COMANCHE PEAK RESPONSE TEAM

RESULTS REPORT

ISAP: I.b.3

Title: Conduit to Cable Tray Separation

REVISION 1

Robert J. Bigger — Issue Coordinator — March 20, 1986 — Date

John J. Mallanda — Review Team Leader — 3/20/86 — Date

John W. Beck — John W. Beck, Chairman CPRT-SRT — 3/26/86 — Date

RESULTS REPORT

ISAP I.b.3

Conduit to Cable Tray Separation

1.0 DESCRIPTION OF ISSUE IDENTIFIED BY NRC (NUREG-0797, Supplement No. 7, Page J-42)

"The TRT found no evidence that the existing G&H analysis for establishing the criteria for a 1-inch separation between rigid conduits and cable trays, as stated in G&H Electrical Erection Specification 2323-ES-100, had been evaluated by the NRC staff for Comanche Peak. This analysis should have been referenced in the FSAR."

2.0 ACTION IDENTIFIED BY NRC (NUREG 0797, Supplement No. 7, Item 6(e), Page J-44)

"TUEC shall accomplish the following actions prior to fuel load: Submit to the NRC the analysis substantiating the acceptability of the criteria stated in G&H electrical erection specification governing the separation between separate conduits and cable trays. This analysis shall be supported with the necessary documentation in sufficient detail to perform an independent evaluation of how these criteria were established based on the analysis."

3.0 BACKGROUND

Raceway separation criteria utilized in Gibbs & Hill electrical drawings and specifications were based upon the requirements of IEEE 384-1974, "IEEE Trial-Use Standard Criteria for Separation of Class 1E Equipment and Circuits", and Regulatory Guide 1.75, Revision 1, January 1975, "Physical Independence of Electric Systems". Although very specific criteria are provided in the standard and regulatory guide for separation between redundant* cable trays, the same degree of specificity is not provided for separation between conduits and cable trays.

---

* All separation requirements in this report are for redundant cable trays and/or conduits. The word "redundant" as used herein means that the cable trays and/or conduits requiring separation belong to different trains, i.e., Class 1E train A, Class 1E train B, or non-Class 1E train C. Note that cable trays and/or conduits of the same train require no separation.

RESULTS REPORT

ISAP I.b.3
(Cont'd)

3.0 BACKGROUND (Cont'd)

Since Regulatory Guide 1.75, Revision 1, January 1975, and IEEE 384-1974 do not specifically provide criteria for conduit-to-cable tray separation, Gibbs & Hill originally interpreted these documents to require a one-inch minimum separation between a safety-related conduit and an open cable tray when the conduit is below the top of the side rails of the cable tray. This interpretation was included in a Gibbs & Hill document entitled "Criteria for Separation of Class 1E Equipment and Circuits". This document was transmitted to the TUGCO project for their information and use via letter GTN-2441, dated February 19, 1975. The above criterion, along with separation requirements for safety-related conduits above cable trays, was added to Electrical Erection Specification 2323-ES-100 in the form of Design Change Authorization (DCA) 6132, dated November 16, 1979. This DCA also included all separation criteria for non-safety related conduit.

Specification 2323-ES-100, Revision 2, dated January 1981, which incorporates DCA-6132, states in Section 4.11.1 that the Engineering drawings showing the plant layout utilized the separation criteria transmitted via Gibbs & Hill letter GTN-2441. The separation criteria, as stated in 2323-ES-100, are to provide "the necessary information for assisting the contractor in field routing the conduit . . . ."

During the Gibbs & Hill review of DCA-15917, which authorized a reduction in the separation criterion for a conduit above an enclosed raceway from four inches to one inch, the adequacy of the existing one-inch separation criterion for safety-related conduits and open cable trays was questioned. This issue was resolved by Gibbs & Hill memo EE-863, dated January 17, 1984, which included the Gibbs & Hill report and simplified analysis that the NRC-TRT reviewed on site (See Section 1.0). The purpose of the memo was to establish the engineering interpretation of required separation between conduits and cable trays in accordance with established criteria in the standard and regulatory guide. This supporting documentation was not submitted to the NRC staff for review because the interpretation was not considered a deviation to the standard or regulatory guide, but was considered documentation supporting the implementation of these requirements.

RESULTS REPORT

ISAP I.b.3
(Cont'd)

4.0 CPRT ACTION PLAN

4.1 Scope and Methodology

The objective of this action plan was to substantiate the acceptability of the criteria governing the separation between conduits and cable trays and to submit the evaluation and supporting documentation to the NRC.

To achieve this objective, the following tasks were implemented:

- Gibbs & Hill prepared a report compiling criteria and supporting analyses
- The Electrical Review Team reviewed the report substantiating the separation criteria
- The TUGCO Coordinator initiated the submittal of the report to the NRC

4.1.1 Report Preparation

Gibbs & Hill prepared a report for TUGCO presenting the methodology and criteria used in applying IEEE 384-1974 and Regulatory Guide 1.75, Revision 1, January 1975, to conduits requiring separation from cable trays. Included was a copy of a Sandia Report ("Cable Tray Fire Tests", SAND 77-1125C), which documents a series of tests funded "by the Nuclear Regulatory Commission to provide data needed for confirmation of the suitability of current design standards and regulatory guides for fire protection and control in water (cooled) reactor power plants".

4.1.2 Report Review

The above report was submitted to the Electrical Review Team for review.

4.1.3 Report Submittal to NRC

The TUGCO Coordinator submitted an FSAR Change Request to TUGCO Nuclear Engineering for submittal to the NRC for review. The FSAR Change Request provides a description of the existing conduit-to-cable tray separation criteria. Supporting documents are attached to the FSAR Change Request.

RESULTS REPORT

ISAP I.b.3
(Cont'd)

4.0 CPRT ACTION PLAN (Cont'd)

4.2 Participants Roles and Responsibilities

The organizations and personnel that participated in this effort are described below with their respective work scope.

4.2.1 TUGCO Comanche Peak Project

4.2.1.1 Assisted the Electrical Review Team in reviewing the report compiling the Gibbs & Hill criteria.

4.2.1.2 Will submit, upon approval, the FSAR Change Request and supporting documents to the NRC.

4.2.1.3 Personnel

Mr. W. I. Vogelsang, TUGCO Coordinator

4.2.2 Electrical Review Team

4.2.2.1 Reviewed the report compiling the Gibbs & Hill criteria.

4.2.2.2 Personnel (prior to October 18, 1985)

Mr. M. B. Jones, Jr., Review Team Leader

Mr. E. P. Stroupe, Issue Coordinator

4.2.2.3 Personnel (starting October 18, 1985)

Mr. J. J. Mallanda, Review Team Leader

Mr. R. J. Bizzak, Issue Coordinator

Mr. M. B. Jones, Jr., Third-Party Adviser

Mr. E. P. Stroupe, Third-Party Adviser

4.2.3 Gibbs & Hill

4.2.3.1 Prepared a report compiling the criteria used in confirming the adequacy of conduit-to-cable tray separation.

RESULTS REPORT

ISAP I.b.3
(Cont'd)

4.0 CPRT ACTION PLAN (Cont'd)

4.2.3.2 Personnel

Mr. S. P. Martinovich, Principal Engineer-Electrical

4.2.4 Third-Party Adviser (prior to October 18, 1985)

4.2.4.1 Reviewed the report compiling the Gibbs & Hill criteria.

4.2.4.2 Personnel

Mr. L. D. Bates, Third-Party Adviser

4.3 Qualification of Personnel

Third-party participants in the implementation of this action plan met the personnel qualification and objectivity requirements of the CPRT Program Plan and its implementing procedures.

Other participants were qualified to the requirements of the CPSES Quality Assurance Program or to the specific requirements of the CPRT Program Plan. Activities performed by other than third-party personnel were governed by the applicable principles of Section III.K, "Assurance of CPRT Program Quality", of the CPRT Program Plan.

4.4 Procedures

Not applicable.

4.5 Acceptance Criteria

The acceptance criterion for the report was that it demonstrate that the conduit-to-cable tray separation criteria meet the intent of IEEE 384-1974 and Regulatory Guide 1.75, Revision 1, January 1975. This was met as discussed in Section 5.0.

4.6 Decision Criteria

If compliance with IEEE 384-1974 and Regulatory Guide 1.75, Revision 1, January 1975 could not be adequately demonstrated, the conduits and cable trays would have to be modified, as appropriate, to achieve compliance. This was not necessary as discussed in Section 5.0.

RESULTS REPORT

ISAP I.b.3
(Cont'd)

5.0 IMPLEMENTATION OF ACTION PLAN AND DISCUSSION OF RESULTS

5.1 Summary

A report based on the information contained in Gibbs & Hill memo EE-863 was prepared by Gibbs and Hill. This report addressed those separation distances between a conduit and an open cable tray which did not meet the criteria given in IEEE 384-1974 for open cable trays. The primary reference used to substantiate the conduit-to-cable tray separation criteria was a Sandia report documenting a series of electrically initiated cable tray fires. One case which is not directly evaluated in the Sandia report is the case of a safety related conduit one inch beside or below an open cable tray. The justification presented in the Gibbs & Hill report for the one inch separation case mentioned above was a simplified analysis from EE-863 which utilized cold wall heat flux values from the Sandia report.

The above Gibbs & Hill report, originally issued in September 1984, was reviewed by the Electrical Review Team during the late 1984/early 1985 time frame and revised several times to incorporate comments. Subsequent to the above review cycle, questions remained on the simplified analysis presented in the report. To alleviate these concerns, Gibbs & Hill performed computer analyses in the summer of 1985, using an alternate methodology, to substantiate the simplified analyses. Although the computer analyses were in agreement with the results of the simplified analysis, a subsequent review of the report and analyses in the last quarter of 1985 by the Electrical Review Team identified inconsistent assumptions in the simplified analysis which required subsequent justifications. A final report utilizing a revised computer analysis was completed and issued to TUGCO by Gibbs & Hill.

The final report and analyses have been reviewed by the Electrical Review Team Leader and Issue Coordinator. The conclusion is that the above documents provide adequate justification of the existing conduit-to-cable tray separation; therefore, no plant modifications are required. A summary of the report is given in the following section.

5.2 Conduit/Cable Tray Separation Criteria

The separation criteria in Gibbs & Hill Electrical Erection Specification 2323-ES-100 are graphically presented on Drawing 2323-E1-1702-02, Revision 2, "Cable and Raceway Separation Typical Details".

RESULTS REPORT

ISAP I.b.3
(Cont'd)

5.0 IMPLEMENTATION OF ACTION PLAN AND DISCUSSION OF RESULTS (Cont'd)

The separation criteria shown on Gibbs & Hill Drawing 2323-E1-1702-02 apply only when hazards are limited to electrically-initiated fires due to failures or faults internal to electrical equipment or raceways. This is consistent with the definitions given in IEEE 384-1974 for the cable spreading area and general plant areas.

The criteria given in IEEE 384-1974 for separation of redundant cable trays for the above areas are:

Cable Spreading Area - Both cable trays are open ventilated trays.	1 foot horizontally 3 feet vertically
General Plant Areas - Both cable trays are open ventilated trays.	3 feet horizontally 5 feet vertically
Cable Spreading Area and General Plant Areas - Both cable trays are enclosed.	1 inch horizontally 1 inch vertically

The IEEE standard also allows the separation distances to be alternatively established by analyses/testing "to determine the flame retardant characteristics of the proposed cable installation, . . ."

Although the above specific criteria for redundant, open cable trays are provided in IEEE 384-1974 and Regulatory Guide 1.75, Revision 1, January 1975, the same degree of specificity is not provided for separation between conduits and cable trays. However, the above separation distances for open cable trays could be reduced when one train of circuits is in conduit since a barrier* now exists between the two redundant trains.

The current CPSES conduit-to-cable tray separation criteria are depicted in Details 45 thru 49, 52 thru 55, and 57 of Drawing 2323-E1-1702-02. A summary of these criteria follows:

* The IEEE 384-1974 definition of a barrier is "a device or structure interposed between Class 1E equipment or circuits and a potential source of damage to limit damage to Class 1E systems to an acceptable level."

RESULTS REPORT

ISAP I.b.3
(Cont'd)

5.0 IMPLEMENTATION OF ACTION PLAN AND DISCUSSION OF RESULTS (Cont'd)

Cable Spreading Area	1 foot horizontally 2 feet vertically	When conduit elevation* is above the top of the cable tray side rails or when the cable tray is vertical.
General Plant Area	3 feet horizontally 3 feet vertically	When conduit elevation* is above the top of the cable tray side rails or when the cable tray is vertical.
Cable Spreading Area and General Plant Areas	1 inch horizontally 1 inch vertically	When conduit elevation* is below the top of the cable tray side rails (cable tray horizontal), conduit is non-safety related, or cable tray is enclosed.

In comparing the conduit-to-cable tray separation criteria given above to the criteria provided in IEEE 384-1974 for open cable trays, the following three categories of differences are noted:

Category 1 - Non-Safety Related Conduit

Separation between conduit and cable tray is one inch when conduit is non-safety-related.

Category 2 - Safety-Related Conduit Above Cable Trays

Vertical distances are 2 feet/3 feet for safety-related conduits over open cable trays in the cable spreading/general plant areas, respectively.

Category 3 - Safety-Related Conduit Below the Top of the Cable Tray Side Rails

Separation between conduit and cable tray is one inch when conduit elevation is below the top of the cable tray side rails.

---

* Conduit elevation is top of conduit.

RESULTS REPORT

ISAP I.b.3
(Cont'd)

5.0 IMPLEMENTATION OF ACTION PLAN AND DISCUSSION OF RESULTS (Cont'd)

Category 1 - Non-Safety-Related Conduit

The CPSES minimum separation for non-safety-related conduits adjacent to safety-related cable trays is one inch, regardless of orientation. The non-Class 1E circuits in the conduit do not have to be protected from a cable fire in the cable tray since the non-Class 1E circuits do not provide a safety function. However, the Class 1E cables in the cable tray do have to be protected from a fire in the conduit. The conduit in combination with a one inch air space will provide adequate protection to the safety-related cable tray. This configuration is similar to Figure 5 of IEEE 384-1974.

It should be noted that a fire in a conduit represents a less severe source of damage than a fire in an enclosed cable tray since:

- Conduit size is limited to five inches thus limiting the volume of cables contained.

- Threaded connections provide an essentially air-tight medium which inhibits internal combustion and effectively isolates internal events from the surroundings.

- The curved surface of the conduit provides a radial distribution of radiant heat and, therefore, less favorable heat transfer characteristics to or from an adjacent cable tray than a flat surface of equivalent area.

Category 2 - Safety-Related Conduit Above Cable Trays

The basis for the adequacy of vertical separations given in this category is electrically initiated fire tests conducted by Sandia Laboratories and presented in Report SAND77-1125C, "Cable Tray Fire Tests." One of the objectives of these tests was to use cables representative of those used in the nuclear industry. An industry survey of 13 leading architect-engineering firms, 13 utility companies, and 13 cable manufacturers was performed. Twenty (20) different cable types were screened on the basis of popularity of use, small scale electrically initiated cable insulation fire tests, UL FR-1 flame test, and pyrolyzer and thermal chromatograph testing (which measured insulation outgassing as a function of temperature). The cable constructions tested are

RESULTS REPORT

ISAP I.b.3
(Cont'd)

5.0 IMPLEMENTATION OF ACTION PLAN AND DISCUSSION OF RESULTS (Cont'd)

representative of those used at CPSES. The cables used at CPSES comply with IEEE 383-1974, "Standard for Type Test of Class 1E Electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations". The cables used in the Sandia tests "were capable of passing IEEE Standard 383-74". Therefore, the Class 1E cables at CPSES and the cables used in the Sandia tests have similar flame-retardant characteristics.

The Sandia testing showed that, for an electrically initiated cable tray fire, cables in an open tray located 10.5 inches vertically above the tray with the fire did not burn. All circuits in the cables above the fire remained functional. As noted above, the CPSES criteria for safety-related conduits located above cable trays is a minimum of two feet. It should be emphasized that the Sandia tests were performed using exposed cable; therefore, the CPSES criteria are even more conservative since the cables at CPSES are enclosed in a barrier.

Some of the more significant observations of the nature of electrically initiated fires noted in the Sandia Report are:

- The fire characteristics do not vary greatly from one cable fire to another.

- The intense period of the fire at a particular location lasts between 40 and 240 seconds before die-out begins to occur.

- The luminous zone of the fire is optically thin which means that the major heat transfer mechanism is convection versus radiation.

Based on the above, given a specified separation, the worst configuration is conduit over the cable tray since the conduit will be exposed to both convective as well as radiation heat transfer. Since the exposed cable 10.5 inches above the fire remained functional, any cable enclosed in a conduit (which provides additional heat protection for the cable) 10.5 inches or more from an electrically initiated fire will also remain functional.

RESULTS REPORT

ISAP I.b.3
(Cont'd)

5.0 IMPLEMENTATION OF ACTION PLAN AND DISCUSSION OF RESULTS (Cont'd)

Category 3 - Safety-Related Conduit Below the Top of the Cable Tray Side Rails

The only case where a safety-related conduit at CPSES can be less than 10.5 inches from an open cable tray is when the conduit elevation is below the top of the cable tray side rails. The major heat transfer mechanism for this configuration is radiation. Based on the above noted characteristic of the Sandia test fires (i.e. the luminous zone of the fire is optically thin), radiation is a minor part of the heat transferred from the fire to objects immersed in the flame.

In order to quantify the response of a conduit beside or below a cable tray, a computer analysis was performed by Gibbs & Hill for the case of a conduit one inch directly below the fire. (Note that conduits alongside cable trays are partially blocked from the radiation from the flame by the cable tray side rails.) Cable fire parameters taken from the Sandia Report were used as inputs to this analysis.

The above analysis included the following conservatisms:

- The fire data used in the analysis was for the October 5, 1976, fire test, one of the most intense and longest duration fires studied.

- The radiation heat flux applied to the conduit was taken just slightly above the burning tray (i.e., in the flame) rather than one inch away from the flame.

- The radiation heat flux, based on the maximum flame temperature, was held constant from 30 seconds to 240 seconds. The test data showed that temperatures measured by a thermocouple in the flame varied from 1150°F to 700°F during this period.

- The flame diameter was held constant at eight inches.

- No blockage was assumed by other cables in the cable tray with the fire.

- The cable enclosed in the conduit was assumed to be at the same temperature as the conduit. No credit was taken for the cable acting as a heat sink.

RESULTS REPORT

ISAP I.b.3
(Cont'd)

5.0 IMPLEMENTATION OF ACTION PLAN AND DISCUSSION OF RESULTS (Cont'd)

The results of the analysis showed that the conduit exceeded 302°F (150°C) for approximately 4-1/4 minutes with a maximum temperature of 357°F (181°C), assuming an ambient temperature of 122°F (50°C).

The Electrical Review Team reviewed the manufacturers' data for the cables used at CPSES. All cables are qualified for 302°F (150°C) for a minimum period of one week. Additionally, the cables with silicone insulation were tested at a minimum temperature of 392°F (200°C) for seven days and remained functional. Anaconda FR-EP cables were qualified for a LOCA environment by testing at 385°F (196°C) for two twelve-minute periods. The remaining cables were LOCA tested at a minimum of 345°F (174°C) for a minimum of four hours. The cables subjected to the above tests to simulate LOCA environmental conditions remained functional.

Additional evidence which supports the adequacy of CPSES conduit separation one inch below cable trays is provided in the results of the propane-fueled exposure fire tests also conducted by Sandia in which conduits and trays were included. In these tests, fourteen (14) trays were stacked seven (7) high by two (2) wide separated vertically 10.5 inches. Directly below each tray (except for the bottom tray exposed to the propane-fueled source) was a conduit containing additional cables. Although all circuits in the conduits above the third tray failed during the exposure fire (the higher conduits experiencing heat input from all fires below them), circuits in the lower two (2) conduits maintained circuit integrity throughout the duration of the fire.

Considering that the fire in the lower two (2) trays was more severe than in an electrically initiated fire, being larger in size and of longer duration, the results provide an indication of the adequacy of protection offered by conduits installed with an air gap of one inch during the less severe electrical fire.

5.3 FSAR Change Request Submittal

The TUGCO Coordinator submitted an FSAR Change Request to TUGCO Nuclear Engineering for submittal to the NRC for review. The FSAR Change Request provides a description of the existing conduit-to-cable tray separation criteria. Supporting documents were attached to the FSAR Change Request.

RESULTS REPORT

ISAP I.b.3
(Cont'd)

5.0 IMPLEMENTATION OF ACTION PLAN AND DISCUSSION OF RESULTS (Cont'd)

5.4 Classification and Evaluation of Discrepancies

No design deviations were noted in the implementation of this action plan. However, two design observations were noted. The first observation was that analyses did not exist at the time that the criteria for conduit-to-cable tray separation were placed in design and construction documents. The basis for the criteria appeared to have been engineering judgment based on experience with other nuclear projects. The second observation was that inconsistent assumptions used in the Gibbs & Hill simplified analysis verifying the one-inch separation criteria were not discovered during the design verification process.

Since no deviations were found, no root cause analysis was performed. The observations were too few in number and too limited in scope to identify a trend. Therefore, the facts relating to these observations were transmitted to the Design Adequacy Review Team Leader in accordance with Appendix A, "Design Adequacy Program Plan", to be included in the collective evaluations of that plan.

6.0 CONCLUSIONS

The established conduit-to-cable tray separation criteria meet the intent of IEEE 384-1974 and Regulatory Guide 1.75, Revision 1, January 1975. No corrective actions are required.

7.0 ONGOING ACTIVITIES

The FSAR Change Request and supporting documents have been issued to TUGCO Nuclear Engineering (TNE) by the TUGCO Coordinator. TNE will transmit the information to TUGCO Licensing, which is the formal channel for submitting information to the NRC.

The design observations noted in Section 5.4 were forwarded to the DAP RTL in accordance with Appendix A, "Design Adequacy Program Plan", to be included in the collective evaluations of that plan.

8.0 ACTION TO PRECLUDE OCCURRENCE IN THE FUTURE

Since no design deviations were found, no corrective actions were required.