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ENCLOSURE

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

CABLE AMPACITY AND CABLE INSTALLATION ISSUES

TENNESSEE VALLEY AUTHORITY

SEQUOYAH NUCLEAR PLANT, UNITS 1 & 2

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1.0 INTRODUCTION

The Sequoyah Nuclear Plant cable testing program was developed by the Tennessee Valley Authority (TVA) in 1987 to address various employee concerns that were raised about the cable installation practices used at Watts Bar that may have also been a concern for Sequoyah. Following staff review of TVA's cable evaluation and testing programs at Sequoyah, the staff concluded that the cable installation was acceptable and was not a restart issue.

On July 7, 1989, significant cable damage was discovered at Watts Bar and the staff requested that TVA reevaluate the cable installation integrity at Sequoyah, in light of the cable damage discovered at Watts Bar. On March 28, 1990, TVA submitted a reevaluation of the cable installation practices at Sequoyah and claimed that previously conducted evaluations adequately addressed the cable installation issue.

On May 30, 1990, the NRC staff received an anonymous letter containing allegations that calculations used by TVA to determine the worst case cable pulls in conduits for testing were never issued or approved. On June 19-21, 1990, the NRC staff performed an on-site review of the calculations and determined that the allegation was valid.

Following the staff on-site review, a meeting was held between TVA and the staff on July 23, 1990, to discuss the justification for continued operation (JCO) at Sequoyah. On August 8, 1990, the staff issued its evaluation of the acceptability of the JCO and requested TVA to submit a corrective action plan to resolve all concerns raised by the allegation. On August 17, 1990, TVA submitted a resolution plan for a new cable test program to test cables selected based on new criteria developed following the cable damage discovered at Watts Bar. A meeting was held on October 5, 1990, to discuss the plan; based on this meeting, TVA submitted an updated resolution plan by letter dated October 23, 1990.

In addition to the concerns raised by the allegation related to cable installation, the allegation also raised questions regarding the validity of cable ampacity derating for cables in covered trays. TVA applied a 25 percent derating factor for tray covers longer than 10 feet but did not derate for tray covers up to 10 feet. The National Electrical Code (NEC) requires a 5 percent derating for tray covers longer than 6 feet.

2.0 EVALUATION

The staff and its consultants conducted an audit of documentation during the weeks of February 25, and March 11, 1991, at the Sequoyah site. During this audit, the staff reviewed calculations and documentation for the selection of the worst case conduit installation to determine cable damage from pullbys, jamming, and vertical supports. Also, some conduits were inspected to verify accuracy of input data used in the calculations. The staff also discussed the cable ampacity issue with the licensee. The following documents the staff's evaluation of these issues.

2.1 Cable Pullbys

2.1.1 Documentation Review

In order to fill a conduit with cables during initial installation and subsequent pulls, pull cords, ropes or wires were used by plant personnel. The pulling of additional cables through the conduit over the top of existing ones is called pullby. Potentially, this practice can cause damage to the existing cables from the sawing action generated by the pull cords and by the cables themselves as they are pulled over existing cables in the conduit. Usually, damage can be avoided by using an adequate amount of lubricant, by controlling pull tensions, by choosing appropriate pull cords, by controlling the distance between pull points, and by minimizing the number and angle of bends allowed in the conduit run.

The audit team reviewed TVA Calculation SQN-CSS-033, which documented the selection of the worst case cable pulls for testing to determine whether pullbys had caused cable damage. The selection was based on criteria previously reviewed and accepted by the staff and documented in a TVA letter dated August 17, 1990. The selection of the worst case cable pulls for testing was based on the following four steps:

1. A review of the Conduit and Cable routing schedule (CCRS) to determine which conduits contain Class 1E cables.

2. Examination of approximately 9500 conduits to identify those conduits with seven or more cables. This examination yielded 803 conduits that contained seven or more cables.

3. Examination of existing field sketches from prior walkdowns or scaling of design drawings to screen out conduits which were 20 feet or longer. This examination yielded 269 conduits which were 20 feet or longer.

4. Walkdowns of the top 60 conduits ranked by a new sidewall bearing pressure (SWBP) formula, which gave results far different from those identified in the July 23, 1990 meeting with TVA. A total of 93 conduits were ranked by SWBP calculations.

Assumptions for screening out conduits and calculations were reviewed by the staff and found acceptable with the exception of the CCRS which was listed as an unverified assumption. Further validation of the CCRS database by TVA was left as an open item. By letter dated June 19, 1991, TVA provided the basis for the acceptability of CCRS and removed the unverified assumption from the calculation. The staff reviewed the TVA justification and found it acceptable.

The audit team selected the following four conduits for review to verify accuracy of SWBP calculations and walkdown generated data:

1PM2136I	Top ranked for SWBP
1MC2796A	5th ranked
1PM4704A	19th ranked
1PM4454A	30th ranked

The above review confirmed the accuracy of the first three steps of the screening process but review of additional conduits was required in order to confirm the accuracy of the fourth step as indicated in Section 2.1.2 below.

Conversion of isometric information to computer input geometry data of Attachment G of the calculation was checked and validated for all conduits.

Pull card installation dates identified in Attachment F of the calculations supported the cable marks and pull groups indicated on the computer input date. Approximately 10 percent of the dates, however, were not legible on the copies available for audit.

The audit confirmed that the worst case pull groups, conduit worst case pull segment and direction of pull were in agreement with information on the computer printouts and ranking list.

The accuracy of the calculated cable pull tension was confirmed by check of isometric lengths, cable weights, conduit orientation and degrees of bend used as input to the calculation and no deviations were noted. Independent calculations were not performed by the team.

The final SWBP calculations, percent of allowable values, and relative ranking listed in Table 2 (pg 21) of the calculation were found to be correct.

2.1.2 Plant Walkdown

The objective of the team walkdown of a sample of conduits was to verify that TVA accurately recorded conduit lengths, angles of bend, and conduit sizes. Also, the team wanted to confirm that parachute cords were not used for pulling cables, that lubricant was used during pulling, and that there was no evidence of pullby damage in the sample.

In addition to the four conduits identified above (Section 2.1.1), two additional conduits (1SG266S, 2PM2140I) were also walked down to determine the presence or absence of parachute cords. All conduits and junction boxes involved in the conduit runs were opened for inspection, were inaccessible. Detailed observations were noted on of the conduit runs, and the team confirmed:

1. Accuracy of conduit lengths and of angles of bend.

2. Absence of parachute cord. Many conduits contained 3/8" mann. which is less abrasive than parachute cord.

3. Accuracy of conduit sizes.

4. Evidence of pulling lubricants, sometimes in rather excessive quantity.

5. No evidence of abrasive grooving pullby damage.

In conduit 1PM2136I, the cables in junction boxes (JBs) at each end were found to be under substantial tension and were passing over a sharp bend at the conduit end bushings. In junction box JB2222, some damage was observed to one cable (indentation to jacket) where the cable was over the conduit edge. In the same JB, another cable not under tension was found kinked to a permanent "S" bend deformation. It was noted that the pullby immediately preceding the critical pull group was a single cable, so it is suspected that the kinked cable may have been that of the single pullby deformed during the subsequent pull. Further, it was judged that a source of pullby damage, not previously anticipated, may be caused by reduction of the slack of in-place cables which may be placed in tension due to the dragging friction of subsequent pullbys. Where cables pass through elbow or "T" conduits, or not straight through JBs, tension will result in resident cables being below minimum bend radius, and/or severe deformation forces may be developed.

Relative to the above, it was observed that in about one-third of those conduits observed, the tension in the cables at the bottom of the cable group (subject to sharpest bend) was such that the cables were not movable by hand.

In their letter of October 23, 1990, TVA committed to test three worst case cable pulls. These were in conduits that the staff found acceptable, as indicated in the minutes of the meeting with TVA dated November 17, 1990. From the results, the integrity of the overall cable installation would be determined. The test program also included conduit 1PM2136I, for which the staff had a concern regarding pull tension and bend radius violations.

By letter dated January 10, 1992, TVA submitted the test results. During the test, three cables failed. However, subsequent examination by TVA and the University of Connecticut revealed that the failures were not caused by cable damage due to pullbys. The failures were determined to be random and the staff agreed with TVA's conclusion.

For the concern which relates to high tension at bends, TVA has instituted a cable monitoring program. This program requires that all medium voltage cables, and low voltage cables for motors 100 horsepower and above, be periodically hi-pot tested to determine any age-related degradation. This will include the degradation caused by bend radius violation. The staff considers TVA's program adequately addresses this staff concern.

2.1.3 Conclusion

Based on our review of TVA's new calculations and walkdowns, the staff has concluded that the worst case cable pulls were selected and tested by TVA to determine the integrity of the installation at Sequoyah with regard to pullby damage.

2.2 Cable Jamming

2.2.1 Documentation Review

The team reviewed TVA calculation EEB-CSTF-0008, which identified the population of Class 1E conduits with the potential for cable jamming damage. The potential for damage to cables by jamming exists whenever three single conductor cables of equal diameter are pulled simultaneously into a conduit having an inside diameter approximately equal to the total outside diameter of the three cables. Jamming is most likely to occur when cables are pulled around a bend rather than being pulled in a straight run. The ratio of the diameter of the conduit (D) to the diameter of the cable (d) is called the jam ratio. The critical jam ratio ($2.8 \leq D/d \leq 3.1$) must be avoided in order to remove the concern of jamming. TVA did not take into account the jam ratio during sizing of conduits, and thus could not ensure that cable damage has not occurred from jamming.

To establish a preliminary ranking of suspect conduits, a CCRS listing of all Class 1E mark numbers was obtained and D/d ratios calculated by utilizing average cable outside diameter (d) and the inside diameter from the standard conduit sizes (D) utilized at the facility. Cable mark numbers, description, and average outside diameter were then tabulated on data sheets. All conduits which fell into the critical jamming ratio of 2.8 to 3.1 were also tabulated. Following this sort the conduits were further screened based on the following criteria:

1. The cables within the subject conduits must have one or more condulets in their route.

2. The conduit size satisfied the criteria for a critical jamming ratio.

3. The number of single conductor cables in the conduit was three.

4. The mark numbers of the three cables were identical, thus ensuring the cables were of equal size.

5. Cables were greater than No. 10 AWG in size.

As a result of this screening, the calculation yielded a total of 48 conduits for which potential jamming existed.

Subsequent to this sort, TVA performed calculation SQN-CSS-035 which utilized the list of 48 conduits derived from calculation EEF-CSTF-0008, in order to identify the worst case cable pull population in conduits. The calculation involved the application of several additional criteria as committed to the NRC in the July 31, 1987 letter from TVA. These criteria were as follows:

1. The conduit must contain either factory or field bends.

2. Conduit lengths and degrees of bend must exceed or come close to exceeding the requirements of installation specification G-38.

3. The conduits must exhibit at least two potential pulling points before the segment of conduit that would have experienced the highest pulling tension.

As a result of this process, TVA identified 19 conduits meeting the additional criteria, and hence were considered the worst case conduits.

During the review of this calculation, the NRC staff noted that several cables with mark numbers that would indicate cable sizes that may have a D/d ratio in the critical range of 2.8 to 3.1 for certain conduit sizes were not included. This concern was discussed with TVA personnel and revealed that the cable mark numbers in question had not been utilized in Class 1E cable installations and thus were not further considered in the screening process. All other assumptions for the calculation and subsequent screening were reviewed and found acceptable.

The NRC staff then selected a total of three cables and tracked them through the screening process to determine if they had been properly evaluated. The following cables were selected:

2PL4962A 2PL4949B 2PL6040A

These cables and associated conduits were reviewed against the [illegible]ia stipulated in the TVA calculations and it was determined that th[illegible]ere properly screened. No additional concerns were identified.

2.2.2 Plant Walkdown

A walkdown of the subject cables and associated conduits was performed to ensure that calculation screening criteria were accurate with regard to installed field configurations. In particular, the walkdown confirmed that conduit lengths and bend geometries shown on TVA generated isometrics accurately depicted field configurations.

Each of the three conduits selected was examined by physical walkdown and measurements were taken at critical points to verify conduit lengths and bend angles. The examination indicated that TVA isometrics were accurate in all respects.

2.2.3 Conclusion

Based on the audit team's review of the calculations and plant walkdowns, the staff has concluded that the jamming calculations were done properly to select the worst case cable pulls.

2.3 Vertical Support

2.3.1 Documentation Review

Vertically run cables tend to creep downward and pull on the upper horizontal cable section, causing high stresses at the 90° bend and cutting of the insulation. The 90° condulets located at or near the top of the vertical run represent a major potential for damage to cables.

The team reviewed the revised calculation, SQN-CSS-034, which identified the worst case cable runs for support. The criteria for selection were previously documented by TVA in their letter of July 31, 1987. The NRC found these criteria to be acceptable.

The criteria were as follows:

1. The conduit will contain only cables with silicone rubber insulation.

2. The conduit shall have a minimum of five cables and a minimum fill of 20 percent.

3. The cables will be supported by a 90° condulet at the top of the run.

4. The cables will have a vertical drop immediately below the 90° condulet that exceeds the requirements of NEC Article 300-19.

Based on the more accurate application of the criteria, TVA identified an additional 210 conduits that required evaluation for vertical support in addition to the 367 originally identified in 1987.

In addition to walkdowns performed in 1987, TVA performed walkdowns of two additional cable runs which were documented in field sketches. The team questioned the integrity of this documentation carried in informal field sketches. As a result, in a letter dated June 19, 1991, TVA committed to include these sketches in the formal calculation after two-party verification that would be completed by the end of Unit 2, Cycle 5 refueling outage.

Based on the new calculations, TVA's conclusion was the same as previously reported in 1987. However, the staff was concerned that the TVA calculations did not use the effective vertical length to determine whether the NEC requirement was violated. The effective vertical length is defined as the sum of all vertical segments in the cable run between the support points minus the appropriate credit of the horizontal run segments. The staff believes that if the effective vertical length was used in the calculation, there would have been more conduits which would have violated the NEC requirements and the worst case conduit may have been a different one.

In their letter of June 19, 1991, TVA stated that the concept of effective vertical length was added to TVA General Construction Specification (G-38) in April 1988, and the NEC adopted it in a revision to the Standard in 1990. Therefore, the effective vertical length would not have been used in 1987 when TVA originally conducted its evaluation. However, as a post restart commitment, TVA performed an evaluation and took corrective actions for vertical conduits containing environmentally-qualified electrical equipment per 10 CFR 50.49 outside containment. This effort incorporates the later G-38 methodology and provides confidence that vertical conduits outside containment containing other than silicone rubber insulated cables (which were previously evaluated and accepted by the staff) have adequately addressed the vertical support issue including the effective vertical length. Additionally, the cable monitoring program will monitor degradation in cable performance and a root cause analysis of failures that may occur in the future will provide guidance for corrective action to be taken.

Based on this evaluation, the staff concludes that to apply revised criteria to establish the worst case conduit selection for testing would be a backfit. Based on the post restart corrective actions and cable monitoring program, the need to backfit the revised criteria is not justified.

2.3.2 Plant Walkdown

Since all the conduits were located in the containment and annulus area, the inspection team was not able to perform any walkdowns related to the vertical support issue. However, the team verified the accuracy of the calculations against the conduit layout drawings. The staff concluded that for the vertical support issue, the main concern was the straight vertical drop (since the effective vertical length was not used). This can easily be calculated from design drawings and walkdowns.

2.3.3 Conclusion

Based on the team's review of the calculations, the staff has concluded that the calculations were properly conducted for selecting the worst case conduit.

2.4 <u>Cable Ampacity</u>

The Sequoyah cable ampacity program utilized Electrical Design Standard DS-E 12.6.3, Rev. 1. The standard provides guidance regarding several derating factors needed to be considered during the cable sizing process. One of the derating factors is related to cable tray covers. In accordance with the design standard, TVA derated cables by 25 percent for tray covers longer than 10 feet. No derating was applied for tray covers up to 10 feet. NEC require a five percent derating factor for tray covers longer than 6 feet.

The staff questioned TVA's decision to use 1ᴗ feet as a cutoff point for der--ng. TVA subsequently stated that they based their decision on engineering judgement and an industry survey in this area, which showed that approximately 50 percent of the installations have applied the same derating factor as TVA and that there are no regulatory standards available in this area. However, TVA has agreed to derate cables routed in trays with covers from 6 feet to 10 feet by five percent, and has already used a 25 percent derating for cables in tray with covers longer than 10 feet.

The staff accepted TVA's commitment until a generic resolution is achieved. Since the NEC derating factor is also based on engineering judgement, the staff is evaluating this issue generically to determine any changes that may be required in the future.

3.0 CONCLUSION

Based on the above evaluation, the staff has concluded that TVA has adequately addressed the cable installation issues. In addition, the additional testing conducted on the three highest ranked conduits for pullby damage, has demonstrated that the cables at Sequoyah will perform their intended safety function. Also, the action taken by TVA to derate cables by five percent with tray covers from 6 feet to 10 feet is acceptable.

Principal Contributor: H. ´ rg

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