Engineering Basis for Structural Integrity of Raceway Supports Associated With One Hour Rated Cable Protective Envelope Systems Upon Exposure to Fire

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It is the position of CPSES that cable tray structural supports used on cable trays with one hour fire rated protective envelopes, (1) will not be exposed to fires of sufficient duration and temperatures to cause failure of the support, and (2) because of the seismic spacing and load carrying ability of the supports, even a failure of a support can be tolerated without loss of the essential cables.

The basis for the one hour rating of the protective cable envelope systems is to meet the NRC requirements as clarified by comments to 10CFR50, Appendix R, "...the activation of an automatic...suppression system does not occur until sufficient...heat has been developed by the fire. Therefore, the commission is requiring a one (1) hour barrier to ensure that the fire damage will be limited to one train until the fire is extinguished."[1] This one hour barrier is designed to provide interim protection of cables until suppression systems can bring the fire under control.

CPSES accepts this NRC position for cables since the failure mode of cable (insulation degradation with resultant grounds) can occur very rapidly, especially in the presence of even relatively small quantities of transient combustibles. It is concievable that such failures could occur prior to initiation of automatic suppression and thus it is prudent to protect cables until suppression systems are actuated. Cable tray structural supports, however, do not have the same failure mode and, for a given fire, require a much longer duration and higher temperatures to fail than do the unprotected cables. Thus what may be reasonable and prudent for protection of cables is not necessarily reasonable and prudent for the cable tray structural supports.

Three aspects of the Comanche Peak (SES) plant design ensure that structural integrity will be maintained during and after a fire; (1) the fire detection and automatic water suppression system, (2) the seismic support design criteria, and (3) the plant configuration.

1) Automatic water suppression and fire detection.

The water suppression system for CPSES is designed hydraulically by Grinnell Fire Protection Special Hazards to meet the requirements of NFPA 13 and NFPA 15. The area sprinkler coverage is typically installed at three separate elevations in the areas of the plant where protection is provided. Area sprinklers are installed at the ceiling level to sense heated gases of combustion, limit the spread of these gases, and control the spread of the fire in combustible materials. Area sprinklers are also installed beneath congestion (i.e., ducts, pipe) but above insitu combustibles (cable jacket, insulation) and area sprinklers are installed below all congestion to provide protection against transient combustibles. In addition to area coverage, special hazard sprinklers are installed where horizontal cable tray configurations are stacked more than three high; these sprinklers are positioned to direct water individually on each tray in these concentrated configurations. The heads are designed to actuate at temperatures of 175 to 212°F based on ambient plant operating conditions. The effectiveness of this design is illustrated by preliminary test results presented in NUREG/CR-2607, pg. 46-51.[2] The times required to sense and even extinguish IEEE/383 qualified cable fires in the Sandia tests were significantly less than one hour.

Rapid Fire detection also provides an effective manual backup to the automatic suppression systems.

It is apparent that actuation of automatic suppression will not only prevent structural support damage, but in all probability extinguish the fire.

2) Seismic design of supports.

The factors important to maintaining structural integrity in a fire include the structural support stress level and the steel temperature.[3] The cable raceway support systems at CPSES are

designed to carry load combinations that include deadweight and seismic loads based on 60% of minimum yield stress of A-36 steel.

The tray supports are typically four to six inch channel installed with approximately eight feet spacing. The seismic design requires a load carrying capability four to eight times the deadweight load of a fully loaded raceway. Thus the stress level in these supports is very low.

The temperature of the support member will be lower than the surrounding gas temperature and is a function of the ability of the steel to conduct and radiate heat away. Heat removal is in turn a function of the surface to volume ratio[4] and the cross-sectional area of the member. Because of the seismic design, CPSES supports have better heat removal capabilities than typical non-seismic supports and thus will be at a lower temperature. Also, critical temperature (maximum temperature without failure) increases with decreasing stress. Again, because of the seismic design of the supports with its resultant low stresses, a higher critical temperature is expected. Accepted critical temperatures for ASTM A36 steel in the usage anticipated at CPSES ranges from 1000^{o}F[5] to 1100^{o}F.[6]

3) Plant Configuration

The characteristics of a fire are influenced by four factors related to plant configuration: a) combustible loading (fuel/area), b) ventilation (natural or forced draft), c) compartment geometry and thermal properties of construction, and d) the combustion characteristics of the fuel (rate of heat release).[7]

To establish a point of reference, these factors will be compared to those seen in an ASTM E-119 fire. The ASTM E-119 fire was chosen because it is extremely conservative and a fire of this severity is not expected in those areas where one hour fire barriers are used.

a) The combined insitu and transient combustible loading at CPSES ranges from 250 to 90,000 Btu/ft^2 (as defined in the Fire Hazard Analysis) and typically is significantly less than that used in the E-119 fire. In the most severe case (full burnout), fire duration is less than 60 minutes and is less severe than the E-119 time-temperature curve. Full burnout is not anticipated, however, due to the presence of sprinkler protection and the effect of the other three factors that inhibit fire development compared to the E-119 fire as discussed below.

b) The ventilation system at CPSES is designed to isolate fires by use of fire dampers in the ducts at fire barriers. This design generates a ventilation controlled fire and tends to slow the heat release compared to an optimum ventilated fire.[8]

c) Compartment geometry and the thermal properties of construction. The typical E-119 furnance is designed to efficiently utilize the burned fuel, reflecting heat back into the enclosed compartment furnance space (approximately 8'x10'x9') and effectively insulate the furnance. Heat sinks consists only of the test assembly. By contrast CPSES compartments are large and have 20 ft. ceilings. The concrete surface of the ceilings and floors absorb over 80% of the incident radiant heat.[9] The installed cable trays are generally more then 6 feet from ceiling/wall corners so radiant energy reflection does not play a significant role in fire development.[10] The TSI one hour barriers used on the protected cable raceways utilizes a sublimation heat removal process and thus provides an additional heat sink. The coated raceways also act as a heat shield for portions of the structural support. The overall effect of plant geometry is the reduction of temperature by dissipation and heat removal.

d) Combustion characteristics of the fuel - The insitu combustibles are the dominant loading in areas where one hour rated protective envelopes are utilized. The CPSES plant design incorporates

features to limit the potential for and the severity of fires. Interior finish items have generally been limited to ASTM E84 valves of 25. The primary insitu combustible material is IEEE 383 qualified CPE and CSPE jacketed cables which by nature of its construction is a slow heat release material and resists progagation of flames due to the high radiant flux levels required to achieve ignition. Critical heat flux for cross linked PE is 200% higher than non IEEE-383 qualified cable.[11] This tends to localize the effects of the fire to a limited number of structural supports and reduces even these effects in severity to a level well below those experienced in an ASTM E-119 fire. Also, since the structural supports of concern are associated with cable raceways already protected with one hour rated barriers, the local insitu combustible loading is generally significantly lower than the average loading of the compartment. Combustibles enclosed in one hour barriers are not considered part of the combustible loading.

In summary, it is the CPSES position that the structural integrity of the cable raceway supports is assured in a fire environment without the need for supplemental fire resistant coatings. Integrity is assured because of the limited nature and duration of the potential fires and because of the cooling and suppression effects of automatic sprinkler systems. This position is consistant with: the Nuclear Fire Protection Group's interpretation of the 10CFR50 Appendix R requirements; the utility industry practice of not coating other similar steel supports (pipe, platforms, HVAC, etc.); and, the results of the B&B fire test of the HEMYC system where non-seismic supports (2-1/2" x 2-1/2" x 1/4") without fire resistant coating did not structurally fail in an ASTM E-119 fire.[12]

REFERENCES

1. "Fire Protection Program for Operating Nuclear Power Plants", 10CFR50, Appendix R, 76602 Federal Register, Vol. 45, No. 225, November 1980.

2. D. A. Dube, "Fire Protection Research Program for the U.S. Nuclear Regulatory Commission 1975-1981" SAND 82-0431, NUREG/CR-2607, Sandia National Laboratories, Albuquerque, N.M., April 1983.

3. D. F. Boring, J. C. Spence, W. G. Wells, Fire Protection Through Modern Building Codes, fifth edition, American Iron and Steel Institute, Washington, D.C., 1981.

4. Manual of Steel Construction, seventh edition, American Institute of Steel Construction, Inc. New York, 1970 and 1973.

5. Boring, pg. 37.

6. Fire Protection Handbook, fourteenth edition, Gordon P. McKinnon Editor, National Fire Protection Association, Boston, Mass. 1976, pg. 6-56

7. Boring, pg. 38.

8. D. A. Dube, pg. 88.

9. Mark's Standard Handbook for Mechanical Engineers, seventh edition. T. Baumeister, Editor, McGraw-Hill Book Co., New York, pg. 4-110, fig. 1, 1967.

10. Ibid, pg. 71.

11. D. A. Dube, pgs. 68-71.

12. "Fire Test for Electrical Cable Tray Protection with the HEMYC System" Fire Test Report, B&B Insulation, Inc., Houston, TX., October 21, 1981.