U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF SPECIAL PROJECTS

Comanche Peak Project Division

Report Numbers: 50-445/88-33; 50-446/88-29

Docket Numbers: 50-445, 50-446

Licensee: Texas Utilities Electric Company (TU Electric)
400 North Olive St., L. B. 81
Dallas, Texas 75201

Facility Name: Comanche Peak Steam Electric Station, Units 1 and 2

Location of Inspections: Ebasco Services Incorporated
2 World Trade Center
New York, New York

Comanche Peak Steam Electric Station
Glen Rose, Texas

Inspection Period: March 30-April 29, 1988

Inspection Team: NRC
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1. Inspection Summary

Areas Inspected: The inspection team conducted (a) followup inspections of applicant actions on previous open items identified in Inspection Report 50-445/87-39, 50-446/87-30 related to the design criteria and analytical methodologies used by Ebasco Services Incorporated for the design validation of the cable tray hanger, the conduit support (Trains A and B, and Train C greater than two inches), and the heating, ventilation, and air-conditioning (HVAC) structural integrity; (b) inspection of applicant actions taken to determine root causes for the issues identified in the design areas related to cable tray hangers, conduit supports, and HVAC; and (c) inspection of design criteria and analytical methodologies used by Impell Corporation for the design validation of cable tray hangers.

Results: (a) As a result of this followup inspection, many open items identified in Inspection Report 50-445/87-39, 50-446/87-30 were closed. The status of the previous open items are listed below. The details of each item are provided in Section 2 of this inspection report.

Open Item No.	Status	Description
Cable Tray Hangers:		
CT-2.1-1	Closed	Connectivity for Unit 2 Supports
CT-2.1-2	Closed	Tray Frequency
CT-2.1-3	Closed	Buckling Factor of Safety
CT-2.1-4	Closed	Shared Anchorage
CT-2.1-5	Closed	Thermal Stress
CT-2.1-6	Closed	Attachment to Secondary Walls
CT-2.1-7	Open	Anchorage Stiffness
CT-2.1-8	Closed	Tier Flange Bending
CT-2.2-1	Closed	Impell/Ebasco Benchmark Problem
CT-2.2-2	Closed	Modeling Differences
CT-2.2-3	Closed	RSM String Analysis
CT-2.3-1	Closed	Prying Action Factor
CT-2.3-2	Closed	Oversize Bolt Holes
CT-2.3-3	Closed	Minimum Bolt Hole Edge Distance
CT-2.4-1	Closed	Elimination of Grouped Supports
CT-2.6-1	Closed	Noncompliance Submittals
Conduit Supports:		
CS-3.1-1	Open	Seismic Adequacy of Flexible Conduit and Cable Air Drops
CS-3.1-2	Closed	Seismic Interaction
CS-3.2-1	A) Closed	Damping Value for Aircraft Cable Supports
	B) Closed	Damping Value for SP Supports
CS-3.4-1	Open	Inertial Effect of Clamp and Filler Plate
CS-3.4-2	Open	Safety Factors for Anchor With Oversize Bolt Holes
CS-3.4-3	Closed	Oversize Bolt Hole Criteria
CS-3.4-4	Open	Code Differences
CS-3.6-1	Closed	LOCA and Seismic Load Combination
CS-3.7-1 (New)	Open	Unistrut Support Qualification
CS-3.7-2 (New)	Closed	Elimination of LA Spans

Heating, Ventilation, and Air-Conditioning:

HV-4.1-1	Closed	Effect of Relative Stiffness Between the Plenum and Filter Assemblies
HV-4.1-2	Closed	Special Study on Seismic Displacements in HVAC Components
HV-4.2-1	Open	Results of HVAC Test Program and Correlation Report
HV-4.3-1	Closed	Analysis Results for Gasket Flexibility
HV-4.5-1	Open	Tornado Pressure Effects on HVAC
HV-4.6-1	Open	Secondary Wall Effect on HVAC Supports
HV-4.7-1	Open	Justification for 1.6 Increase in Compression Members
HV-4.8-1	Open	Procedure for Qualifying Attachments for Lateral Supports
HV-4.9-1	Closed	Resolution of Anchorage Assembly Spring Rate Error
HV-4.9-2	Closed	Sensitivity of Response and Anchor Loads on Stiffness

(b) The inspection team is continuing its review of the root causes for the cable tray, conduit support, and HVAC design issues. No open items were identified at this time. The details of this review are discussed in Section 3 of this inspection report.

(c) The inspection team reviewed the design criteria and analytical methodologies used by Impell in their design validation of cable tray hangers. No open items were identified but additional information was requested as detailed in Section 4 of this inspection report.

2. Applicant Actions on Previous NRC Inspection Findings (Inspection Report 50-445/87-39, 50-446/87-30)

The following open items were identified in Inspection Report 50-445/87-39, 50-446/87-30 related to the design criteria and analytical methodologies used by Ebasco in the design validation of cable tray hangers, conduit supports, and HVAC structural integrity. On March 30-31, 1988, and April 18-21, 1988, the inspection team discussed the resolution to the open items at the offices of Ebasco (New York, NY) and at the Comanche Peak Steam Electric Station site (Glen Rose, TX). The results of our review follow.

a. Cable Tray Hangers

CT-2.1-1 Connectivity for Unit 2 Supports

All Unit 1 supports have been, or will be, analyzed using connectivity between the transverse support tiers and the cable tray. The design validation of Unit 2 supports, which was completed earlier, was based on the assumption of no connectivity between these members. Ebasco is to evaluate the need for reanalysis of the Unit 2 supports and document their conclusion.

Ebasco has concluded that connectivity between trays and hangers must be considered in the Unit 2 design validation in an identical manner to its use on Unit 1 (Ref. Ebasco letter EB-T-3886, January 20, 1988).

Findings: This item is closed.

Action Required: None.

CT-2.1-2 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.

Ebasco has conducted a study which demonstrates the applicability of the tray frequency tables in CP-34 for elbow spans (Ref: Vol. I-Book 1, Part 2, Item No. 2)

Findings: This item is closed.

Action Required: None.

CT-2.1-3 Buckling Factor of Safety

Allowable stresses for the loading combinations including SSE are permitted to be increased by 1.6 times the normal allowables providing 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.

A position paper (Impell IM-P-004) has been prepared which justifies the use of a 1.6 increase factor for SSE allowables without an additional limit for critical buckling stress. For cable supports at CPSES, angle braces are the typical and predominant axial compression members. For these, the axial stress interaction ratios are very small with the average less than 12% of the allowable and with the maximum approximately 50% of the allowable. An inventory of axial stress interaction ratios for angle braces was provided by Impell.

This item is closed.

Action Required: None

CT-2.1-4 Shared Anchorage:

There are cases where two or more cable tray supports, or a cable tray support and a pipe support, share a common anchorage (baseplate). Ebasco is to provide documentation describing the transmittal of information such as baseplate loadings, baseplate flexibility, etc., between the groups responsible for anchorage design and support design.

Ebasco presented a detailed response which outlined the manner in which the Ebasco Site Engineering Group is informed of anchorage failures as well as hanger failures in which other cable tray hangers are involved. Samples of such transmittals to the Site Engineering Group were provided.

Findings: This item is closed.

Action Required: None.

CT-2.1-5 Thermal Stress

For certain types of support configurations, it is possible that large thermal stresses could be generated due to support self-constraint during a LOCA.

Impell has prepared a revision to their report (M-27) on thermal stress evaluation to include the effects of support self-constraint during a LOCA, as well as the effect of the simultaneous occurrence of a LOCA and and SSE. It was found that allowables were not exceeded for these events.

Findings: This item is closed.

Action Required: None.

CT-2.1-6 Attachment to Secondary Walls

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.

Impell has conducted a study which demonstrates by rigorous analysis of relatively rigid "worst case" supports that relative wall displacements can be accommodated, in addition to all other loads, within the applicable acceptance criteria (Ref: Impell No. 09-0210-0099, Rev. 1).

Findings: This item is closed.

Action Required: None.

CT-2.1-7 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.

Ebasco has prepared an "Anchor Bolt Sensitivity Study" which is intended to show that the fundamental frequency of a cable tray system is not sensitive to large changes in anchor bolt stiffness and that member stress interaction ratios, as well as anchor bolt interaction ratios, are acceptable for the range of anchor bolt stiffness considered in the study (Ref: Vol. I, Book 25).

Findings: This item remains open.

Action Required: Further review of the Ebasco study will be performed.

CT-2.1-8 Tier Flange 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 which is not considered in design validation.

Ebasco has prepared an evaluation of the local bending of the cable tray tier flange and has concluded that the maximum allowable load capacity of the clamp in the vertical direction automatically limits the tier flange bending stresses to acceptable values (Ref: Vol. I Book 27).

Findings: This item is closed.

Action Required: None.

CT-2.2-1 Impell/Ebasco Benchmark Problem

Impell uses their computer program SUPERPIPE for design validation while Ebasco uses STRUDL. A comparison should be made to determine any major differences between the two methods.

Impell and Ebasco have prepared two reports (09-0210-0136 and -0138) which demonstrate that the two computer programs provide close agreement for analysis of an identical system model and that both methods give conservative results when compared to actual seismic system responses as measured by testing.

Findings: This item is closed.

Action Required: None.

CT-2.2-2 Modeling Differences

Impell and Ebasco have differences in their modeling of cable tray systems for RSM analysis. All these differences and their impact on design validation should be described.

Impell and Ebasco have prepared a report (09-0210-0137) which discussed the difference in modeling procedures used by the two organizations and shows that both procedures are sufficiently detailed to produce accurate and conservative response predictions.

Findings: This item is closed.

Action Required: None.

CT-2.3-1 Prying Action Factors

In calculating prying action factors, the average stiffness was used for Richmond inserts while the maximum stiffness was used for Hilti inserts. Ebasco is to provide justification to show that this results in conservative prying action factors.

Ebasco has conducted a study which shows that Richmond insert stiffness variation does not strongly affect the prying action factor (Vol. 1, Book 3, Section V).

Findings: This item is closed.

Action Required: None.

CT-2.3-2 Oversize Bolt Holes

Oversize bolt holes are present in anchorages and in clamp-tier-tray connections. Ebasco is to determine the effects that oversize bolt holes have on the adequacy of the cable tray hangers and tray systems.

Ebasco has prepared a study which concludes that even for "worst-case" conditions the safety factors of the connections are acceptable with oversized bolt holes (Vol. I, Book 22, Part 2, Rev. 6).

Findings: This item is closed.

Action Required: None.

CT-2.3-3 Minimum Bolt Hole Edge Distance

Minimum edge distance requirements as prescribed by the AISC code are not followed in all cases. Ebasco provided justification for this noncompliance in a study which qualified minimum edge distances less than those provided by the AISC code by establishing compliance with AISC code allowable bearing stress limits. The team finds this to be acceptable compliance with the AISC code.

Findings: This item is closed.

Action Required: None.

CT-2.4-1 Grouped Supports By Similarity

Supports in Unit 1 which were design-verified by grouping were all requalified by individual analysis. Ebasco is to determine if the supports in Unit 2 were design-verified by grouping will be reanalyzed.

Ebasco has stated that the use of grouping in design validation of Unit 2 supports will be extremely limited due to the extensive reevaluation of Unit 2 supports required for other reasons (Ref: Ebasco letter, EB-T-3995, March 8, 1988).

Findings: This item is closed.

Action Required: None.

b. Conduit Supports

CS-3.1-1 Seismic Adequacy of Flexible Conduit and Cable Air Drops

Ebasco was requested previously to provide the basis for the seismic adequacy of the flexible conduit and electrical cable air drops.

The following two Impell Reports were provided for review:

1. Report No. 09-0210-78, Rev. 0, "Cable Slack Evaluation for CPSES"

2. Report No. 09-0210-104, Rev. 0, "Flexible Conduit Slack Evaluation for CPSES"

BNL is in the process of reviewing these reports. However, it appears that these reports address the cable slack aspect of the problem only.

Findings: This item is still open.

Action Required: TU Electric to determine responsible individual who could provide additional information/basis to demonstrate seismic adequacy.

CS-3.1-2 Seismic Interaction

Ebasco was requested to explain how seismic interaction between rigid conduit and equipment was addressed.

Ebasco provided Gibbs & Hill drawing 2323-E1-1702 which presents acceptable details for attaching conduit to equipment. This drawing shows flexible conduits are used to connect to switchgear, MCCs, panels, motor boxes, etc. while rigid conduits are used to connect to wall mounted equipment if the first conduit support adjacent to the equipment is mounted on the same wall (or column) as the equipment.

Findings: This item is closed.

Action Required: None.

CS-3.2-1 Damping Value for Aircraft Cable Supports & SP Supports

The design validation of CSR (aircraft cable) supports was based on 7% damping for the Safe Shutdown Earthquake (SSE) event. In addition, SP type supports were utilizing damping values of 4% for Operating Basis Earthquake (OBE) and 7% for SSE. These damping values are higher than the damping values used for the other conduit supports and are higher than the values presented in the FSAR.

A. For CSR Supports - Impell Report "Justification of Damping Value," Report No. 01-0210-1527, Rev. 1, December 1986, was provided to justify the use of higher damping values. The report provides justification for the use of 7% damping for two-inch and under Train C conduit when subjected to the SSE. The conclusions in the report for utilizing 7% damping for the SSE were based on actual test data.

It was also explained that the nature of the CSR support components; aircraft cable, bolted connection, and anchors, were comparable to bolted steel structures where 7% damping is generally accepted. In addition, these supports are not safety related but must only be designed such that they do not adversely affect the functioning of safety related components. Thus, they could deform beyond the elastic limit whereby the equivalent damping would be higher.

B. For SP Supports - SP type supports are conduit supports which are attached to the Spread Room Frame (SRF) in the Spread Room. Ebasco explained that their criteria requires SP conduit supports to be dynamically rigid and conduits supported by SP supports to have a frequency above 28 Hz (which corresponds to the zero period acceleration for these locations). Thus, Ebasco concludes that the seismic response of these SP conduit/supports are equal to the response of the SRF. Ebasco stated that the SRF is constructed of structural steel with bolted connections. Thus, the use of 4% damping for OBE and 7% for SSE to obtain the seismic acceleration response of the SRF, are justified based on Reg. Guide 1.61. Since the SP conduit/support response equals the SRF response, then the design validation of the SP support can be based on 4% and 7% damping for OBE and SSE, respectively.

Findings:

A. This item is closed.

B. This item is closed.

Action Required:

A. None.

B. None.

CS-3.4-1 Inertial Effect of Clamps and Filler Plate

In determining the loads acting on conduit clamps, Ebasco only considered the seismic inertial loads of the conduit and neglected the inertial load of the filler plate and clamp.

Ebasco made an evaluation of the effect of the additional inertial loads due to the filler plate and clamp. This evaluation, contained in Calculation Book No. SPAN-1204, led to reduction in clamp capacity for certain cases. Therefore, the calculation was revised to take advantage of frictional resistance capability due to the torque applied to the clamp connection.

Findings: This item is open.

Action Required: BNL to review revised Calculation Book No. SPAN-1204.

CS-3.4-2 Safety Factors for Anchor With Oversize .olt Holes

Ebasco Calculation No. 0253 addressed the concern of oversized bolt holes for two bolted Hilti anchor connections. This calculation, although conservative, resulted in factors of safety below allowables for the anchors.

Ebasco revised Calculation No. 0253 (now Rev. 2) to reflect the use of a 5/3 power interaction equation for expansion anchors. Previously, a linear interaction equation was used. Ebasco indicated that this 5/3 power interaction equation is permitted by DBD-CS-15. Rev. 1, prepared by Stone & Webster Engineering Corp. (SWEC). The revised calculation shows that with the use of the non-linear interaction equation the factors of safety are acceptable.

Findings: This item is still open.

Action Required: BNL to review revised calculation and DBD-CS-15, Rev. 1.

CS-3.4-3 Oversize Bolt Hole Criteria

This concern relates to the resolution of open item CS-3.4-2 where the two bolted Hilti anchor connection was selected as the governing case (as compared to a four bolted connection). Ebasco was requested to demonstrate why the two bolted connection would govern.

Ebasco provided their position paper, "Effect of Bolt Hole Oversize in CTH and Conduit System Adequacy," Rev. 6, which presents justification on this subject. This report contends that the two bolt case governs because "three or more bolt connections have even lower probability of being configured so that only one bolt is initially loaded and must deflect through the amount of oversize before the others begin to share the load".

Findings: This item is closed.

Action Required: None.

CS-3.4-4 Code Differences

Ebasco was requested to identify and provide the basis for any differences between design criteria and code requirements. The requested information was provided in a letter from W. G. Counsil to USNRC, dated December 15, 1987. Some of the concerns and resolutions described in the letter are covered by the other open items discussed in this audit report while the remaining resolutions are still being reviewed. At this time, however, the issue of bolt hole oversize as it affects steel to steel connections has not yet been resolved.

Ebasco stated that for generic supports, only CSM 23 contains steel to steel connections and its adequacy was demonstrated in Calculation No. SUPT-0253. For IN supports, they will be identified as part of the Post Construction Hardware Validation Program (PCHVP). Then, the connections will either be checked as friction type connections or they will be replaced.

Findings: This item is still open.

Action Required: Ebasco/TU Electric to specifically identify the criteria/methodology for resolving the steel to steel connection concern. In addition, the staff will complete its review of the information provided in the TU Electric letter referenced above.

CS-3.6-1 LOCA and Seismic Load Combination

The basis for the specified thermal accident temperature occurring simultaneously with the seismic event was not justified. Ebasco did not consider peak accident thermal loads at the same time as seismic loads. Instead, the following two cases were considered:

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

2. Peak accident thermal with no seismic.

Ebasco performed an additional study whereby seismic plus peak accident thermal load was considered simultaneously for a "worst case" configuration. The study is contained in Ebasco Calculation Book No. 92, Vol. II, Attachment J.

Findings: This item is closed.

Action Required: None.

Additional items that arose during this audit/meeting are summarized below along with the planned action.

CS-3.7-1 (New) Unistrut Support Qualification

During discussion of the criteria/methodology of the Unistrut support qualification, it appeared that the calculation portion did not check for both cases of OBE and SSE.

Ebasco stated that to provide additional margin for the stress levels in these calculations, they would prefer to utilize a yield stress of 42 ksi rather than 33 ksi for the Unistrut members. In addition, they will review the affected supports to ensure that the stress levels are below OBE and SSE allowables.

Findings: This item is still open.

Action Required: Ebasco to perform the resolution they presented above.

CS-3.7-2 (New) Elimination of LA Spans

To resolve some of the concerns raised by CYGNA, Ebasco committed to remove LA (assumed dynamically rigid) conduits. However, the criteria documents (e.g., SAG, Dwgs. 2323-S-0910, etc.) provided previously for review still permitted the use of LA spans.

Recent revisions of these documents were provided and it was demonstrated that the use of LA spans has been eliminated.

Findings: This item is closed.

Action Required: None.

c. Heating Ventilation and Air Conditioning

HV-4.1-1 Effect of Relative Stiffness Between the Plenum and Filter Assemblies

Ebasco has obtained the seismic qualification documentation for the air filter assemblies from Impell. A review of these documents indicates that the filter assemblies are rigid with a frequency greater than 33 Hz. In the direction perpendicular to the centerline, the filter assemblies were assumed supported at the bottom, at its supports only, ignoring any connection to the plenum. In the direction along the centerline, load transfer to the plenum was considered. These assumptions are similar to those used in the qualification of the plenum. For the plenum validation, only filter mass along the centerline was considered in its qualification. The design validation of the plenum used 1.5 x peak "g". In response to this issue, Ebasco reevaluated the intake plenum, conservatively assuming the plenum carried 100% of the filter mass in both the transverse and centerline directions. The additional stresses on the plenum for this assumption were found to be insignificant. For both the air filters and plenum assemblies, the resulting seismic displacements are small and neglecting the structural stiffness of the connecting element appears to be an acceptable analytical approach.

Findings: The audit team has reviewed the documentation provided and found the justification acceptable. The issue is closed.

HV-4.1-2 Special Study on Seismic Displacements in HVAC Components to be Completed

The team has reviewed the special study for seismic displacements at the HVAC Equipment and Duct intersection. The four worst cases evaluated indicate that seismic displacements are less the 1/32 of an inch. Therefore, with such small displacements, the loads induced in the immediate few duct supports adjacent to the intersection will be insignificant and the effect can be ignored.

Findings: This issue is closed.

HV-4.2-1 Results of HVAC Test Program and Correlation Report

The Correlation Test Report has not addressed the question of joint leakage. Ebasco is currently working at answering this concern.

Findings: The audit team will complete its evaluation when the Ebasco position on the remaining question is available. This issue is still open.

HV-4.3-1 Thermal Expansion Effects Based on Gasket Flexibility Determined From Duct Testing

The team reviewed and discussed the results of the Ebasco study, "Thermal Load Study for HVAC Duct System No. 200," dated 12/21/87 (Volume I, Book 14, (Part 1). This study determined the thermal expansion effects on a typical duct system by three different approaches. The study first used the equivalent thermal coefficient of expansion as determined in the CCL test report of 2/19/82. Secondly, an equivalent modulus of elasticity det rmined from the CCL test report of 10/23/87 was used. Lastly, the origina analysis where duct joint gasket elements were used in the system model was included in the study. The results of the study concluded that thermal expansion effects are insignificant.

Findings: The audit team has completed its review of the study and agrees that the thermal expansion effects can be reasonably neglected in the design load combinations. This issue is closed.

HV-4.5-1 Tornado Pressure Effects On HVAC

Ebasco has provided a study, "Tornado Effects on HVAC Duct Systems," dated 2/12/88 (Volume 1, Book 24) that establishes an expected differential pressure across the duct not to exceed 15.9 " of H_2O. This maximum differential pressure occurs in a duct of size 54" x 38" in the Safe Guard Building. The study reports the results of a duct of size 60" x 24" that successfully withstood a test subjected to a negative pressure differential of 36 " of H_2O. This is considered a bounding case with a safety factor of 2.26 compared to the maximum expected pressure. The Ebasco study predicts the next highest pressure differential is 8.2 " of H_2O. The actual pressure fluctuations due to a tornado are being evaluated by SWEC. This evaluation is not available for review at this time.

Findings: The team will complete its review of this issue when the SWEC report is available. A comparison of the Ebasco study and SWEC pressure levels will be made at that time. This issue is still open.

HV-4.6-1 Secondary Wall Effect On HVAC Supports

The audit team re-visited the question of differential building motion. Ebasco has provided a description of a program to identify all duct expansion joints between buildings. These expansion joints, which are currently Garlock type joints, are to be replaced with PATHWAY joints. During this study, it has been determined that some of the expansion joints are ineffective and require rework. The audit team has asked for a sample of some of the DCAs to accomplish this change-out. In addition, a copy of the PATHWAY flex joint specifications to be used in these duct systems has been requested.

Concerning the evaluation of the attachment of commodities to secondary walls, the audit team discussed at length the documentation provided by Ebasco concerning this issue. Ebasco has provided the data requested in response to the questions raised in the initial audit. The discussion has provided clarification of the additional analysis and assumptions used in the generic study of secondary wall displacement issue. The audit team is currently reviewing this additional data and clarification.

Findings: These issues are open pending completion of audit team review.

HV-4.7-1 Justification For 1.6 Increase In Compression Members

For duct supports, normal allowable stresses are multiplied by a factor of 1.6 for evaluation of the safe-shutdown earthquake load condition. This 1.6 increase is also allowed by design validation procedures for compression members. The team is reviewing additional information which justifies the 1.6 increase for compression members.

Finding: This issue is open pending further review.

HV-4.8-1 Procedure For Qualifying Attachments For Lateral Supports

The audit team had requested further examples of the use of additional interior welds or bolts, without restriction, to qualify the support to duct attachment. Ebasco had provided a further sample of twenty hangers and the detail evaluation of two of these hangers.

Findings: The audit team has evaluated the data provided for the two analyses. Considering the data using an evaluation technique the audit team considers more appropriate, further questions have been raised. The audit team has requested detail loading data for a number of the remaining sample of twenty supports. This issue remains open pending further review by the audit team.

HV-4.9-1 Resolution of Anchorage Assembly Spring Rate Error and
HV-4.9-2 Sensitivity of Response and Anchor Loads on Stiffness

The two open items HV-4.9-1 and HV-4.9-2 are discussed together below. In a previous audit, the audit team expressed a concern on the impact of variations of the bolt tensile and shear stiffnesses used in the evaluation of the duct systems. Ebasco has provided an Anchor Bolt Sensitivity Study (Volume I, Book 25) that evaluates the impact on the seismic analysis of the duct and hanger systems. The study in considering the scatter of the bolt stiffnesses has chosen to evaluate two typical systems. Each system considered three bolt stiffness ranging from one half, full value, to twice the stiffnesses used in typical analyses to SAG.CP24.

Findings: The audit team has reviewed the data presented and generally agrees with the conclusions of the study. The fundamental frequency of the system is not sensitive to large changes in the anchor bolt stiffnesses nor are the member stress interaction ratios. The anchor bolt interaction ratios are only moderately sensitive. It appears from the data that the greatest percent change in the interaction ratios occur in those elements at the lower stress levels. The effects of the stiffness variation due to scatter of the data can be considered small and do not appear to alter the final conclusion of a systems acceptability.

Ebasco has also provided a letter that identifies 12 HVAC system supports that utilized an L 3x3x3/8 anchorage. The error in the linear tensile stiffness has been corrected in the STRUDL program and the latest SAG.CP24 table. The audit team has been advised that the revision of these supports will be performed during the final design reconciliation stage.

These issues are considered closed.

3. <u>Root Causes For Cable Tray Hangers, Conduit Supports, and HVAC Design Issues</u>

The NRC inspection team discussed the development of the root causes identified by the applicant in its letter from W. G. Counsil to USNRC dated March 16, 1988 (TXX-88254). In its letter, the applicant identified six broad, programmatic categories for the root causes of the design issues discussed in Appendices A and B of its project status reports. The six root cause categories are as follows:

(1) translation of licensing commitments into design criteria
(2) design document development, control and verification
(3) translation of design criteria into engineering installation and procurement documents (specifications and detail drawings)
(4) interface control
(5) audits
(6) other

The inspection team focused its review on the applicant's categorization of the types of design issues for each of the three design areas of cable tray hangers, conduit supports, and HVAC. The team requested that the applicant describe how the issues from the project status reports were categorized into the six root cause categories. The team also discussed the types of designs used at CPSES, the primary reasons for initiating a complete design validation, the nature of the hardware modifications implemented, and reasons for the extensive testing and special studies performed in each of the three design areas. The following paragraphs summarize the discussions for cable tray hangers, conduit supports, and HVAC.

(a) Cable Tray Hangers

Typically at CPSES, the cable tray hangers consist of welded structural channel members onto which the cable tray are bolted. The majority of the design issues were categorized into the root causes associated with Categories (1), (2) and (3) above.

For Unit 1 and Common, there are a total of 7566 cable tray hangers. To date, 874 cable tray hangers and 93 cable tray span modifications have been identified as a result of design validation. Of the 874 cable tray hanger modifications, 364 are related to overstress (including slenderness ratio exceedances), 150 are related to weld overstress, 82 are related to anchorage overload, and 278 are related to cable tray clamp overstress. The 93 cable tray span modifications are related to tray overstress. These modifications do not include the types of modifications attributed to as-built conformance.

(b) Conduit Supports

For conduit supports, the typical design at CPSES consists of tube steel members or Unistrut members (flush-mounted against the walls). The majority of the design issues were categorized into the root causes associated with Categories (1) and (2) above. The primary activity was the development of a technical basis for the design criteria.

For Unit 1 and Common, there are approximately 6,000 isometric lines (Trains A and B and Train C greater than two inch) and 30,000 conduit supports. Approximately 6,500 conduit supports including 2,600 conduit support clamps have been identified for modifications for Unit 1 and Common. The modifications were associated with replacing A307 Grade B bolts for conduit clamp attachments, Unistrut clamps and supports, individually designed supports, spread room framing, aircraft cable supports to be added, and design validation modifications.

The testing in the conduit support area was associated with developing clamp allowable and Unistrut support capacities. Special studies were performed to evaluate the effect of environmental thermal loadings on the conduit support structural integrity.

(c) HVAC

For HVAC supports, the typical design at CPSES consists of structural angle members. The majority of the design issues were categorized into the root causes associated with Categories (1), (2), (3), and (6) above. Category (6), "Other," is related to weaknesses in the HVAC constructor's (Bahnson's) quality control program. The HVAC design validation was initiated primarily as a result of TU Electric audits, CPRT Quality of Construction results, and the applicability of external source issues identified in piping, cable tray hangers, and conduit supports to HVAC structural design.

For Unit 1 and Common, there are approximately 4,100 HVAC supports. To date, approximately 800 modifications to the HVAC supports have been identified as a result of design validation. The majority of modifications are related to welding (size, length, placement) and to a lesser extent to member overstress and anchorage overloads. However, the majority of the HVAC supports include some degree of as-built modifications which are identified separately from design validation (e.g., grouting of baseplates, Richmond insert installation).

Testing was performed to supplement existing test data from previous (1981 to 1982) tests and to address specific questions related to the effects of openings in ducting and the effect of axial tension in the ducting.

During the root cause inspection of April 19-April 23, 1988, applicable specifications procedures and design drawings for the procurement, design process and installation, respectively, of cable tray hangers (CTH) and conduit and HVAC supports were reviewed. Additionally, interviews of Ebasco and Impell personnel involved in the current CTH and/or conduit design verification programs and ex-Bahnson personnel involved in the past Bahnson HVAC system and support installation program were conducted. These reviews and interviews were conducted as part of continuing inspections to understand the issues in the CTH, conduit and HVAC support design issues and to determine their root causes. Further inspections are planned in this area.

There were no open or unresolved items identified in the inspection team's review of the root cause determination. The team is continuing its review in this area and its conclusions will be provided in supplements to the CPSES Safety Evaluation Report.

4. Impell Design Criteria and Methodologies for Cable Tray Hangers

On April 10-21, 1988, the inspection team conducted an audit at the CPSES site (Glen Rose, TX) of the design criteria and analytical methodologies used by Impell Corporation in its design validation of cable tray hangers under the TU Electric Corrective Action Program. An important objective of the audit was to assure that the design criteria and verification methods were responsive to the external source concerns and were in compliance with licensing commitments.

Impell's design validation scope consists of all cable trays and supports located in the Unit 1 reactor and safeguard buildings.

Impell's implementation of their design verification methods to validation of actual hardware was not part of this inspection, except as certain sample problems were reviewed in order to gain a better understanding of the design validation methodology. Supporting studies and tests which were conducted to substantiate the design validation methods were included in this inspection to the extent that they were related to the design criteria or methods which were being inspected.

The areas inspected by the team included:

(a) Response Spectrum Method (RSM)
(b) Testing
(c) Acceptance Criteria

4.1 Response Spectrum Method (RSM)

4.1.1 Description

The Response Spectrum Method (RSM) is used by Impell for the design validation of all cable trays and cable tray supports in their scope of work which includes the Reactor Building and Safeguards Building of Unit 1. This scope consisted of 200 system analysis packages which included approximately 2300 supports. The systems (cable tray runs) which were analyzed usually consisted of 10-15 supports with a "break" support at each end and "analysis only" supports extending beyond the "break" supports to simulate the proper boundary conditions. The cable tray runs for analysis were preselected by choosing "break" locations based on prescribed characteristics. The "break" supports appear in two analyses and are design validated for both systems. These supports are design validated in a system where they are modeled as "real" supports.

All significant components of the cable tray systems and supports are modeled in detail in order to obtain the system response to the design loads. Separate analyses are performed for OBE and SSE using 4% and 5% structural damping respectively.

Impell uses the SUPERPIPE computer program to obtain loads and displacements, and uses SUPERPOST for design validation of support members and welds. Anchorages, trays and clamps are design validated separately using loads obtained from the SUPERPIPE analysis.

4.1.2 Evaluation

In the audit of the RSM method, Impell personnel presented the methodology including discussions of the pertinent procedures, instructions, supporting studies and test data. Overlap criteria which are used to break systems down into smaller analysis packages, requirements for "break" supports and modeling of "analysis only" supports were covered and the justification for this methodology was presented. The forces and moments on supports and trays in the overlap region are multiplied by a factor of 1.1 for addition conservatism.

A sample system analysis (Calc./Probl. No. 187-82-05) was reviewed as well as one of the "break" supports (CTH-1-2539) included in the analysis. The following aspects of the analysis were reviewed:

a) Modeling of supports for SUPERPIPE including eccentricities, brace connections, anchorages

b) Modeling of tray, tray fittings, clamps

c) Justifications for neglecting certain eccentricities in SUPERPOST model

d) Validation of support members and welds using SUPERPOST with loads extracted from SUPERPIPE

e) Validation of tray, anchorages and clamps using loads from SUPERPIPE and allowables from test results or special studies

The SUPERPIPE computer program was evaluated by means of a benchmark problem (see Section 2.0, Item No. CT-2.2-1) using a typical tray system and making a comparison by running the sample problem with P-Delta Strudl. Close agreement was obtained between the two computer programs. In addition, one of the ANCO test configurations was modeled for SUPERPIPE and the computer results were compared to the actual seismic system responses. The computer analysis gave conservative predictions compared to the test results.

The SUPERPOST computer program, which is a post-processor for SUPERPIPE used for validation of support members and welds, is verified by comparison with hand calculations.

4.1.3 Findings

None

The Impell criteria and methodology for RSM analysis were found to be adequate for design validation of CPSES cable trays and supports. The following additional information was requested:

a) rerun of the "benchmark" problems using the SUPERPIPE curved element (elbow) and comparison of results with P-Delta Strudl

b) verification documentation for the SUPERPIPE curved element when used as a cable tray elbow

c) three system calculation packages demonstrating various "overlap" features

d) one tray support design validation package from each of the three system packages

4.1.4 References

The following Impell documents were reviewed for the evaluation of the Response Spectrum Method:

Report No. 09-0210-0136, "Impell/Ebasco Comparison of Computer Programs used in CPSES Cable Tray System Analysis"

Report No. 09-0210-0137, "Impell/Ebasco Comparison of Modelling Procedures used in CPSES Cable Tray Analysis"

Report No. 09-0210-0138, "Impell/Ebasco CPSES Cable Tray System Comparison of Analysis Results and Tests Measurements for Test Configuration 7"

Project Instruction PI-02, "Dynamic Analysis of Cable Tray Systems"

Calculation No. M-13, "Development of System Overlap Procedures"

Calculation No. M-14, "Stiffness Approximation for Typical Cable Tray Hangers"

Calculation No. M-28, "Justification of Clip Modelling Procedures"

Calculation No. M-12, "Qualification Procedures for Cable Tray Support Evaluation"

Calculation No. M-04, "Base Angle Stiffness"

Calculation No. M-10, "Cable Tray-Clip Angle Stiffness"

4.2 Testing

4.2.1 Description

The testing program was not evaluated in detail during this audit but test results were evaluated as a comparison to analysis results and as justification for assumptions used in analysis. Dynamic testing of cable tray systems was performed by ANCO Engineers, Inc. while static testing of trays, tray fittings, clamps and splice plates was performed by Corporate Consulting and Development Company, Ltd. (CCL). Cyclic testing of clamps was also performed by CCL.

In the ANCO test series, five configurations of cable tray support systems including five supports and one configuration including three supports were tested. Each of the six configurations had at least one longitudinal support and used support spacings of 6-7 feet. Two of the tests were conducted with construction deficiencies such as bolt undercut welds, oversize holes, clamp gaps, out-of-plumbness, and small bolt hole edge distance. Each test configuration was run for various tray fills up to 100%. Each fill level was tested for various seismic excitations, i.e., 0.5 OBE, 1.0 OBE, 1 SSE, was acceptable. In addition, the tests provided additional confidence that:

a) Linear analysis methods did provide conservative estimates of cable tray response.

b) Connectivity exists between the tray and the support.

c) Construction deficiencies such as gaps, oversize holes, out-of-plumbness, etc., have no significant effect on system response.

d) Buckling does not occur even with very large Kl/r.

Impell in their correlation study modeled all the test configurations for SUPERPIPE analysis. The seismic input was the average of the ANCO individual seismic response measurements. Correlations were performed for modal response, acceleration and displacement. It was observed that the predicted accelerations and displacements for both supports and tray were conservative when compared to test results and that the predicted and measured modal responses were in good agreement.

It was found in the tests that the damping factors depended on the seismic excitation level and on tray fill. Damping factors were found to be directly related to excitation level, i.e., higher excitation level resulted in higher damping. The damping factors were found to be highest for 50% fill, while 0 and 100% fill resulted in the least damping. All damping factors were found to be higher than 4% and 7% used in analysis.

Findings

None.

The assumptions used in the Impell RSM analysis, especially the damping values, are corroborated by the ANCO tests. The following additional information was requested:

a) Using the SUPERPIPE analysis for Test 7, provide stress results for one of the supports.

4.2.1 References

The following documents were reviewed for the evaluation of analysis assumptions based on test results:

Impell/ANCO Test Report No. 09-0210-0017, "CPSES Cable Tray System Analysis/Test Correlations"

Impell Report No. 09-0210-0138, "System Comparison of Analysis Results and Measurements for Test Configuration"

4.3 Acceptance Criteria

4.3.1 Description

The following topics were reviewed in order to evaluate the adequacy of the pertinent acceptance criteria used in each case:

a) structural members and welds

b) anchorages, including bolts, inserts, base plates, base angles, prying action factors
c) slenderness ratio, twist buckling, warping stresses
d) trays, tray fittings, clamps

4.3.2 Evaluation

In the audit of acceptance criteria, Impell personnel responsible for specific areas of design validation presented the methodology, procedures, supporting studies, and test results on which the acceptance criteria are based.

All loads used for design validation are obtained from the system analysis performed by SUPERPIPE. Structural members and welds are automatically analyzed by SUPERPOST for the following loadings: DW+OBE, DW-OBE, DW+SSE, and DW-SSE. The acceptance criteria are in accordance with the AISC Code, 7th Edition, except as modified by project commitments, i.e., load factors for OBE and SSE, and limitation on allowable yield and shear stress.

Detailed procedures are provided for design validation of anchorages including the use of prying action factors. Allowables for attachment bolts and inserts are based on test data and appropriate factors of safety.

Allowable forces and moments for trays, fittings and clamps are established based on the CCL test results and on analysis.

Detailed instructions are provided for checking permissible slenderness ratio and for evaluation of warping induced stresses.

4.3.3 Findings

None

The Impell acceptance criteria for design validation of cable trays and supports were found to be adequate and in conformance with project commitments and applicable codes.

4.3.4 References

The following Impell documents were reviewed for the evaluation of the acceptance criteria:

Project Instruction PI-03, "Design Verification of Cable Tray Supports"

Project Instruction PI-06, "Design Verification of Cable Trays and Clamps"

Project Instruciton PI-07, "Design Verification of Base Plates, Base Angles and Embedment Plates"

Calculation No. M-15, "Base Plate & Base Angle Interaction Diagram Generation"

Calculation No. M-12, "Qualification Procedures for Cable Tray Support Evaluation"

Calculation No. M-22, "Automated Support Evaluation Program 'SUPERPOST' Specification"

Calculation No. M-25, "Base Plate Prying Action Factors"

Calculation No. M-34, "Straight Cable Tray Moment Allowables"

Calculation No. M-36, Cable Tray Allowables for Tee and Cross"

Calculation No. M-52, "Cable Tray Torsional Moment Allowables"

Appendix A
List of Persons Contacted

March 30, 1988 - Ebasco (New York, NY)

Open Items for HVAC Cable Tray and Conduit Supports

Name	Affiliation
John Finneran	TU Electric
B. S. Dacko	TU Electric
Scott Harrison	TU Electric
Frank Hettinger	Ebasco
Manoon Chuaprasert	Ebasco
C. Y. Chiou	Ebasco
Rene Alexandru	Ebasco
Joe Padalino	Ebasco
K. T. Wu	Ebasco
W. Chao	Ebasco
H. S. Yu	Ebasco
P. Harrison	Ebasco
S. J. Chen	Ebasco
M. Khan	Ebasco

March 31, 1988 - Ebasco (New York, NY)

Root Causes of Design Issues

Name	Affiliation
J. C. Finneran	TU Electric
J. E. Krechting	TU Electric
Scott Harrison	TU Electric
B. S. Dacko	TU Electric
Rene Alexandru	Ebasco
Frank Hettinger	Ebasco
C. Y. Chiou	Ebasco
W. Chao	Ebasco

April 18-21, 1988 - Impell (Glen Rose, TX)

Impell Design Criteria and Methodologies

Organization/Name	Title
TU Electric	
J. W. Muffett	Manager of Civil Engineering
J. Finneran	CPE Manager
S. Harrison	Support Engineering Supervisor
J. Nandi	TU Electric
B. Dacko	Licensing
Impell	
G. Ashley	Project Manager
H. Rains	Supervising Engineer
R. Kaczkowski	Supervising Engineer
S. Abuyounes	
J. Ramuta	
Ebasco	
F. Hettinger	Supervising Engineer
P. Harrison	Senior Engineer
S. J. Chen	Supervising Engineer
R. Chen	Project Engineer

Root Cause Assessment

Organization/Name	Title
TU Electric	
J. W. Muffett	Manager of Civil Engineering
S. Harrison	Support Engineering Supervisor
Ebasco	
R. C. Iotti	Vice President
E. Odar	Project Manager
Impell	
G. Ashley	Project Manager

Root Cause Inspection April 19-April 23, 1988

Persons Contacted

Bob Iotti	Ebasco
Ram Shetty	Ebasco
Pat Harrison	Ebasco
Enver Odar	Ebasco
John Aaen	Ebasco
Mike Ryan	Ebasco
Scott Harrison	TU Electric
Bob Dacko	TU Electric
Dick Kissinger	TU Electric
Pravin Patel	TU Electric
Bill Williams	TU Electric
Harold Crockett	TU Electric
George Biandis	TU Electric
Greg Ashley	Impell

Appendix B

Status of Previous Design Audit Items (HVAC)

Status Of Previous Design Audit Items (HVAC)

a. HVAC As-Built Verification Program Audit, August 12-14, 1987

(1) HVAC/Commodity Clearance Issue

Ebasco has provided the inspection team with the SWEC-issued walkdown procedure CPE-SWEC-FVM-CS-068 for review; however, Ebasco did not know if the effort has been started at the site. Ebasco has not yet received any requests from SWEC pertaining to any conflicts as yet. Ebasco advised that SWEC will be the lead for the entire effort and is responsible for the resolution of any conflicts. The inspection team was advised that TUEC has also established procedures for the interface of the various disciplines and SWEC. A request for these procedures pertinent to HVAC was made.

Findings: The team will continue its evaluation of this issue. This issue is still open.

(2) Mistagging of Duct Hanger DH-1-2N-1EC and Mislabeling of Duct Segments B-1-758-203 and B-1-758-205

Ebasco has stated that this has been resolved. Ebasco will provide a copy of the close-out documentation.

Findings: Issue closed upon review and acceptance of documentation.

b. HVAC (APES) As-Built Verification Program Audit, September 8-11, 1987

(1) UT Instrument Used By the Q.C. Inspection Group For Measuring Duct Thicknesses Deemed Inadequate For Thin Gage Use

Ebasco has provided a resolution of this finding in the form of a closed-out NCR-87-10260 that requires the use of the StressTel T-3000 UT Instrument.

Findings: This issue is closed.

(2) Subcontractor Interface Procedures

Ebasco has advised that there are procedures for the interface control and that the audit team has been supplied with the procedures.

Findings: The audit team will review the procedures and evaluate the implementation during the upcoming implementation audit. This issue is still open.

(3) Missing Bolts In Stacked Air Filter Assemblies (Attached To Intake Plenum "A"

Ebasco has advised that the bolts have been installed. Ebasco will provide a copy of the closed-out DCA or NCR from Impell.

Findings: This issue will be closed upon review of documentation by the audit team.

c. Generic Technical Issues Audit, September 15, 1987

(1) Issue A-3 - Attachment of Transverse Supports to Ducts Issues Such As Bending Effects In Bridge Welds and Local Sheet Metal Failure

In accordance with the latest revision of SAG.CP24, bridge welds are no longer considered as structural elements. The duct-to-support fillet welds are designed to AWS criteria with acceptance based on the strength of both the weld and the duct sheet metal whichever is controlling.

Findings: Issue closed contingent upon audit team review of latest revision of SAG.CP24 to be supplied by Ebasco.

(2) Issue A-4 - Integrity of Duct Joints Under Tension

The duct testing program by CCL has been completed and the structural integrity of the joints under tension demonstrated. The Ebasco Duct Test Correlation Report (Volume 1, Book 18) presents the results of the test.

The correlation report, however, does not address the question of leak tightness. Ebasco will provide a section evaluating pressure leakage and acceptance criteria.

Findings: This issue is still open pending completion of evaluation of the question of leakage.

(3) Issue A.5 - Effects of Opening in Ducts

The Ebasco Duct Test Correlation Report presents the results of the testing for duct openings and branch connections. The testing has demonstrated that the typical openings will not impact the current duct design acceptance criteria. However, a reduction in the allowable stress level at branch connections is required. This reduction has been incorporated in SAG.CP24.

Findings: The audit team is currently reviewing the Duct Test Correlation Report. In addition, a request for the latest revision of SAG.CP24 has been made for review. This issue is still open.

(4) Issue A.14 - Richmond Inserts With Less Than Minimum Required Thread Engagement and Pretensioning

SWEC has conducted an evaluation of this issue and recommended a procedure for the evaluation of this condition that will be included in the next revision of SAG.CP24. The SWEC position of the issue is contained in DBD-CS-015, The Qualification of Embedments in Concrete. Ebasco has provided the audit team with the SWEC documentation for review.

Findings: The audit team is currently continuing its review of the provided documentation. The team will also review the revised SAG.CP24 when available. This issue is still open.

(5) Issue A.16 - No Inspection Documentation Located For Selected Sample for Bahnson

This issue is eliminated by the as-builting program by Ebasco that has resulted in a complete set of as-built drawings of the HVAC supports, ducts and equipment and their attributes. The remaining open item concerned the inspection of coated welds. Ebasco has stated that the current inspection procedures provide for the removal of all weld coating before inspection of existing welds.

Findings: Ebasco has provided the latest revision of the inspection criteria for the "As-Built" inspection. The audit team has verified the instructions to remove the coating for inspection of previously coated welds in both the NQI-3.09-M-006 and CHV-106 procedures. This issue is considered closed.

(6) Issue A.19 - Bahnson Square Groove Welds In Ducts

A sample of typical square groove welds were removed from the field and tested. The results of the test are contained in the Duct Test Correlation Report.

Findings: The audit team has reviewed the test results as reported and agrees with the finding that the welds are acceptable. This issue is closed.

(7) Issue B.10 - Deviations From SMACNA and ERDA Specifications for Duct Work

The reference to ERDA Specifications have been removed from the MS-85 specification. Ebasco has stated that the ducts meet all the requirements of the SMACNA Specifications. For those duct attributes and concerns not addressed specifically in the SMACNA Code, the duct qualification is predicated on the CCL Duct Test Program which is presented in the Duct Test Correlation Report by Ebasco.

Findings: This issue is open pending completion of a review of the SMACNA Specifications and Correlation Report by the audit team.

(8) Issue B.13 - Measurement Of Embedment From Top Of Concrete Topping

The question of the integrity of the topping material to complete the anchor system has not been completed. Ebasco will investigate the topping for compressive continuity.

Findings: This issue is open pending completion of the study of the topping.

(9) Issue B.14 - Bolt Hole Tolerance and Edge Distance Violations

Bolt hole tolerances and minimum edge distance requirements do not meet AISC specification. Ebasco has indicated that this issue is addressed by a study.

Findings: This issue is open pending a review of the Ebasco study.

(10) Issue B.28 - Nonconformance With AISC Specification

Differences between the HVAC criteria and codes and standards are addressed in a letter from W. Counsil to USNRC dated December 15, 1987.

Findings: This issue is still open pending completion of the team review of the letter.

(11) Issue B.33 - FSAR Load Combinations

Ebasco has provided the requested Thermal Load Study for HVAC Duct System No. 200 (Volume 1, Book 14) which presents justification for neglecting the thermal load on the ducts. The results of the report demonstrate that the thermal expansion loads on the ducts are not significant.

Findings: Following a review of the study, the audit team agrees with the conclusions that the thermal loads will not be significant. This issue is closed.