SEISMIC DESIGN CRITERIA FOR CABLE TRAY HANGERS

EBASCO SERVICES INCORPORATED

Seismic Design Criteria For Cable Tray Hangers For Comanche Peak Steam Electric Station No. 2

REVISION	PREPARED BY	REVIEWED BY	APPROVED BY	DATE	PAGES AFFECTED
R0	Z. T. Shi	R. Alexandru	G. Kanakaris	3/22/85	
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I. Purpose

A cable tray hanger is classified as a seismic Category I structure, and therefore, it shall be adequately designed for the effect of the postulated seismic event combined with other applicable and concurrent loads. The design requirements for seismic Category I structure are delineated in Regulatory Guide 1.29. This document provides the seismic design guideline for cable tray hangers of Comanche Peak Steam Electric Station Unit No. 2. These guidelines summarize the design parameters, applicable load combinations and their associated acceptance criteria, the various design approaches and their corresponding seismic input criteria. The following sections describe in detail the guidelines for the seismic design of the cable tray hangers and lists the applicable reference documents. In addition, cable trays shall be design verified per Reference 13 and cable tray clamps shall be design verified per Reference 14. R6

II. Reference Documents

The following lists the documents referenced or prepared by Gibbs & Hill Inc. which will continue to be used for the design of seismic Category I cable tray hangers for Comanche Peak Steam Electric Station Unit No. 2.

1. Applicable Codes And Regulatory Guides

- Regulatory Guide 1.29 - Seismic Design Classification, Rev. 3, September 1978.
- Regulatory Guide 1.61 - Damping Values for Seismic Design of Nuclear Power Plants, October 1973.
- Regulatory Guide 1.89 - Qualification of Class 1E Equipment for Nuclear Power Plants, Rev. 1, June 1984.
- Regulatory Guide 1.92 - Combining Modal Responses and Spatial Components in Seismic Response Analyses, Rev. 1, February 1976.
- NUREG 1.75 - Standard Review Plan Section 3.8.4, November 1975.
- AISC - Manual of Steel Construction, 7th Edition, including Supplements No. 1, 2 & 3.
- AWS D1.1-75 - Structural Welding Code.

2. Cable tray specification No. 2323-ES-19, Revision 1, dated Nov. 22, 1976.

3. CPSES/FSAR Section 3.8.4.3.3 "Load Combinations and Acceptance Criteria for Other Seismic Category I Steel Structures"

4. Design Criteria for Cable Tray Supports and Their Arrangement, Gibbs and Hill Calculation Book No. SCS - 113C 3/9-3/24

5. Structural Embedments Specification No. 2323-SS-30 Gibbs & Hill, Revision 2, June 13, 1986.

6. Design procedure: DP-1 Seismic Category I, Electrical Cable Tray Supports dated June 11, 1984.

7. Refined Response Spectra for Fuel Handling Building, dated Oct. 1985 for SSE and OBE.

8. Refined Response Spectra for Reactor Building Internal Structure, dated Jan. 1985 for SSE and Jan. 1983 for OBE.

9. Refined Response Spectra for Containment Building, dated Jan. 1985 for SSE and Jan. 1983 for OBE.

10. Refined Response Spectra for Auxiliary Building, dated Nov. 1984 for SSE and Jan. 1983 for OBE.

11. Refined Response Spectra for Electrical Building, dated Nov. 1984 for SSE and Nov. 1982 for OBE.

12. Refined Response Spectra for Safeguards Building, dated Nov. 1984 for SSE and Jan. 1983 for OBE.

13. Ebasco Comanche Peak SES Cable Tray Hanger Volume I, Book 1, Part 1 (Rev. 3), Part 2 (Rev. 0) and Part 3 (Rev. 0). |R7

14. Ebasco document SAG.CP19, Design Criteria and Procedures for Design Verification of Cable Tray Clamps for CPSES Units 1 & 2, Rev. 1, 1/15/87. |R6

III. Design Parameters for Cable Tray Hangers

The parameters considered in the design of cable tray hangers are as follows:

1. Cable tray span length

"As-built" span lengths shall be used in the hanger design verification.

2. Maximum cable tray loading

Tray Size	Total Unit Weight (Lbs/Foot)
6"	18
12"	35
18"	53
24"	70
30"	88
36"	105

Note: a. The above data is applicable for both ladder and solid bottom types of trays.

b. The above data is also applicable for various heights of tray side rails.

c. The above unit weight includes cable, tray, tray cover and side rail extension.

d. The above unit weight does not include fire proofing material weight (Thermolag and Thermoblanket).

e. For trays which are fire proofed, the unit weight of cable tray including the weight of fireproofing to be used is in the "General Instructions For Cable Tray Hanger Analysis".

f. All cable tray hangers shall be design verified based on "as-built" drawings (ie. hanger members, connection and anchorage details). R6

g. All cable tray hanger components (members, connections base angles, base plates and anchor bolts) shall be design verified.

3. Material

a. Support structure is ASTM A36
b. Expansion anchors are Hilti Kwik and Super Kwik Drilled-in bolts
c. Screw anchors are Richmond inserts
d. Embedded plates (strip and area plates) are ASTM A36

4. Design loads

The cable tray hangers shall be designed for the following loads and load combinations:

a. Load definitions

Normal loads, which are those loads encountered during normal plant operation and shutdown, include:

D - Dead loads and their related moments and forces.

L - Live load equals zero. R6

To - Thermal effects and loads during normal operating or shutdown conditions, based on the most critical transient or steady state condition.*

Severe environmental load includes:

F_{eqo} - Loads generated by the operating basis earthquake including secondary wall displacement effects. R6

* Except for anchorage components, accident temperatures (Ta) are not considered in design verification per CPSES FSAR (Pg. 3.8-83 and 3.8-110). Accident thermal loads on anchorages are considered generically by studies. Furthermore, per AISC Manual of Steel Construction (Pg. 6-9), no reductions in F_y are required for temperatures up to 700°F. R6

Extreme environmental load includes:

F_{eqs} - Loads generated by the safe shutdown earthquake including secondary wall displacement effects. |R6

b. Load combinations

The following load combinations shall be considered in design of cable tray hangers:

i. $D + L + F_{eqo} = S$
ii. $D + L + To + F_{eqo} = 1.5S$
iii. $D + L + To + F_{eqs} = 1.6S$

where S is the required strength based on elastic design methods and the allowable stresses defined in Part 1 of the AISC "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings" (published in the Manual of Steel Construction, seventh edition). In no case shall allowable stress exceed 0.90 F_y for normal tensile stresses and 0.50 F_y for shear stresses. |R6

IV. Seismic Design Approaches, Seismic Input Requirement, and Design Acceptance Criteria

There are several analytical methods available which will be used in design or design verification of cable tray hangers. Because the level of sophistication is not the same for each method, the seismic input requirement must vary in order to compensate for whatever the method lacks in sophistication, and therefore the conservatism of results associated with each analysis method also varies.

For span layouts not in conformance with Appendix 4 of this design criteria, design verification may be performed by the Response Spectrum Method (Section IV.3) or, if appropriate, by the Equivalent Static Method (Section IV.2) per Attachment Y of the General Instructions.

The following procedures describe the three (3) most acceptable methods: static analysis, equivalent static method and response spectrum method. The seismic input criteria for each analysis method is also addressed.

IV.1 STATIC ANALYSIS

a. Finite Element Model

A 3-D model shall be prepared to represent cable tray hangers. An offset or eccentricity due to the assemblage of various types of structural members and/or transmission of loads shall be considered in the preparation of the computer model.

Boundary conditions at anchorage points shall properly represent the actual anchorage condition. |R6

b. Cable Tray Loading

The total cable tray loading for each run shall be calculated based on the size of tray and the actual tray span lengths which are shown on the support drawing.

The cable tray loading shall be lumped as a nodal weight at the actual location on the tier and, if not known, at such a location on the tier that it will induce the worst member stress responses and the maximum anchorage reactions.

c. Seismic Input "g" Values

For a static analysis the peak spectral "g" values from the 4% damping OBE curves and the 7% damping SSE curves which were generated at the mounting locations of cable tray hangers shall be used multiplied by a coefficient to account for multimode response. These peak spectral "g" values for various buildings and different floor elevations can be found in the Appendix 1. For the case where the hangers were supported off the wall, the envelope of the the response spectrum curves for the floor immediately above and below the hanger location shall be used. The required seismic design "g" values in three (3) orthogonal directions are 1.25 (multimode response multiplier-MRM) times the peak spectral "g" values. R6

d. Static Analysis

The seismic load effect on the cable tray hangers will treated as a static load. The dynamic effect from both seismic event and response characteristics of support structure are conservatively considered by using the 1.25 times the peak spectral "g" value as an input. However, for transverse type cantilever and trapeze cable tray hangers, the seismic load effect due to the hanger's self-weight in the longitudinal direction (direction parallel to tray run) shall be determined by multiplying the spectral "g" value corresponding to the CTH fundamental (lowest) longitudinal frequency by 1.25 regardless of whether that frequency is to the left or right of the peak response frequency.

If the cable tray hanger is attached to a steel structure, use 1.5 times the peak spectral "g" value and a fixed base boundary condition.

The static analysis shall be performed for the following load cases individually:

i) Dead load

ii) Seismic load in vertical direction

iii) Seismic load in transverse direction

iv) Seismic load in longitudinal direction

v) Thermal load if any

Note: Seismic load includes both OBE and SSE events.

e. Analysis Results

The following maximum responses shall be obtained for each load combination:

i) Maximum member stresses (bending, axial and shear) and nodal displacements shall be obtained. The stresses and displacements resulting from the simultaneous effect of three earthquake components shall be obtained by using the SRSS method. |R6

ii) Maximum anchorage reactions shall also be obtained by using SRSS method to account for the simultaneous effect of three earthquake components.

f. Seismic Design Acceptance of Cable Tray Hangers and their Anchorages

The cable tray hangers and their anchorages are considered to be acceptable when the structural member and connection stresses and the anchorage reactions, which are induced by the load combinations described in Sections III.4.b, are within the allowable stress limits and allowable anchorage carrying capacity. The following describes the acceptance criteria for both support structure and anchorages:

i. Support Structure

The structural member seismic design acceptance shall be evaluated using AISC interaction formula with modification for various load combinations as follows:

$$\left(\frac{fa}{Fa} + \frac{fbx}{Fbx} + \frac{fby}{Fby}\right) \leq 1.0$$ for load combination III.4.b.i

$$\left(\frac{fa}{1.5\ Fa} + \frac{fbx}{1.5\ Fbx} + \frac{fby}{1.5\ Fby}\right) \leq 1.0$$ for load combination III.4.b.ii |R7

$$\left(\frac{fa}{1.6\ Fa} + \frac{fbx}{1.6\ Fbx} + \frac{fby}{1.6\ Fby}\right) \leq 1.0$$ for load combination III.4.b.iii |R7

$f_v \leq F_v$ for load combination III.4.b.i

$f_v \leq 1.5F_v \leq 0.50\ Fy$ for load combination III.4.b.ii |R6

$f_v \leq 1.6\ F_v \leq 0.50\ Fy$ for load combination IV.4.b.iii |R6

where fa = axial stress

f_v = shear stress

fbi = bending stress

F_a, F_{bi} and F_v = allowable stresses for axial, bending and shear stress, per AISC 7th edition. In all cases each individual denominator above for load combinations III.4.b.i, ii, and iii shall be less than 0.9Fy. R7

ii. Anchorage (anchors)

o Kwik-bolt and Super Kwik-bolt.

The design criteria and allowable loads for above driven-in bolts are tabulated in Appendix 2.

o Screw Anchors.

The design criteria and allowable loads for screw anchors are contained in Appendix 2. When a redline drawing does not identify the bolt/thread rod material in a Richmond Insert, A-36 material shall be assumed in the cable tray hanger design verification.

Note:

1. The allowable loads for Hilti expansion anchors for the load combination involving OBE are the load capacities corresponding to a safety factor of 5, and for the load combination involving SSE are the load capacities corresponding to a safety factor of 4.

2. The safety factors for Richmond Anchors are 3.0 for both OBE and SSE. R6

3. Prying action on anchor bolt, if any, shall be included. The effects of the flexibility of the base plate on the anchor bolt shall be considered.

4. For floor-mounted CTHs in building areas with concrete topping, the actual anchor bolt embedded length (as determined from the redline drawing) shall be reduced by two inches (2") to account for the topping.

IV.2 EQUIVALENT STATIC METHOD

a. Finite Element Model

See Section IV.1.a

b. Cable Tray Loading

See Section IV.1.b

c. Seismic Input "g" Value

i. The fundamental (lowest) frequency of cable tray hanger (f_h) shall be determined in each of three (3) orthogonal directions separately.

ii. Determine the frequency of cable tray itself corresponding to the actual span length (f_c) in each of three (3) orthogonal directions separately.

iii. Determine the system frequency using the following conservative formula:

$$\frac{1}{fsys^2} = \frac{1}{f_c^2} + \frac{1}{f_h^2}$$

When f_c or f_h are 33 H_z or larger this term's contribution to system frequency may be disregarded.

The above system frequency will be calculated for each of three (3) orthogonal directions separately.

iv. Obtain the spectral "g" value corresponding to the system frequency (fsys) for each direction separately when fsys is on the right side of the peak response frequency. If fsys is at the left side of the peak frequency, the peak spectral "g" value shall be used except as noted in Section IV.1.c and d.

v. Determine the required seismic design "g" values for the cable tray hanger by multiplying 1.25 to the above "g" value (obtained in Step iv) to account for multimode response except as noted in Section IV.1.c and d.

d. Equivalent Static Method

The stress analysis for the cable tray hangers shall be performed on the 3-D finite element model using the "g" value obtained in Step c. The load cases which shall be considered are the same as those listed in Section IV.1.d.

e. Analysis Results

See Section IV.1.e.

f. Seismic Design Acceptance of Cable Tray Hangers and their Anchorages

See Section IV.1.f.

IV.3 RESPONSE SPECTRUM METHOD

a. 3-D Model of Cable Tray and Tray Hangers

Construct a 3-D model of tray systems which include and therefore simulate the dynamic behavior of cable tray itself and cable tray hangers.

In order to adequately simulate the seismic response of the cable tray system, a minimum of 4 cable tray spans shall be included in the model, with two spans on each side of the hanger under consideration. The cable tray will be represented by a beam type finite element in the 3-D model, with properties obtained from tray Vendor's static load test report.

The stiffness of longitudinal supports shall also be considered and simulated by a spring constant attached to the ends of 3-D model.

b. Frequency Analysis

Perform a frequency analysis on the above 3-D model which includes all modes up to 33 Hz, or up to the highest cutoff frequency of the input spectra. R6 R7

c. Spectral Analysis

Perform seismic response analysis for the above 3-D model using the appropriate floor response spectrum as an input. NRC Reg. Guide 1.92 shall be followed in calculating the modal response. Missing mass correction shall be applied to account for rigid mode effects for modal frequencies higher than 33 Hz or the input spectra cutoff frequency. R7

The 4% damping of OBE curves and 7% damping of SSE curves shall be used as an input for each direction separately. Seismic responses are obtained directly from these analyses using modal superposition per NRC Reg. Guide 1.92.

d. Response Spectra Analysis

The stress analysis for cable tray hangers shall be performed on the 3-D finite element model using the "g" value obtained in Step c. The load cases which shall be considered are the same as those listed in Section IV.1.d. R6

e. Analysis Results

See Section IV.1.e

f. Seismic Design Acceptance of Cable Tray Hangers and their Anchorages

See Section IV.1.f.

V. Recommendation of Successive Methods to be Used for Design of Cable Tray Hangers

The cable tray hangers may be designed or design verified by a static analysis method first (IV.1). If the cable tray hangers fail to meet the seismic requirement under this most conservative method, a refined analysis method of equivalent static method (IV.2) shall be used. If the cable tray hangers still fail to meet the design criteria, then the response spectrum method (IV.3), may be used. The response spectrum method approach simulates better the dynamic behavior of the cable tray system under the effect of the postulated seismic event and thus may produce seismic responses of the structural system closer to reality. Therefore, by response spectrum method, the conservatism associated with the seismic response obtained from static analysis and equivalent static method can be reduced to a minimum. In conclusion, if the cable tray hangers still fail to pass the acceptance criteria by a spectral response analysis, a much more refined analysis such as a time history analysis method can be used. A procedure for such analyses will be given, should the need arise.

Ebasco - "General Instructions For Cable Tray Hanger Analysis For Comanche Peak Steam Electric Station No. 1 and 2", (Replace pages - cover page, x, 1, 1.1, 2 thru 6, 6.1, 7 thru 13.1, 36, 36.1, 36.2, 158, 160, 169.3 thru 169.9, 187 in Reference 36)