TVA

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January 14, 2009 10 CFR 50.54f

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Mail Stop: OWFN P1-35
Washington, D.C. 20555-0001

In the Matter of	)	Docket No. 50-391
Tennessee Valley Authority	)	

WATTS BAR NUCLEAR PLANT (WBN) - UNIT 2 - RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING CABLE ISSUE CORRECTIVE ACTION PROGRAM (TAC NO. MD9182)

References: 1. NRC letter dated November 25, 2008, "Watts Bar Nuclear Plant - Unit 2 - Request for Additional Information Regarding Cable Issues Corrective Action Program (TAC NO. MD9182)"

2. TVA letter dated May 29, 2008, "Watts Bar Nuclear Plant (WBN) - Unit 2 - Cable Issues Corrective Action Program for Completion of WBN Unit 2"

The purpose of this letter is to respond to an NRC request for additional information (Reference 1) regarding the Cable Issues Corrective Action Program. TVA's proposed program methods to resolve sub-issues of the Cable Issues Corrective Action Program at WBN Unit 2 that are different from those used for WBN Unit 1 were submitted to NRC on May 29, 2008 (Reference 2).

Enclosure 1 provides the NRC requests and TVA's responses. Enclosure 2 provides the listing of commitments made in Enclosure 1.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 14th day of January, 2009.

If you have any questions, please contact me at (423) 365-2351.

Sincerely,

M. Bajestani

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Watts Bar Unit 2 Vice President

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Enclosure 1
TVA Responses to NRC Requests

Background:

In the mid-1980s, the Tennessee Valley Authority (TVA) and Region II of the U.S. Nuclear Regulatory Commission (NRC) received reports of concerns from TVA employees and contractors relating to the adequacy of construction practices at Watts Bar Nuclear Plant (WBN). In 1987, Region II of the NRC contracted Franklin Research Center (FRC) to review and organize these concerns. The review revealed that a significant number of concerns centered around potential damage to electrical cables from deficient cable pulling techniques. Upon request from the NRC, FRC assembled a team of cable manufacturers and industry experts. Their report was documented in Technical Evaluation Report, TER-C5506-649, "Evaluation of Watts Bar Units 1 and 2 Cable Pulling and Cable Bend Radii Concerns", which was sent to TVA by letter dated March 10, 1987. The report documented that the bulk of the cables at WBN were installed between 1978 and 1983.

TVA has requested that the NRC approve an approach for resolving some of the identified cable issues at Unit 2 different from how those issues were resolved for Unit 1, or consider the issue closed. The following is a summary of the pertinent history of NRC's acceptance of those issues followed by a response to each question in the NRC November 25, 2008, Request for Additional Information on these issues.

1. CABLE JAMMING ISSUE

History of NRC Acceptance of Jamming Issue for WBN Unit 1

NUREG 0847; Watts Bar Supplemental Safety Evaluation Report (SSER), Supplement 7, Appendix P, Page 4 states:

"TVA approach for resolving the cable jamming issue is to identify cables with jam ratio violation and visually inspect those cables that are being removed for other related concerns and that also violate the jam ratio. Based on the visual inspections (assuming no damage from jamming is identified), cables in other conduits ranked lower according to SWBP calculations will be bounded by the inspected cables. TVA will analyze, inspect, rework or test to confirm that no damage has occurred on higher ranked cables. The staff considers TVA's approach acceptable. However, acceptability of the installation will be determined by the sample size inspected. The sample inspected must be sufficiently large to allow a statistical inference to be made about the integrity of the overall installation. If damage is found, TVA will perform a root cause analysis and inform the staff about the finding. The staff at that point may perform a visual inspection of the damaged cables."

NRC Inspection Report 50-390, 391/94-53 (75% CAP Completion Milestone) states:

"In January 1987, the NRC issued a Technical Evaluation Report on cable pulling and cable bend radii concerns for WBN. The evaluation concluded that damage to cables could have occurred from jamming during the initial cable installations. During the initial cable and conduit sizing at WBN, cable jam ratio was not adequately considered in the licensee's design criteria. Cable jam ratio is the ratio of the inside diameter of a conduit to the outside diameter of one

cable in a three single-conductor cable pull. A jam ratio between 2.8 and 3.1 can result in cable damage due to jamming or wedging at conduit bends. The licensee's approach to resolve the cable jamming issue consists of identifying criteria to allow the selection of representative worst-case cable configurations with the potential for cable jamming. The selection criteria consisted of:

- *conduit contained three (3) cables of the same size*
- *conductors were larger than No. 10 AWG*
- *jam ratio in the range of 2.8-3.1*
- *conduit length greater than 10 feet*

The identified cable/conduit configurations which met the above criteria were then ranked by conduits according to the expected cable SWBP. Affected cables within these conduits, which were scheduled to be replaced due to other cable concerns, were selected to be inspected for possible cable damage. The results of the cable inspections would provide information as to whether additional cables were required to be removed and replaced. The licensee identified 76 conduits which had jam ratios within the critical range. Twenty-four (24) of these conduits contained cables which were scheduled to be pulled back due to Ampacity concerns. Therefore, the 24 conduits were selected as the representative sample of conduits for inspection. Six (6) cables routed within the 24 conduits were pulled back and inspected for possible damage. The cables which were to be pulled back and inspected were: I PL4982B, IPL4975A, IPL4985B I PL4961A, 2PL4975A, 2PL4978A. The pullback and inspection of the above cables was implemented through DCN M-14543-A. NRC inspectors have previously witnessed the removal of the six (6) subject cables during the implementation of this DCN. Independent inspections confirmed the licensee's cable damage observations during inspection of the removed cables. These inspections were documented in NRC IRs 50-390, 391/92-01, 92-22, 92-26, and 92-35. The NRC review of this issue included inspections at the licensee's Central Laboratory in Chattanooga, Tennessee. The licensee submitted the results of the cable inspections to the NRC via letter dated December 21, 1993. The licensee's findings and conclusions are summarized below. Cable 1PL4975A had jacket and slight insulation damage at the conduit/tray interface possibly caused by a rope burn from installing cables in the tray. Cables IPL4982B, 1PL4985B, 2PL2975A, and 2PL4978A had insulation damage in the conduits or junction boxes within the conduit runs. Cable IPL4961A was inspected and no cable damage was found. The above conditions were documented in PER WBPER920162. The observed insulation damage consisted of:

- *Kinks with some flattening of the cable jacket with "bird-caging" of the conductor under the kinked areas;*
- *taped repairs of deep cuts in the insulation exposing the conductor;*
- *Raychem sleeve covering a splice;*
- *Marks, indentations, and scratches on the cable jacket; and*
- *Stranding marks, thinning, compression, and scratches to the cable insulation.*

Based on the identified cable damage and engineering analysis documented in Calculation WBPEVAR9008003, Cable Issues – Cable Jamming Evaluation and Inspection, Revision 2, the licensee concluded that the damage was most likely the result of kinks which occurred during the installation of these large, stiff cables. These configurations result in high pull tensions due to the passage of the kinks through the conduits. Cable jamming was not considered to have *caused the cable damage and therefore the licensee considered this issue resolved. This conclusion was documented in the licensee's December 1993 letter to the NRC. The NRC is currently reviewing the licensee's submittal. With respect to the conclusion that the observed cable damage was most likely due to kinks which occurred during the cable installation practices, the licensee has implemented additional cable inspections to assess the impact on other installed cables. The inspection criteria and methodology were also presented to the NRC for approval subsequent to the removal of the cable jamming cables. The results of these additional inspections were also discussed in the licensee's December 1993 submittal.*

The inspector reviewed Procedure MAI-3.2, "Cable Pulling For Insulated Cables Rated Up To 15,000 Volts, Revision 12", to evaluate the existing controls with regard to cable jamming. Appendix E, step E.3.0 requires that when the calculated jam ratio is in the critical range of 2.8-3.1, the cables shall not be pulled without approval from site engineering. These controls were determined to be adequate for the installation of cables. Previous NRC inspections since the licensee's construction restart in 1991 have also reviewed the established recurrence controls for consideration of cable jamming."

The inspection at the 100-percent Corrective Action Program (CAP) completion milestone did not alter prior NRC conclusions or TVA results.

<u>Response to Questions on Jamming Issue</u>

NRC question a):

Justify the acceptance criteria regarding the assumed relationship between sidewall bearing pressure (SWBP) and jamming. If applicable, provide industry references.

TVA response:

Jamming may occur at bends in a conduit system when the summation of the cable diameters approximately matches the conduit diameter. When pull tension is high, a sufficient SWBP may be developed to force the middle conductor in between the outer two conductors and freeze the cables in the conduit (this is further described in IEEE 690-1984, Cable Systems for Class 1E Circuits in NPGS, Sections A.9.2.4.4 and A.9.2.4.5). Because of the high force required to pull through such a jam condition, the concern for an undetected jam has always been more an issue for cables in distribution service than in industrial facilities and generating stations where runs are shorter, cables are smaller, and pulls are more likely to be made by hand. With lower installation forces, the likelihood of an undetected jam is quite low even for the larger cables at WBN Unit 2. For small cables (or large cables in simple runs) in generating stations where pull tensions are naturally low, any tendency to jam would produce an even more dramatic relative increase in pull tension and most certainly be detected. These practical physical considerations have been borne out by the Sequoyah Nuclear Plant (SQN), Browns Ferry Nuclear Plant (BFN), and WBN Unit 1 inspections as well as by industry experience.

TVA calculations WBPEVAR8905050 (which references IEEE 690-1984) and WBPEVAR9008003 provide the identification of cables with potential for jamming and the evaluation and inspection of these cables. The results included in these calculations provide justification for acceptance of the assumed relationship between SWBP and jamming.

NRC question b):

Identify the manufacturer and types of cable used at WBN Unit 2. Also, identify the manufacturer and types of the six cables that formed the basis for the conclusions.

TVA response:

Material types and manufacturers for the cables used at Unit 2 are the same as those for Unit 1. The manufacturers and cable types for the environmentally qualified cables are listed below. Other manufacturers have been used at WBN; however, the same TVA specifications were used for all cable purchases.

Manufacturers

CPJ – Triangle – Plastic Wire and Cable

CPJJ – Essex Wire Corp, Triangle – Plastic Wire and Cable

CPSJ – Triangle – Plastic Wire and Cable

EPSJ – Anaconda Wire and Cable, Okonite Company

PJJ – Brand Rex, Cyprus wire and Cable, Rockbestos

PXJ – American Insulated Wire, Brand Rex, Okonite Company, Rockbestos

PXMJ – Anaconda Wire and Cable, American Insulated Wire, Brand Rex, Essex Wire Corp, Okonite Company

SROAJ – Rockbestos

Low Voltage Control and Low Voltage Power Cable Types

PJJ - 600 Vac rated, multiconductor, unshielded

PN - 600 Vac rated, single conductor, unshielded

PNJ - 600 Vac rated, multiconductor, unshielded

CPJ - 600 Vac rated, single conductor, unshielded

CPJJ - 600 Vac rated, multiconductor, unshielded

PXJ - 600 Vac rated, single conductor, unshielded

PXMJ - 600 Vac rated, multiconductor, unshielded

SROAJ - 600 rated, single conductor, unshielded

SROAJJ - 600 Vac rated, multiconductor, unshielded

SROAJH - 600 Vac rated, single conductor, unshielded

Medium Voltage Power Cable Types

CPSJ - 5, 8 or 15 kVac rated, single conductor, extruded conductor shield

EPSJ - 5, 8 or 15 kVac rated, single conductor, extruded conductor shield

Material Abbreviations

CPE - Chlorinated polyethylene

CSPE - Chlorosulfonated polyethylene (Hypalon)

EPR - Ethylene propylene rubber

PE - Polyethylene

PVC - Polyvinyl chloride

SR - Silicone rubber

XLPE - Cross-linked polyethylene

The following six cables were removed from 24 conduits and formed the basis for the conclusions on the jamming issue:

Cable No:	Manufacturer	Type
1PL4961A	Triangle	XLPE w/ PVC jacket
1PL4975A	Triangle	XLPE w/ PVC jacket
1PL4982B	Brand Rex	XLPE w/ PVC jacket
1PL4985B	Okonite	EPR w/ CSPE jacket
2PL4975A	Okonite	EPR w/ CSPE jacket
2PL4978A	Okonite	EPR w/ CSPE jacket

NRC question c):

Provide a detailed justification on how TVA was able to extrapolate the results of the six cables to a total of 39 cables. Also, provide a detailed discussion on the condition of the additional 37 conduits found with unacceptable jamming ratios during walkdowns. Furthermore, explain why the additional 37 conduits were not identified during the original investigation that discovered 39 cables with unacceptable jamming ratios.

TVA response:

The methodology consisted of ranking conduits according to their calculated SWBP, removing the cables which were scheduled to be replaced for other issues, and inspecting those removed cables for jamming damage. If inspection showed no damage, the cables in conduits ranked below the inspected conduits would be accepted as-is. In NUREG 0847, SSER (September 1991) Supplement 7, Appendix P, NRC staff agreed to this methodology for resolution of the jamming issue.

The above methodology is documented in the conclusion section, page 11 of calculation WBPEVAR8905050. Ninety four (94) conduit runs were identified as having potential for cable damage due to jamming. Ten (10) of these conduit runs were 10 feet or less in length and, therefore, not considered jamming candidates. Out of the remaining 84 conduits, 7 had cables which were in the process of being replaced or deleted for various reasons. Therefore, 77 conduits required evaluation for potential jamming.

Calculation WBPEVAR9008003 evaluated these conduits. Of the 77 conduits, conduit 1PLC2495A was deleted from further consideration because cable 1PL4950A was no longer routed in that conduit. The remaining 76 conduits were walked down, and their installed configuration was sketched. Expected pull tension as well as expected SWBP was then calculated for both forward direction pull as well as reverse direction pull. Seventy six (76) conduits were then ranked based upon their maximum expected SWBP as percentage of allowable SWBP. Six cables which were routed in 24 conduits out of a total population of 76 conduits were removed and inspected to see if damage indicative of jamming had occurred. No damage indicative of jamming was found. Attachment 6 of calculation WBPEVAR9008003 documents this ranking. These 6 cables were representative of cable configurations and construction. Furthermore, the 24 conduits represent a significant percentage (32 percent) of the total population of conduits and include those cables subjected to the highest SWBP. On this basis, the results of the inspection of these 6 cables were extrapolated to the 39 cables.

NRC question d):

Describe the circumstances that would lead TVA to accepting a jamming ratio outside the requirements of General Construction Specification G-38.

TVA response:

A review of exceptions granted to the requirements of G-38 regarding jam ratio indicates that there was one exception (G-38-WBN-32) granted for the installation of a 3-750KCMIL in a five (5) inch conduit. The inside diameter/outside diameter (D/d) for this installation was 2.98. The following special requirements were imposed by engineering for this exception:

1. The conduit and cable shall be lubricated with ample amount of Polywater J both prior to and during the cable pull, or Ductlube Cable Lubricating System shall be used. No dry cable shall be pulled into the conduit.
2. The three conductors of each cable shall be tied or taped in a triplex formation at 6 to 10-foot intervals prior to pulling the cable in conduit.
3. The maximum pull tension for this cable will be 800 pounds.
4. A Nuclear Engineering Electrical Engineering Representative will be present during the preparation and pull of cable in conduit to witness and provide direction.

NRC question e):

Regarding TVA Calculation WBPEVAR8905050, which establishes the criteria for selecting cables in the jamming population (2.8 -3.1) based on SWBP:

1. The calculation appears to define jam ratio as the ratio of the conduit inside diameter (D) to the average cable outside diameter (d). This is contrary to other industry guidance on cable pulling, which defines the jam ratio as 1.05 D/d (e.g., Okonite Cable Installation Manual; Polywater Technical Paper; Electric Power Research Institute (EPRI) EL-5036, "Power Plant Electrical Reference Series, Vol. 4, Wire and Cable;" Thue, et al., *Electrical Power Cable Engineering,* 2nd Edition; and Southwire Power Cable Installation Guide). In addition, many of these industry sources extend the jam ratio upper limit to 3.2, and at least two sources use a jam ratio lower limit of 2.6.

   Discuss the discrepancy between TVA's criteria and the recommended industry criteria, and explain how TVA's criteria bound the recommended industry criteria.

TVA response:

Calculation WBPEVAR8905050 documents that the basis of jam ratio 2.8-3.1 is IEEE 690-1984, "IEEE Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations," which is the appropriate industry standard for jamming at a nuclear power station. Section A.9.2.4.4 of that standard states that to allow for tolerances in cable and conduit sizes, and for the ovality in the conduit at a bend, the D/d ratios between 2.8 and 3.1 should be avoided.

2. Describe whether pulling tensions and SWBP were calculated in both directions and whether the samples were categorized by the worst-case results.

TVA response:

Please refer to TVA calculation WBPEVAR9008003, Attachment 6. This attachment documents the calculation of maximum expected forward pull tension, maximum expected reverse pull tension, and the maximum expected forward SWBP as well as maximum expected reverse SWBP. TVA considered the worst case, which was based on the highest SWBP.

3. The basic assumption used in the calculation is that damage from jamming is worse with higher SWBP. However, SWBP is calculated without regard to jamming. Therefore, a cable with a lower value of SWBP could jam and result in higher SWBP than calculated. Provide the technical basis for the above mentioned assumption.

TVA response:

TVA's response to question a) discusses the relationship between jamming and SWBP when pulling through a bend, with reference to IEEE 690-1984. It points out that when jamming does occur the SWBP and pulling resistance increase drastically. Generally, this condition should be noted by the pullers. However, as noted below, the inspections were performed for both higher and lower ranked cables and, therefore, are representative of the spectrum of conditions.

TVA calculation WBPEVAR8905050 identified cables with the potential for damage due to cable jamming. This was accomplished by calculating the jam ratio based on the cable and conduit diameters.

TVA calculation WBPEVAR9008003 provided instructions for the evaluation and inspection of the cables identified by the WBPEVAR8905050 calculation. The conduits were walked down and detailed information relative to conduit geometry determined. Individual pull tension and SWBP were calculated for each conduit (both allowable and estimated). Conduits were ranked highest to lowest based on maximum SWBP as a percentage of allowable SWBP. Cables being replaced for other electrical issues were chosen for visual inspection. This approach was reviewed and considered acceptable by NRC in NUREG 0847, SSER 7, Appendix P. Cables inspected were representative of both higher ranked and lower ranked conduits. These 24 conduits represent 32 percent of the 76 conduits requiring evaluation for potential jamming. Cables were removed and inspected and found to be free of damage due to cable jamming.

4. Confirm that SWBP was not calculated with tension assumed at the breaking point of the pull rope or conductor.

TVA response:

A review of TVA calculation WBPEVAR9008003, section 6.0, indicates that SWBP calculations were based on field configuration. They were not based on the breaking point of the pull rope or conductor.

NRC question f):

Regarding TVA calculation WBPEVAR9008003, which provided the results of inspections and evaluation of the sample of six cables in 34 conduits:

1. Provide a detailed discussion on the follow-up actions that were performed after cable 1PL4985B was found in different conduits.

TVA response:

For clarification, the sample consisted of 6 cables in 24 conduits. A review of design and installation documents shows the following sequence of events:

Cable 1PL4985B was installed from 480-V shutdown board 1B2-B, compartment 8D to motor control center 1-MCC-215-B2/1A1-B using the conduit route 1PLC3380B, 1PLC3382B, 1PLC3384B, 1PLC3386B and 1PLC3388B in July 1983.

Design change M-12064-A, issued on May 9, 1992, revised the design of this cable, and cable 1PL4985B was relocated into 480-V shutdown board 1B2-B, compartment 1D to motor control center 1-MCC-215-B2/1A1-B using the conduit route 1PLC3381B, 1PLC3383B, 1PLC3384B, 1PLC 3386B, and 1PLC3388B. As documented in calculation WBPEVAR9008003, Revision 2, the jamming inspection was performed on October 19, 1992. Therefore, no follow-up actions were required because the field installation matched the revised design.

2. The TVA analysis addressed only single conductor power cables (e.g., 3-1/c, 400 and 500 MCM, 600 V with jam ratios in the range 2.8-3.0 and a single 3-1/c, 2/0, 8 kV cable with a jam ratio of 2.9). Provide a detailed technical justification for routing the one medium voltage cable in a three inch conduit. Describe any corrective actions that may be associated with this cable routing.

TVA response:

TVA calculation WBPEVAR8905050, section 4.1.a, delineates that the computerized cable routing system (CCRS) database available as of April 4, 1989, was used to obtain a printout of all Class 1E conduits with three cables in the conduit. Only one NV5 (6.9 KV rated, 8KV nominal) cable, 1PP652B routed in five (5) feet long conduit 1PP2290B, which is a horizontal conduit connecting two trays, met the jamming criteria of D/d=2.9 (reference sheet 8 of 11 of calculation WBPEVAR8905050). However, this conduit was less than 10 feet and was accepted as is. Therefore, no corrective action was required.

3. Provide a detailed technical justification as to why the three-multi-conductor cables (either multi-conductor control cable (2/c #14 and 7/c #14), low voltage power cables (3/c #10,1 /c#12 and 2/c #12), or instrumentation cables (2/c#16 SHLD, 3/c#16 TW)) with the same outside diameter were not addressed in the acceptance criteria even though their jam ratios were within the target range.

TVA response:

IEEE 690-1984 clearly identifies single conductor cables as the ones having potential for jamming. IEEE 690-1984 states:

"When three single-conductor cables are pulled into a conduit it is possible for the center cable to be forced between the two outer cables, while being pulled around a bend, if the D/d ratio approaches a value to 3.0. Up to a ratio of 2.5 the cables are constrained into a triangular configuration. However, as the value approaches 3.0, jamming of the cables could occur and the cables would freeze in the duct causing serious cable damage. To allow for tolerances in cable and conduit sizes, and for ovality in the conduit at a bend, the D/d ratio's between 2.8 and 3.1 should be avoided."

2. CABLE PULL-BY ISSUE

<u>History of NRC Acceptance of Pull-by Issue for WBN Unit 1</u>

NUREG 0847; Watts Bar SSER, Supplement 7, Appendix P, Page 2 states:

"In June of 1989, to resolve an employee concern, TVA removed the cables from a conduit run in the reactor protection system of Unit 2 to inspect for damage. This conduit was selected in response to an employee concern that a welding arc that struck the conduit during construction may have damaged cables in the conduit. When the cables were removed, significant damage was found in the insulation of some cables. However, this damage was not attributed to heat generated by the alleged welding arc. The damage was principally attributed to the pulling stresses exerted during the initial installation of the cables.

In order to fill a conduit, pull cords were used by Watts Bar personnel to pull additional cables through the conduit over the top of existing ones in the conduit (pull-by). 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 the existing cables. Usually, damage can be avoided by using adequate amounts of lubricants, by controlling pulling tension, 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. Currently, industry standards provide no specific guidance for performing multiple pulls of cables in conduits. The concerns raised by TVA employees and the NRC staff have heightened industry interest in this subject.

To assess the adequacy of cable installation at its nuclear facilities, TVA instituted programs for corrective action. At Watts Bar, overlays of the damaged cables on plant isometric diagrams of conduit runs have indicated that cables appear to have been damaged at locations of the conduit runs where pull tensions and side wall bearing pressures (SWBPs) have exceeded certain safe threshold values (high risk). The TVA program for corrective action calls for replacement of cables that have exceeded the threshold values of SWBP. SWBP values are calculated as a function of the physical parameters of the cables and the conduit configuration. TVA's cable installation procedures (G-38) included conservative values of SWBP that the cable installation crews may not have followed at the time of major construction at Watts Bar. At a meeting on November 17, 1989 between the staff and TVA, TVA proposed a program for resolving the cable pull-by issues, and by letter dated December 12, 1989 (should be December 20, 1989), submitted the program for staff review. The submittal included the U-CONN report on the damaged cables which were discovered while cables were being removed to resolve the employee concern regarding possible damage due to the welding arc. U-CONN determined that the root cause of damage was cable pull-by. TVA determined that cables that have not exceeded the safe threshold values (low risk) would not have experienced damage and are acceptable without any further action. The staff did not accept this determination, because the staff was concerned that the threshold value for damage may not have been conservatively defined. Therefore, during the meeting of February 15 and 16, 1990, the staff suggested that TVA either hi-pot (high potential) test a sample (in the low risk population) of 20 worst-case conduits from the v1/v2 voltage level and 20 worst-case conduits from v3/v4 voltage level, or remove the cables for visual inspection to assure that cables are not damaged by cable pullby. During the meeting of May 22, 1990, TVA agreed to hi-pot test the 20 worst-case conduits of each group, and subsequently documented its intent in a submittal dated June 15, 1990.

TVA's program stipulated that cable damaged from pull-by that failed the hi-pot testing of the worst-case sample would require replacement of all cables in that conduit and the sample would increase to twenty more worst-case below the original sample. TVA's program further stipulated, however, that cables in conduits that passed the test, in the sample, at higher ranking from those identified to have the damage would be accepted as undamaged cables. The staff disagreed with this stipulation and asked TVA to replace or pull back for inspection all cables ranked above the damaged cables that passed the test. The staff was concerned that since the test can only determine gross damage to cables, cables that passed the test at higher ranking may have unacceptable damage. This has become a moot point however, since TVA has completed testing of all worst case conduits and has identified no cable failure from pull-by.

However, recently the staff became aware that TVA has not included spare and abandoned cables in the test program. Since the pull-by concern affects all cables in the conduit, the staff requested TVA to test all those cables unless it was determined that they were abandoned because of known damage to those cables. Hence this issue will remain open until all testing has been completed.

In its submittal of June 15, 1990, TVA further proposed to include some high-risk category conduit in the low-risk population. The staff disagreed with TVA's proposal because as indicated previously, hi-pot testing at voltage levels agreed upon can only detect gross damage to cables. During the meeting of August 1-3, 1990, TVA presented its argument to remove five conduits from the high risk population and include them in the test sample. TVA's argument was based on the fact that the calculated value of SWBP for these conduits was not very far from the low-risk value and also assumptions used in the calculation are very conservative. The staff disagreed with TVA for one conduit and TVA agreed to retain that conduit in the high-risk population.

The staff also expressed the concern that TVA was not using the recommendation of the IEEE-400 for hi-pot testing which requires the use of negative polarity DC. TVA agreed to use the negative polarity DC on future hi-pot testing and the staff did not require the repeat of the test on the one conduit which was conducted with positive polarity DC. Based on the above, the staff finds TVA's program to resolve the cable pull-by issue acceptable, except for the issue related to spare and abandoned cables."

<u>Response to Questions on Pull-by Issue</u>

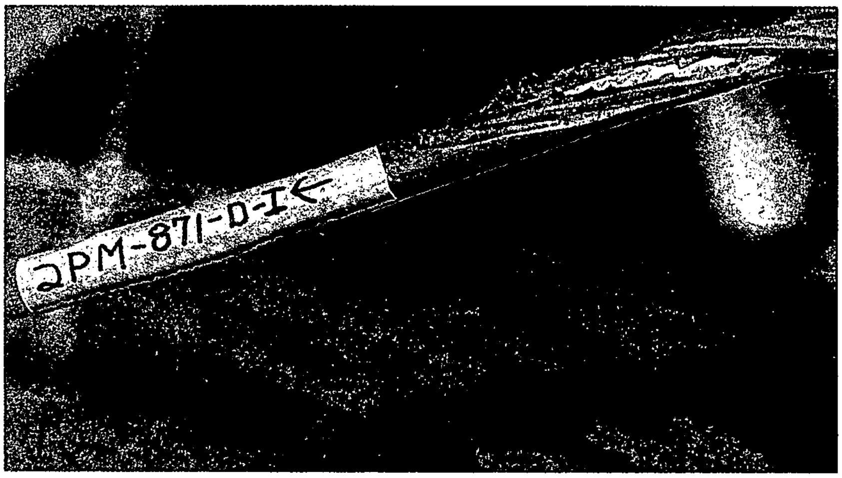
NRC question a):

Identify the physical mechanisms that could result in cable damage from pull-bys. This should include damage that may result from the pulling rope on existing cables and the residual dried cable pulling lubricant in the conduit on the new cable.

TVA response:

IEEE 1185 describes the mechanisms that could result in damage from pull-bys. The following photograph taken by the Electrical Insulation Research Center (EIRC) of the University of Connecticut (UCONN) in 1989 shows the actual damage that did result from a pull-by. UCONN also performed the pull-by simulation tests in their laboratory using a parachute cord similar to the ones used at WBN in 1978-1983 time period. For cable identified in the photograph below and identified as 2PM-871-D, UCONN analysis is as follows:

"Of the cables listed in Table 6, cables 2PS-284-D, 2PM-516-D, 2PM-871-D, and 1-3M-74-2451-B were found to have deep, narrow grooves in their surfaces, sharing virtually all features with those produced in the pull-by simulation with parachute cord over the jacketing materials."



The UCONN report further stated that they found no residue of a pulling compound. Thus, the only physical mechanism identified at WBN for developing pull-by damage was pulling using a parachute cord.

Please note that the UCONN report for the resolution of the pullby issue was submitted to the NRC via letter dated December 20, 1989.

NRC question b)

Clarify the relationship of SWBP on cable pull-by damage. If applicable, provide industry references.

TVA response:

The relationship between SWBP and pull-by damage is discussed in TVA QIR EEBWBN89003, Paragraph II:

"Following the discovery of exposed conductors in WBN's Unit 2, damage mechanism evaluations were made by TVA personnel, independent specialists and the UCONN's Electrical Insulation Research Center. The visual and laboratory analysis confirmed that the damage had been the result of the performance of pull-bys. Evaluations by WBN personnel of the subject raceways revealed that the damage occurred (as expected) at bends which calculations showed to be the location of high SWBP and pull tensions during the cable pulling process."

Pull charts were developed to identify conduits where high SWBP may have occurred during pull-bys. The pull charts were developed for voltage classes, cable configurations, and cable construction.

Please note that TVA's plan to resolve the pull-by issue and the use of pull charts was submitted to the NRC via TVA letter dated December 20, 1989. NRC staff found TVA's approach satisfactory in NUREG 0847 SSER 7, Appendix P.

NRC question c):

The assumption that pull-bys have always occurred does not appear to be conservative. This could imply that any cable could be subject to pull-by damage, and the lack of evidence on any cable selected could be used for justification of not having a problem with cable damage due to pull-bys. Given this scenario, describe how the assumption that pull-bys have always occurred is conservative.

TVA response:

This assumption was only used to develop conservative screening criteria for determining which conduits needed further evaluation. After the screening, a review of the pull records for the high and medium risk conduits was performed to determine if cables were pulled at the same time. If all cables in a conduit were pulled at the same time, they were eliminated as requiring re-pull. Thus, the inspections performed were representative of actual pull-bys. NRC staff found the TVA approach satisfactory in NUREG 0847 SSER 7, Appendix P.

NRC question d):

Describe how SWBP is calculated with existing cables in the conduit. If applicable, provide industry references. Explain the basis for crediting a coefficient of friction less than 1.0. In the response, discuss how the presence of foreign material in the conduit (e.g., other cables and dried lubricant) would impact the coefficient of friction?

TVA response:

Historically, coefficient of friction tests evaluated the coefficient of friction between conduit and cable. Cable-to-cable tests had not been previously performed. TVA conducted tests in their Central Laboratory using the methodology inherited from the earlier cable to conduit assessments. These tests indicated that a 0.75 value of coefficient of friction K was conservative, since the highest coefficient of friction measured for lubricated cables was 0.612 (refer to QIR EEBWBN89003, Revision 0).

In developing pull charts, TVA used varying coefficient of friction because as the conduit fill increases it becomes more and more difficult for cables to find a clear path. For 10, 20, 30, and 40 percent fill categories, the value of 0.75 from G-38 was applied. In the 50 and 60 percent fill categories, values of 0.85 and 1.0, respectively, were used. Since the coefficient of friction appears in the exponent, its increase is rather dramatic.

All conduit fills of 65 percent and above were automatically classified as being in the "high risk" category. The conduit in the high risk group which contained pull-by was targeted for rework without further evaluation (reference QIR EEBWBN89003 Revision 0).

TVA testing results for cable-to-cable coefficients of friction bound dry lubricant to cable coefficients of friction because even dry lubricants offer less resistance to the movement of a cable than another cable jacket would.

NRC question e):

Provide the total number of cables that were high-pot tested. Provide the total number of cables that only received a visual inspection.

TVA response:

TVA calculation WBPEVAR9006013 documents the methodology used to select conduits for high-pot testing. Attachment P3 of this calculation lists the conduits, which contain 492 cable segments, that were high-pot tested. This included 301 V1/V2 cable segments and 191 V3/V4 cable segments.

The total number of cables that received a visual inspection was 2,838. This is discussed in the WBNP Special Trend Report, dated December 17, 1993.

NRC question f):

Define "short length" of conduit.

TVA response:

For the pull-by issue, "short length" was defined as a conduit with a design length of 20 feet or less as documented in a letter to the NRC dated June 15, 1990.

NRC question g):

TVA's proposed corrective action for WBN Unit 2 states that "[i]f any segment remains in a high risk category, the cables in that conduit will be replaced." Confirm that the entire length of cable will be replaced, not just the cable in the high-risk segment.

TVA response:

As stated in TVA's letter to the NRC dated May 29, 2008, Unit 2 cables that were not evaluated under Unit 1 scope will be evaluated for the pull-by issue using the same approach as was used on Unit 1. For cables that remain in the high risk category and are routed entirely in a conduit, cables will be replaced.

For Unit 2 cables that are routed in a cable tray with part of the route in a conduit, the conduit route portion will be evaluated segment by segment. For those portions of the cable that remain as high risk, the conduit segment will be replaced. This is based on the fact that during installation, pull-by damage occurs to the stationary cable, not the pulled cable.

NRC question h):

The TVA Cable Issues CAP noted that industry guidance did not exist for cable pull-bys. The Institute of Electrical and Electronics Engineers (IEEE) Standard 1185-1994, "IEEE Guide for Installation Methods for Generating Station Cables," provides guidance for cable pull-bys. Address the recommended precautions contained in IEEE 1185, Section 9, "Cable Pull-bys," and identify how concerns similar to those identified in the industry guidance as noted below were addressed.

TVA response:

The statement in the TVA cable issues CAP that "industry guidance did not exist for cable pull-bys" refers to the time period 1978-1983, when the bulk of the cables were installed at WBN. This statement is also confirmed by the NRC in NUREG 0847 SSER 7, Appendix P (September 1991), paragraph 2.1.1, Cable Pull-by, which states "Currently, the industry standards provide no specific guidance for performing multiple pulls of cables in conduits."

As noted, IEEE standard 1185-1994 provides guidance for installation made after the standard was issued. This guidance was authored by TVA and is patterned after the requirements in TVA's G-38 installation specification, which is now the basis for performing pull-bys.

NRC question i):

The following question relates to TVA calculation WBPEVAR8906036, which is the cable pull-by analysis.

Criterion 3 requires three polyvinyl chloride (PVC) jacketed cables in the conduit prior to the final pull-by. Criterion 4 requires the initial pull and at least two pull-bys be made prior to August 1984 (the time when the use of Polywater J began to be used for a cable lubricant). Criterion 7b requires a minimum of two cables with either Hypalon or CPE jackets installed prior to August 1984. Explain the technical bases for these criteria.

TVA response:

Calculation WBPEVAR8906036 was an early approach to resolution of the pullby issue when it was believed that such damage would have been the result of cable-to-cable abrasion. It was thus sensitive to conduit geometry and those factors which would impact the coefficient of friction: jacket material (of the stationary and moving cables) and pull dates (as date of the pull was related to the type of lubrication applied). The discovery that the abrasive parachute cord was used in pull-by operations meant that the usual factors associated with coefficient of friction were no longer the issues of concern. As a result, TVA changed the method of analysis to focus on finding conduits with complex geometry in which large pullbys had occurred. This combination was the most likely to produce the adverse result when parachute cords were used. QIR EEBWBN89003, Revision 0, outlines the approach used for resolution.

NRC question j):

The following question relates to TVA calculation QIR EEB WBN 890003, which discusses the basis for the pull charts.

The coefficient of friction assumptions of 0.75 for fills of <40%, 0.85 for fills of 50%, and 1.0 for fills of 60% appear to be non-conservative when compared to the latest industry standards. Provide a detailed technical discussion on the apparent non-conservative coefficient of friction assumptions.

TVA response:

The response to item d) above provides the response to this question, as well. TVA is not aware of any standard that previously existed, or exists now, that provides coefficients of friction for overfill conditions.

3. CABLE SWBP ISSUE

History of NRC Acceptance of SWBP Issue for WBN Unit 1

Watts Bar SSER, Supplement 7, Appendix P, Page 6 states:

"Sidewall bearing pressure (SWBP) is the radial force exerted on the cable insulation at a bend while the cable is being pulled in a raceway or around a sheave. At WBN, SWBP was not properly addressed in the design and installation process and may have exceeded the allowable values. By letter dated June 15, 1990, TVA submitted its program plan to resolve the issue. TVA has performed testing to confirm that higher SWBP values would not affect the integrity of cables. The staff has previously reviewed the test report and requested additional information on the test program. In its letter of October 11, 1990, TVA committed to provide a response to the staff's request. TVA walked down 81 worst-case conduits and calculated the SWBP for these conduits. Only one conduit exceeded the new design limits established by the test results and TVA committed to replace the cables in that conduit. The staff asked TVA to walkdown an additional 40 conduits from the harsh environment to confirm that no other violations of SWBP are present. By letter dated November 5, 1990, TVA documented that the additional 40 conduits have been walked down and no violations of SWBP were observed. Therefore, the staff agrees with TVA's resolution of the issue".

Response to Questions on SWBP

NRC question a):

Define "severe case conduit configurations."

TVA response:

The severe case conduit configuration is defined by four 90-degree bends. This is considered to be the worst case based on National Electrical Code (Article 346-11) guidance and is consistent with the TVA G-38 specification. To ensure that this is conservative, TVA has also assumed that the conduit is vertically oriented. This is further explained in WBPEVAR8603006, Attachment 7.1.

NRC question b):

Provide the cable manufacturers' allowable pulling tensions and SWBP for each Class 1E cable installed in WBN UNIT 2.

TVA response:

Since manufacturers and industry guidance at the time of cable installation was inconsistent or nonexistent, TVA developed its own test program to determine maximum SWBPs. It is discussed in calculation WBPEVAR8603006.

The test results were transmitted to the NRC as Enclosure 3 in TVA's letter dated June 15, 1990. TVA contracted D. A. Silver & Associate Inc. to independently review the SWBP test. Mr. Silver directed the EPRI program described in the calculation. Their evaluation was also transmitted to the NRC in TVA's letter dated June 15, 1990.

The allowable values are consistent with IEEE 1185. For currently Nuclear Power Group (NPG)-purchased safety-related cable, the SWBP requirements are defined in the purchasing specification. Manufacturers have neither endorsed nor objected to the NPG SWBP values identified in purchasing packages. Additionally, many of the manufacturers are involved in the authoring of IEEE 1185.

NRC question c):

If applicable, identify all construction specifications (other than G-38) that were revised as a result of the SWBP issue.

TVA response:

The G-40 specification was also revised as a result of the SWBP issue.

NRC question d):

Confirm that a minimum of 10 WBN UNIT 2 cables of each type (i.e., V2, V3, V4, and V5) were included in the WBN Unit 1 analysis. Identify the cable manufacturer and cable type and construction for each of these cables.

TVA response:

As documented in NUREG 0847 SSER 7, Appendix P, Section 2.1.8, Sidewall Bearing Pressure, TVA walked down 81 worst-case conduits and calculated the SWBP for these conduits. Only one conduit exceeded the new design limits established by the test results, and TVA committed to replace the cables in that conduit. The staff asked TVA to walk down an additional 40 conduits from the harsh environment to confirm that no other violations of SWBP are present. Out of a total population of 121 conduits, the following 52 conduits were Unit 2 conduits. (The conduits identified as "No" in the column entitled "Unit 2 required for Unit 1" are those conduits required only for Unit 2 operation.)

	Conduit Number	Voltage Level	Unit 2 required for Unit 1
1	2NM3256E	2	No
2	2PM6426D	2	No
3	2PM6444E	2	No

4	2PM7269G	2	Yes
5	2PM7400B	2	No
6	2PM7401A	2	No
7	2PM7869D	2	No
8	2PM7872F	2	No
9	2PS704E	2	No
10	2RM438A	2	No
11	2M2987B	3	Yes
12	2M3360A	3	No
13	2M4338B	3	No
14	2PLC1184A	3	No
15	2PLC1185B	3	No
16	2PLC1928B	3	No
17	2PLC215B	3	Yes
18	2PLC2303A	3	Yes
19	2PLC2519A	3	No
20	2PV825E	3	No
21	2VC1259B	3	No
22	2VC2035B	3	No
23	2VC2069B	3	No
24	2VC2347A	3	Yes
25	2VC2577A	3	No
26	2VC2650B	3	Yes
27	2PLC1136A	4	No
28	2PLC1276A	4	No
29	2PLC1280B	4	Yes
30	2PLC2300A	4	Yes
31	2PLC2763A	4	No
32	2PLC2766A	4	No
33	2PLC2841B	4	Yes
34	2PLC2844B	4	Yes
35	2PLC2850A	4	No
36	2PLC2855A	4	No
37	2PLC2882A	4	Yes
38	2PLC2922B	4	Yes
39	2PLC631B	4	No
40	2PLC852A	4	Yes
41	2PLC853B	4	Yes
42	2PLC860A	4	Yes
43	2VC1078A	4	No
44	2VC1083B	4	No
45	2PP2183A	5	No
46	2PP2190B	5	No
47	2PP2191A	5	No
48	2PP2291A	5	No
49	2PP2292A	5	No

50	2PP2296B	5	Yes
51	2PP2297B	5	Yes
52	2PP2656A	5	No

With the exception of 2 voltage level 2 conduits and 1 voltage level 4 conduit, all of the remaining conduits contain at least 2 cables, and most have 3 or more cables. The cable types, construction, and manufacturers will be available on completion of walkdowns and a subsequent comparison to the EQ binders.

NRC question e):

Did the manufacturers of cables for WBN UNIT 2 concur with the higher allowable SWBP values used by TVA? Provide the cable manufacturers' concurrence correspondence or a detailed technical justification that supports these higher allowable SWBP values.

TVA response:

The response to question b) addresses this question as well.

NRC question f):

Reference 7 appears to be a TVA report on cable ampacity, not SWBP. Please clarify.

TVA response:

There were two letters that were sent to the NRC on June 15, 1990. The subject of the first letter sent on June 15, 1990, was "Electrical Cable Damage Assessment and Resolution Plan". This letter transmitted among others, the result of TVA's SWBP tests. The second TVA letter dated June 15, 1990, addressed ampacity and large low voltage power cables in standard conduit bodies.

NRC question g):

Identify the contents of the one WBN UNIT 1 conduit that did not meet the new higher SWBP criteria. Describe the corrective action that was performed to assure that this condition does not exist in WBN UNIT 2.

TVA response:

The conduit that exceeded the new higher SWBP design limits was 1B1054G. It is identified in the conclusion section of calculation WBPEVAR8603006. DCN M-14241 replaced cables in this conduit. The cables replaced are as follows:

Cable No:	Cable Size	
1B26G	2-1/C No: 6 AWG	CPJ-XLPE with PVC Jacket
1B27G	2-1/C No: 6 AWG	CPJ-XLPE with PVC Jacket
1B31G	2-1/C No: 6 AWG	CPJ-XLPE with PVC Jacket
1B32G	2-1/C No: 6 AWG	CPJ-XLPE with PVC Jacket

The walkdown of an additional 40 conduits from the harsh environment confirmed that no other violations of SWBP were present. As indicated in the response to question d), the total walkdown population of 121 conduits included 52 Unit 2 conduits.

NRC question h):

The following question refers to TVA calculation WBPEVAR9010001, which relates to cable SWBP in harsh environments.

Describe how a random sampling of 40 cables out of a population of 1914 cables in harsh environments with the potential for damage from excessive SWBP is a conservative sample size without regard to the amount of excessive SWBP.

TVA response:

The sample of 40 conduits was based on the determination of worst-case configuration using an evaluation included in WBPEVAR8603006, Attachment 7.1.

Please see response to question d) above which describes the entire population included in the sample. It should be noted that the total sample included 121 conduits, a statistically significant sample.

4. PULLING CABLES THROUGH 90-DEGREE CONDULETS AND MID-ROUTE FLEXIBLE CONDUITS ISSUE

<u>History of NRC Acceptance of the Pulling Cable Through 90 Degree Condulet and Flexible Conduit Issue for WBN Unit 1</u>

NUREG 0847; Watts Bar SSER, Supplement 7, Appendix P, Page 7 states:

"Concern of potential damage to cables in 90 degrees condulets was raised, because of the small supporting surface the inside corners of condulets provide for cables under tension. The sharp inside corners can in time cut into the insulation, or the conductors can creep through the insulation, reducing the insulation level of the cable. TVA plans to evaluate the effects of the 90-degree condulets on silicone rubber insulated cables which are more susceptible to damage than cables with other types of insulation. Also, a selection criterion for the worst-case silicone rubber insulated cables requires that cables as a minimum should have two 90-degree condulets within their route. The staff agrees with the TVA program to resolve this issue.

Also, concerns were raised regarding flexible conduits used at WBN in the middle of a conduit run. Since the inside surface of a flexible conduit has overlapping corrugations, the entire surface of the cable pulled through a flexible conduit segment in a bend will be subjected to very high frictional forces that can severely tear the cable jacket and insulation. At the meeting of August 1-3, 1990 the staff requested TVA to provide a program for resolving the concern involving pulling cable through midroute flexible conduits. TVA plans to evaluate cables pulled through midroute flexible conduits which have been tested for pull-by damage, and inspect cables removed because of other concerns to confirm that no damage was caused by the *midroute flexible conduits. If a sufficient sample exists to make that determination, then this will resolve the issue. If a sufficient sample does not exist, TVA will perform additional walkdowns to visually inspect cables at access points to confirm that no evidence of physical damage exists from pulling through flexible conduits. The staff agrees with TVA's program to resolve this issue."*

<u>Response to Questions on Issue Involving Pulling Cables Through 90-Degree Condulets and Mid Route Flexible Conduits</u>

NRC question a):

In an earlier submittal, TVA stated that there were no cases of cables actually being pulled through 90-degree conduits. Describe how TVA determined that no cables were pulled through 90-degree conduits. Also, clarify whether this statement is also applicable to 90-degree condulets.

TVA response:

This issue only involved 90-degree condulets, not conduits; and no documentation could be found that indicates that cables were pulled through 90-degree condulets. However, as discussed in TER-C5506-649, it is highly unlikely that cable could be pulled through a condulet due to the physical impracticality of doing so. Further, TVA has found no evidence of such a pull.

NRC question b):

Define "Critical case condulets."

TVA response:

TVA's response assumes the question is one regarding "critical case conduits."

The selection of critical case conduits is documented in TVA calculation WBPEVAR8806004, Specimen Selection Criteria for Silicone Rubber Insulated Cable." The purpose of this calculation was to identify test specimen cables that represented the worst case plant configuration for certain Class 1E silicone rubber insulated cables. This was done to satisfy a commitment TVA made to the NRC as documented in TVA's letter dated July 6, 1988.

As discussed in WBPEVAR8806004, Section VI, critical case conduits were determined as follows:

1. *"The first step of the process will be to identify all 10 CFR 50.49 silicon rubber cables manufactured by Anaconda (Unit 1 and 2) and Rockbestos (Unit 1 only).*
2. *General Construction Specification (G-38), Installing Insulated Cables Rated up to 15,000 volts, Appendix F, Table F1 for power and Table F2 for control cables G-38, will be used to determine worst case cable pulls. These tables show the maximum cable length allowed for a given conduit size that can be pulled without performing a sidewall*

pressure calculation. Using these tables as a guide, all cables with a circuit length less than those defined in Appendix F will be eliminated from the selection process.

3. *Additional eliminations may be made for circuit lengths that are less than those defined in G-38, Appendix F as requiring sidewall pressure calculations based on conduit size. If an adequate sample is not found, the scope of the selection process will be expanded by reducing the Appendix F values by 25 percent.*
4. *The next step in the process will be to eliminate the cables installed in conduits that have less than two 90-degree condulets in the run. This number of condulets will be determined by field walkdowns.*
5. *Five cables will be selected from each manufacturer for the test specimens. Each of the samples for a given manufacturer will be selected from different conduits. The selection will be based on actual length between points relative to the length allowed by G-38. For the purpose of this evaluation "C" condulets are not considered as pull points. Cables that exceed or come closest to exceeding the values given in Appendix F of G-38 by the greatest percent will be selected.*
6. *After identifying the worst-case section of the conduit run, the cable sample will be carefully removed from this section of the conduit by the field. Each sample will be approximately 15 feet in length and tagged with a unique cable identifier number."*

NRC question c):

The TVA evaluation was limited to silicone rubber (SR) cables pulled through two 90-degree condulets. Describe how TVA has determined that this was the worst-case scenario for SR cables and not, for instance, longer pulls through one 90-degree condulet.

TVA response:

As discussed in TER-C5506-649, page 21, "considerable damage is likely to occur if cables are pulled under tension around the inside edge of a 90º condulet." Silicone rubber insulated cable was considered worst case due to the known susceptibility of this insulation to "crush" damage. The requirement for a minimum of two condulets was specified to ensure that the specimen was subjected to a condulet in either pull direction.

NRC question d):

Provide the construction details for all of the SR cables installed in WBN Unit 2, including the construction details of all SR cables used in the loss of coolant accident (LOCA) testing.

TVA response:

The test cables for this issue were 12 and 14 AWG, single conductor, stranded copper, insulated with 45 mils of silicone rubber and jacketed with an impregnated (aramid or asbestos) braid. The cables were rated 125C and 600 Vac.

NRC question e):

The TVA LOCA evaluation was limited to SR cables pulled through 90-degree condulets. Describe how this envelopes other cable constructions that may have had longer pulls.

TVA response:

As discussed in TER-C5506-649 “considerable damage is likely to occur if cables are pulled under tension around the inside edge of a 90º condulet.” Silicone rubber insulated cable was considered worst case due to the known susceptibility of this insulation to “crush” damage. This susceptibility was considered more significant than the SWBP exerted by longer pulls on other insulation types. The requirement for a minimum of two condulets was specified to ensure that the specimen was subjected to a condulet in either pull direction.

5. COMPUTER CABLE ROUTING SYSTEM (CCRS) SOFTWARE AND DATABASE VERIFICATION AND VALIDATION ISSUE

History of NRC Acceptance of the Computerized Cable Routing System (CCRS) Software and Database Verification and Validation Issue for WBN Unit 1

NUREG 0847; Watts Bar SSER, Supplement 7, Appendix P, Page 7 states:

“At WBN, TVA is using the CCRS to document information regarding cable routing. The information includes cable routing in trays and conduits, cable type, cable weight, cable splices, circuit function, cable separation, etc. Concerns regarding the adequacy of CCRS have been expressed and documented in various CAQRs, employee concerns and NRC inspection reports for SQN. By letter dated June 27, 1989, TVA submitted a program plan to resolve these concerns. TVA plans to: (a) qualify the computer software, (b) verify existing data, (c) revise procedures for controlling data entry, revision, and utilization, (d) expand the data base to support other activities, and (e) validate the system. The staff agreed with the TVA approach but asked TVA to also validate the CCRS with cables being removed or inspected because of other issues. TVA has agreed to evaluate the cable routing of cables removed to further validate the CCRS. Therefore, the staff finds TVA's approach to resolution acceptable.”

Response to Questions on CCRS Database Verification and Validation Issue

NRC question a):

TVA identified two contributing factors that resulted in this issue: (1) lack of verification procedures and (2) failure to follow installation procedures. TVA’s resolution statement for this issue did not address failure to follow the installation procedures. Describe the corrective actions that were performed to assure that all cables were correctly installed or how the incorrectly installed cables were removed and then correctly routed.

TVA response:

Action was taken to correct the items that were identified by calculation WBPEVAR8810018 and documented in TVA’s letter to NRC dated December 3, 1990. In the late 1980s, TVA revised the cable pulling process to require design change notices (DCNs) to issue the cable pull cards instead of having the option to fill them out manually. For any cable pulls that were in progress prior to this process change, Nuclear Engineering had to sign off on the existing cable pull slips prior to commencement of a cable pull. Following the completion of the cable pulling process, the completed cable pull slip was to be transmitted to Nuclear Engineering.

NRC question b):

TVA's verification of cable routing appears to have only addressed WBN Unit 1 cables. Describe how the cable routing of WBN Unit 2 cables that were previously installed using the original CCRS software was verified.

TVA response:

As documented in TVA calculation WBPEVAR8810018, Section 8.0, a total of 4,595 cable records, out of approximately 15,000 for both units, were reviewed; and 304 records were found discrepant. This equates to a discrepancy rate of 6.62 percent in cable documentation attributes. However, only 34 cables (12 EQ and 22 Appendix R) were identified as having the potential to impact safety and required corrective action as a result of program implementation.

With respect to Unit 2 data in the Integrated Cable and Raceway Design System (ICRDS), TVA plans to use cable pull cards to verify the cable as-installed configuration or signal trace, as required, for EQ and Appendix R cables.

NRC question c):

TVA's verification of cable routing appears to have only addressed Class 1E cables. The NRC staff is concerned that this could affect raceway fill and raceway permissible loading weights. Describe how non-Class 1E cables routed with Class 1E cables have been considered in determining the adequacy of raceway fill (e.g., permissible loading weights and ampacity).

TVA response:

The validation was performed on safety-related cable because the routing information was readily available for these cables and they are the most significant from a safety perspective. However, the same control processes are in place for both safety-related and non-safety-related cables. These control processes are embedded in the logic of the ICRDS program.

NRC question d):

Provide the total number of overfilled cable raceways that are identified in the CCRS/Integrated Cable and Raceway Design System (ICRDS) database. Provide a detailed technical justification for concluding that it is acceptable to allow overfilled raceways.

TVA response:

There are a total of 832 safety-related raceways that are overfilled according to ICRDS. This is supported by documented technical justification for all 832 overfilled safety-related raceways, including support loads. The technical justifications are provided on a case-by-case basis and address issues like ampacity, pulling limitation/damage (SWBP, etc.) and seismic adequacy of raceways and their supports, and are documented as an exception request. An example of such a request is EX-WB-DC-30-22-51 R1.

NRC question e):

Provide documentation for the cable ampacity derating analyses that resulted from the overfilled raceways.

TVA response:

The ampacity analysis for cable tray depth of fill is performed using the ICRDS Cable Ampacity program. The ICRDS limits cable accumulations in power cable trays to 30 percent of the useable inside area as indicated in Electrical Design Standard DS-E12.6.3. If the cable tray fill accumulation exceeds the 30 percent limitation, the allowable ampacities are adjusted downward to account for the increased depth of fill. The derating factor, adjustment of ampacities, and the calculation of heat intensity values are based on Stolpe's equations as noted in Section 10.1.1.1 and Appendix A of the ICRDS Software Requirements Specification. The ICRDS Software Verification and Validation Plan, Revision 6, is available for review.

The ampacity analysis for cables in conduit is also performed by the ICRDS program; however, conduit ampacities are not tied to percentage of fill but rather to the number of conductors. This is consistent with industry practice and is addressed in TVA's Electrical Design Standard, DS-E12.6.3, Auxiliary and Control Power Cable Sizing Up to 15,000 Volts, Table 3.3-1, Ampacity Correction Factor for More than Three Current Carrying Conductors in Conduit (as is shown below).

No. of Conductors	Ampacity Correction Factor
4 through 6	0.80
7 through 9	0.70
10 through 24	0.70
25 through 42	0.60
43 and above	0.50

NRC question f):

Provide a detailed technical justification for determining that the raceway supports for the overfilled raceways is adequate.

TVA response:

The justifications for the acceptability of supports are provided on a case-by-case basis and are documented as an exception request. An example of such a request is EX-WB-DC-30-22-51 R1.

NRC question g):

Describe how cables designated as "abandoned-in-place" were handled in the CCRS/ICRDS database.

TVA response:

TVA Design Criteria WB-DC-30-5, section 3.2.6, states "Spare and abandoned cables (System 285) shall not be reused for active circuits."

Engineering Administrative Instructions EAI-3.15, Revision 0, "Cable and Conduit Record Development and Issue Procedure", which governed this process at the time of Unit 1 completion, delineates the requirement for abandoned cables as follows:

"Abandoned cables are treated in the same manner as spare cables were prior to EAI-3.15, Revision 0, except that the abandoned cable number (ID1-'ABN', '1ABN', '2ABN') is assigned by engineering. To abandon a cable, the record should be superseded by a cable record with an ABN number........"

This procedure has been superseded by the ICRDS routing procedure. Abandoned cables are maintained in the ICRDS database, but are assumed to be de-energized. This ensures that the impact on fill and weight is addressed.

NRC question h):

Describe the independent verification steps in the procedure (for controlling data entry, data revision, and data utilization) that verify data entry into the CCSR/ICRDS database reflects the "as-built configuration".

TVA response:

ICRDS is an as-designed database for Unit 1. As constructed data (e.g., length) for input to calculations is retrievable from pull card data, which represents the as-constructed values for safety-related cables. The following actions are required to verify that the database contains as-designed data. The ICRDS database requires 3 signatures (electronic) to complete a record: a preparer, a checker, and an approver. These signatures have to be performed in the order they are listed. The preparer and checker are not permitted to be the same person. In order to sign (electronically), each person has to be logged into the program using their login ID and password.

NRC question i):

The CCRS/ICRDS cable data sheets in Sampling Report Number WBNLEE-SR-2004-0001, provided as part of our supplemental information request, reflect design lengths. However, the installed length field is blank. Describe how the "as-built" lengths were verified and documented. In addition, describe how the electrical calculations/analyses involving cable length considered "as-built" cable lengths.

TVA response:

For existing safety-related cables on Unit 2, cable reel number and cable cut lengths were obtained from the pull cards. The installed cable length field in ICRDS for safety-related Node Voltage V4 and V5 power cables is based on the cable cut lengths extracted from pull cards, and the ICRDS database has been populated with the "as-built" lengths. The electrical calculation/analyses will use these "as-built" cable lengths for performing the evaluation. However, for safety-related node voltage V3 control cables, a 20 percent cable margin will be added to the "as-designed" cable lengths extracted from ICRDS to allow for all unknown factors, which is considered conservative and adequate. For new construction on Unit 2, Version 12 of ICRDS will make it a requirement to have installed length documented before the status of cable record is changed to installed/verified.

NRC question j):

With regard to page 30 of Sampling Report Number WBNLEE-SR-2004-0001, it appears that the one cable splits into two cables starting from route 3643. Describe how cable 2PP 675 A was routed. Also, describe the ampere value that is reflected in AMP field (i.e., cable ampere, load ampere, derated ampere, etc.).

TVA response:

This cable is made up of three single conductors; from the notes, this cable contains more than one splice. Due to the splices, there are 7 route parts which are:

Part 1 – 3 conductors from the 6.9KV Shutdown Board to splice in Manhole 1
Part 2 – 3 conductors from splice in Manhole 1 to splice in Manhole 2
Part 3 – 3 conductors from splice in Manhole 2 to splice in Manhole 3
Part 4 – 1 conductor from splice in Manhole 3 to splice at the motor (A Ø)
Part 5 – 2 conductors from splice in Manhole 3 to splice in Manhole 3 (B & C Ø)
Part 6 – 2 conductors from splice in Manhole 3 to splice in Manhole 3 (B & C Ø)
Part 7 – 2 conductors from splice in Manhole 3 to splice at the motor (B & C Ø)

The ampacity evaluation of cable 2PP675A routed in conduit and trays is documented in cable ampacity calculation WBPEVAR8909010, Appendix A, page 996. The ampacity for cable routed in underground duct bank is performed in calculation WBPEVAR9003002 and the results tabulated in Section 9.0.

The following parameters are documented in calculation WBPEVAR8909010 for cable 2PP675A:

Load Amperes:	63.0 Amps
Required Ampacity for Cable:	133.02 Amps
Allowable Ampacity for Cable:	190.00 Amps
Derating Factor:	0.592

This evaluation is based on a worst-case derating factor for conduit wrapped with TSI Fire wrap and demonstrates that the allowable ampacity for the cable is more than the required ampacity and hence is acceptable for ampacity.

NRC question k):

The Note at the bottom of hand written sheet 30 of Sampling Report Number WBNLEE-SR-2004-0001 states that the exact insulation type of cable 2PP 675 A is unknown and requires further research. How many such cases exist, and when will this issue be verified and resolved?

TVA response:

The cable associated with a given circuit number (such as 2PP675A) is described via systems of cable codes known as mark numbers and cable types. The mark number follows the pattern Wxx-yy where the "xx" represents alpha characters and "yy" represents numeric characters. At the beginning of plant design, the system was intended to only convey the general construction of a cable (i.e., 1/c-2/0 AWG, stranded copper, 8000 Vac). The type system further described families of cables with a two to six alpha character designation (i.e., CPSJ, EPSJ, see the response to your question b relative to cable jamming). The cable type codes described the allowable materials for insulation and jacket, whether the cable is shielded or non-shielded, and other general attributes. Cable type codes are typically associated with a unique TVA Procurement Standard Specification. Following the BFN fire of March 1975, TVA changed its cable specifications to require cables with enhanced fire resistance through the use of new materials (both insulation and jacket). In keeping with those changes, new cable type codes were assigned. Initially, the existing mark letters were retained since the basic construction was the same (i.e., 1/c-2/0 AWG, stranded copper, 8000 Vac). Very shortly thereafter, it was recognized that it was desirable to have the mark letter system at least partially reflect the cable's pedigree. After this time, significant changes to the cable's description resulted in the mark letter being incremented (WNB became WNB-1, then -2, then -3 and so on). However, for a period of time before this change, it was possible to have one mark letter (representing a unique construction) supplied as two different cable types. With respect to mark letter WNB, it was purchased as both TVA type CPSJ (XLPE insulation, shielded, PVC jacketed) and type EPSJ (EPR insulation, shielded, CSPE or CPE jacketed). Both were 90C copper conductor, tape shielded and jacketed constructions and both were specified to meet then current ICEA specifications. Functionally, they are interchangeable, and TVA has made no effort to distinguish them across the board.

Like WNB, certain other mark letters (approximately 60) were impacted by this philosophy. To address this concern, users are made aware of the procurement history through notes in the associated ICRDS records (there are currently 14,391 cables with this note). In EQ applications where the knowledge of specific materials is required to satisfy 10CFR50.49 driven analysis, verification efforts were undertaken. There may be other safety-related cables which have the same mark number that are not EQ and have not undergone this evaluation. The note was added to the records for these cables. There is no intention to perform this type of verification for the noted cables.

The circuit in question, 2PP675A, is a Unit 2 for Unit 1 cable. It is a non-EQ cable, and therefore the cable contract number and type code would not have been verified for the reasons described above.

NRC question l):

With regard to hand written sheet 27 of Sampling Report Number WBNLEE-SR-2004-0001, describe why cable 2PL 3960 A is routed as #4/0 American wire gauge (AWG) (49.8 amps) for 75 feet and then changes cable size to #1/0 AWG (24.9 amps) for 2013 feet in a cable tray and then changes back to cable size #4/0 AWG (49.8 amps) for 334 feet. Provide the amperage value that was used to size the protection for this cable.

TVA response:

Cable 2PL3960A feeds a 40 HP Essential Raw Cooling Water Screen Wash Pump Motor 2-MTR-067-437-A located in the intake pumping station. This motor carries full load ampere value of 49.8 Amperes. To provide adequate voltage at the motor terminals, the cable starts as 3-1/C, 4/0AWG, then changes to 3-1/C, 1/0 AWG in parallel (2PL3960A and 2PL5401A), until it reaches 0-JB-297-3813-A. It then changes again into 3-1/C, 4/0AWG.

The amperage value used in the 480-V protection calculation WBN-EEB-MS-TI08-0008, Rev.132, Appendix 2, page 5 is 49.8 Amps and is demonstrated to adequately protect the cable as indicated in Appendix 6, page 7 of the protection calculation.

6. TVA CABLE ISSUE CAP

NRC question a):

The WBN Unit 2 Cable Issue CAP did not address how TVA will comply with General Design Criterion (GDC) 18, "Inspection and testing of electric power systems," of Appendix A to part 50 of Title 10 of the Code of Federal Regulations. Describe the plant programs or procedures that address periodic inspection and testing of underground cables (including cable insulation) important to safety.

TVA response:

These programs are described in TVA's letter dated May 4, 2007, which responds to GL 2007-01, Inaccessible or Underground Power Cable Failures that Disable Accident Mitigation Systems or Cause Plant Transients," and the response for WBN Unit 2, September 7, 2007, which were previously provided to NRC, as follows:

"The TVAN Cable Condition Monitoring Program (CCMP) is controlled under General Engineering Specification G-38, Installation, Modification and Maintenance of Insulated Cables Rated Up to 15,000 Volts. The TVAN CCMP is consistent with industry practices and recommendations as provided in the Nuclear Energy Institute (NEI) Medium Voltage Underground Cable White Paper (NEI 06-05, ADAMS ML061220137). The program consists of two complimentary tests, both performed with a very low frequency (VLF), 0.1 Hertz, power supply. The first test is an age condition assessment technique known as "tan delta", "loss angle" or "dissipation factor." While preferably used as part of a trending program, one-shot readings are also used to predict remaining life or prioritize cable replacement. When the insulation is sound (i.e.; no water trees, voids or moisture), a cable is essentially a long capacitor. In the ideal capacitor, current and voltage are 90 degrees out of phase. If wet

service-aged cable contains water trees, voids and moisture, the resistive component of electrical current through the insulation increases. Thus, the dielectric no longer mimics the ideal capacitor and the resultant phase shift will be something less than 90 degrees. How much the dielectric departs from the ideal capacitor is an indication of insulation degradation. Tests have shown that the magnitude of this "loss angle" increases with decreasing power supply frequency. Thus, the sensitivity of such measurements is significantly increased when using a VLF power source. The results of the tests are used to establish the required re-test interval.

While the above method provides an overall assessment of insulation condition, it is not as responsive to highly localized defects. To ensure that cables have not been adversely degraded by localized defects and rendered susceptible to switching induced surges, "VLF withstand" testing is performed. This go-no/go method identifies those localized defects and permits repair/replacement before the cable is returned to service.

The tests are described in greater detail in Guides prepared by the IEEE Insulated Conductors Committee; IEEE 400 and IEEE 400.2. TVAN actively participated in the development of these guides.

The above tests are required for all new medium voltage installation and replacements (whether safety-related or non-safety-related) and for all existing underground safety-related circuits. The tests are also recommended for existing non-safety-related underground cables which are important to plant operation."

The WBN Unit 2 response to GL 2007-01 indicated that there are 4 Unit 2 CCW pump cables that will be tested for Unit 2, and that Unit 2 will complete the testing of these 4 additional cables before fuel load. All other underground medium voltage cables are under the Unit 1 testing program.

NRC question b):

TVA's description of the various inspections and tests performed to justify acceptability of the as-installed cables stated that a sample of cables was selected for WBN Unit 1, WBN Unit 2, and common areas. Describe the sampling criteria. For the cables selected for WBN Unit 2, indicate how many of those cables are required to support WBN Unit 1 operations. Furthermore, describe how many WBN Unit 2 cables are required exclusively for WBN Unit 2 operation.

TVA response:

For the cable pull-by issue, the hi-pot testing was performed on cables in 20 voltage level V1/V2 and 20 voltage level V3/V4 conduits. The test criteria were agreed to by NRC. As stated in NUREG 0847 SSER 7, Appendix P, paragraph 2.1.1, *"Therefore, during a meeting of February 15 and 16, 1990, the staff suggested that TVA either hi-pot (high potential) test a sample (in low risk population) of 20 worst-case conduits from the v1/v2 voltage level and 20 worst-case conduits from v3/v4 voltage level, or remove the cables for visual inspection to assure cables are not damaged by cable pull-by. During the meeting of May 22, 1990, TVA agreed to hi-pot test the 20 worst case conduits of each group, and subsequently documented its intent in a submittal dated June 15, 1990."* The hi-pot testing of these 40 conduits (20 conduits from V1/V2 and 20 conduits from V3/V4) is documented in TVA calculation WBPEVAR9006013, Revision 2 (June 20, 1992), Attachment P.

With respect to evaluation of additional conduits to address the SWBP issue, as stated in NUREG 0847, SSER 7, Appendix P, paragraph 2.1.8, *"The staff asked TVA to walkdown an additional 40 conduits from the harsh environment to confirm that no other violations of SWBP are present." The selection of additional 40 conduits is documented in TVA calculation WBPEVAR9010001, paragraph 6.1, "Conduit Random Sample."*

The total number of Unit 2 cables hi-potted was 155. Of these cables, 25 were required to support Unit 1 operation and 130 cables were required exclusively for WBN Unit 2 operation.

Enclosure 2
Commitment Summary

1. To address potential cable damage due to pull-bys, Unit 2 cables that remain in the high risk category after evaluation and in the following circumstances will be replaced:

   - Cables that are routed entirely in a conduit will be replaced.
   - Cables that are routed in a cable tray with part of the route in a conduit will have the portion routed in conduit replaced.

2. The list of cable manufacturers will be identified, and available for review, at completion of walkdowns and subsequent comparison to information in EQ binders.

3. With respect to Unit 2 data in ICRDS, TVA plans to use cable pull cards to verify cable as-installed configuration or signal trace, as required, for EQ and Appendix R cables.