceeds 1/16 inch. On a case-by-case basis, higher SAM displacements may be ignored if justifications are provided. The SAM analysis and the seismic inertial analysis shall be performed either:

(1) separately, with their responses combined by the SRSS method, or

(2) simultaneously, with their responses combined algebraically at each time step. For simultaneous excitation, acceleration input motions at support points shall be used in calculating the "dynamic" response, resulting from inertial resistance of the piping system; displacement input motions at support points, obtained by double integrations of the acceleration input motions, shall be used in calculating the "pseudo-static" or "seismic anchor motion" response, resulting from support movements alone. The total response shall be obtained by combining the dynamic and pseudo-static time history responses by algebraic summation.

Other Dynamic Events

The maximum time history seismic stresses and reactions shall be combined with the stresses and reactions from LOCA or water hammer/steam hammer loading (e.g. rapid valve closure or opening) by the SRSS method [14] [15].

Table 4-1

Determination of Parameters for the Equivalent Static Coefficient Method

System Fundamental Natural Frequency [a] (f)	Response Spectra Acceleration [b] (S_a)	Equivalent Static Coefficient (K)
$f \geq f_{(rigid)}$	$S_{a(rigid)}$	1.0
$f_{(peak)} < f < f_{(rigid)}$	S_{af}	1.5
$f \leq f_{(peak)}$	$S_{a(peak)}$	1.5
Unknown	$S_{a(peak)}$	1.5

Notes: [a] f = Fundamental natural frequency of the system

$f_{(rigid)}$ = Cut-off freque. . response spectrum or 33 Hz, whichever is ess

$f_{(peak)}$ = Frequency of response spectrum peak.

[b] S_{af} = Spectral acceleration at system fundamental natural frequency

$S_{a(rigid)}$ = Spectral acceleration above cut-off frequency

$S_{a(peak)}$ = Peak spectral acceleration.

5.0 HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)

The qualification criteria and seismic analysis methods for HVAC systems and components are provided in Subsections 5.1 and 5.2, respectively.

5.1 QUALIFICATION CRITERIA FOR HVAC

The qualification criteria given in this Subsection are applicable to all FCS Seismic Category I HVAC systems and components. The criteria address the following HVAC attributes:

(1)	HVAC Ducts	• Cold-formed sheet steel ducts • Pipe section ducts
(2)	HVAC Supports	• Structural steel members • Penetrations • Welds
(3)	Miscellaneous Hardware	• Structural steel bolts • Duct straps • Screws (i.e., connecting ducts to supports, etc.) • Duct stiffeners • Duct joints (i.e., companion angles, flanges, pocket-locks, etc.)

HVAC ducts, supports and miscellaneous hardware designed in accordance with these criteria, when exposed to loading in the applicable Design Specifications, shall not experience stresses or loads in excess of the allowable limits indicated in the following Subsubsections and summarized in Table 5-1.

5.1.1. HVAC DUCTS

The criteria for the qualification of HVAC ducts are dependent on the duct material. Cold-formed steel duct sections shall be evaluated by analysis in accordance with AISI Manual [17], by comparison with test data, or through the use of experience data. Pipe section ducts shall be evaluated by analysis in accordance with the FCS design basis code USAS B31.1 - 1967 Edition [18].

<u>Qualification by Analysis</u>

Duct stresses shall be evaluated in accordance with either the AISI Manual [17] for cold-formed steel duct material or in accordance with USAS B31.1 - 1967 Edition [18] for pipe section (hot-rolled) duct material. For cold-formed steel ducts, allowable stresses for each applicable load condition shall be increased by the following factors:

Load Condition	Allowable Stress Increase
Normal	1.0
Upset	1.0
Emergency	1.33
Faulted	1.6

The 1.6 increase for faulted condition shall not be applied to compression members. The compression stresses shall be limited to the allowables of AISI Manual [17]. ITEM 8

Because cold-formed ducts are thin-walled, evaluations shall address the following special items, in accordance with the AISI Manual [17]:

(1) Effective section properties for rectangular ducts.

(2) Curling of duct walls toward the neutral axis.

(3) Local wall buckling of round ducts.

For pipe section ducts, allowable stresses for each applicable load condition are provided in Table F-1 of the FCS USAR Appendix F [1], which meets the intent of USAS B31.1 - 1967 Edition [18].

Qualification by Test

Where test results are available, a review shall be performed to determine whether the configuration and the loading considered in the test are applicable to the design being considered. The review shall include, as a minimum, the following attributes:

(1) Duct size, gauge, and material.

(2) Duct joint fabrication details.

(3) Duct-to-support connection details.

(4) Typical natural frequency of the duct system.

(5) Loading (static and seismic).

(6) Duct spans.

(7) Duct stiffener details.

(8) Overall configuration.

For test results where the component was tested to failure, the factors of safety for static load rating shall be applied for each applicable loading condition as follows:

Load Condition	Allowable load
Normal	Test Ultimate/3.0
Upset	Test Ultimate/3.0
Emergency	Test Ultimate/2.25
Faulted	Test Ultimate/1.5

The test ultimate load is the average ultimate load of three tests, provided no individual test result deviates more than ± 10% from the average. Alternatively, (i) if less than three tests are performed, the test ultimate load is taken as the lowest test result reduced by 10%; (ii) if one or more result out of three tests deviates more than ± 10% from the average, the test ultimate load is taken as the lowest of the three test results; and (iii) if more than three tests are performed, the test ultimate load is taken as the average of the three lowest results.

Qualification by Experience Data

Experience data showing that HVAC systems and components survived the actual earthquake may be used to show the acceptability of similar HVAC systems and components at FCS. The review for similarity shall include the same attributes described for qualification by test above. The review must also show that the intensity of the earthquake motion experienced by the HVAC systems and components envelops the intensity of the SSE event for FCS defined in Section 3.0.

The sources of experience data to be used to qualify HVAC systems and components have not been identified. OPPD will submit the data and methodology to the NRC for review and approval prior to any application of experience data for qualification of HVAC systems and components.

5.1? HVAC SUPPORTS

The qualification of HVAC supports shall be evaluated by analysis, test, or experience data.

Qualification by Analysis

HVAC support components shall be evaluated using conventional stress analysis methods and qualified in accordance with the FCS design basis code AISC Steel Construction Manual, 7th Edition [19]. Allowable stresses for each applicable load condition are provided in Table F-1 of the FCS USAR Appendix F [1], which meets the intent of AISC Steel Construction Manual, 7th Edition [19].

Certain ducts pass through leak-tight penetrations in the building structures. Loads on the penetrations from the ducts shall be calculated and compared with the design allowables of the penetrations.

Qualification by Test

Support components shall be qualified by test where test data are available. The allowable load shall be calculated based on the test ultimate load of the component. The factor of safety for static load rating and the derivation of test ultimate load given in Subsubsection 5.1.1 for HVAC ducts are also applicable to HVAC supports.

Qualification by Experience Data

Where experience data are available that show HVAC support components survived the actual earthquake, these data may be used to show the acceptability of the HVAC support components at FCS. The application constraints of earthquake experience data discussed in Subsubsection 5.1.1 for HVAC ducts are also applicable to HVAC supports.

5.1.3 MISCELLANEOUS HARDWARE

The balance of miscellaneous hardware for HVAC systems and components shall be evaluated by comparison to allowable loads determined from the manufacturers' catalogs, analysis, test, or experience data.

Qualification by Manufacturers' Allowables

Manufacturers' catalogs typically provide allowable working loads for catalog items. These allowable loads shall be taken to be applicable to normal and upset conditions. Allowable load increase factors for emergency and faulted conditions, as shown below, shall be applied to manufacturers' specified allowable loads, provided a minimum factor of safety of 1.5 is maintained.

Load Condition	Allowable Stress Increase
Normal	1.0
Upset	1.0
Emergency	1.33
Faulted	2.0

Qualification by Analysis

The allowable loads shall be determined analytically by considering the physical and material properties for the hardware and using the allowable load increases for the applicable loading conditions for cold-formed steel per AISI Manual [17] and hot-rolled steel per AISC Steel Construction Manual, 7th Edition [19] and Table F-1 of the FCS USAR Appendix F [1].

Qualification by Test

HVAC miscellaneous hardware shall be qualified by test where test data are available. The allowable load may be calculated based on the test ultimate load of the component. The factor of safety for static load rating and the derivation of test ultimate load given in Subsubsection 5.1.1 for HVAC ducts are also applicable to HVAC miscellaneous hardware.

Qualification by Experience Data

Where experience data are available that show HVAC miscellaneous hardware components survived the actual earthquake, these data may be used to show the acceptability of the HVAC miscellaneous hardware components at FCS. The application constraints of earthquake experience data discussed in Subsubsection 5.1.1 for HVAC ducts are also applicable to HVAC miscellaneous hardware.

5.2 SEISMIC ANALYSIS METHODS FOR HVAC

In general, simple beam or frame equations can be used to determine load and stress levels of HVAC systems and components (ducts, supports and miscellaneous hardware) for other than seismic type loading. For seismic loading, HVAC systems and components shall be analyzed by either the equivalent static coefficient method or the response spectra method.

5.2.1 EQUIVALENT STATIC COEFFICIENT METHOD

Equivalent static seismic loads shall be calculated in accordance with the procedure outlined below. The loads shall then be combined with other design loads as defined in the appropriate Design Specifications. A representative HVAC system from FCS has been analyzed using this method and the calculation [16] has been submitted to the NRC for review in [6].

(1) Mass Distribution. The masses to be considered for all frequency and loading determinations shall include all permanent dead loads. This includes the self weights of ducts, companion angles, duct stiffeners, support steels, insulations, and any other permanently attached components.

(2) Frequency Calculation. When frequency calculation is performed, the frequency in each of the three orthogonal directions shall be determined. The response of both the ducts and supports shall be considered in this evaluation. Frequency calculation shall be in accordance with the method given in Subsection 4.2 for piping. When no frequency calculation is performed, the system shall be evaluated using the peak acceleration from the appropriate response spectrum

(3) Damping. Critical damping values of 4% and 7% for OBE and SSE, respectively, shall be used for cold-formed ducts for determining the seismic response loads. For piping section ducts, the piping damping values per NRC Regulatory Guide 1.61 shall be used.

(4) Seismic Response Load. The seismic response load shall be calculated based on the frequency calculation indicated above with acceleration (S_a) and equivalent static coefficient (K) selected in accordance with Table 4-1. The seismic response load (U) for each direction of loading shall be calculated with the equation given in Subsection 4.2 for piping.

(5) Load Combination. The seismic response loads acting on a duct support shall be calculated separately for each of three orthogonal directions using the above procedure. The total seismic response of any particular support in any direction shall then be calculated by using the SRSS method to combine the directional response due to each of the three seismic load inputs. The response due to gravity shall be added to the total seismic response by absolute summation.

5.2.2 RESPONSE SPECTRA METHOD

The response spectra method shall be used by modeling the ducts and supports together as one system model. The application and associated constraints given in Subsection 4.1 for piping are also applicable to HVAC systems except the critical damping values for cold-formed steel ducts. Critical damping values of 4% and 7% for OBE and SSE, respectively, shall be used for cold-formed ducts.

Detailed representations of HVAC supports may be included in the system model. Alternatively, the supports may be separately evaluated for equivalent stiffnesses modeled in the analysis.

Table 5-1

Stress Limits for HVAC Components

Component	Qualified by	Criteria [a] Normal	Upset	Emergency	Faulted [b]
Ducts					
Cold-Formed Steel Ducts	Analysis	1.0xAISI	1.0xAISI	1.33xAISI	1.6xAISI [c]
	Test	$T_u/3.0$	$T_u/3.0$	$T_u/2.25$	$T_u/1.5$
	Exp. Data	[d]	[d]	[d]	[d]
Pipe Section Steel Ducts	Analysis	(USAS B31.1 - 1967 Edition and FCS USAR Table F-1)			
Supports	Analysis	(AISC Steel Construction Manual, 7th Edition and FCS USAR Table F-1)			
	Test	$T_u/3.0$	$T_u/3.0$	$T_u/2.25$	$T_u/1.5$
	Exp. Data	[d]	[d]	[d]	[d]
Miscellaneous Hardware	Mgf. Allow.	$1.0L_c$	$1.0L_c$	$1.33L_c$	$2.0L_c$
	Analysis	1.0xAISI (or AISC Steel Construction Manual, 7th Edition and FCS USAR Table F-1)	1.0xAISI	1.33xAISI	1.6xAISI [c]
	Test	$T_u/3.0$	$T_u/3.0$	$T_u/2.25$	$T_u/1.5$
	Exp. Data	[d]	[d]	[d]	[d]

Notes: [a] L_c = Manufacturer's catalog allowable for normal load condition.

T_u = Test ultimate load.

[b] A minimum fac :r of safety of 1.5 shall be maintained.

[c] Compression stresses shall be limited to the allowables of AISI Manual. ITEM 8

[d] Experience data and methodology are to be identified later. NRC's review and approval is required prior to any application.

6.0 REFERENCES

[1] Docket No. 50285, Fort Calhoun Updated Safety Analysis Report (USAR), Revision 7/87.

[2] Letter from OPPD to NRC, Letter No. LIC-88-506, "Request for Review of Alternate Seismic Criteria," Dated December 2, 1988. The criteria document, attached to this letter, entitled "Alternate Seismic Criteria and Methodologies for Fort Calhoun Station" contains two volumes: Volume 1 "Criteria and Methodologies" and Volume 2 "Justifications of Criteria and Methodologies."

[3] Letter from OPPD to NRC, Letter No. LIC-89-199, "Request for Review of Refined Seismic Response Spectra," Dated February 21, 1989. The response spectra document, attached to this letter, entitled "Generation of In-Structure Response Spectra for Fort Calhoun Unit 1" contains three volumes: Volume 1 "Spectra Generation Methodologies," Volume 2 "OBE Spectra" and Volume 3 "SSE Spectra."

[4] Letter from NRC to OPPD, "Questions and Comments on Alternate Criteria and Methodologies, Fort Calhoun (TAC No. 71408)," Dated December 6, 1989.

[5] Letter from OPPD to NRC, Letter No. LIC-90-0447, "Requested Seismic References," Dated May 23, 1990.

[6] Letter from OPPD to NRC, Letter No. LIC-90-417, "Response to NRC Questions on Fort Calhoun's Alternate Seismic Criteria," Dated July 6, 1990.

[7] Letter from NRC to OPPD, "Questions on Fort Calhoun's Refined Seismic Spectra," Dated August 7, 1990.

[8] Letter from OPPD to NRC, Letter No. LIC-90-778, "Response to NRC questions on Fort Calhoun's Refined Seismic Spectra," Dated October 29, 1990.

[9] Letter from NRC to OPPD, "Questions and Comments on Alternate Criteria and Methodologies for Fort Calhoun Station (TAC No. 71408)," Dated June 3, 1991.

[10] Letter from NRC to OPPD, "Review and Evaluation of Alternate Seismic Criteria and Methodologies (ASCM) for the Fort Calhoun Station (FCS), Unit 1 (TAC No. 71408)," Dated June 17, 1991.

[11] Draft Letter from OPPD to NRC, Letter No. LIC-92-016R, "Resolution of Remaining NRC Open Items on Alternate Seismic Criteria and Methodologies (ASCM)," Dated January 31, 1992.

[12] USNRC Standard Review Plan, Section 3.7.1, "Seismic Design Parameters," Revision 1, July 1981.

[13] Chen, C., " Definition of Statistically Independent Time Histories," Journal of the Structural Division, ASCE, February 1975.

[14] "Report of the U.S. NRC Piping Review Committee: Evaluation of Other Loads and Load Combinations," NUREG-1061 Volume 4, December 1984.

[15] Mattu, R.K., "Methodology for Combining Dynamic Responses," NUREG-0484, Revision 1, April 1980.

[16] ABB Impell Corporation, Calculation No. HVAC-ESM-1, Revision 0, "Example HVAC Analysis Using the Equivalent Static Method," Job No. 1390-027-1355.
(Submitted to the NRC in [6])

[17] American Iron and Steel Institute (AISI), "Cold-Formed Steel Design Manual," 1986 Edition.

[18] USA Standard B31.1, "Power Piping," 1967 Edition.

[19] American Institute of Steel Construction (AISC), "Manual of Steel Construction," 7th Edition.

[20] Report from OPPD to NRC, "Soil Variation Analysis and Generation of In-Structure Response Spectra for Fort Calhoun Unit 1," July 1992.

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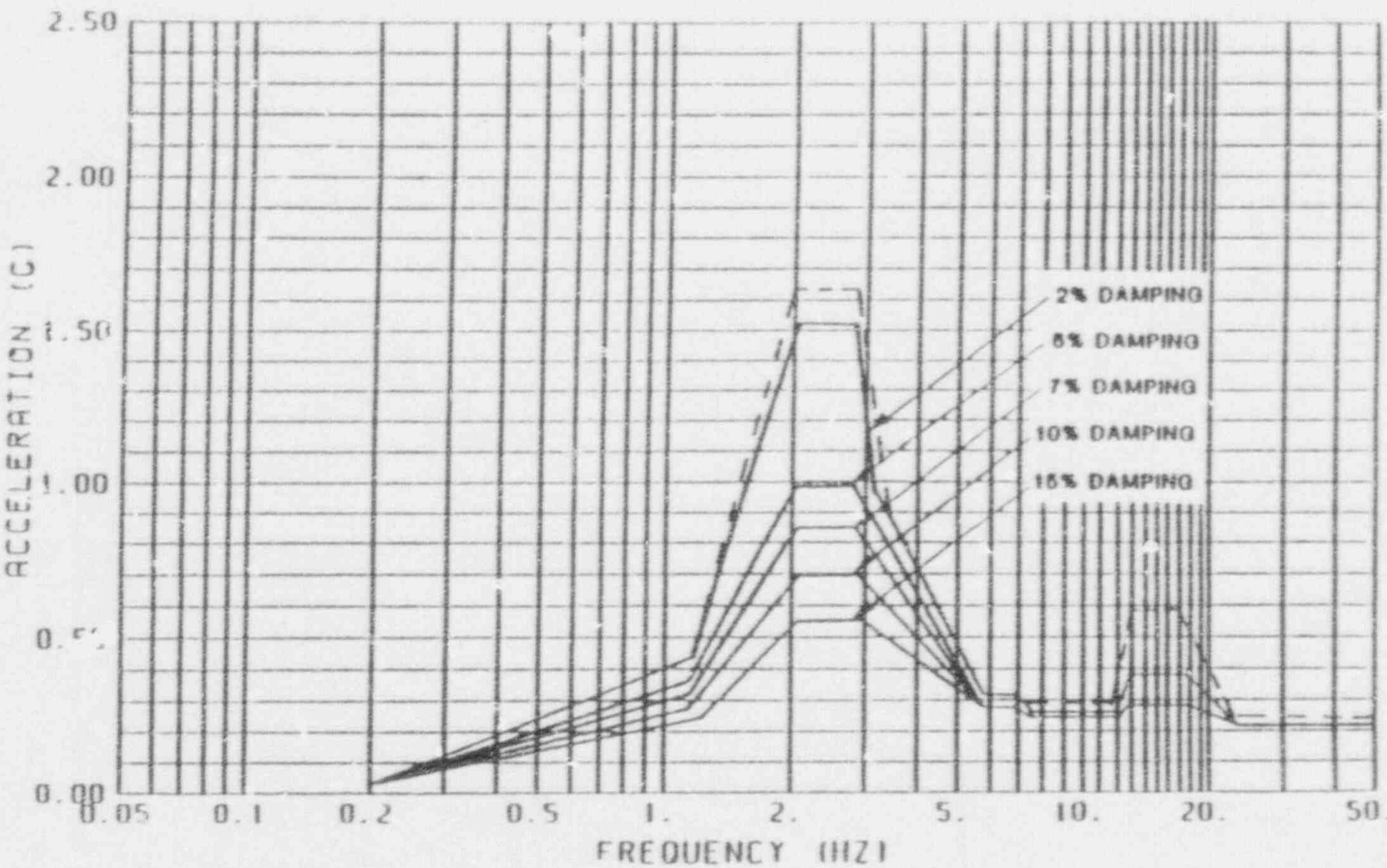
ENCLOSURE 2

ACCIDENTAL TORSION

COMPARISON OF CORNER SPECTRA TO CENTER OF GRAVITY SPECTRA



----- ENVELOPE (DUE TO TORSION) OF CORNER SPECTRA AT 2% DAMPING

OMAHA PUBLIC POWER DISTRICT FORT CALHOUN STATION, UNIT 1	HORIZONTAL (NORTH-SOUTH) DIRECTION AT ELEVATION 1045'-0" (C.G.) INTERNAL STRUCTURE	
SAFE SHUTDOWN EARTHQUAKE		
BY BPI DATE 6/23/88 CHKD [illegible] DATE 6/30/88	SKETCH NO.	REV.