U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF SPECIAL PROJECTS
COMMANCHE PEAK PROJECT DIVISION

Report Nos.	50-445/87-39; 50-446/87-30
Docket Nos:	50-445 and 50-446
Applicant:	Texas Utilities Electric Company (TU Electric) 400 North Olive Street, L. B. 81 Dallas, Texas 75201
Facility:	Comanche Peak Steam Electric Station, Units 1 and 2
Location of Inspection:	Ebasco Services Incorporated 2 World Trade Center New York, New York
Inspection Period:	November 2, 1987 through December 31, 1987

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1.0 INTRODUCTION AND SUMMARY

1.1 Background

In early 1987, the applicant (TU Electric) initiated a comprehensive Corrective Action Program (CAP) which consisted of a complete design and hardware validation. In the design area, the CAP scope was divided into eleven design disciplines. The work scopes were contracted to three major design organizations: 1) Ebasco Services, Incorporated, 2) Impell Corporation, and 3) Stone & Webster Engineering Corporation.

This report addresses the inspection of three of the eleven design elements of the CAP; 1) cable tray hangers, 2) conduit supports (Trains A and B, and C greater than 2 inches), and 3) heating, ventilation, and air-conditioning (HVAC). For these three design elements, Ebasco Services Incorporated is the responsible CAP design contractor.* Staff inspections and audits of the remaining eight design elements - large bore piping, small bore piping, Train C conduit supports less than or equal to 2 inches, equipment qualification, mechanical systems, civil/structural, electrical, and instrumentation and control - are currently in progress and are being documented in separate inspection reports and audit summaries.

1.2 Scope of Inspection

During the period from November 2 through December 31, 1987, the inspection team conducted design inspections at the offices of Ebasco Services Incorporated (Ebasco) in New York, New York. The purpose of the inspections was to review the adequacy of the design criteria and analytical methodologies developed by Ebasco for the design validation of the cable tray hanger, the conduit support (Trains A and B, and C greater than 2 inches), and the heating, ventilation, and air-conditioning (HVAC) structural integrity. In addition, as a continuation of the staff evaluation of the overall CAP design validation process, the staff reviewed the appropriateness and completeness of selected design criteria used in the design validation of as-built drawings developed from the as-built verification walkdowns. The implementation of the design criteria and methodologies for cable tray hangers, conduit supports, and HVAC will be reviewed by the staff in future design inspections and audits.

In establishing the scope of the inspection, the staff held several public meetings with the applicant and its CAP contractors prior to the inspection. At these meetings, the staff discussed the generic technical issues applicable to cable tray hanger, conduit support and HVAC design which had been raised previously by sources external to the TU Electric project organization (e.g., Cygna, ASLB, CASE,** NRC staff) as well as by internal and CPRT self-initiated reviews (e.g., Ebasco, TENERA L.P.). These meetings are documented in NRC meeting summaries; 1) "Summary Meeting and Audit on August 26-27, 1987 - Cable Tray Hanger Generic Technical Issues," dated

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* For cable tray hangers, Impell Corporation is also a CAP design contractor for a portion of the scope. Staff review of Impell's scope of work will be conducted under a separate review.

**Citizens Association for Sound Energy (CASE) is an intervenor in the CPSES operating license proceedings.

October 9, 1987, 2) "Summary of Meeting on September 14, 1987 - Conduit Supports Generic Technical Issues," dated October 20, 1987, and 3) "Summary of Meeting on September 15, 1987 - HVAC Generic Technical Issues," dated October 19, 1987. Discussions from these generic technical issue meetings provided the staff with a clearer understanding of the nature of the technical issues involved, the extent of their applicability to the various design disciplines, and the overall approach to resolve the issues and preclude their recurrence.

In addition to the generic technical issue meetings, the staff conducted audits of the CPRT third-party (TENERA, L.P.) review of the cable tray hanger and conduit support design criteria. These audits are documented in NRC audit summaries; 1) "Summary of Audit on September 28 - October 1, 1987 - Comanche Peak Response Team Third-Party Review of Cable Tray/Supports," dated November 5, 1987, and 2) "Summary of Audit on October 5-9, 1987 - Comanche Peak Third-Party Review of Train A and B Conduit and Supports," dated November 25, 1987. The results of these audits provided the staff an understanding of the scope of the CPRT third-party review and the depth and comprehensiveness of the CPRT third-party reviews of the Ebasco design criteria and methodologies used in the design validation of cable tray hangers and conduit support design.

As a result of the above staff meetings and audits, the staff was able to conduct a more effective and efficient inspection by focusing on those issues of primary technical concern and by avoiding unnecessary duplication of effort. Accordingly, the staff selected specific design criteria and analytical methodologies for this inspection. The design criteria and methodologies selected for this inspection are discussed in detail in Sections 2.0, 3.0, and 4.0 of this report for cable tray hangers, conduit supports, and HVAC, respectively. A description of the design criterion/methodology, a discussion of the inspection approach used, and the inspection findings are provided in this report for each design criterion or methodology audited by the Staff. All identified open items, discussed in detail in this report, are summarized in Section 1.3.

As a part of the staff's continuing review of the overall CAP design validation process, this inspection included a review of selected design criteria used for qualifying the as-installed condition of the cable tray hanger, conduit support, and HVAC hardware. Prior to this inspection, the staff conducted several audits of the as-built verification program as performed by Ebasco for the initial phase of the CAP design validation effort. The staff audits are documented in NRC staff audit summaries; 1) "Summary of Audit on August 12-14, 1987 - HVAC As-Built Verification Program," dated October 29, 1987, 2) "Summary of Audit on September 8-10, 1987, - Cable Tray Hanger As-Built," dated November 9, 1987, 3) "Summary of Audit on September 8-11, 1987 - HVAC As-Builting Verification Program," dated November 10, 1987, and 4) "Summary of Audit on September 8-10, 1987 - Conduit Support (Trains A, B and C greater than 2") As-Built Verification Program," dated November 25, 1987. The foregoing audits of the as-built plant configuration provided the staff with an understanding of the as-installed condition of the cable tray hanger, conduit support, and HVAC hardware and a basis to determine the appropriateness and completeness of the design criteria and methodologies as required for an adequate design validation and resolution of the generic technical issues.

1.3 Summary of Results

The inspection team generally found the Ebasco design criteria and analytical methodologies used in the CAP design validation for cable tray hangers, conduit supports, and HVAC to be technically adequate to resolve the generic technical issues and qualify the structural integrity of the as-built hardware condition. The overall design validation process evaluated to date, including the as-built field verification program and the development of the CAP design criteria by Ebasco, appears to be a comprehensive and complete program which can effectively resolve the design anomalies that may have resulted from improper construction and design practices in the past. This inspection did not cover implementation of the design criteria and analytical methodologies. The following open items identified as a result of this inspection:

Cable Tray Hangers

OPEN ITEM No.	TITLE	REFERENCE (Inspection Report Sect. No.)
CT-2.1-1	Connectivity for Unit 2 Supports	2.1.3(a)
CT-2.1-2	Tray Frequency	2.1.3(b)
CT-2.1-3	Buckling factor of safety	2.1.3(c)
CT-2.1-4	Shared anchorage	2.1.3(d)
CT-2.1-5	Thermal stress	2.1.3(e)
CT-2.1-6	Attachment to secondary walls	2.1.3(f)
CT-2.1-7	Anchorage stiffness	2.1.3(g)
CT-2.1-8	Tier Flange bending	2.1.3(h)
CT-2.2-1	Impell/Ebasco benchmark problem	2.2.3(a)
CT-2.2-2	TU Electric response to CYGNA	2.2.3(b)
CT-2.2-3	RSM String analysis	2.2.3(c)
CT-2.3-1	Prying action factor	2.3.3(a)
CT-2.3-2	Oversize bolt holes	2.3.3(b)
CT-2.3-3	Bolt hole edge distance	2.3.3(c)
CT-2.4-1	Elimination of grouped supports	2.4.2
CT-2.6-1	Noncompliance submittals	2.6.3

Conduit Supports

CS-3.1-1	Seismic Adequacy of Flexible Conduit and Cable Air Drops	3.1.3.b
CS-3.1-2	Seismic Interaction	3.1.3.c
CS-3.2-1	Damping Value for Aircraft Cable Supports	3.2.3.c and 3.2.3.d
CS-3.4-1	Inertial Effect of Clamp and Filler Plate	3.4.3.a
CS-3.4-2	Safety Factors for Anchor With Oversize Bolt Holes	3.4.3.b
CS-3.4-3	Oversize Bolt Holes Criteria	3.4.3.b
CS-3.4-4	Code Differences	3.4.3.e
CS-3.6-1	LOCA and Seismic Load Combination	3.6.3

HVAC

HV-4.1-1	Effect of relative stiffness between the plenum and filter assemblies to be reviewed by Ebasco	4.1.3
HV-4.1-2	Special Study on seismic displacements in HVAC components to be completed	4.1.3
HV-4.2.1	Results of HVAC test program and correlation report	4.2.3
HV-4.3-1	Analysis results for gasket flexibility	4.3.3
HV-4.5-1	Tornado pressure effects on HVAC	4.5.2
HV-4.6-1	Secondary wall effect on HVAC supports	4.6.3
HV-4.7-1	Justification for 1.6 increase in compression members	4.7.3
HV-4.8-1	Procedure for qualifying attachments for lateral supports	4.8.3
HV-4.9-1	Resolution of anchorage assembly spring rate error	4.9.3
HV-4.9-2	Sensitivity of response and anchor loads on stiffness	4.9.3

2.0 CABLE TRAY HANGERS

2.1 ESM and Static Analysis Methods

2.1.1 Description

The Equivalent Static Analysis Method (ESM) and the Static Analysis Method are simplified, conservative methods used by Ebasco in the design verification of cable tray supports and systems as an alternative to dynamic analysis methods. The ESM method uses seismic loads based on the system fundamental frequency (support and tributary cable tray span length) while the Static Analysis Method uses loads based on the peak acceleration regardless of frequency. Acceleration values are obtained from the floor response spectra curves. In practice, the Static Analysis Method has been used infrequently.

The ESM method was used by Ebasco for design verification of all Unit 2 supports and for approximately 80% of Unit 1 supports. The remaining supports were design verified by a dynamic analysis method.

2.1.2 Evaluation

The inspection team selected a support which was design-verified by the ESM method in order to evaluate the application of the verification procedures. The support package selected was CTH-1-2088, Rev. 1, located in the Unit 1 Diesel-Generator Building. The following features of ESM design verification were reviewed by the team:

a) Modelling of supports for STRUDL, including eccentricities, load application, brace connections, etc.
b) System fundamental frequency
c) Multiple Response Mode (MRM) justification and application
d) Load distribution between supports
e) Connectivity effects
f) Load combinations of seismic and dead loads
g) Axial and torsional buckling criteria
h) Anchorage flexibility effects

In addition, the "User's Manual" and the "Verification Manual for CPSES In-House Safety Related Computer Programs" (9/1/87) were reviewed.

In conjunction with the ESM inspection, the responsible Ebasco personnel (Appendix A) presented the methodology used for ESM design verification, including discussions of the pertinent procedures, instructions, supporting studies and test data. The Ebasco responses to the team's questions were generally considered complete. However, the team requested the following additional documentation for further review:

a) Additional support package with at least two trays and a bolted anchorage.
b) Justification for calculating system fundamental frequency for non-straight tray runs (horizontal or vertical elbow)
c) Procedure for transmitting information when two or more supports attach to a common base plate
d) Procedure for attachment to secondary walls

e) Anchorage stiffness effect on support frequency
f) Warping stress calculation
g) Procedure for evaluating connectivity effects
h) Evaluation of thermal stress due to support self-constraint

2.1.3 Findings

The Ebasco criteria and methodology for ESM analysis, as demonstrated by the general instructions (SAG.CP34) and supporting studies, were found to be adequate for design verification of cable trays and supports. The general instructions with attachments, although complex in some parts, are sufficiently clear and detailed to ensure correct implementation by engineers knowledgeable of the instructions.

Because of the complexity of some instructions, the work is organized so that certain evaluations such as the screening procedure* (SAG.CP28), the use of Attachments Y and Z of SAG.CP34 for load distribution and longitudinal connectivity, the calculation of stiffnesses for non-standard anchorage configurations, and the qualification of cable trays, fitting and clamps are handled by special groups who provide the required information to the analysts.

The following findings, or observations, require additional clarification from Ebasco:

a) Connectivity - All Unit 1 supports have been, or will be, analyzed using connectivity between the transverse support tiers and the cable tray. Unit 2 supports, which were completed earlier, used no connectivity in the analysis. Ebasco is to evaluate the need for reanalysis of the Unit 2 supports and document their conclusion. (Open Item CT-2.1-1)

b) Tray frequency - The same frequency tables are used for straight and non-straight tray spans (CP-34, Appendix 1). Ebasco is to provide justification for this approach. (Open Item CT-2.1-2)

c) Buckling allowable - Allowable stresses for the factored load conditions including SSE are permitted by Ebasco to be increased by 1.6 times the normal allowables provided that 0.9Fy is not exceeded. This also applies to allowable compressive stress on axially loaded compression members (Fa), resulting in factors of safety against buckling which are lower than permitted by the AISC Code. Ebasco is to provide justification for this approach. (Open Item CT-2.1-3)

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*The screening procedure for determining the applicability of the 1.25 MRM factor was used for all Unit 1 supports. Approximately 40 out of 1800 ESM analyzed supports were found to be outside the range of acceptability (Appendix 4 violation or adjacent support stiffness variation by more than a factor of 2). The screening procedure will also be applied to the Unit 2 supports but Ebasco does not expect many problem cases to arise.

d) Shared anchorage - There are some cases where two or more cable tray supports, or a cable tray support and a pipe support, share a common anchorage (baseplate). The concern is in regard to transmittal of information such as base plate loadings or baseplate flexibility between the groups responsible for anchorage design and support design. Ebasco is to provide documentation describing this interface. (Open Item CT-2.1-4)

e) Thermal stress - For certain types of support configurations, large thermal stresses could potentially be generated due to support self-constraint during a LOCA. Ebasco will request Impell to check this case as part of their M-27 report. (Open Item CT-2.1-5)

f) Differential support motion - If a support is attached to a secondary wall it is possible to get differential motion between supports resulting in added cable tray and support loads. Ebasco is to submit documentation describing how attachment to secondary walls is treated. (Open Item CT-2.1-6)

g) Anchorage stiffness - Since the calculated estimates of anchorage stiffness involve some uncertainty the corresponding estimates of support frequency are affected. An evaluation should be made of how anchorage stiffness affects support frequency. Ebasco is to provide a sensitivity study. (Open Item CT-2.1-7)

Tier bending - In Attachment B2, Sheet 24.1 of SAG.CP34, it appears that the moment P_1 X B may cause bending of the tier flange. Ebasco is to demonstrate that this effect is negligible as stated at the meeting. (Open Item CT-2.1-8)

2.1.4 References

SAG.CP4	Seismic Design Criteria - Unit 1
SAG.CP28	Screening Procedure - Unit 1 and 2
SAG.CP34	General Instructions - Unit 1 and 2
Vol. I - Book 2:	STRUDL Modelling and Load Application Procedures, and Code Checking Verification
Vol. I - Book 5:	Torsional Sectional Properties and Warping Stresses
Vol. I - Book 7:	Load Application Locations
Vol. I - Books 9, 10, 15, 23:	Dynamic Multimode Response and Load Distribution Effects
Vol. I - Books 11, 12:	Anchorage Flexibilities and Concrete Compressive Stresses
Vol. I - Book 25:	Effect of Bolt Holes in Hanger Tier Members
Impell Calculation M-27	Thermal Load Evaluation

2.2 Response Spectrum Analysis Method

2.2.1 Description

The Response Spectrum Analysis Method (RSM), which was used by Ebasco for 475 supports in Unit 1 out of a total of 2309 supports, is more rigorous and less conservative than the ESM analysis. Ebasco selected this method for 47 cable tray runs, or "strings," each of which contained from 2 to 22 supports. The cable trays and supports were modelled for the STRUDL computer program and used the same floor response spectra as was used for the ESM analysis.

The criteria used by Ebasco for selecting the tray runs for RSM analysis was based on a review of all 45 "span length sketches" of Unit 1, and determining which runs had Appendix 4 violations (longitudinal supports with more than 40 ft spans), multilayers runs and adjacent supports which appeared to have large differences in stiffness. In addition, the experience gained from the Unit 2 work indicated where the ESM analysis approach may become too cumbersome or give overly conservative results.

2.2.2 Evaluation

The RSM methodology was reviewed to the extent of its applicability to Ebasco's work. As noted above, it was used by Ebasco for a relatively small number of supports and is based on procedures which are essentially the same as the Impell RSM methodology. A sample "string", RSM-1-AUX-25, containing 14 supports was reviewed by the team in order to determine how the RSM procedures are used. Ebasco personnel (Appendix A) explained the analysis in detail, particularly modeling techniques used for member eccentricities, tier loading, and/or stiffness calculations. Additional information which was requested for later review was an RSM "string" analysis involving "overlap" and "analysis only" supports. The Ebasco RSM methodology will be reviewed in detail at a later date in conjunction with a review of the Impell RSM methodology.

In order to compare Impell's computer program (SUPERPIPE) to STRUDL, as used by Ebasco, a sample problem had been previously generated by both organizations. This problem, as generated by Impell and Ebasco, was reviewed by the team. Several unexplained discrepancies were identified in displacements, support reactions, member forces and frequencies. However, the reasons for the discrepancies could not be identified due to the varying and uncontrolled input parameters used at the time. In order to resolve the discrepancies, TU Electric was requested by the team to have Ebasco and Impell run a control problem with each organization using their own procedures and computer programs. The goal of this comparison is to verify that there are no major differences in the two programs' calculations of significant parameters such as fundamental frequency and magnitude of peak stresses.

In addition, TU Electric was requested to furnish the inspection team with the documentation responding to CYGNA's concern regarding differences in modelling between Impell and Ebasco for RSM analysis.

2.2.3 Findings

As stated above, the Ebasco methodology for RSM analysis as presented in SAG.CP11 and Vol. I, Book 26, will be evaluated in detail later, and therefore there are no findings at this time. However, additional information was requested for further evaluation consisting of:

a) Results of Impell/Ebasco comparison run of benchmark problem. (Open Item CT-2.2-1)
b) TU Electric response to CYGNA concern regarding modelling differences. (Open Item CT-2.2-2)
c) RSM string analysis containing "overlap" and "analysis only" support. (Open Item CT-2.2-3)

2.2.4 References

SAG.CP4	Seismic Design Criteria - Unit 1
SAG.CP11	System Analysis - Unit 1 and 2
Vol I - Book 26:	System Boundary Conditions

2.3 Acceptance Criteria

2.3.1 Description

The inspection team reviewed the methods used for:

a) checking acceptability of welds, bolts, oversize bolt holes and bolt hole/edge distance effects under specified loading conditions.
b) developing "K" values for structural members and prying action factors for anchor bolts to be used in analysis
c) qualifying cable trays, fittings and clamps under specified loading conditions

These methods are used for design verification by both ESM and RSM analysis.

2.3.2 Evaluation

The inspection approach for reviewing the cable tray hanger acceptance criteria included presentations by responsible Ebasco personnel (Appendix A) of the methodology, procedures, supporting studies, test procedures and test results on which the acceptance criteria for cable tray hanger design validation are based. Additional documentation which was requested by the team for further review consisted of:

a) Position paper on oversize holes
b) K-values for longitudinal supports with in-plane loads
c) Tray qualification package
d) System effects on tray qualification

2.3.3 Findings

Contingent upon acceptable resolutions to the findings discussed below, the team finds the development of the Ebasco acceptance criteria and the implementing procedures to be adequate for design validation of cable trays and supports. The procedures and studies which were presented and reviewed are listed in Section 2.3.4.

The following findings require additional clarification:

a) Prying action factors - In calculating prying action factors (Vol. I, Book 3), the average stiffness was used for Richmond inserts while the maximum stiffness was used for Hilti inserts. Ebasco is to provide justification to shown that this results in conservative prying action factors. Also, the anchorage sensitivity study (see par. 2.1.3g) should include the effect of bolt stiffness variation on prying action. (Open Item CT-2.3-1)

b) Oversize bolt holes - Ebasco position paper justifying oversize bolt hole is to be provided to the team for evaluation. (Open Item CT-2.3-2)

c) Bolt hole edge distance - Calculations are performed by Ebasco to justify noncompliance with AISC recommendations. Any deviations, or justified noncompliances with AISC recommendations, are to be submitted for approval (see Section 2.6). (Open Item CT-2.3-3)

2.3.4 References

SAG.CP4	Seismic Design Criteria - Unit 1
SAG.CP34	General Instruction - Unit 1 and 2
SAG.CP18	Qualification of Cable Trays
SAG.CP19	Qualification of Clamps
Vol. I - Book 1:	Cable Tray Properties and Qualification Procedures Development
Vol. I - Book 3:	Prying Action Factors
Vol. I - Book 6:	Slenderness Ratio "K" Values
Vol. I - Book 13:	Hanger Tier Bolt Edge Distances
Vol. I - Book 15:	Section IV: System Effects in ESM Analysis for Cable Trays
Vol I - Book 20:	Weld Related Studies
Vol. I - Book 21:	Cable Tray Clamp Qualification Procedures Development
Vol. I - Book 22:	Anchorage Bolt Holes/Edge Distances

2.4 Qualification By Similarity

2.4.1 Description

A procedure for grouping cable tray supports by similarity for design verification is described in Volume I, Book 8. This procedure was not reviewed by the team since Ebasco stated that the few supports in Unit 1 which were design-verified by grouping are all being qualified by reanalysis, and that the larger number of supports design verified by similarity in Unit 2 will be eliminated if the Unit 2 supports are reanalyzed due to connectivity.

2.4.2 Evaluation

The grouping procedure was not evaluated at this time. Ebasco is to document their decision on Unit 2 support reanalysis (see 2.1.3a) including elimination of supports qualified by grouping. (Open Item CT-2.4-1)

2.4.3 Findings

None

2.4.4 References

Vol. I, Book 8 - Cable Tray Hanger Geometry Grouping

2.5 Inaccessible Attributes

2.5.1 Description

Dimensions and characteristics of structural members, welds, bolts, cable trays, clamps, etc. which were not accessible during "as-builting" because of thermolag covering, or other obstructions, were designated as "IA" on the as-built drawings. Procedures were developed by which these inaccessible attributes could be evaluated during the design verification process.

2.5.2 Evaluation

The inspection team reviewed the procedures and supporting studies used for design verification of cable trays and supports having inaccessible attributes.

2.5.3 Findings

The procedures given in Attachment X of SAG.CP34 for the resolution of IA's and the supporting statistical studies were found to be adequate for design verification of cable trays and supports.

2.5.4 References

SAG.CP4	Seismic Design Criteria - Unit 1
SAG.CP34	General Instructions - Unit 1 and 2
Vol. I - Book 18, 20:	Hidden Attributes

2.6 Code Differences

2.6.1 Description

Design criteria which differ from the AISC specification, or construction noncompliance with AISC guidelines have been justified by Ebasco by means of detailed analysis and testing to show that stresses are within allowable limits under all specified loading conditions. Examples of these Code differences include:

Oversize bolt holes
Less than minimum edge distance for bolt holes
Less than minimum fillet weld size
Reduced factor of safety against buckling for SSE

2.6.2 Evaluation

The work performed by Ebasco to justify the AISC noncompliances provides a technical basis to permit design validation of the cable tray supports. However, the inspection team requested that all design criteria which differ from that in the AISC specification be identified and submitted to the staff for review and approval. Additional documentation which is required for review is the Ebasco position paper on oversize holes.

2.6.3 Findings

All design criteria used which are differrent from that in the AISC specification, or other FSAR commitments, have been submitted to the NRC staff in a letter from W. G. Counsil to USNRC dated December 15, 1987. The staff is currently reviewing these Code differences. (Open Item CT-2.6-1)

2.6.4 Reference

Vol. I - Book 13	CTH Tier Bolt Hole Edge Distance Study
Vol. I - Book 20	CTH Weld-Related Studies
Vol. I - Book 22	Statistical Analysis of Bolt Holes/Edge Distances in Cable Tray Hangers
Vol. I - Book 22 Part 2:	Effects of Bolt Hole Oversize in CTH and Conduit System
Impell Report, 09-0210-0017	CPSES Cable Tray System Analysis Test Correlation
Impell Special Study No. 5.9	Oversize Bolt Holes
Impell M-73	Acceptability of Oversized Bolt Holes

3.0 CONDUIT SUPPORTS

3.1 Allowable Span Criteria

3.1.1 Description

The allowable conduit spans which determine conduit support locations are presented on Drawings 2323-S-0910 and 2323-S2-0910 for CPSES Unit 1 and Unit 2, respectively. The criteria presented on the "LS" series drawings ensure that desired minimum frequencies are maintained, reasonable acceleration values (less than peak "g") can be used, and conduit stress values are less than allowables. The drawings provide allowable span lengths between conduit supports for a range of conduit configurations, conduit sizes, end conditions, buildings/elevations, and for various conduit fittings/components (such as LBD's, BC's, and flexible conduits). The drawings also provide equations to calculate tributary weights on supports which are required for design validation of the supports.

The criteria presented on the drawings were design verified using criteria presented in Ebasco's Specification No. SAG.CP10 and SAG.CP2 for Unit 1 and Unit 2, respectively. These documents provide the guidelines, criteria, and procedures to be used in the design and analysis of the conduit systems. When actual conduit configurations and spans cannot satisfy the criteria in the 2323-S-0910 and 2323-S2-0910 packages, seismic analysis is performed in accordance with the criteria presented in SAG.CP10 for Unit 1 and SAG.CP2 for Unit 2.

3.1.2 Evaluation

The inspection approach included discussions with Ebasco personnel, review of information contained in criteria documents and review of design validation calculations performed for a representative LS series drawing and for actual conduit isometric drawings.

The inspection team held discussions with the Ebasco personnel (see Appendix A) on the following criteria related to the analysis and design of the conduits:

a) Modeling - Configurations, boundary conditions, concentrated masses, support representation, and clamps

b) Frequency Calculation - frequency requirements and calculation methods

c) Seismic Loads - spectra, "design g values"

d) Method of Seismic Analysis - equivalent static and response spectra

The Ebasco personnel described the analytical techniques and design methods as well as other Ebasco guidelines, calculations, studies and test results to substantiate many of their approaches and assumptions.

In addition to discussions and the limited review of the criteria documents described earlier, the following design validation documents were reviewed:

a) Calculation Book No. SPAN-1125 sheets 28 through 35 of 181

b) Conduit Isometric Evaluation Calc. No. 07362, Rev. 0, (Unit 1)

c) Conduit Isometric Evaluation Calc. No. 15264, Rev. 0, (Unit 1)

d) Conduit Isometric Evaluation Calc. No. 07194, Rev. 0, (Unit 2)

c) Conduit Isometric Evaluation Calc. No. 10279, Rev. 0, (Unit 2)

During the partial review of each of the above calculations, questions arose which led to further discussions with the Ebasco personnel. A summary of our findings is presented in the following section of this report.

In addition to documents referenced in this section, Ebasco Book No. 127, Unit 2, K Factors, was also obtained for further review.

3.1.3 Findings

From the discussions and reviews performed to date, the Ebasco criteria and methodology for establishing conduit allowable spans were found to be acceptable. However, there were some findings/open items that were identified which need to be resolved.

An observation made during the inspection was the complexity of the criteria presented in the 2323-S-0910 and 2323-S2-0910 drawings as well as in the other documents. Ebasco indicated that this occurred because of the desire to maintain the previous conduit/support designs which were based on a prior revision of the 2323-S-0910 and 2323-S2-0910 drawings. Although the criteria is complex, all requirements are available and documented in project documents. The impact of this complexity will be assessed in future staff reviews dealing with criteria implementation. In the meantime, Ebasco provided the team with two Ebasco Technical Guidelines CP-SG-02, Rev. 1 and CP-SG-03, Rev. 0 which provide guidelines for evaluating the conduit spans and supports for Unit 2 in accordance with the 2323-S2-0910 package and design criteria SAG.CP2.

The system analysis used to design verify the span criteria presented in Drawings 2323-S-0910 and 2323-S2-0910 packages were discussed and reviewed. Ebasco has developed Technical Guideline No. SAG.CP20 for Unit 1 to provide specific guidelines for the design verification of the span criteria. Although the approach utilized appears adequate at this time, the team will continue review of SAG.CP20 in future inspections of its implementation.

Ebasco has also prepared a technical guideline No. SAG.CP25 which provides procedures for performing isometric design validation for Unit 1 and 2 conduits. When conduit spans and/or supports cannot meet the 2323-S-0910 requirements, the isometric drawing is evaluated to the SAG.CP10 and CP25 documents. The team is continuing its review of SAG.CP25.

During the review of Ebasco calculation No. 07362, Rev. 0, a question arose concerning the correct interpretation of span length criteria for conduits with junction boxes. Although, the particular calculation was revised to consider the worst case, Ebasco stated they will review this question as it applies to other isometrics. The review of calculation No. 07362 also identified the improper use of Nelson stud clamp capacities. Subsequent to this inspection, Ebasco has reviewed other randomly selected isometric validation calculations for the occurrence of these errors and found that the errors in calculation No. 07362 were and isolated case.

While most questions and findings were resolved during the inspection, the following findings are still outstanding at this time:

a) The complexity of the criteria could potentially result in erroneous implementation. This will be reviewed in future inspections or audits.

b) The basis for seismic adequacy of the flexible conduit and electrical cable air drops should be addressed by Ebasco. (Open Item CS-3.1-1)

c) The seismic interaction between rigid conduit and equipment should be addressed by Ebasco. (Open Item CS-3.1-2)

3.1.4 References

1. TU Electric Drawing No. 2323-S-0910
2. TU Electric Drawing No. 2323-S2-0910
3. Ebasco, SAG.CP10, Rev. 4, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 1
4. Ebasco, SAG.CP2, Rev. 8, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 2
5. Ebasco, Calcn. Bk. No. SPAN-1125, S-0910 Conduit Design Verification, CPSES Unit 1
6. Ebasco, Conduit Isometric Evaluation Calc. No. 07362, Rev. 0, Unit 1
7. Ebasco, Conduit Isometric Evaluation Calc. No. 15264, Rev. 0, Unit 1
8. Ebasco, Conduit Isometric Evaluation Calc. No. 07194, Rev. 0, Unit 2
9. Ebasco, Conduit Isometric Evaluation Calc. No. 10279, Rev. 0, Unit 2
10. Ebasco, Book No. 127, Unit 2, K Factors
11. Ebasco, CP-SG-02, Rev. 1, Technical Guidelines for Seismic Category I Electrical Conduit System, Unit 2
12. Ebasco, CP-SG-03, Rev. 0, Guidelines for Preparation and Checking of Calculation for Seismic Category I Electrical Conduit System
13. Ebasco, SAG.CP20, Rev. 3, Technical Guidelines for System Analysis of Conduit Span Configuration
14. Ebasco, SAG.CP25, Rev. 0, Technical Guidelines for Seismic Category I Electrical Conduit Isometric Evaluation

3.2 Support Adequacy

3.2.1 Description

Conduit support adequacy is determined by satisfying support criteria presented in TU Electric drawing packages 2323-S-0910 for Unit 1 and 2323-S2-0910 for Unit 2. Supports conforming to the 0910 package typical details in all respects are labeled "generic" supports. If a support configuration does not match the support details in the 0910 package, then it is categorized as either a "modified" or "individually engineered" support. Modified supports are supports which have some deviation(s) from the 0910 package typical details. Individual engineered (IN) supports are supports which do not conform to the 0910 package typical details and are analyzed on a case-by-case basis.

The criteria in the 0910 packages for generic supports ensure that minimum support frequencies are maintained, reasonable acceleration values (less than peak) can be used, and support member stresses are less than allowables. Once a support conforms to a particular generic support detail in the 0910 package, the support capacity presented on the drawing can be compared to the tributary weights calculated from the conduit span length evaluation (see section 3.1.1).

Modified or IN supports are analyzed for minimum frequency requirements and for support loads in accordance with SAG.CP10 and SAG.CP? for Unit 1 and Unit 2 respectively. These documents provide the criteria to be used in the analysis and design of conduit supports.

In addition, Ebasco has prepared SAG.CP25 and SAG.CP29 to provide more detailed procedures and guidelines for the evaluation of the conduit supports.

Thus, these four criteria documents are used to design verify the generic supports contained in the 0910 packages, the modified and IN supports, and any supports/conduit system that cannot satisfy the 0910 package criteria. If supports or span criteria cannot be satisfied then "custom ISO" evaluation in accordance with SAG.CP25 Appendix 1 is performed. This appendix provides criteria for performing a response spectra modal analysis of the conduit and supports.

3.2.2 Evaluation

The team's inspection approach consisted of discussions with Ebasco personnel, review of information contained in criteria documents, and reviews of support design verification calculations and test data.

Ebasco personnel described the analysis and design criteria utilized to qualify the conduit supports. Discussions were held on the following major topics:

a) Modeling
b) Frequency Calculation
c) Seismic Loads - Spectra vs. "design g values"
d) Method of Analysis - Equivalent Static and response spectra
e) Dynamic Amplification Factors
f) Load Determination - K factors, L_L and L_T
g) Inaccessible Attributes

To assist in the understanding of the criteria for conduit supports the four conduit isometric evaluation calculations referenced in Section 3.1.2 were reviewed with Ebasco personnel.

In addition, various calculations which were performed to develop the criteria or confirm design assumptions were requested. The calculations which were obtained for subsequent review were:

a) Calculation No. TNE-CS-CA-CA-1a, Rev. 2 (based on test data)
b) Calculation No. TNE-CS-CA-CA-2b (common wall mounted support)
c) Calculation No. SU[illegible]-1015-1, Rev. 0 (common cantilever support)

3.2.3 Findings

Most questions and concerns were addressed adequately by Ebasco. However, the following items still require resolution:

a) The Ebasco methodology for modeling supports in system analysis is to use an "equivalent" stiffness based on the minimum required support frequency which is the same for all supports. Ebasco performed a study on this subject and concluded that varying the adjacent stiffnesses would have little effect on the system. The CPRT third-party (TENERA, L.P.) has conducted a detailed review of this item and its conclusions are documented in an Engineering Evaluation. The staff will review the adequacy of the CPRT evaluation.

b) The staff will review of the Unistrut support qualification criteria in a subsequent meeting.

c) CSR (aircraft cable - non structural) supports also were not reviewed and will be addressed in a subsequent inspection or audit. During a discussion on damping values it was indicated that 7% damping for the SSE event was utilized for CSR supports which is inconsistent with damping values presented in the FSAR. Ebasco stated that they would provide available document(s) that justify its use. (Open Item CS-3.2-1)

d) During a subsequent review of criteria documents, the team found that damping values of 4% for OBE and 7% for SSE were utilized in developing SP type support capacities. This also does not appear to be consistent with the damping values presented in the FSAR. (Open Item CS-3.2-1)

e) Other findings/outstanding items relating to support adequacy are described in Section 3.4 Acceptance Criteria.

3.2.4 References

1. TU Electric Drawing No. 2323-S-0910

2. TU Electric Drawing No. 2323-S2-0910

3. Ebasco, SAG.CP10, Rev. 4, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 1

4. Ebasco, SAG.CP2, Rev. 8, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 2

5. Ebasco, SAG.CP25, Rev. 0, Technical Guidelines for Seismic Category I Electrical Conduit Isometric Evaluation

6. Ebasco, SAG.CP29, Rev. 3, General Instructions for Design Verification of Electrical Conduit and Box Supports

7. Ebasco, Calculation No. TNE-CS-CA-CA-1a, Rev. 2

8. Ebasco, Calculation No. TNE-CS-CA-2b, Rev. 1

9. Ebasco, Calculation No. SUPT-1015-1, Rev. 0

3.3 Junction Box/Support Adequacy

3.3.1 Description

Junction Box and junction box support adequacy is determined by verifying its compliance to criteria presented in TU Electric drawings 2323-S-0910 for Unit 1 and 2323-S2-0910 for Unit 2. The "JA" and "JS" series of drawings in the 0910 packages provide the generically qualified junction box/supports.

If the actual junction box and its support match the typical details presented in the JA/JS drawings and the calculated conduit loads on the junction boxes are less than capacities tabulated on the JA/JS drawings then the junction box/support is considered qualified.

The criteria used to design verify the 0910 packages for junction box supports is presented in Ebasco SAG.CP10 for Unit 1 and SAG.CP2 for Unit 2. Criteria, guidelines, and procedures for the qualification of the junction boxes are provided in SAG.CP17 for Unit 1 and SAG.CP12 for Unit 2.

3.3.2 Evaluation

In conjunction with this inspection, presentations were given by Ebasco personnel on the criteria, analysis, and design methods used to design verify the junction box/support adequacy. This was done separately for Unit 1 and Unit 2 due to the different approaches.

The inspection team reviewed the following items related to junction box/support adequacy:

a) Support drawing parameters
b) Junction box classifications/grouping
c) Modeling
d) Seismic loads
e) Analytical approach
f) Stress/component qualification

3.3.3 Findings

Based upon the presentation and discussions held to date, the criteria and methodology used by Ebasco were found to be acceptable. No specific findings or open items have been identified. Review of specific junction box calculations will be performed as part of our inspection on criteria implementation.

3.3.4 References

1. TU Electric Drawing No. 2323-S-0910

2. TU Electric Drawing No. 2323-S2-0910

3. Ebasco, SAG.CP10, Rev. 4, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 1

4. Ebasco, SAG.CP2, Rev. 8, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 2

5. Ebasco, SAG.CP17, Rev. 6, Design Criteria for Junction Boxes for Seismic Category I Electrical Conduit Systems, Unit 1

6. Ebasco, SAG.CP12, Rev. 3, Design Criteria for Junction Boxes for Seismic Category I Electrical Conduit Systems, Unit 2

3.4 Acceptance Criteria

3.4.1 Description

Specific topics relating to acceptance criteria not discussed in other sections were evaluated in this section. The major topics of review were:

a) Clamps - Clamp allowable loads for every clamp type, for each conduit size and for various means of attachment (Nelson stud, Unistrut bolt, and Hilti Kwik bolts) are presented in tabular form in SAG.CP10 and SAG.CP2 for Unit 1 and 2 respectively. These allowables were based on static and cyclic tests performed by CCL.

b) Oversize bolt holes - Ebasco has addressed this issue through a combination of calculations, a study, and some additional design requirements presented in their SAG criteria documents.

c) Edge distance violation - Ebasco has addressed this issue through a combination of calculations, a study, and tests on clamps.

d) Baseplate anchorage - Design criteria and design consideration for support anchorages including allowable loads, installation requirements, and prying/flexibility consideration, are presented in SAG.CP10 for Unit 1 and SAG.CP2 for Unit 2.

e) Differences between design criteria and code requirements.

3.4.2 Evaluation

The inspection approach consisted of presentations, discussions and partial review of representative calculations and test reports depending on the criteria reviewed. The evaluation for each of the topics listed in section 3.4.1 is presented below:

a) Clamps - The team inspected the test configurations, test set-up, test results, and conversion of test data to allowable loads. The information provided was supplemented by the actual test reports. Copies of the following test reports were obtained for further review:

- CCL, Conduit Clamp Test Report, Phase I, No. A-699-85
- CCL, Conduit Clamp Test Report, Phase II, No. A-702-86
- ANCO, Final Summary Report, Comanche Peak Conduit Tests, Vol. I, No. A-000197

The third test summary report, performed by ANCO, has not as yet been incorporated into the criteria documents. That test which was a dynamic test will be utilized if a number of clamps cannot meet the existing allowable clamp loads presented in the SAG criteria documents.

The calculation which presented the clamp allowables based on the test data is Calc. No. SPAN 1200. This calculation was also obtained for further review.

b) Oversize bolt holes - The inspection team reviewed Calc. No. SUPT-0253 for the effects of oversize bolt holes on Hilti, Super/Hilti and steel to steel connections, all for "generic" supports. This calculation was prepared in support of an Ebasco report "Effects of Bolt Hole Oversize In CTH and Conduit System Adequacy."

c) Edge distance violation - The inspection team reviewed Calc. No. SUPT-0246 for the adequacy of steel to steel connections having reduced edge distances for all applicable generic supports. For conduit clamps, tests are relied upon to demonstrate adequacy. For base plate anchorage connection, reference is made to a cable tray hanger study/report to qualify reduced edge distances. The conclusions of this report were extrapolated to conduit systems as well.

d) Baseplate anchorage - The inspection team reviewed the criteria and design methods for design validation of baseplate anchorage. Prying factor tables and equations for anchor load calculations were also reviewed.

e) Differences between design criteria and code requirements - Ebasco was requested to identify and provide the basis for any differences between design criteria and code requirements.

3.4.3 Findings

The findings relating to each of the topics described in the previous section are:

a) Clamps - The methodology for developing clamp allowable loads is considered acceptable pending completion of review of Calc. No. SPAN 1200 and the test reports referenced in section 3.4.2a. However, a finding relating to the method of calculating conduit system loads applied to the clamps arose during the review of one of the isometric design validation calculations. The calculated loads on the clamps only considered the inertial load of the conduit and neglected the inertial loading of the filler plate and clamp. Ebasco indicated that they would determine the significance of the additional loading. (Open Item CS-3.4-1)

b) Oversize bolt holes - Two areas of concern were raised. First, from the review of Calc. No. 0253 for two bolted Hilti anchor connections, the calculations for the oversize bolt holes demonstrated a minimum factor of safety of 4.44 for OBE and 3.36 for SSE. These are less than the allowables permitted in the existing criteria documents. (Open Item CS-3.4-2) The second concern deals with the additional criteria placed in SAG.CP29 to address oversize bolt holes for "IN" and "Modified" supports. The criteria only addresses two bolted anchor connections and does not address four or more bolted connections. (Open Item CS-3.4-3)

c) Edge distance violation - Acceptable pending further review of Calc. No. 0246, clamp test reports and cable tray report.

d) Baseplate anchorage - Acceptable pending the completion of review of existing criteria documents.

e) Differences between design criteria and code requirements - The information was provided to the staff in a letter from W. G. Counsil to USNRC dated December 15, 1987. The staff is currently reviewing this information. (Open Item CS-3.4-4)

3.4.4 References

1. Ebasco, SAG.CP10, Rev. 4, Design Criteria for Seismic Category I Electrical Conduit Systems Unit 1.

2. Ebasco, SAG.CP2, Rev. 8, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 2.

3. CCL, Conduit Clamp Test Report, Phase I, Report A-699-85, 12/17/85.

4. CCL, Conduit Clamp Test Report, Phase II, Report A-702-86, 4/7/86.

5. ANCO, Final Summary Report, Comanche Peak Conduit Tests, Vol. I, Doc. No. A-000197, Rev. 1, Oct. 1987.

6. Ebasco, Calc. No. SPAN 1200, Rev. 0, Generic Study on Revised Clamp Allowables.

7. Ebasco, Calc. No. SUPT-0253, Rev. 1, Conduit/Junction Box Support Design Verification - Effects of Bolt Hole Oversize

8. Ebasco Report, "Effects of Bolt Hole Oversize in CTH and Conduit System Adequacy," Rev. 4, 10/6/87.

9. Ebasco, Calc. No. 0246, Rev. 2, Conduit/Junction Box Support Design Verification - Cygna Issue No. 5.

10. Ebasco, SAG.CP29, Rev. 3, General Instructions for Design Verification of Electrical Conduit and Box Supports.

3.5 Seismic Anchor Movements

3.5.1 Description

Current criteria in SAG.CP10 for Unit 1 and SAG.CP2 for Unit 2 state that conduits which are attached simultaneously to secondary walls and either to ceiling or adjacent primary walls will be evaluated on a case-by-case basis for seismic displacements. However, during the inspection, the team understood that seismic anchor movements are not being considered on a case-by-case basis since a study has shown that the secondary wall displacements have negligible effect.

3.5.2 Evaluation

The inspection approach included discussions with Ebasco personnel and a request for review of the Impell study "Engineering Evaluation of Non-Piping Commodities Attached to Secondary Walls" referenced in section 3.5.1 above.

The discussions on seismic anchor movements were not limited to secondary wall movements but also included non-secondary walls as well as building to building movements.

3.5.3 Findings

Ebasco explained that flexible conduits rather than rigid conduits span from building to building so seismic anchor movements have no effect for this case. As for displacements within a building, the relative secondary wall displacements are much larger than for non-secondary walls. Thus, the results of the secondary wall study is the governing case and it demonstrates that secondary wall displacements have negligible effects.

The above explanation is considered acceptable pending review of the referenced study.

3.5.4 References

1. Ebasco, SAG.CP10, Rev. 4, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 1
2. Ebasco, SAG.CP2, Rev. 8, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 2
3. Impell Report No. 09-0210-0099, Rev. 0, Engineering Evaluation of Non-Piping Commodities Attached to Secondary Walls

3.6 Thermal Analyses

3.6.1 Description

Criteria for thermal effects is provided in SAG.CP10 for Unit 1 and SAG.CP2 for Unit 2. These documents also indicate that the thermal load effects were not included in the design verification of generic conduit supports and spans contained in the 2323-S-0910 and 2323-S2-0910 packages. The basis for this is presented in the thermal analysis study contained in Appendix 10 of the same criteria documents.

Additional guidelines for thermal analysis of conduits, junction boxes, conduit supports and junction box supports are provided in SAG.CP21 for Unit 1 and SAG.CP22 for Unit 2.

3.6.2 Evaluation

The inspection approach consisted of discussions with Ebasco personnel and a review of the applicable criteria documents. The discussions primarily dealt with the thermal analysis study. Areas of review included the conduit configurations considered, the representation of supports, the thermal loads evaluated and the method of analysis.

3.6.3 Findings

The inspection team finds that the specified thermal accident temperature occurring simultaneously with the seismic event needs to be justified. The Ebasco study does not consider peak thermal loads at the same time as seismic loads. Instead, it considers two accident loading conditions based on the assumption that the seismic event causes the LOCA. Thus, taking advantage of the transient nature of the accident temperature has led Ebasco to consider the following two load cases:

1. Seismic plus accident thermal case during the short period of the seismic event. This results in a substantially lower temperature than peak thermal.

2. Peak accident thermal with no seismic. This case assumes that since the seismic event caused the LOCA, by the time the peak temperature is reached the earthquake event has passed already.

There does not appear to be adequate justification to utilize the approach described above. (Open Item CS-3.6-1)

3.6.4 References

1. Ebasco, SAG.CP10, Rev. 4, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 1

2. Ebasco, SAG.CP2, Rev. 8, Design Criteria for Seismic Category I Electrical Conduit Systems, Unit 2

3. Ebasco, SAG.CP21, Rev. 2, Technical Guidelines for Thermal Analysis of Seismic Category I Electrical Conduit Systems, Unit 1

4. Ebasco, SAG.CP22, Rev. 1, Technical Guidelines for Thermal Analysis of Seismic Category I Electrical Conduit Systems, Unit 2

4.0 HEATING, VENTILATION, AND AIR-CONDITIONING

4.1 Analytical Interfaces

4.1.1 Description

In the HVAC systems there exists jurisdiction boundaries of design responsibility between components within the system. For example, in the analytical evaluation of a duct system, the duct with its supports normally is decoupled from HVAC components such as an air handling unit or a plenum to which it is attached. There are also cases where HVAC components which are the responsibility of Ebasco are attached to HVAC equipment which are the responsibility of Impell. The decoupling guidelines must ensure that the separate responses of the decoupled components are not underestimated.

4.1.2 Evaluation

The inspection team discussed this issue with responsible Ebasco personnel and reviewed a sample of the design data transmittal correspondence between Ebasco and Impell and Ebasco interoffice correspondence which established interface guidelines.

The team also selected two (2) HVAC samples for further evaluation. The two were the same components which were audited at the site as part of the as-builting verification audit. These were (1) the Air Handling Unit AHU-1-VAFNAV-09 and (2) Intake Plenum "A" (Dwg. P-1-844-IK-INT-A): the Ebasco calculation packages for these components are Volume IV, Book 22, APES Calculation 04 and Volume IV, Book 02, Calculation 02, (References 4.1-1 and 4.1-2), respectively.

The team also reviewed the analytical interface between the Ebasco HVAC duct/support group and the APES (air handling units, plenums, and equipment support) group. Ebasco presented the preliminary results of a study on seismic end effects of plenums.

4.1.3 Findings

Based on review of the Ebasco/Impell interface procedures and sample equipment analyses, the team concluded that the preliminary boundary assumptions made by Ebasco for the two pieces of equipment reviewed were appropriate. However, because of the lack of correspondence that exists between Ebasco and Impell, the team's concern remains an outstanding issue and the team will continue its review in this area in a future audit.

In the case of the Intake Plenum, there are two filter units, one stacked on top of the other, which are in turn attached integrally with the plenum structure. The Ebasco procedure for decoupling the air filter units from the plenum was to distribute the mass of the filter units at the appropriate nodes of the plenum model in the direction where potential coupling effects were most likely to occur, i.e., the horizontal axis of their common plane. The structural stiffness contribution of the stacked filter units was not considered. The seismic analysis results for the plenum model indicated that the seismic displacements were small and consequently neglecting the structural stiffness of the filter units would not have a significant effect on the plenum response. However, the Impell results for the air filter units should be reviewed by Ebasco to assess relative stiffness between the plenum and filter assemblies in the other two directions. Should the air filter assembly displacements be large compared to those of the plenum, the plenum will carry some inertia loads of the air filter assembly in those directions. (Open Item HV-4.1-1)

For the air handling unit, Ebasco initially included both mass and stiffness effects of the cooling coil assembly which is an integral part of the unit. The dynamic analysis performed by Ebasco indicated that the displacements at the top of the unit are small, however, the Ebasco stiffness representation of the cooling coil assembly was considered optimistically high by the inspection team. The team felt that the analysis should be repeated with no stiffness contribution of the coil assembly.

Ebasco ran this second case with only the cooling coil assembly mass but no stiffness considered in the air handling unit model. The results did not significantly change indicating that the response of this air handling unit was not influenced by the coil stiffness.

The team did find more explicit interface procedures or guidelines between the HVAC duct/support group and the APES group. The guidelines were defined in Ebasco's interoffice correspondence (File Ref. 3-A-2 dated July 13, 1987). The inspection team reviewed the guidelines and found them to be appropriate with one stipulation. The stipulation is that the displacements and rotations of the HVAC component to which the duct is attached are determined to be small, otherwise additional displacement loads would be generated in the first few duct supports. Ebasco has performed a special study on seismic displacements in HVAC components; the results will be reported in Volume 1, Book 21. In the study, they have taken four (4) worst cases which include three (3) plenums supported by a trapeze type of support and an air handling unit. The calculations in all four cases indicated that seismic displacements are less than 1/32 of an inch. The team will review the results of this study upon completion by Ebasco. (Open Item HV-4.1-2)

4.1.4 References

4.1-1 Impell letter of September 30, 1987 to Ebasco requesting outlet duct loads for certain air conditions.

4.1.2 Impell letter of August 3, 1987 to Ebasco, Equipment Footprint Load Transmittal.

4.1.3 Ebasco Interoffice Correspondence, File Ref. 3-A2, July 13, 1987. Interface Between Duct/Supports and APES.

4.1.4 Ebasco Calculation Package, Volume IV, Book 22, APES Calculation 04.

4.1-5 Ebasco Calculation Package, Volume IV, Book 02, Calculation 02.

4.2 Duct Work Beam Properties

4.2.1 Description

The duct beam properties that are used in the design verification calculations are based on both empirical and analytical work. The principal consideration in developing equivalent beam properties for the duct work is to accurately represent the dynamic response behavior, i.e., stiffness and frequency. A series of modal tests were performed by CC&L in 1982 and reported in Reference 4.2-1. Based on the results of these tests, the beam properties were empirically determined for both circular and rectangular ducts. These properties are given in Attachment C2 of Reference 4.2-2. Additional tests were deemed necessary by Ebasco to assess the effects of elbows, branch connections, openings, weld undercuts, effects of quantity of duct joints, etc. These additional tests were run by CCL this year and are reported in Reference 4.2-3..

4.2.2 Evaluation

The inspection team has reviewed the 1982 CCL tests results and the evaluation of those tests to determine the representative beam properties and the allowable stresses. In addition, the team visited the CCL facilities in Raleigh, North Carolina on October 7, 1987 to hear a presentation of the recent test program which was initiated to augment the 1982 test results, witness two actual tests (one an elbow test and the other a straight segment under combined axial bending and pressure loading) and discuss the test data and conclusions to date. The team is presently reviewing the CCL test report, Reference 4.2-3, and will also review the Ebasco correlation report when issued.

A preliminary evaluation by Ebasco of the new test program results indicates that beam properties and allowable stresses for straight segments will not change but that allowable stresses and stiffnesses for branch connections could.

4.2.3 Findings

The inspection team will continue to review the results of the current test program and correlation report when available and report its findings in a future audit or inspection report. (Open Item HV-4.2-1)

4.2.4 References

4.2-1 CCL Report No. A-414-81, "Duct Test Evaluation," February 19, 1982.

4.2-2 SAG. CP24 "General Instructions for Seismic Category I HVAC Duct and Duct Support Analysis," Revision R3, dated August 14, 1987.

4.2-3 CCL Report No. A-749-87, "Test Report for Static Load Tests of HVAC Duct Work," dated October 23, 1987.

4.3 Thermal Expansion Effects

4.3.1 Description

In their design verification of the HVAC systems, Ebasco has not evaluated the effects of thermal expansion because they are considered secondary, i.e., restrained rather than load induced. In addition, Ebasco performed a thermal expansion analysis for one sample HVAC duct work system to demonstrate that these effects are insignificant.

4.3.2 Evaluation

The team reviewed the sample analysis, Reference 4.3-1, and discussed the study with Ebasco analysts. The system selected for the study was ID200DG which has seventeen (17) hangers and features a relatively long run of fifty feet. Ebasco modeled in equivalent gasket elements. The results of this analysis indicated that for a 50° temperature differential thermal displacement, duct members and hanger members stresses are low.

4.3.3 Findings

Based on its review of the Ebasco analysis, the inspection team finds the representation of the gasket elements flexibility to be overestimated. Ebasco agreed to reevaluate the model using an equivalent thermal expansion coefficient derived from the CCL test program, References 4.3-2 and 4.3-3. Ebasco has presented preliminary results for the case using the test derived expansion properties for the duct work. These results also show that duct and hanger loads are low. The team will review the analysis when released by Ebasco and discuss its findings in a future audit or inspection report. (Open Item HV-4.3-1)

4.3.4 References

4.3-1 Ebasco Calculation Package, Volume I, Book 14' Rev. 0' "Thermal Load Analysis for HVAC Ducts and Duct Support System, ID200DG, July 9, 1987.

4.3-2 CCL Report No. A-414-81, "Duct Test Evaluation," February 19, 1982.

4.3-3 CCL Report No. A-749-87, "Test Report for Static Load Tests of HVAC Duct Work," October 23, 1987.

4.4 Loads and Load Combinations

4.4.1 Description

There are a number of special studies in progress which address unusual and/or abnormal loads and their effect on the HVAC systems. These include: 1) LOCA pressure effects; 2) transient tornado pressure effects; and 3) differential building motion including secondary wall movement effects. This section will address the LOCA pressure effects issues and Sections 4.5 and 4.6 will address the transient tornado effects and differential building motion effects, respectively.

4.4.2 Evaluation

Ebasco has performed a study to evaluate the LOCA pressure effects on the structural integrity of the HVAC duct/support system. The focus of the study was to evaluate the longitudinal forces that are transmitted to the duct supports due to two effects: 1) the forces due to catenary action that result from inward deformation of the ducts under large positive pressure differentials and 2) unbalanced pressure loads due to elbows and tees. The team reviewed the Ebasco study and the Ebasco calculation package 3-E-24-018 with attachments, Reference 4.4-1. This package with attachments contains 1) the results of a survey to select the duct segments to be analyzed for containment pressurization; 2) the parametric studies to evaluate the significance of support stiffnesses, duct size and span on collapse pressure: and 3) the linear and/or nonlinear finite element analysis utilized to evaluate the fourteen (14) cases selected for the study.

4.4.3 Findings

The inspection team has reviewed the methodology, results and conclusions of the Ebasco study and in general finds them acceptable contingent on a detailed review which is currently in progress. Upon completion of this detailed review, the team will confirm its findings.

4.4.4 References

4.4-1 Ebasco Calculation Package 3-E-24-018, Rev. 1,
"LOCA Pressure Transient Effects on Duct Work,"
November 30, 1987.

4.5 Tornado Pressure Loads

4.5.1 Description

Although no Category I HVAC systems are outside, there are systems which will be subjected to transient pressure loads as building compartments which contain them experience pressure fluctuations during a tornado event.

4.5.2 Evaluation

Stone & Webster Engineering Corporation (SWEC) is performing a study to evaluate these compartment pressure fluctuations. Since this study is still in progress, the team will review this issue in a future inspection or audit. (Open Item HV-4.5-1)

4.5.3 Finding

The inspection team has not reviewed this issue as yet.

4.6 Differential Building Motion

4.6.1 Description

The seismic induced loads are generated both by inertia effects and differential support motion. In their standard design verification analysis, Ebasco has been evaluating inertia effects but not differential support motion. However, Ebasco has a program in progress to evaluate differential building seismic motion and Impell has performed a generic study to assess secondary wall displacement effects of all non piping equipment and systems.

4.6.2 Evaluation

The inspection team reviewed the Ebasco program for evaluating differential building motion effects on HVAC systems. The first step in the Ebasco program was to ensure that the HVAC systems contain flexible connections at the building interface. In addition, Ebasco performed actual walkdowns to identify the location, type, series, and preset conditions of the existing flexible connection. The last step is to evaluate whether the installed flexible connection can absorb the design differential seismic motion. The staff will review the program implementation in a future inspection.

Impell has performed an engineering evaluation of nonpiping commodities attached to secondary walls. The team requested and is presently reviewing this report, Impell Report No. 09-0210-0099, Reference 4.6-1. In addition, the team has requested and received the Ebasco Calculation File 3-E-24, Calculation No. 031, Reference 4.6-2, with the analytical model and evaluation of the worst HVAC supports in terms of secondary wall effects. Based on a preliminary review of the Reference 4.6-1 and 4.6-2 documents, the team raised several questions with the Ebasco analysis to clarify assumptions and data in the Ebasco report.

4.6.3 Finding

The inspection team finds that the Ebasco program which was outlined to evaluate the effects of the differential building seismic motions is appropriate and adequate.

The review of the secondary wall effect is still in progress and the team's findings will be discussed in a future report. (Open Item HV-4.6-1)

4.6.4 References

4.6-1 Impell Report No. 09-0210-0099, Rev. 0, "Engineering Evaluation of Non-Piping Commodities Attached to Secondary Walls," August 5, 1987.

4.6-2 Ebasco Calculation File 3-E-24, Calculation 031, "Secondary Wall Effects on HVAC Duct Supports, August 6, 1987.

4.7 Load Combination and Acceptance Criteria

4.7.1 Description

The load combinations and allowables are provided in the HVAC seismic design criteria document SAG. CP23, Reference 4.7-1. The load combinations and acceptance criteria are also provided in paragraph 3.8.4.33 of the FSAR, Reference 4.7-2 for seismic category I steel structure. In the design verification evaluation of HVAC ducts and duct supports, there are certain loads which are not explicitly considered. Thermal expansion effects, for example, are not explicitly considered in the analysis since they are secondary and self-limiting; the thermal expansion issue is discussed in Section 4.3. Differential pressure effects during normal plant operation are also not explicitly considered in the analysis. The duct test program, References 4.7-3 and 4.7-4, have included pressure effects, both positive and negative, in many of the test specimens subjected to bending and axial loads. Consequently, the team finds that the allowable load factor generated from the duct tests reflects the effects of normal operation pressure loadings.

The allowable load factors generated for duct work are used for all load conditions.

For duct supports, allowable loads and stresses defined in Part 1 of AISC steel construction code, Reference 4.7-5, are used to evaluate normal and upset plant conditions. These allowables are multiplied by a factor of 1.6 for emergency and faulted conditions not to exceed 0.9 Fy for normal stresses and 0.50 for shear stresses.

4.7.2 Evaluation

The inspection team has reviewed the acceptance criteria in both SAG. CP23 and the CPSES FSAR and found them to be consistent. The inspection team has also reviewed the duct test results presented in References 4.7-3 and 4.7-4 and compared the applied test pressure loads to the normal plant operating loads given in Appendix 3 of SAG. CP24.

4.7.3 Finding

Based on a review of the Ebasco seismic design criteria including load combinations and allowables, the team concluded that the criteria are acceptable with the exception of the allowable for compression members in duct supports for emergency and faulted conditions. The team feels that further justification is required to demonstrate the adequacy of the .6 factor for compression members. (Open Item HV-4.7-1)

4.7.4 References

4.7-1 Ebasco Document SAG. CP23, "Seismic Design Criteria for Criteria for Seismic Category I HVAC Ducts and Duct Supports for Comanche Peak Steam Electric Station Nos. 1 and 2," Rev. 1, dated June 5, 1987.

4.7-2 Final Safety Analysis Report, Amendment 57, Comanche Peak Station, issued December 20, 1985.

4.7-3 CCL Report No. A-414-81, "Duct Test Evaluation to Verify Structural Integrity of Pittsburg Seam and to Determine Flexibility and Seismic Capacity of Safety-Related Duct," dated February 19, 1982.

4.7-4 CCL Report No. A-749-87, "Test Report for Static Load Tests of HVAC Duct Work," dated October 23, 1987.

4.7-5 AISC Manual of Steel Construction, 7th Edition.

4.7-6 Ebasco Document SAG.CP24, "General Instructions for Seismic Category I HVAC Ducts and Duct Support Analysis for Comanche Peak Steam Electric Station Nos. 1 and 2," Revision 3, dated August 14, 1987.

4.8 Attachment of Supports to Ducts

4.8.1 Description

The longitudinal supports have been designed for combined longitudinal, transverse, and vertical loadings. The transverse HVAC loads are designed for transverse and vertical loading only, however, a positive attachment, i.e., bolting or welding, of the duct to a support may generate longitudinal loading. The design verification is being performed based on the actual "as-built" duct to support connection details. For example, if a lateral support is welded to the duct, that support or its representative stiffness (in the longitudinal direction) is considered in the design verification model and, hence, the appropriate contribution of longitudinal load in the transverse support is calculated.

In the September 15, 1987 public meeting on HVAC generic technical issues, the staff identified several areas of potential concern. The first deals with welds that bridge an existing gap between the support members and duct; these are referred to as "bridge welds." Since the Ebasco evaluation of these welds considers only shear, the bending effects produced by a large gap are ignored; in addition, the effective throat dimensions of the weld may be indeterminable.

4.8.2 Evaluation

In this design criteria inspection, Ebasco discussed that they have modified their qualification procedure for the duct to support attachments. The first level of qualification, now used by Ebasco, is to assume the total load is taken only by the weld(s) or bolt(s) closest to the duct corner(s). If the attachment weld or bolt cannot be qualified on this basis, inboard welds and bolts are then considered as required. Furthermore, Ebasco now does not take structural credit for bridge welds.

Ebasco is in the process of revising SAG. 24 to exclude use of bridge welds in evaluating attachments. The team expressed a concern about the use of inboard welds or bolts to carry an equal share of the transmitted load particularly in view of the structural load carrying characteristics of the duct work, i.e., that tensile and compression loads are primarily transmitted by the corner regions of the duct work. The team discussed with Ebasco the extent to which this attachment evaluation considered inboard bolts or welds; Ebasco reviewed 64 evaluation packages of lateral supports with positive connections or shimmed connections and found that 47 of them were shimmed and 17 had positive connections. Out of the latter group, the shear out-of-plane load had to be distributed over more than the corner connections in only five (5) cases. Of the five cases, four involved small ducts with only a limited number of bolts or welds on a side. The fifth case represented a large duct with as many as eleven bolts on the longer side. Ebasco had used nine of 11 of the bolts to carry the out-of-plane shear load. The team selected this latter case, References 4.8.1 and 4.8.2 for review.

4.8.3 Findings

The inspection team finds the Ebasco procedures and methods, as modified, to be adequate and acceptable, except as note below. The team concluded that the Ebasco analytical models properly represent the lateral supports which have positive or shimmed connections. The team also finds the exclusion of bridge welds in transmitted loads between the duct work and supports to be appropriate. The team is not in full agreement with the Ebasco evaluation procedure for qualifying the attachments for lateral supports. While there is no disagreement with Ebasco's first evaluation step of assuming only the end bolts or welds (i.e., those closest to duct corners) to transmit the load, the team does not agree with the alternative step used when the connection cannot be qualified with step one. (Open Item HV-4.8-1) The second step allows for the use of additional bolts or welds, without restrictions, to qualify the connection. While the team did not agree with the evaluation method used by Ebasco for the hanger case selected for review above, the team found the connection to be adequate using a more realistic evaluation model. This issue will be examine more closely in the staff review of program implementation.

4.8.4 References

4.8.1 HVAC Support Drawing DH-1-854-IN-WP1, Rev. 0.
4.8.2 Ebasco Calculation Sheets for DH-1-8541N-WP1.

4.9 Anchor Bolt Stiffnesses

4.9.1 Description

The boundary conditions used in the design verification analytical models for HVAC duct supports involve the use of anchorage spring rates. The spring rates for five degrees of freedom restraint (tensile, two directional shear, and two directional bending) at the anchorage point are given in Appendix G of SAG CP24, Reference 4.9-1. The anchorage point is defined as the center of the anchor bolt at the face of the concrete. In the models, the moment about the bolt centerline has been released.

The spring rates given in SAG CP24 (Reference 4.9-1) are a function of anchor bolt size and embedments, base angle cross-sectional dimensions and bolt locations.

4.9.2 Evaluation

The team reviewed the methodology related to the use of spring rates to represent the duct support anchorage that are contained in SAG CP24. In addition, the team reviewed a sample analysis performed by Ebasco to establish rotational spring rates. The analytical package and the section reviewed was Volume I, Book 3 and the calculation for base angle 4x4x1/2 and 3/4 diameter Hilti Kwik bolts. The STRUDL Baseplate computer run HV-191B for a supplied with the package was also reviewed.

The team reviewed Hilti Kwik-Bolt test data in References 4.9-2 and 4.9-3 to assess bolt stiffness variations and reviewed the basis for the Ebasco anchorage spring rate tables.

4.9.3 Findings

In reviewing the tabulated anchorage assembly spring rates in SAG. CP24, the inspection team identified an error in the table on sheet 3 of 11. The value given for the linear tensile stiffness for 1" Hilti System Kwik bolt is 46 kips/inch whereas it should be 461 kips/inch for the L3x3x3/8 angle size. Ebasco checked their STRUDL program file and found the same error existed in their support evaluation program. The team went through the remaining tables and concluded that this is an isolated error. The team will review Ebasco's resolution of this error in a future audit. (Open Item HV 4.9 1)

Based on its review of the Ebasco modeling procedures for the anchorages, the audit team agrees that the general method is acceptable but is concerned that variations to the bolt tensile and shear stiffness values used in the evaluation could impact the system dynamic response and anchor loads. The team requested Ebasco to perform a sensitivity study to assess the sensitivity of system response and anchor loads to stiffness. The team will review the results of the sensitivity study in a future inspection or audit. (Open Item HV 4.9-2)

4.9.4 References

4.9-1 SAG. CP24, "General Instructions for Seismic Category I HVAC Duct and Ducting Supports Analysis for Comanche Peak Steam Electric Station Nos. 1 and 2," Revision 3, August 14, 1987.

4.9-2 Abbot A. Hanks Report 8784, "Kwik-Bolt Testing Program, Load vs. Displacement Graphs," January 30, 1974.

APPENDIX A

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