Tennessee Valley Authority, Post Office Box 2000, Spring City, TN 37381-2000

April 6, 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)
Tennessee Valley Authority)

Docket No. 50-391

WATTS BAR NUCLEAR PLANT (WBN) - UNIT 2 – ADDITIONAL INFORMATION REGARDING WBN UNIT 2 CORRECTIVE ACTION PROGRAMS (TAC NO. MD9182 and MD9424)

The purpose of this letter is to provide additional information regarding the following WBN Unit 2 Corrective Action Programs (CAPs): Cable Issues, Electrical Issues, Quality Assurance (QA) Records and the Replacement Items Program (Piece Parts). The CAPs are discussed in Reference 1, section 1.13.1, under items (1) Cable Issues, (5) Electrical Issues, (13) QA Records, and (15) Replacement Items Program, respectively.

Regarding the Cable Issues Program, TVA submitted a proposed approach to resolution of sub-issues of the Cable Issues CAP at WBN Unit 2 different from the approach used for WBN Unit 1 to the NRC on May 29, 2008 (Reference 2). TVA submitted a proposed approach to resolve sub-issues of the Cable Issues CAP using the WBN Unit 1 approach on September 26, 2008 (Reference 3). In Reference 4, the NRC requested additional information. TVA responded to the NRC's request for additional information on January 14, 2009 (Reference 5). Subsequently, a teleconference was held on February 10, 2009, and a public meeting on March 17, 2009 (Reference 6). At the public meeting, TVA presented information to answer the questions from the teleconference.

Enclosure 1 provides the NRC questions from the February 10 teleconference and TVA's responses. Enclosure 2 provides TVA responses to additional NRC questions provided at the March 10 public meeting.

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TVA submitted a proposed approach to resolve sub-issues of the Electrical Issues CAP using the WBN Unit 1 approach on September 26, 2008 (Reference 3). The Electrical Issues CAP was also discussed at the public meeting that was held on March 17, 2009 (Reference 6). Enclosure 2 provides TVA responses to NRC questions pertaining to the Electrical Issues CAP that were raised at the March 17 public meeting.

In Reference 3, TVA requested NRC close the QA Records CAP. In Reference 7, NRC requested additional clarification. Based on a subsequent discussion, TVA will statistically sample the WBN Unit 2 QA records by record type to determine their retrievability, storage integrity and completeness. TVA will resolve any technical or quality problems found.

In Reference 3, TVA requested NRC review and approval of the approach for closing the Replacement Items CAP. In Reference 6, NRC requested additional clarification. Based on a subsequent discussion, TVA will perform back checks of the previously installed replacement items to ensure that a proper documentation trail exists from the warehouse to maintenance history for each of the small number of safety-related components that are not refurbished.

Enclosure 3 provides the listing of open actions required for licensing made in this letter and in Enclosures 1 and 2. I declare under penalty of perjury that the foregoing is true and correct. Executed on the 6th day of April, 2009.

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

Sincerely,

M. Bajestani

Masoud Bajestani
Watts Bar Unit 2 Vice President

Enclosures
cc (See page 4):

References: 1. NRC Safety Evaluation Report Related to the Operation of Watts Bar Nuclear Plant, Unit 2 NUREG-0847 Supplement 21, February 2009

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" (T02 080529 001)

3. TVA letter dated September 26, 2008, "Watts Bar Nuclear Plant (WBN) – Unit 2 – Regulatory Framework for the Completion of Construction and Licensing Activities for Unit 2 - Corrective Action and Special Programs, and Unresolved Safety Issues" (T02 080926 001)

4. 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)" (A02 081203 001)

5. TVA letter dated January 14, 2009,"Watts Bar Nuclear Plant (WBN) - Unit 2 – Response to Request for Additional Information Regarding Cable Issues Corrective Action Program (TAC NO. MD9182)" (T02 090114 001)

6. 2009/03/17 - Slides and Handouts from TVA Public Meeting (ADAMS Accession No. ML090771062)

7. NRC letter dated February 11, 2009, "Watts Bar Nuclear Plant - Unit 2 – Status of Regulatory Framework for the Completion of Corrective Action and Special Programs and Unresolved Safety Issues (TAC NO. MD9424)" (A02 090223 001)

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Enclosure 1

Response to Cable Issues Questions as a Result of February 10, 2009 Conference Call

1. *NRC Question 5j, page 27: NRC questioned the calculated length of cable 2PP675A. NRC calculated circuit as 2732 (a), 2722 (b) and 2772 (c) ft. vs TVA calculation (ICRDS) of 4787 ft.*

   TVA Response:

   See Enclosure 2, Section 11, "CCRS Software and Database Verification and Validation"

2. *NRC Question 4a, page 21: TVA to provide additional clarification that the condulet was used as a pull point and that the size of the opening was enough to not cause a problem with the bend radius of the cable. Also confirm that 90º condulet was only used for I&C cable.*

   TVA Response:

   Ninety-degree condulets were used in other applications in addition to instrumentation and control cables. The cables that were of concern for the "pull through" issue were smaller gauge cables, since it is impractical to "pull through" larger gauge cables.

   As part of the Bend Radius Baseline verification, condulet sizes are being determined for all conduits containing safety-related cable. Sizes will be validated against current TVA standards.

3. *NRC Question 5k, page 28: NRC requested additional clarification on the note that indicated further research is needed to determine the exact insulation type.*

   TVA Response:

   This note was added to non-environmentally qualified (EQ) cables that had the same mark number as EQ cables. EQ cables must have a documentation trail to the original contract to ascertain a trail to a specific manufacturer and applicable EQ test. TVA ONMark is used to connect non-EQ cables to data pertinent for calculation basis, such as insulation type, number of conductors, gauge, etc. This note only makes the user of the Integrated Cables and Raceway Design System (ICRDS) aware of the fact that the EQ collected data for cable with a similar mark number is not applicable to this particular cable.

4. *NRC Question 1a, page 3: Confirm cables were typically hand pulled and that no indications of jamming occurred. Staff finds TVA's methodology based on a single conductor is too restrictive. High tensions from jamming are not included in the TVA pulling tensions calculations that go into calculating SWBP. Therefore the staff finds that TVA's selection process is questionable. Based on this TVA must confirm that all safety-related cables were hand pulled or, if not hand pulled,*

describe how pulling tensions were monitored for potential jamming and how deviations between calculated and actual pulling tensions were justified.

TVA Response:

See the responses to Questions a and b under "Jamming" in Enclosure 2.

5. *NRC Question 1b, page 5: NRC requested the voltage level and cable size for the 6 cables in the chart.*

TVA Response:

Cable No:	Manufacturer	Type	Size
1PL4961A	Triangle	XLPE w/ PVC jacket	3-1/C-400MCM, 600V
1PL4975A	Triangle	XLPE w/ PVC jacket	3-1/C-400MCM, 600V
1PL4982B	Brand Rex	XLPE w/ PVC jacket	3-1/C-400MCM, 600V
1PL4985B	Okonite	EPR w/ CSPE jacket	3-1/C-400MCM, 600V
2PL4975A	Okonite	EPR w/ CSPE jacket	3-1/C-400MCM, 600V
2PL4978A	Okonite	EPR w/ CSPE jacket	3-1/C-400MCM, 600V

The complete list of cables including their size, type, voltage level, and length is delineated in calculation WBPEVAR8905050, Table 4.1.

6. *NRC Question 1d, page 6: NRC requested additional information on the exception to G-38. Provide the date of the exception and describe how the 6 to 10 foot interval taping or tying was achieved.*

TVA Response:

Exception G-38-WBN-32 was approved on March 3, 1994.

As documented in Exception G-38-WBN-32, this was a pull of less than 70 feet in a 5-inch conduit. DCN W-29725-A included design work to install cables 1PP1042 and 1PP1043 from containment penetration 1-PENT-293-4 to the WBN Unit 1 reactor coolant pump motor 1-MTR-68-73. There is no documentation in the implementing work order (WO) 94-04231-00 with respect to how the taping or tying the cable at 6-10 foot interval was achieved. However, because the evidence shows that all three conductors of these cables were cut from one reel (Reel No. WB15554), it is logical to conclude that three 70-foot length pieces, one conductor for each phase A, B, and C, were cut and then shaped into triplex formation before the cable was pulled. Page 43 of the WO documents that Nuclear Engineering (NE) instructions were followed and an NE cable specialist witnessed the cable pull. Please note that Exception G-38-WBN-32 was written for a Unit 1 cable. There are no exceptions in G-38 against Unit 2 cables. In the future, if there are any exceptions, the requirements of G-38 will be followed.

7. *NRC Question 2a, page 11: Type and size of the four cables. When was parachute cord used at WBN?*

   TVA Response:

   2PS284D: 1/2C No. 14AWG, Copper, Insulation Type PXMJ: 600V; Mark Number WHB-1
   2PM516D: 1/4C No. 16AWG, Insulation Type MS: 300V; Mark Number WVC
   2PM871D: 1/4C No. 16AWG, Insulation Type MS: 300V; Mark Number WVC
   1M2451B: 1/2C No. 14AWG, Copper, Insulation Type PXMJ: 600V;Mark Number WHB-1

   A review of specification G-38, revision 2, shows that for cables No. 4 AWG and smaller the specification permitted use of twine or fish line with a known "break" test of less than maximum tension specified for the cable size. For cables larger than No. 4 AWG, specification permitted use of Manila Rope or reliable break-links of known break strength in place of break ropes. WBN cannot establish the time frame when parachute cord was used to pull cables into conduits.

8. *NRC Question 2d, page 13: NRC wants the test report for the coefficient of friction. Justify deviations from the 1185 recommendations for a successful cable pullby (65% vs 20% fill). Also describe what happened to conduits with between 60% and 65% fill.*

   TVA Response:

   See response to Question e under Jamming in Enclosure 2 for discussion on friction test.

   Conduits were categorized in fill groups. The 60% fill group included cables between 55.00 to 64.99%.

   For the WBN Unit 2 project, a review of 5,279 Unit 2 safety-related conduits shows that 5,012 conduits are less than or equal to 40% full. Thus, approximately 95% of the total number of Unit 2 safety-related conduits are within the fill range allowed by G-38/G-40 (i.e., less than or equal to 40% full). Engineering has documented an exception to the requirement of design criteria WB-DC-30-22 for the remaining 267 overfilled conduits. This is based on current as-designed data.

   For conduits in the pullby evaluation, which are moderate and high risk, cables are eliminated based on the following factors:
   - They have not experienced a pullby,
   - They are less than 20 feet long, or
   - They are being replaced.

There are 8 conduits with fills greater than 35% and 3 conduits with fills greater than 40% using as-installed data. None are greater than 49%. These overfill conditions are justified in ICRDS.

The moderate and high-risk conduits have had the as-constructed data compiled (cables not pulled and actual conduit size identified). For low-risk conduits, the as-constructed data is still being compiled. It is expected that the as-constructed fill will be less than the as-designed fill in many cases.

9. *NRC Question 2e, page 14: How many cables in the 492 cable segments were high-pot tested?*

TVA Response:

441 cables were tested.

The complete list of cables that were hi-pot tested to validate the threshold between low risk category and moderate risk category can be found in calculation WBPEVAR9006013, Attachment P2. Note that no low risk cables failed the hi-pot test as a result of pullby damage.

10. *NRC Question 3b, page 17: What do the cable manufacturers do to meet the purchase specifications? Describe how TVA confirmed that the cable manufacturers met the purchase specification (e.g., SWBP).*

TVA Response:

For current 1E cable purchases, the allowable sidewall pressure is specified in the Certificate of Compliance from the vendor.

11. *NRC Question 3d, pages 17-19: Provide the cable types, manufacturers and construction details (size and number) for the 52 conduits.*

TVA Response:

The requested information is shown in the table that follows. The manufacturer listed is based on the current as-designed data. The as-constructed Unit 2 data is in the process of being compiled, and therefore, the manufacturer listed is subject to change. Additionally, many of the cables have been subsequently re-pulled or deleted for various reasons. Therefore, the manufacturer for the cables present during the SWP evaluation may not be available. This is noted by N/A.

No.	Conduit Number	No. Cables	Mark Number	Cable Type	No. Cond.	Size	Manufacturer
1	2NM3256E	25 3	WVK WVA	MS MS	2 2	16 16	TIME/Anaconda/N/A TIME/Anaconda
2	2PM6426D	4	WVA	MS	2	16	N/A
3	2PM6444E	2 2 4	WVA WVC WHB-1	MS MS PXMJ	2 2 2	16 16 14	N/A

4	2PM7269G	7	WVA	MS	2	16	Eaton/Anaconda
5	2PM7400B	4 2 1 19	WTK WWK WVB WVA	COAX COAX XLPE MS	 3 2	23 20 16 16	N/A
6	2PM7401A	3 22 1 4	WWK WVA WVB WTK	COAX MS XLPE COAX	 2 3 	20 16 16 23	N/A
7	2PM7869D	1	WVA	MS	2	16	N/A
8	2PM7872F	1	WVA	MS	2	16	N/A
9	2PS704E	4	WHB-1	PXMJ	2	14	AIW
10	2RM438A	2	WTK	COAX		23	N/A
11	2M2987B	14 3 2 1	WHB-1 WHC-1 WHE-1 WGK	PXMJ PXMJ PXMJ PJJ	2 3 5 12	14 14 14 12	N/A
12	2M3360A	1 1 1	WGM WFG-1 WGH	PJJ PXMJ PJJ	16 7 9	12 10 12	Cyprus Okonite Cyprus
13	2M4338B	2 2 1 2 1 2	WHD-1 WHB-1 WHG-1 WGD-1 WFH-1 WGG-1	PXMJ PXMJ PXMJ PXMJ PXMJ PXMJ	4 2 7 4 9 7	14 14 14 12 10 12	N/A
14	2PLC1184A	1 1	WHC WHB-1	PJJ PXMJ	3 2	14 14	Cyprus AIW
15	2PLC1185B	1 1	WHC WHB-1	PJJ PXMJ	3 2	14 14	Cyprus AIW
16	2PLC1928C	1 1	WHE WHB-1	PJJ PXMJ	5 2	14 14	N/A
17	2PLC215B	10 1 1 2 1 1 1 2	WHB-1 WHC WVA WLN WGB WGC-1 WGC WHE-1	PXMJ PJJ MS CPJJ PJJ PXMJ PJJ PXMJ	2 2 2 2 2 3 3 5	14 14 16 10 12 12 12 14	N/A
18	2PLC2303A	1 4 1 2 1	WGD WGB-1 WHB-1 WHC WGE	PJJ PXMJ PXMJ PJJ PJJ	4 2 2 3 5	12 12 14 14 12	Cyprus AIW AIW Cyprus Cyprus
19	2PLC2519A	3	WDO	CPJ	1	400	N/A
20	2PV825E	2 2	WLN WDE-1	CPJJ PXJ	2 1	10 6	Plastic AIW
21	2VC1259B	10	WPA	SROAJ	1	14	Rockbestos
22	2VC2035B	1	WGE	PJJ	5	12	Cyprus

		1	WGC-1	PXMJ	3	12	AIW
23	2VC2069B	1 1 1	WGB-1 WGB WGK-1	PXMJ PJJ PXMJ	2 2 12	12 12 12	N/A
24	2VC2347A	4 1	WHL-1 WHH	PXMJ PJJ	16 9	14 14	Okonite/Plastic Cyprus
25	2VC2577A	8	WPA	SROAJ	1	14	N/A
26	2VC2650B	6	WHB-1	PXMJ	2	14	Rockbestos/AIW/Later
27	2PLC1136A	3	WPJ	SROAJ	1	1/0	Rockbestos
28	2PLC1276A	3	WDO	CPJ	1	400	N/A
29	2PLC1280B	3	WDH-1	PXJ	1	1/0	N/A
30	2PLC2300A	1 1	WGC-1 WMT	PXMJ CPJJ	3 3	12 12	N/A
31	2PLC2763A	3	WDO	CPJ	1	400	N/A
32	2PLC2766A	3	WDO	CPJ	1	400	N/A
33	2PLC2841B	3	WDO	CPJ	1	400	Okonite
34	2PLC2844B	3	WDO	CPJ	1	400	General Cable
35	2PLC2850A	3	WDO	CPJ	1	400	N/A
36	2PLC2855A	3	WDO	CPJ	1	400	N/A
37	2PLC2882A	3	WDO	CPJ	1	400	Plastic
36	2PLC2922B	3	WDO	CPJ	1	400	Plastic
39	2PLC631B	1	WLO	CPJJ	1	10	Plastic
40	2PLC852A	3	WDO	CPJ	1	400	AIW/General Cable
41	2PLC853B	3	WDO	CPJ	1	400	General/Plastic /Later
42	2PLC860A	3	WDQ	CPJ	1	750	Plastic
43	2VC1078A	1 2 1	WFC-1 WLO WGC-1	PXMJ CPJJ PXMJ	3 3 3	10 10 12	AIW Plastic AIW
44	2VC1083B	1 2 1	WFC-1 WLO WGC-1	PXMJ CPJJ PXMJ	3 3 3	10 10 12	AIW Plastic AIW
45	2PP2183A	3	WNB-1	ESPJ	1	2/0	Anaconda
46	2PP2190B	3	WNB	CPSJ	1	2/0	Anaconda
47	2PP2191A	3	WNB	CPSJ	1	2/0	Anaconda
48	2PP2291A	3	WNB	CPSJ	1	2/0	N/A
49	2PP2292A	3	WNB	CPSJ	1	2/0	N/A
50	2PP2296B	3	WNB	CPSJ	1	2/0	N/A
51	2PP2297B	3	WNB	CPSJ	1	2/0	N/A
52	2PP2656A	3	WNB	CPSJ	1	2/0	N/A

12. *NRC Question 3g, page 19: How was the SWBP corrected for 1B1054G, additional information needed on DCN M-14241?*

TVA Response:

Conduit 1B1054G was reworked in accordance with Design Change M-14241-A as follows:

a. Cables 1B26G, 1B27G, 1B31G and 1B32G were removed from the conduit 1B1054G and replaced.
b. Conduit 1B1054G was removed in its entirety.
c. In addition to a shortened 1B1054G, two new conduits and two new pull boxes were added to the installation to reduce the length between pull points and hence, sidewall bearing pressure (SWBP).

13. *NRC Question 3h, page 20: Provide additional clarification on the sample. How many cables in the 40 conduits?*

TVA Response:

The total number of cables in the 40 conduits was 203.

TVA calculation WBPEVAR8603006, Section 5.1, describes the overall program for the resolution of the SWBP issue. TVA established a "smart" sample program that involved approximately 10,400 conduits containing Class 1E cables from voltage levels V2, V3, V4, and V5. Screening calculations were performed to reduce this number to 1,914 conduits containing Class 1E cables with potential of exceeding the cable SWBP.

After one failure was identified out of 81 conduits in the original sample, the NRC staff asked TVA to walk down an additional 40 conduits in harsh environment to confirm that no other violations of SWBP occurred. The available population included:

Total number of conduits with potential of exceeding SWBP:	1,914
Number of conduits initially walked down to select 81 worst cases:	727
Remaining number of conduits: (1914-727):	1,187

The process of random sample selection is documented in TVA calculation WBPEVAR9010001, page 11. It included the following steps:

The list of 1,187 conduits was entered into a database. This file was printed out to identify a record number for each of the 1,187 records. Random numbers were then generated and compared to the record numbers in the database file. The corresponding conduit identifiers were then cross-checked against TVA's Computerized Cable Routing System (CCRS) and the plant environmental drawings to determine those conduit records that had no open design change against them. This cross-check resulted in 40 conduits located in harsh environment with no design change against them.

TVA has previously described the entire population in the sample, which included 121 conduits (81 + 40), a statistically significant sample.

14. *NRC Question 6a, page 29: Confirm that all cables important to safety are included in the WBN Unit 2 CAP program.*

TVA Response:

The cables included in the Unit 2 Cable Issues CAP are safety related, as well as EQ and Appendix R cables. Associated cables are evaluated for appropriate electrical separation.

Enclosure 2

Response to Cable Issues and Electrical Issues Questions from the March 17, 2009 Public Meeting

1. **Silicone Rubber Insulated Cable**

NRC Question a: TVA to provide the number of silicone rubber insulated conduit samples taken from Unit 1 and Unit 2.

TVA Response:

Silicone rubber insulated cables manufactured by Anaconda and Rockbestos Corp. were installed in the WBN Unit 1 and Unit 2 reactor buildings. These cables have 45 mils of silicone rubber insulation covered by either an asbestos fiber braid jacket or an Aramid fiber braid jacket. Units 1 and 2 cables were pulled using the same procedures and by the same personnel, with Unit 2 cable being pulled within approximately six months after Unit 1 cable. The testing samples consisted of five (5) critical case conduits containing Anaconda cable and five (5) critical case conduits containing Rockbestos cable. The following table shows the conduits selected from each unit.

Cable Manufacturer	No. of Unit 1 Conduits	No. of Unit 2 conduits
Rockbestos samples	5	-
Anaconda samples	2	3

NRC Question b: TVA to provide the total number of silicone rubber insulated cables installed in Unit 2.

TVA Response:

The following table provides the quantity of silicone rubber insulated cables in Unit 2.

Voltage Level	No. of Cables
V4-Low Voltage Power	52
V3- Control Power	419
V2-Sheilded cables carrying medium-level signals	0
V1-Shelded cables carrying low-level signals	0
Total	471

NRC Question c: TVA to provide the process/justification used to qualify Unit 2 cables for 40 year life.

TVA Response:

With respect to EQ testing of the silicone rubber insulated cables, the samples of Anaconda and Rockbestos cables removed from WBN Units 1 and 2 were sent to Wyle Laboratories for testing. These samples were aged according to the plant's environmental conditions. The samples were then subjected to a simulated loss of coolant accident environment, including steam/chemical spray. After completion of the accident simulation, the cables were subjected to a mandrel re-bend and a successful hi-pot withstand test for margin assessment.

The silicone rubber insulated cables are rated at 125° C. Although these cables have been installed in situ for over 25 years, most of the Unit 2 cables have never been energized and have remained in an ambient environment. This situation is no different than if a reel of these cables was stored in the warehouse for that duration. As part of the EQ program, the impact on life due to external heating, i.e., ambient temperatures, will be assessed. It is expected that this impact will be minimal since the ambient temperature is significantly less than the cable rating.

2. **<u>Jamming</u>**

NRC Question a: TVA to provide the results of their review of cable pulling techniques including hand pulled versus assisted pull findings.

TVA Response:

TVA Quality Control Procedure WBNP-QCP-3.5, paragraph 6.3.5.2 required the responsible engineer to provide the following pulling instructions for individual cables on the cable pull slip:

- Maximum allowable pull tension in lbs.
- Rope pull device size.
- Indicate if the pull required power assist.
- Special pull instructions.

The WBN Unit 2 project is reviewing cable pull slips for each Class 1E cable to verify and validate their as-installed configuration. The project is also reviewing the pull slip for each Class 1E cable to determine if a power assist pull was documented for that cable by the responsible engineer. As of March 25, 2009, the project has reviewed approximately 1,400 cables out of a total Unit 2 Class 1E cable population of approximately 4,000. This review has found no Unit 2 Class 1E cable that was pulled using a power assist pull.

NRC Question b: If cases are found where cables were assisted pull, provide the evaluation methodology for ensuring jamming did not occur.

TVA Response:

If a single-conductor Class 1E cable is found to be installed using a power assisted pull, TVA will evaluate the controls in place during the pull and the jam ratio of the cable. Appropriate corrective action will be taken based on this evaluation. The evaluation and corrective action will be available for review.

NRC Question c: TVA to provide a discussion of the technique for taping single conductors into a triplex configuration along with clarification that the cables in question were reactor coolant pump cables.

TVA Response:

As documented in Exception G-38-WBN-32, this was a pull of less than 70 feet in a 5 inch conduit. DCN W-29725-A issued a design to install cables 1PP1042 and 1PP1043 from containment penetration 1-PENT-293-4 to the WBN Unit 1 reactor coolant pump motor 1-MTR-68-73. There is no documentation in the implementing WO 94-04231-00 with respect to how taping or tying the cable at 6-10 foot intervals was achieved. However, because the documentation shows that all three conductors of these cables were cut from one reel (Reel No. WB15554) it is logical to conclude that three 70-foot lengths, one conductor for each phase A, B and C, were cut and then shaped into triplex formation before the cable was pulled. The WO documents that NE instructions were followed and a NE cable specialist witnessed the cable pull.

NRC Question d: Explain why single conductor cables are more likely to jam as compared to the multi-conductor cables.

TVA Response:

IEEE 690-1984 describes the critical jamming ratio as follows:

"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, when being pulled around a bend.................."

The technical basis for the above statement is as follows:

Single conductor cables, especially conductor size larger than 1/0 AWG, are very stiff and require a high pull tension to pull them through a conduit. High pull tension can result in excessive SWBP. Because these large conductors are under excessive pull tension, there is greater likelihood that the middle conductor will slip between the two outer conductors when going around a bend thus resulting in a jam. This is especially true if D/d (where D is conduit inside diameter and d is cable outside diameter) approaches 3. When jamming occurs, the pull tension increases exponentially. On the other hand, the multi-conductor cables consist of several individually insulated small conductors with foam or fiber filling the interstices between conductors to provide a round cable shape. Because of this construction, the multi-conductor cables are more pliable and change shape to fit in the available space, making them less likely to jam. Therefore, industry is more concerned with large single conductor cable pulls. Single conductor cable pulls are used for distribution system applications and are generally used as 3 single conductor feeders for auxiliary power distribution in nuclear power plants.

NRC Question e: TVA to provide a discussion of how the coefficient of friction was determined and supporting docketed documentation.

TVA Response:

To determine static and kinetic coefficients of friction for cable-to-cable friction with and without lubricant, TVA performed testing in 1989 using the inclined plane method with low normal loads.

The tests were performed with only the weight of the cable sample as a load and two or more cables of one jacket material as the bearing surface. The cable surfaces were made as flat and straight as possible. The test set had cables of each jacket type as a bearing surface for each type of cable to be tested. The sample cables were 6 inches long for each jacket for testing with and without lubricant.

Each test was repeated at least ten times to ensure sufficient data for an average, which became the recorded coefficient of friction for that set. This was done with and without lubricant for static and kinetic coefficients of friction.

The results were presented to NRC at a meeting on November 17, 1989, and submitted to NRC on December 20, 1989, as part of the resolution plan for Unit 1.

NRC Question f: How many Unit 2 conduits were included in the total population of 76 conduits walked down to resolve the jamming issue?

TVA Response:

Thirty nine (39) conduits were Unit 1 conduits and thirty seven (37) conduits were Unit 2 conduits.

3. <u>Support in Vertical Conduits</u>

NRC Question a: TVA to provide a definition and characterization of "rework" regarding conduits.

TVA Response:

Rework means that the installation will be modified such that it meets the requirements of TVA specifications. In this case, the specification is G-38, "General Construction Specification for Installing Insulated Cables Rated up to 15,000 Volts", Section 8.7.1, "Cables Routed in Vertical Conduits-Support Intervals." This section provides the spacing requirements for vertical conduit supports. Cable supports will be added to Class 1E conduits according to the methods described in Section 8.7.2 of G-38, which includes selection of support type and installation practices.

NRC Question b: TVA to provide a justification for the determination that "creep" did not occur in the vertical conduits.

TVA Response:

As discussed in the response to Question c, the "looseness" of the cable will be assessed to demonstrate that the cable was subjected to minimal pressure. Calculation WBPEVAR9005001 assessed the impact of the SWBP on the cable at the transition due to the weight of the cable vertical drop. This was done based on the cable being at rated temperature. The Unit 2 specific cables have been de-energized and therefore have been at a much lower temperature than rated. This lower temperature, in conjunction with the verification that the cable is "loose," provides assurance that insulation creep has not occurred.

NRC Question c: TVA to provide the basis for "hand-lifting" cables.

TVA Response:

Class 1E cables are supported at or near the top of a conduit run by the curvature of a conduit, the inside radius of condulets, or a pull box. A visual inspection of those conduits that do not meet the G-38 vertical support requirements will be conducted to determine if the cables are loose. This will be measured by a craft's ability to lift the cables off the support point with one hand and without mechanical assistance. The basis for this is that looseness of the cable indicates an insignificant pressure on the cable jacket that is in contact with the surface supporting it. If the cables are found to be under tension, which is indicated by the craft's inability to lift them off the support point, the portion of these cables that has stayed under tension since their original installation will be replaced.

4. <u>Support in Vertical Tray</u>

NRC Question a: TVA to amend the submittal to summarize how the vertical cable trays were assessed to determine that no cable damage occurred.

TVA Response:

WBN performed the following actions to determine that no damage occurred to the safety-related cables in long vertical tray runs:

a. Identified those families of cable trays containing safety-related cables where the potential existed that an adequate support was not provided to meet the recommended requirements of NEC (1987) Article 300-19.
b. Performed walkdowns of the trays to determine their exact configuration.
c. Where the length of the vertical drop exceeded the support requirement stipulated in the NEC and a discrete support was not present, prepared a calculation to determine the impact of unsupported load with respect to cable and any connected equipment at the top resulting from (1) the weight on the copper conductors and potential for the load to stretch the copper; (2) pullout of conductors from crimped lugs at termination; (3) potential cutting of cables by tie wraps used to secure cables in trays; and (4) static SWBP at support points.
d. Issued design changes to add tray supports where required.

NRC Question b: TVA to provide a discussion that codifies that no credit was taken for tie-wraps to support vertical cables.

TVA Response:

TVA Specification G-38, Section 8.6.3.2, allows the use of cable tie wraps for the following applications:

(a) Where required to maintain a neat orderly arrangement of cables. Cable ties shall be installed at intervals not exceeding 10 feet.

(b) To maintain required nominal spacing between medium-voltage circuits.

TVA calculation WBPEVAR9005001 states that no credit is taken for full support from tie wraps due to lack of EQ of the wraps, and a review of the calculation shows that no credit was taken for such support. This calculation also evaluates the effect of the horizontal section above a vertical tray section. It states that the presence of the cable ties, Vimasco, and fire stops in a horizontal section is considered in establishing a coefficient of friction. However, credit cannot be taken for cable ties in a horizontal section to provide support to a vertical tray section since they are not qualified. The restraint provided by the horizontal section is based on the coefficient of friction between cable jacket and the bottom of the tray in the horizontal section. This coefficient of friction is based on EPRI EI-3333, Table 5-2.

It should be noted that specific direction on applying a tie wrap to cable is provided in G-38, Section 8.6.4.3, thus negating the concern of indenting the cable jacket by making the wrap too tight.

5. Proximity to Hot Pipe

NRC Question a: TVA to provide a definition and characterization of "rework" regarding raceways, including examples.

TVA Response:

A review of TVA calculation WBN-OSG4-139, "Walkdown of Electrical Raceways Within Close Proximity to Hot Pipes; Data Tabulation and Violation Evaluation," indicates that following actions were taken to correct the clearance violations between Class 1E raceways and hot pipes:

- Installed heat shield.
- Restrained flexible conduit to obtain 2 inch clearance.
- Relocated conduit to obtain required clearance.
- Relocated tubing to obtain required clearance.
- Installed additional insulation on the pipe to obtain required surface temperature.

This is the rework that was performed on raceways to address this issue.

NRC Question b: TVA to include the methodology used for developing the criteria for "Hot Pipe" configurations in the submittal.

TVA Response:

TVA calculation WBN-OSG4-138, "Class 1E Electrical Cable/Hot Pipe Clearance Requirements," delineates the criteria for evaluation of "Hot Pipe" configurations.

The primary consideration in developing these criteria in Construction Specification G-40 was the establishment of clearances for electrical cables and piping that must be maintained in order to prevent the electrical cables from overheating due to close proximity to hot pipes that could cause premature aging of the cables.

The clearance requirements were established for electrical cables run in conduits or cable trays, either parallel to, or at an angle to, a hot pipe, and located in any of the environmental situations listed on environmental drawings.

The clearance requirements are based on heat transfer analyses that determine the temperature rise in cables caused by the presence of a nearby hot pipe. These analyses account for (1) the resistance heating of the cables, (2) the heat transfer with the surroundings by natural convection and radiation, (3) the heat transfer by radiation between the cable or conduit surface and the piping insulation surface, and (4) the heat transfer by convection between the cables and the boundary layer of the plume arising from the pipe.

Separate treatment is required for different geometries that may exist in the plant. This is because certain geometries require significantly more clearance than others. Trying to force the more restrictive clearance requirements to be met for all geometries is not economical or feasible.

The geometries that were analyzed in the TVA calculation were considered to be sufficiently varied to cover the vast majority of cases that exist in the plant. However, if geometries existed that did not conform to any that were analyzed, specific analyses was performed for such cases.

NRC Question c: TVA to provide the basis and assumptions for characterizing the piping fluid and ambient room temperatures.

TVA Response:

TVA calculation WBN-OSG4-138 documents the assumptions for characterizing the piping fluid temperatures as follows:

1. All insulated pipes are assumed to have insulation outside diameter of 39 inches or smaller and to have a maximum operating temperature of 650° F. The pipes that do not meet these requirements are considered special cases and require specific analyses.
2. All uninsulated pipes are assumed to be 2 inches in diameter or smaller and to have an operating temperature of 600°F or less. The pipes that do not meet these requirements are considered special cases and require specific analyses.
3. Piping with a surface temperature of 135°F or less is not considered to be hot pipe. Electrical conduits in proximity to piping having this surface temperature require no thermal clearance.

The basis for ambient room temperatures is the WBN plant environmental drawings 47E-235 series. These drawings provide ambient temperature in each room of the plant under normal operating as well as accident conditions.

NRC Question d: TVA stated that walk downs of "Hot Pipe" configurations will be conducted as part of project completion to ensure field run conduit configurations meet installation specifications. Include this statement in the submittal.

TVA Response:

TVA will conduct a final walkdown of the plant after construction is completed to determine if any violation exists with respect to clearance between the hot pipes and Class 1E electrical raceways. Violations will be evaluated and resolved.

NRC Question e: TVA to provide TVA's G-40 specification with the submittal.

TVA response:

TVA has included the G-40 specification on the accompanying disk.

6. **Pullby**

NRC Question a: A discrepancy was noted in Section 8.3 of the WBN Final Safety Analysis Report (FSAR) that indicated that the cable fill criteria did not call for evaluation if the fill percentage was exceeded. TVA will submit a correction to the FSAR that will define when evaluations can be performed.

TVA Response:

WBN FSAR paragraph 8.3.4.1.4, "Cable Derating and Raceway Fill," states:

"Conduit containing only one cable is sized for a maximum of 53% cable fill. Conduit containing two cables is sized for a maximum of 31% cable fill, and conduit containing three or more is sized for a maximum of 40% cable fill of the inside area of the conduit."

TVA will add the following statement to this paragraph: "Exceptions for conduit fills of greater than 40% will be evaluated and justified by engineering."

NRC Question b: Include the current configuration of WBN Unit 2 conduit fill percentages. Specifically, provide the number of conduits with greater than 35% and 40% fill for moderate and high risk cables.

TVA Response:

For conduits in the pullby evaluation, which are moderate and high-risk conduits, if cables are eliminated based on the following factors:

- They have not experienced a pullby.
- They are less than 20 feet long.
- The cables are being replaced.

There are 8 conduits with fills greater than 35% and 3 conduits with fills greater than 40% using as-installed data. None are greater than 49%. All of these overfill conditions are justified in ICRDS.

NRC Question c: TVA to include a commitment to pull new cables in accordance with TVA's G-38 specification in the submittal.

TVA Response:

All new Class 1E cable pulls that involve cable pullby will be accomplished in accordance with TVA's specification G-38.

7. **Bend Radius**

NRC Question a: Include the Bend Radius Report that contains interviews with cable vendors, in the submittal.

TVA Response:

The bend radius report, WBN Training Radius Program, R1, is being forwarded to NRC on the accompanying disk.

8. **Splices**

NRC Question a: Provide a definition and characterization of "rework" regarding splices for cables in mild environments.

TVA Response:

For this issue, rework involved the replacement of intermediate splices for Class 1E cables in mild environments that are susceptible to moisture intrusion from flood, line break, or sprinkler activation.

9. **Sidewall Bearing Pressure (SWBP)**

NRC Question a: Provide a discussion of how the 43 cable samples evaluated were extrapolated to all cable configurations and how margin was applied to SWBP limitations.

TVA Response:

As documented in Attachment 1 of the TVA Central Laboratory Test Procedure, "Sidewall Bearing Pressure Test Composite Results," 43 samples of various cable types and construction from approximately 17 cable manufacturers were tested. Representative test results for each voltage class are summarized below.

For low voltage power and control cables, representative results are:

Cable Description	Cable Manufacturer	Max SWBP lbs/ft
1/C No. 6 AWG	Anaconda	2027
1/C No. 2 AWG	American Insulated Wire	1957
1/C No. 2/0 AWG	Triangle Wire and Cable	2889
7/C No. 14 AWG	Okonite	1563
7/C No. 12 AWG	Pacific Wire and Cable	1563

Based on the above test result, TVA selected a conservative value of 1,000 lbs/ft as a permissible SWBP value for low voltage power and control cables. Using 1,000 lbs/ft provides a minimum margin of 56.3% (1563-1000/1000) and as much as 188.9% (2889-1000/1000) for a 1/C 2/0.

Similarly, representative test results for signal level cables are tabulated below:

Cable Description	Cable Manufacturer	Max SWBP lbs/ft
3/C No. 16 AWG, Shielded	Eaton	643
2/C No. 16 AWG, Shielded	Rockbestos	770
12/C No. 16 AWG, Shielded	Brand Rex	1496
5/C No. 16AWG, Shielded	ITT	937

Based on the above test result, TVA selected a conservative value of 500 lbs/ft as a permissible SWBP value for low voltage signal cables. Using 500 lbs/ft provides a minimum margin of 28.6% (643-500/500) and as much as 199.2% (1496-500/500) for a 12/C No.16AWG, Shielded.

Similarly, for coax cables, representative test results are tabulated below:

Cable Description	Cable Manufacturer	Max SWBP lbs/ft
Coax RG59B/U	Raychem	373
2 Coax W/TPs	Teledyne	1242

Based on the above test result, TVA selected a conservative value of 300 lbs/ft as a permissible SWBP value for coax cables. Using 300 lbs/ft provides a minimum margin of 24.3% (373-300/300) and as much as 314.0% (1242-300/300) for an 8/C coax special. As was the case on Unit 1, Unit 2 EQ coax cable will be replaced with double jacketed cable.

10. Pulling Cables through 90° Condulets and Mid-Route Flexible Conduits

NRC Question a: Provide a discussion of why 12 and 14 gauge wire was determined to be limiting in the submittal.

TVA Response:

As delineated under the silicone rubber insulated cable issue, five critical case conduits containing at lease two 90° condulets in their route were selected that contained cables manufactured by Anaconda and Rockbestos. The installed cables from these conduits were removed and were used as samples for EQ testing. The reason for selecting these No.12 AWG and No. 14 AWG was that, in practice, only small gauge cable can be pulled through a condulet without using the condulet as a pull point. Therefore, testing would reveal any insulation damage that may have occurred if the cables had been installed in this manner. These cables were successfully tested for 40 year life.

11. CCRS Software and Database Verification and Validation

NRC Question a: Provide a discussion on how cable materials are tracked and can be recovered via mark numbers.

TVA Response:

The ONMark database, which is part of ICRDS, identifies the conductor type, including insulation type, associated with a cable mark number. Additionally, the pull record for safety related cables identifies the reel number for the pulled cable. This reel number can be traced to the contract under which the cable was purchased via warehouse records. For EQ cables, the contract number is associated with a specific qualification report, as documented in the EQ binder. In addition, the contract is identified on the cable jacket.

NRC Question b: Provide documentation on how the use of mark numbers is accomplished at the site.

TVA Response:

The process for the use of cable mark numbers is described in ICRDS. The ICRDS procedure states that a WBN cable reel number is recorded on the cable installation record. This cable reel number can be linked to the purchase contract number or TVA's interplant cable transfer documentation through the Warehouse Ledger. The WBN Unit 2 project is currently reviewing cable installation records to establish the pedigree of each Class 1E cable in Unit 2.

NRC Question c: Provide the percent of cables found deficient during the Unit 1 Verification and Validation of the CCRS database to the resident.

TVA Response:

The following information is being provided to the resident:

The percent of cables found deficient during the Unit 1 Verification and Validation of the CCRS database is documented in paragraph 4.2 of the Cable Issues Corrective Action Program Plan, Revision 3, submitted to the NRC on January 13, 1994.

Out of 4,256 cable records reviewed for EQ cables, 4,012 cables had an exact match between the design and the installation records. This resulted in a discrepancy rate of (4256-4012)/4256=5.7%.

Out of the 244 discrepant cables, 110 cable record inconsistencies were resolved through a document search resulting in database update in some cases (e.g., illegible pull cards, misaligned card printer, or mismatch of pull card revision number, mark number, and routing differences).

The remaining 134 cables required field verification of mark number, contract number, and/or routing. This field verification resulted in 100 cables where the design and the installation records matched exactly.

NRC Question d: TVA to provide clarification of design cable length versus installed cable lengths and a discussion of which length is applied to better explain the calculations for cable 2PP675A, which were presented at the meeting.

TVA Response:

The current record (Rev. 5) in ICRDS for cable 2PP675A shows an overall design length of 4,787 ft. and an overall installed length of 3,155 ft. This cable is broken up into 7 route parts in ICRDS.

The ICRDS program automatically provides the design length based on the route of the cable. When determining the design length for a cable record, the ICRDS program sums the length of each raceway listed in the route of the cable plus any listed non-routed lengths of cable not in raceway but required at the ends for termination. If there is more than one route part, the ICRDS program determines the length of each route part as if it were a separate cable record and then calculates the record design length by summing the part lengths from the route parts of the cable (in this case, 463 + 188 + 16 + 2065 + 188 + 19 + 1848 = 4787). Since ICRDS calculates length in a cumulative manner, it cannot recognize that individual route parts may be a single phase instead of all three phases. In this case, the design length should be determined as follows:

> For one of the conductors Route Part 1 (463) + Route Part 2 (188) + Route Part 3 (16) + Route Part 4 (2065) = 2732 ft.
>
> For the other 2 conductors Route Part 1 (463) + Route Part 2 (188) + Route Part 3 (16) + Route Part 5 (188) + Route Part 6 (19) + Route Part 7 (1848) = 2722 ft. for each conductor

A review of the cable installation card (with a written date of 5/4/78 and a stamped date of SEP 23 1986), indicates this cable was installed in 2 pieces. One of the pulls was from 3 reels with the cable length from the reels being recorded as having values of 2200 ft, 2175 ft. and 2190 ft. The other pull was from 3 reels with the recorded cable length from the cable reels of 972 ft., 962 ft. and 966 ft. The sum of these lengths (2200 + 2175 + 2190 + 972 + 962 + 966 = 9465), divided by 3 provides the average length for one conductor (9465 ÷ 3 = 3155). These are the only lengths shown on the installation cards (there are no records of lengths of cable being trimmed from the cables during the termination process). The calculation of record used 3155 feet as the installed length since this is the most conservative length. This is an in-service cable required for Unit 1 operation.

12. Cable Issues CAP

NRC Question a: TVA to provide a discussion outlining the medium voltage cable testing program and the results of this program.

TVA Response:

TVA conducts Very Low Frequency (VLF) testing of underground medium voltage cables in accordance with G-38, Section 19.4.8.1. This specification describes VLF as follows:

Withstand tests performed with a Very Low Frequency (0.1 Hz) alternating current, sinusoidal waveform have been shown to be more revealing of defective cable insulation than high potential DC. Unlike DC, VLF hipots have been shown to be non-destructive to otherwise sound insulation.

WBN Unit 1 has performed VLF testing on all but one essential raw cooling water (ERCW) pump feeder cable. Testing the remaining ERCW pump feeder cable is in progress. To date, data for the seven pumps for which testing has been completed indicate sound cable systems with no problems or anomalies observed. Testing of the diesel generator output supply cables is currently scheduled to be performed during the Unit 1, Cycle 9 refueling outage. After performance testing, periodic testing is planned at 5 year intervals.

13. <u>Flexible Conduit Installation</u>

NRC Question a: TVA to include the G-40 specification to document the methodology used for installation of conduit.

TVA Response:

Section 3.6.2 of the G-40 specification provides the methodology for the installation of flexible conduits. The specification is being provided to NRC on the accompanying disk.

NRC Question b: TVA to provide specific discussions for each item in the February 15, 1989 CAP that resolved the Flexible Conduit Installation issue.

TVA Response:

The problems identified with flexible conduits were:

- Inadequate length to account for seismic/thermal movement.
- Lack of compliance with minimum bend radius requirements.
- Loose fittings.

To resolve these issues for Unit 1, TVA revised design output documents to more specifically define flexible conduit requirements for:

- Seismic/thermal movement.
- Minimum bend radius.
- Tightness of fittings.

A list of flexible conduits attached to Class 1E pipe mounted devices was then developed to identify those flexible conduits that would experience both seismic and thermal movement. Finally, TVA walked down all Class 1E flexible conduits and reworked those found to be damaged or in noncompliance with the design output documents.

14. Physical Separation and Electrical Isolation

NRC Question a: TVA to provide specific discussions for each item in the February 15, 1989 CAP that resolved the Physical Separation and Electrical Isolation issue.

TVA Response:

Resolution of this issue was broken down into three parts:

- Inadequate separation between redundant divisions of Class 1E conduits

  For WBN Unit 1, as corrective action for the originally identified condition, NE issued design output documents to specify separation requirements. TVA revised site implementing procedures to strengthen inspections for separation requirements. This was followed by reworking the raceways to meet the minimum 1-inch separation requirement.

  The long-term corrective action to prevent recurrence was to revise site implementing procedures to require specific signoffs for raceway separation attributes

- Inadequate internal panel separation between redundant divisions of Class 1E cables

  For Unit 1, Design Criteria WB-DC-30-4 was revised to include more detailed requirements for internal panel cables, an engineering output document was issued to define the requirements for internal panel cable separation, and a list of all panels with redundant divisions of Class 1E cables was developed.

  This was followed by walkdowns of panels containing cables of redundant divisions to identify cables that did not comply with the revised engineering output documents. Once identified, nonconforming cables were evaluated to determine acceptability or reworked to meet required separation distances.

  In order to prevent recurrence, engineering output documents were revised to ensure that requirements were defined as appropriate, and site implementing procedures were also revised to specify installation requirements and inspection attributes for separation of internal panel cable.

- Coil-to-contact and contact-to-contact isolation between Class 1E and non-Class 1E circuits

  For Unit 1, a calculation was developed to determine when coil-to-contact and contact-to contact isolation were acceptable, design criteria were revised to specify acceptable isolation methods, and the existing Class 1E coil and contact devices used as isolators were reviewed to determine if they were qualified for their intended use.

15. Torque Switch and Overload Relay Bypass Capability for Active Safety Related Valves

NRC Question a: TVA will provide specific discussions for each item in the February 15, 1989 CAP that resolved the Torque Switch and Overload Relay Bypass Capability for Active Safety Related Valves.

TVA Response:

For Unit 1, TVA issued design criteria and corresponding calculations to provide the basis for determining which active valves were required to have their thermal overload relays and torque switches bypassed. System design criteria or system descriptions were revised to identify which valves within a system required thermal overload and torque switches bypass capability. Design output documents were then revised, and thermal overload and torque switch bypasses were installed where they did not already exist.

To prevent recurrence, Engineering issued the required design input documents.

Enclosure 3
Listing of Open Actions Required for Licensing

1. TVA will statistically sample the WBN Unit 2 QA records by record type to determine their retrievability, storage, and completeness. TVA will resolve any technical or quality problems found.

2. TVA will perform back checks of the previously installed replacement items to ensure that a proper documentation trail exists from the warehouse to maintenance history for each of the small number of safety-related components that are not refurbished.

3. If a single-conductor Class 1E cable is found to be installed using a power assisted pull, TVA will evaluate the controls in place during the pull and the jam ratio of the cable. Appropriate corrective action will be taken based on this evaluation. The evaluation and corrective action will be available for review.

4. A visual inspection of the supports of vertical conduits that do not meet the G-38 vertical support requirements will be conducted. If cables are found to be under tension, the portion under tension will be replaced.

5. A walkdown for "hot pipe" configurations will be conducted after construction completion.

6. TVA will submit an update to the FSAR Section 8.3.4.1 to allow engineering evaluations of pullby if fill percentages are exceeded.

CERTIFIED TEST REPORT AND CERTIFICATE OF COMPLIANCE

THE OKONITE COMPANY
2276 ROWESVILLE ROAD
ORANGEBURG SC 29115

Report No: 6326
DATE : 03/31/04
Reg No :42-5405
Page 1 of 10

Customer: TENNESSEE VALLEY AUTHORITY NUCLEAR
Customer Order Number: 31957 Item No: 1 Code No: WNB-52 / CBR257A
Manufacturing Order No: 04-2939-1 Product Code No: 115-23-2928
Manufacturing Spec: TVAN E12.6.01 REV 4 7/21/03
Cable Description: 1/C 2/0 19X COPPER-SS-140 OKOGUARD EPR-024 SC EPR-005 TINNED COPPER TAPE-080 OKOLON-SEQ.PRINT-8KV

CERTIFICATE OF COMPLIANCE: Issued in conjunction with and subject to OKONITE's standard Warranty and Limitation Liability.

THE OKONITE COMPANY hereby certifies to the customer named above that the above described materials were duly tested during manufacture and that the materials meet or exceed the applicable requirements.

Quantity Ordered 6,000 Quantity Accepted for Shipment 6,120 Number of Reels 2

Cable QC Length No.	Shipping Footage	Sequential Numbers Top End	Test Hole End
474307A	3060	4006168	4003100
474307B	3060	4003068	4000000

CERTIFIED TEST REPORT
The insulated conductor(s) withstood the following tests:
28 Kv Ac for 5 Min
The insulated cable conductor(s) has an INSULATION RESISTANCE of not less than that corresponding to a constant of 50000 at 15.6 C.
The DC RESISTANCE of the conductor(s) at 25 C does not exceed ICEA values of 0.08260 Ohms per 1,000 ft.
Conductor Continuity PASSED
Shield Continuity PASSED
Corona Level per AEIC CS6 PASSED
This report covers material shipped from ORANGEBURG, SC to TVAN /BROWNS FERRY

We hereby certify this to be a true and accurate copy of results of tests conducted in accordance with orders and specifications listed.
Special Statements for this CTR/COC

"CABLES SHIPPED ARE SAME IN DESIGN AND MATERIALS, AND MANUFACTURED UNDER SAME PROCESS AND QUALITY CONTROLS AS CABLE QUALIFIED BY OKONITE EQ REPORT NQRN 3 R4

"MAXIMUM SIDE WALL PRESSURE DURING INSTALLATION = 1000LBS."

"REELS ARE SUITABLE FOR EXPOSURE TO AN OUTDOOR ENVIRONMENT FOR AT LEAST TWO YEARS."

"CABLE SUPPLIED IN ACCORDANCE WITH OKONITE QS MANUAL REV.5 DTD 8/97."

"SOFT / ANNEALED COPPER WIRES PRODUCED FOR STRANDED CONDUCTORS HAVE ACHIEVED ELONGATION AND FINISH REQUIREMENTS OF ASTM B3 DURING MANUFACTURE."

"CABLE SHIPPED MEETS FLAME RESISTANCE REQUIREMENTS OF IEEE 383-1974"

THE OKONITE COMPANY

DON HOLZSCHUH
ENGINEER / MANAGER OF TEST
Q-123-C-el REV 11.2 02/20/02 S

THE ROCKBESTOS COMPANY
20 BRADLEY PARK ROAD • P.O. BOX 1102 • EAST GRANBY, CT 06026-1102 USA • PHONE (203) 653-8300 CABL-052

CERTIFICATE OF CONFORMANCE

Sheet 1 of 9

Customer	TENNESSEE VALLEY AUTHORITY BROWNS FERRY NUCLEAR PLANT UNIT 3	Sales Order No.	8051
Purchase Order No.	21042-BL-017-0	Shop Order No.	25446
Specification No.	SS-E-25.016 R1 SS-E18.10.02 R1	Product Code	P625403
Description	1/C 12 AWG (7 ST) TC XLPE/HYP 90C 600V CABLE	Quantity	6964 ft.
Item No.	22	Total # Reels	1
P.O. Item No. Type	22 PXJ	Mark No.	WDV-52

The Rockbestos Reel Numbers noted below comprise the total population of the inspection lot noted above.

92L0977G

IT IS HEREBY CERTIFIED THAT THE CABLES SUPPLIED ON TVA CONTRACT 21042-BL-017-0 COMPLIES WITH ALL APPLICABLE REQUIREMENTS OF THE PURCHASE DOCUMENTS IN THE QUANTITY SHIPPED.

IT IS ALSO CERTIFIED THAT THE CABLES SUPPLIED ARE THE SAME IN DESIGN AND MATERIALS AND MANUFACTURED AND TESTED UNDER THE SAME PROCESS AND QUALITY CONTROLS AS THOSE CABLES QUALIFIED BY ROCKBESTOS QUALIFICATION TEST REPORT NUMBER QR 5805 REV 2.

IT IS ALSO CERTIFIED THAT THE REELS AND PACKAGING SUPPLIED ON TVA CONTRACT 21042-BL-017-0 ARE SUITABLE FOR EXPOSURE TO AN OUTDOOR ENVIRONMENT FOR AT LEAST TWO YEARS AND MEET THE REQUIREMENTS OF ANSI N45.2.2, LEVEL D CLASSIFICATION.

IT IS ALSO CERTIFIED THAT THE MATERIAL DESCRIBED WAS MANUFACTURED AND TESTED AT THE ROCKBESTOS COMPANY IN EAST GRANBY, CT.

IT IS ALSO CERTIFIED THAT THE ABOVE MATERIAL MEETS THE PERMANENCY OF PRINT REQUIREMENTS AS STATED IN MIL-C-915E.

IT IS ALSO CERTIFIED THAT THE MAXIMUM ALLOWABLE SIDEWALL PRESSURE IS 1000 POUNDS PER FOOT OF BEND RADIUS.

IT IS ALSO CERTIFIED THAT THE ITEM SUPPLIED DOES NOT EXCEED THE MAXIMUM OUTSIDE DIAMETER AND WEIGHT PER FOOT FROM THE TABLE SHOWN IN REQUISITION 21042-BL017 REV 3.

IT IS ALSO CERTIFIED THAT REEL NO. 93B0978G, WHICH WAS USED TO DEMONSTRATE PASSING RESULTS OF THE IEEE-383-1974 VERTICAL TRAY FLAME TEST AS REQUIRED IN TVA SPECIFICATION SS.E25.016 R1, THOUGH NOT INCLUDED IN THE CABLES RELEASED FOR SHIPMENT, WAS MANUFACTURED FROM THE SAME LOT OF MATERIALS AND AT THE SAME TIME AS THE REELS WHICH WERE RELEASED FOR SHIPMENT.

QUALITY CONTROL SUPERVISOR

DATE 3/5/93
REVISED

SHEET E-76 R11

Kiw B/

B43 960322 003

March 22, 1996

M. C. Brickey, IOB 1G-WBN

WATTS BAR NUCLEAR PLANT
REVISION 1 TO THE CABLE BEND RADIUS PROGRAM PLAN

Beginning July 20, 1995, Kent W. Brown of my staff visited Brand Rex, Rockbestos and The Okonite Company for the purpose of reviewing the activities that WBN has undertaken to resolve the issue of tight cable bend radius. As you know, these meetings were held in response to a WBN commitment to the NRC to review the "long-term" portion of the plan for resolution with our major suppliers. Per our agreement with the NRC, the vendors were not requested to "approve" the plan, but to only provide a verbal assessment.

Following those initial meetings, the vendors found that the TVA program was satisfactory as was described in some detail in my memo to you dated July 28, 1995 (B43 950728 005).

It was originally intended that those 10 CFR 50.49, single conductor, low voltage power cables which were found to be above the lower bound but below the ICEA radius would be accepted based on a reduction in life directly proportional to the additional stress. That method would have entailed an assumption that no synergistic effect existed between the additional physical stress and aging and required laboratory confirmation of that assumption as was described in revision 0 of the plan. However, subsequent walkdowns and inspections showed that all single conductor, low voltage power cables within the scope of 10 CFR 50.49 were trained at or above the ICEA limit, obviating the need for further research in this area and resulting in a reduction in the scope of the plan.

The changes to the long term bend radius plan were discussed with each of the above vendors following their review of a draft of that revision (B43 960321 003). The purpose of that review was to ensure that the vendors still agreed that the plan would achieve the desired objective. The results of those discussions were as follows:

- ☐ Brand Rex, in a letter to K. W. Brown dated February 29, 1996 (B43 960321 001), noted that they concurred that the plan would ensure early identification of adverse trends and could not identify any deficiencies in the TVA approach for addressing bend radius concerns.

- ☐ Robert Gehm, Sr of Rockbestos discussed his review of the draft plan with K. W. Brown on February 27, 1996. Gehm noted that Rockbestos had no technical objections to the revised plan.

- ☐ John Cancelosi of Okonite discussed his review of the draft plan with K. W. Brown on March 13, 1996. Cancelosi noted that Okonite also had no technical objections to the revised plan.

We have included a discussion of the results of the 1995 meetings, the reason for revision 1 and the results of the 1996 discussions in the revised plan so that it is as comprehensive as possible. Please forward the attachment to licensing so that the NRC commitment can be revised as necessary. If you have questions regarding the above comments please contact Mr. Brown at 751-8227.

R. C. Williams
Chief Electrical and I&C Engineer
LP4H-C

cc (attachment):
RIMS, CST13B-C, w/attachment

Watts Bar Nuclear Plant - Training Radius Program, Revision 1

Background

In the late 1970s and early 1980s as TVA was constructing its Watts Bar Nuclear Plant, cables were installed which could not, or did not, meet industry standard training radius requirements. The substandard bends resulted from a variety of causes. For example, the Watts Bar tray system was bought with 12" radius fittings, which resulted in potential violations for all of the larger 8kV cables. In other cases, both low and medium voltage cables were bent too tightly as a result of undersized termination housings supplied by end equipment manufacturers. Finally, TVA's construction forces incorrectly installed some cables as a result of inattention to detail and as a result of insufficient direction from engineering.

While at least one deviation from ICEA[1] standards has been noted for almost every category of cable, the most pervasive violations were in the areas of medium voltage power cables and low voltage multiconductor control cables. In the former category, TVA had contacted its major suppliers in the early 1980s and been granted some relief from the ICEA 12x requirements (see Table 1 and Attachment 1). Those relaxations had been incorporated into the referenced internal TVA standard[2] (Attachment 2).

In the latter category, TVA had established its allowable bend radius based on multiples of the diameter of a single conductor from a multiconductor cable, rather than from its overall diameter. When applied to cables with a large number of singles, this methodology represented a significant deviation from ICEA requirements (Attachments 2 and 3).

In the mid-1980s, as a result of internal reviews and NRC inspection findings, bend radius violations were deemed as potentially programmatic. The reviews and findings indicated that TVA standards lacked a documented basis for deviations from industry requirements. It was further noted that installations existed where bends were in violation even of the comparatively relaxed TVA standards.

When vendors were contacted to identify the basis for their previous relaxations of low- and medium-voltage bend radius requirements, most were withdrawn.

Table 1
1983 Training Radius Relaxation, Medium Voltage

Vendor	Multiplier
Okonite	4.4
Collyer	8.0
Anaconda-Ericsson	8.4
Rome Cable Corporation	10.9
Essex	7.0
General Cable	7.0
Triangle-Plastic Wire and Cable	7.0

Method of Resolution:

In order to properly assess the significance of the subject deficiencies, TVA embarked upon a program of testing and analysis with the following salient points:

- Definition of potential degradation mechanisms resulting from the tight bends and the consequent impact on performance.
- Limited literature search and informal industry survey to identify the results of previous research.
- Testing to establish the point of onset for the degrading mechanism(s).
- Definition of an inspection/acceptance criteria based on the above findings and conclusions with consideration for the cables' normal and

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[1] ICEA Standards S-68-516 , "Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy" and S-66-524 "Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy".

[2] Design Standard DS-E12.1.5, Revision 3, "Minimum Radius for Field Installed Insulated Cables Rated 15,000 Volts or Less."

accident service conditions.

- Initiation of a long-term plan comprised of condition monitoring, inspections, failure trending, ongoing upgrades and industry participation to ensure early identification of adverse trends. Following development, a presentation of the program was made to the three primary suppliers of nuclear grade cable to TVA. Each supplier was asked to identify any deficiencies in the TVA approach.

An overview of each of the efforts is provided in the sections which follow.

Evaluation of Mechanism:

Excess bending of safety-related cable is of concern due to the potential impact on performance. To evaluate that impact, the influence of bending was reviewed with respect to the constituent components of the various cable constructions. For the potential bend radius violations under consideration, the effects fell into two major categories. The first is the impact of the supplemental elongation imparted to the primary insulation as a consequence of the tight bend, while the latter is the permanent mechanical deformation of critical cable components (i.e. disruption of the extruded shielding system, deformation of the conductor or metallic tape shield). Each of these categories was reviewed for low- and medium-voltage cable types so that subsequent analysis would account for all known phenomena.

Medium Voltage

For medium-voltage cables, three mechanisms were judged to be of potential concern.

First, bends with radii below those permitted by industry standards result in an additional elongating stress to the insulation system. Since a cable's qualified life is generally defined in terms of retention of elongation, such an additional pre-stress may be viewed as a potential reduction in life. The stress developed in a bend may be readily determined by the following formula:

$$Elongation\% = \frac{100}{2 \cdot BendRadiusFactor + 1}$$

The incremental increase in stress above that experienced by a cable with a "standard" bend is then determined by subtracting the "standard" stress from the value for the overbend. Based on the installed configurations, conversations with its primary suppliers and testing conducted for TVA's Browns Ferry Nuclear Plant, a minimum training radius of 8x had been established as a target for resolving WBN issues (this selection was also supported by ICEA[3] standards which permit medium voltage cables to be shipped on reels with drum diameters sized to ensure a 7x bend radius). For the 8x bends under consideration in medium voltage cables, the incremental stress is less than 2% (5.9%-4%, see Table 2). Thus, unlike low voltage power cables bent to 1x, 2x or 3x, no special consideration was given to a possible synergisms between physical stress and aging for this category.

Table 2
Elongation as a Function of Bend Radius, %

Multiples of Cable OD	Elongating Stress, %
1	33.3
2	20.0
3	14.3
4	11.1
5	9.1
6	7.7
8	5.9
10	4.8
12	4.0

Second, overbending may result in interfacial disruptions between a medium-voltage cable's stress

[3]ICEA Standard A9-428, "Drum Diameters of Reels for Wires and Cables"

control layers and the insulation. These layers (strand shield, insulation, and insulation shield) must remain in intimate contact to ensure proper electric stress distribution and provide protection against corona inception. Additionally, the helically wound copper tape shield must not become so deformed as to potentially pinch or gouge the insulation and/or insulation shield. Such action would again result in the increased likelihood of corona· induced degradation. Therefore, it was decided that tests undertaken by TVA would include direct evaluation of both tape shield and interfacial integrity.

The third consideration was for conductor deformation resulting from the bend. Concern existed that such deformation might result in a residual radial mechanical stress on the insulation system. Therefore, TVA's test program was designed to consider conductor integrity for both overbent specimens and retrained overbent specimens.

Low Voltage

For low-voltage cables, no such interfacial concerns exist due to the absence of electric stress control layers. Only the issues of additional elongating stress and conductor deformation are applicable and were included in TVA's short-term evaluation. However, as a result of the higher level of incremental mechanical stress imparted to tightly bent low voltage power cables, it was recognized that some potential exists for a synergism between physical stress and aging. This latter phenomenon is discussed as a part of the long-term program.

While the above discussion addresses the significant factors associated with single conductor cable bends, TVA recognized that an additional influence may be present in multiconductor cables. For these designs, tight bends result in a flattening of the overall jacket such that the cables' cross section becomes oval rather than circular. In such a bend, mechanical stresses are imparted to the individual conductors from the jacket, other conductors and drain wires (where applicable). The magnitude of such forces is influenced by the specific construction of the cable (size and number of conductors, presence of drain wires, tightness of the core and jacket, type of filler material, etc.). Because of the number of variables involved, TVA opted to follow an existing precedent[4] within the industry for multiconductor cables and confirm its use through limited bending tests described below (Attachment 4).

Literature Search and Informal Industry Survey:

Literature Search

The potential for synergistic effects on nuclear power plant cables has been the subject of considerable interest within the industry since the publication of NUREG/CR-3538[5], which documented the failure of certain EPR/CPE cables during an in-containment accident simulation test. The authors of the report postulated (amongst other things) that the failure during their simultaneous testing of material which had successfully endured the vendor's sequential tests may have been the result of a synergism not noted during the original tests. Consequently, several Sandia programs have evaluated the interplay of thermal and radiation aging[6]. During the same time frame, the IEEE

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[4]Table I, column A of Rockbestos Technical Bulletin No. 28, "Bending Radii and Installation Practices"

[5]NUREG/CR-3538, The Effect of LOCA Simulation Procedures on Ethylene Propylene Rubber's Mechanical and Electrical Properties", Larry D. Bustard, Sandia National Laboratories, October 1983.

[6]NUREG/CR-3629, "The Effect of Thermal and Irradiation Aging Simulation Procedures on Polymer Properties", Bustard et al, Sandia National Laboratories, April 1984. NUREG/CR-4091, "The Effect of Alternative Aging and Accident Simulations on Polymer Properties". NUREG/CR-4536, "Superheated-Steam Test of Ethylene Propylene Rubber Cables Using a Simultaneous Aging and Accident Environment", Bennett et al, Sandia National Laboratories, June 1986. SAND91-0822, "Aging Predictions in Nuclear Power Plants - Crosslinked Polyolefin and EPR Cable Insulation

Dielectric and Electrical Insulation Society formed a Technical Committee on Multifactor Stress. Its primary research seems to have been directed to high-voltage insulation systems and the combination of dielectric stresses with other factors. However, an informal literature search has noted the existence of several papers, guides and standards which bear on the issue or provide guidance in the performance of such testing to quantify the effects.

A short review of some of the findings appears below:

IEEE 1064-1991[7] - This document provides direction for the design and performance of multistress aging programs such as described below to address the cables of concern. The guide adds nothing which impacts directly on the potential thermal-mechanical synergism given a constant mechanical stress. Instead, the guide seems to assume that such stress is cyclical, being either vibratory or related to thermal expansion and contraction. It suggests that such multistress tests are appropriate when the absence of factor interaction is not confidently known. The IEC also has two documents[8] which address this same set of issues. The documents are unavailable within the TVA system and were not consulted as a part of this study.

IEEE 775-1993[9] - This document provides some guidance for the performance of a multistress aging program in a radiation environment but adds nothing which bears directly on the potential thermal-mechanical synergism. Given the low radiation exposure outside of containment, no special consideration is given for this potential stressor.

Ilstad, et al[10] - The subject paper reports on the findings of a study of the influence of mechanical stress on the rate of water tree growth. The authors sharply coiled 12 kV XLPE insulated cables on mandrels, immersed them in room temperature water and energized them at twice their rated potential. Following conclusion of the six month period of accelerated aging they noted, "The enhanced initiation and growth of vented water trees in the stretched zones is clearly demonstrated". This can be observed from Table 1 of the subject paper, which is reproduced in Table 2 of this document. The authors hold to a mechanical damage theory of water tree growth, wherein induced Maxwell stresses at the root of a water-filled craze work to propagate the fracture. They postulate that the increased stresses resulting from the tight bend supplement the Maxwell stresses and stimulate the growth rate. Since the WBN program is limited to cables in 10CFR50.49 service (where there is no long-term submergence), the concern identified by this paper is not applicable.

de Mattos, et al[11] - The subject paper involved the

Materials", Gillen and Clough, Sandia National Laboratories, June 1991. SAND88-0754, "Time-Temperature-Dose Rate Superposition: A Methodology for Predicting Cable Degradation Under Ambient Nuclear Power Plant Aging Conditions", Gillen and Clough, Sandia National Laboratories, August 1988. SAND90-2009, "Predictive Aging Results for Cable Materials in Nuclear Power Plants", Gillen and Clough, Sandia National Laboratories, November 1990.

[7]IEEE 1064-1991, "IEEE Guide for Multifactor Stress Functional Testing of Electrical Insulation Systems"

[8]IEC 792, part 1, "Multi-Factor Functional Testing of Electrical Insulation Systems, Part 1: Test Procedures", 1985 and IEC 792, part 2, "Multi-Factor Functional Testing of Electrical Insulation Systems, Part 2: Bibliography", 1993.

[9]IEEE-775 "IEEE Guide for Designing Multistress Aging Tests of Electrical Insulation in a Radiation Environment"

[10]"Influence of Mechanical Stress and Frequency on Water Treeing in XLPE Cable Insulation", E. Ilstad, H. Bardsen, H. Faremo and B. Knutsen, 1990 IEEE International Symposium on Electrical Insulation, Toronto, Canada.

[11]"Multiple Stress Aging of HV Polymeric Insulation", E. L. de Mattos and C. H. de Tourreil, IEEE Transactions on Electrical Insulation, Vol. 25,

testing of EPDM, EPM and silicone rubber weather sheds used in HV transmission line insulators. The program was multifaceted in that it assessed aging as a function of mechanical, thermal, and electrical stressors in an UV environment. One portion of the program involved the analysis of the effect on aging of mechanical stressors when applied to the slabs of the EPDM and EPM materials only. According to the paper, "The specimens were placed on steel frames in such a way that the narrow part of the specimen was stretched by 0, 30, or 60%. Two specimens of each material at each of the three stress levels were aged for 1000, 2000 and 3000 hours. This aging was done in an air conditioned room at about 23°C and about 40% relative humidity...... At the end of each aging period elongation at rupture tests were performed. The variations of the elongation at rupture values of materials A and B aged for up to 3000 hours was less than 10% of the value measured on the new specimens even for the stretch value of 60%. These variations are within the accuracy of the measurement." The absence of significant thermal stresses on the specimens which were elongated makes this paper of limited value for power cables, while at the same time it confirms the assumptions made with respect to control and instrumentation cables.

Wyle test report 17503-1[12] - Item 3.2 of the subject report, a PE insulated, PVC jacketed cable, was aged (40 years at 75°C), irradiated (1 Mrad) and accident tested while bent to approximately 1.5x. The cable successfully withstood the 320°F exposure and subsequent post-LOCA hipot. Thus, no synergism was noted, though the results for this semi-crystalline material may be deceptive for reasons described in the section entitled "Long Term Program".

Wyle test report 17732-1[13] - This test program involved the preaging of 41 low- and medium-voltage specimens followed by a simulated accident exposure. The specimens (PE, XLPE and EPR insulated) were installed on mandrels which resulted in the cables being bent at their minimum ICEA radius. The intent of the use of the small radius was to permit as many specimens as possible to be installed in a single chamber and not intentionally to evaluate bend radius. Two sets of specimens were prepared. One set received thermal aging equivalent to 40 years and the second 20 years, both at 60°C (based on conservative activation energies). The 40 year set received 75 Mrads of radiation (aging plus accident), while the 20 year set received 65 Mrads. All radiation was applied prior to thermal aging. The peak accident temperature was 255°F. Numerous lab related anomalies were recorded, but all cables were found to be qualified either during the initial exposure or during a subsequent re-test (as a result of the anomalies). Thus no synergism was noted, though the results on semicrystalline materials may be deceptive as noted above.

Wyle test report 17740-1[14] - This program was similar to the 17732-1 report noted above, except that it was limited to 11 PE and XLPE specimens *which had undergone the 17732-1 exposure* and the peak accident temperature was approximately 340°F. Two specimen related anomalies were noted. The first involved a breakdown near the splice to the test lead and was successfully dispositioned. The second

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No. 3, June 1990, pages 521-526.

[12]Wyle test report 17503-1, "Nuclear Environmental Qualification Test Program on Sequoyah Nuclear Station Control Equipment and Cables", TVA contract TV-56071A.

[13]Wyle test report 17732-1, Nuclear Environmental Qualification Test Program on Various Cables Used Outside Containment (Profile 3) for Tennessee Valley Authority for Use in Sequoyah and Watts Bar Nuclear Generating Stations", TVA contract TV-56071A.

[14]Wyle test report 17740-1, Nuclear Environmental Qualification Test Program on Various Cables for use in Sequoyah Nuclear Plant East and West Steam Valve Rooms and East Steam Valve Vault Instrument Rooms and Watts Bar Nuclear Plant North and South Steam Valve Rooms and North Steam Valve Vault Instrument Rooms", TVA contract TV-56071A.

involved a failure on one XLPE/PVC/PVC specimen, near its connection (though outside the defined transitional area). Thus, this cable was deemed to have failed the valve vault profile. Since this was the second accident test for this specimen (the first having been passed), no direct conclusion regarding bend related synergisms can be drawn.

SAND 78-0718[15] - This report is a part of a larger program undertaken to assess possible synergistic effects of different aging and accident scenarios. In this segment of the program, numerous cable specimens were prepared with small radius bends (of an unspecified diameter but well below the 40x of IEEE 383, based on evaluation of the report photographs). The cables (neoprene, EPR and XLPE insulated) were aged and then exposed to a combined thermal-radiation-pressure-spray LOCA.

All cables held rated voltage and current throughout the test and it was concluded that no significant synergisms existed. Some cracking of the cables jackets was noted in the bend areas (particularly specimen A). This should not have been unexpected since the thermal aging portion of the pre-aging was carried out at 175°C, well above the capability for most CSPE jackets. As is the case for the Wyle/TVA programs, the results for semi-crystalline materials may be deceptive as noted above.

Bruning and Campbell[16] - The subject paper deals extensively with multistress aging of polyimide insulation (Kapton) as used by the US Navy. The multi-layer tape insulation is applied in aircraft wiring since its thin walls permit reduction in weight and congestion. Kapton's high thermal rating likewise permits the use of high current densities and thus small gauge wire.

Their research showed that the combination of moisture, high temperature and mechanical strain had led to the premature degradation. In tests conducted by Bruning, cables exposed to 100°C water for only 64 hours while bent to approximately 1.5x, developed cracks. Unlike so many of the papers noted above, electrical aging was not the focus of the program and dielectric stress was only applied during periodic hipot testing to assess for the existence of cracks.

Bruning stated that the process at work here is chemical in nature and that the ordinary Arrhenius relationship is altered by virtue of a change in the activation energy resulting from the mechanical strain.

$$E_{eff} = E_a - E_{str}$$

In this equation, E_a is the material's activation energy as developed in a single stress test (such as thermal aging) and E_{str} is the stress energy. Thus, the effective activation energy, E_{eff}, of the reaction of the polyimide with the sorbed water is reduced by imposition of the strain. The reaction is said to lead to chain scission which lowers the overall molecular weight of the polymer. Thus, its aging is accelerated beyond the single stress model.

In principle many of the conclusions noted above for Kapton should also be true for the XLPE and EPR insulations which are the focus of the WBN study. However, certain qualifiers limit the implied effects. First, the relative stress applied to the WBN cables is far below that imposed by the Bruning study. Shugg[17] notes that the elongation of Kapton at break is only 70%, compared to 250-500% for the other materials. Thus, in the case of Kapton, even a standard ICEA bend represents a significant

[15] SAND78-0718, Preliminary Data Report, Testing to Evaluate Synergistic Effects from LOCA Environments, Frank V. Thoms, Sandia National Laboratories, April 1978

[16] "Aging in Wire Insulation under Multifactor Stress", A. M. Bruning and F. J. Campbell, IEEE Transactions on Electrical Insulation, Vol. 28 No. 5, October 1993, pages 729-754.

[17] "Handbook of Electrical and Electronic Insulating Materials", W. Tillar Shugg, Van Nostrand Reinhold, NY, 1986.

mechanical stress. In contrast, even the reduced bend radii utilized at WBN do not represent a significant percentage of those material's ultimate elongation. From this we conclude that any reduction of the activation energy by E_{su} would be minor.

Second, the Kapton degradation occurred via the hydrolysis process which is not a factor for XLPE or EPR. For insulations typically utilized in the nuclear environment, moisture is not considered an aging stressor. As will be noted below, several individuals contacted as a part of the industry survey noted a similar process involving some materials (notably neoprene) in an ozone rich environment, but none for the WBN materials and environments.

1992 EPRI Workshop[18] - The workshop, jointly sponsored by EPRI, the Office of Naval Research and the Strategic Defense Initiative Organization included eight invited presentations and several breakout sessions among the 65 engineers and scientists from 17 countries who gathered by special invitation. Only the presentations by A. M. Bruning and J. P. Crine seem to have dealt with the issue of mechanical stress as applied to cable insulation. Bruning's presentation was an overview of the work which has been discussed above. Crine noted, "In the case of mechanical aging of polymers an exponential regime was found at high stresses and a tail at low stresses that is very similar to electrical aging. In a plot of log of time-to-breakdown versus mechanical stress, one finds a plateau stress for nearly infinite life". Though it appears that Crine's remarks[19] were given in the context of combined mechanical and electrical stress rather than mechanical-thermal, the conclusion that low stresses (such as those under consideration) have no effect seems to testify to the notion that the low stresses do not alter the apparent activation energy, a process described above by Bruning and Campbell.

G. C. Stone[20] - Stone notes that though models to evaluate mechanical stress are well known for metals, they have infrequently been used for electrical insulation. He suggests that a model proposed for magnetically induced mechanical stresses in turbine generator end-turns might be appropriate for evaluating insulation fatigue at tight cable bends due to load cycling. The proposed models tend to follow the relationship, "...for metal fatigue,

$$L \cdot H \cdot S^{-J}$$

where S is the amplitude of displacement, L is the number of mechanical cycles to failure (which can be converted to time if the mechanical fatigue frequency is constant, e.g. 120 Hz), and H and J are calculated constants". Stone notes that there has been little experimental verification of this model for electrical insulation, "perhaps since there are few situations where mechanical aging is the dominant form of aging". In consideration of the above, this model obviously would not apply to non-power circuits since no "load-cycling" would occur. Likewise, its impact would be minimal for typical generating station power cables since their period of thermal-mechanical cycling is typically measured in hours or days rather than so many cycles per second as in the case of the end-turns.

EPRI transmission cable study[21] - In addition to the

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[18] "Proceedings: Multi-Factor Aging Mechanisms and Models 1992 Workshop", EPRI report TR-103172, June 1994.

[19] Similar comments are made in, "A Model of Solid Dielectrics Aging", J. P. Crine, Conference Record of the 1990 IEEE International Symposium on Electrical Insulation, Toronto, pages 25-26, Canada, 1990 and in "Aging of Extruded Dielectric Power Cables: Theory", EPRI report TR-101660, December 1992.

[20] "The Statistics of Aging Models and Practical Reality", G. C. Stone, IEEE Transactions on Electrical Insulation, Vol. 28 No. 5, October 1993, pages 716-728.

[21] "Multi-Stress Aging of Extruded Insulation Systems for Transmission Cables", EPRI TR-100268,

inverse power model noted above by Stone, the report notes the existence of several exponential models which appear similar in nature to that used by Bruning and Campbell in that they consider the mechanical energy of the stress as reducing effective activation energy of the material.

The report also provided a review of existing test data. One study of a 275 kV cable had shown some conductor movement through the insulation when the operating temperature was in the overload region (90°C to 130°C) as a result of the lateral forces imposed by the conductor and the reduction in the XLPE's compressive modulus at the elevated temperature. It was noted that, "... conductor displacement at 90°C was very small..." and thus their recommendations dealt only with the proper selection of the emergency overload temperature. Though the cited study does not deal with "aging" in a classical sense, it does deal with the concern for interfacial disruptions. TVA's various load cycle and corona tests, described below, would have evaluated this creep tendency on a macro scale, in that substantial conductor displacement would have resulted in detectable corona discharge.

DOE Aging Management Guide[22] - The draft guide includes a discussion of several mechanical aging stressors that are considered significant. Included were vibratory stresses, bending and flexing during maintenance activities and thermomechanical-gravitational forces (the latter being a "ratcheting" effect which can occur when power cables are subject to unsupported vertical drops and load cycled). The report does note the possibility of a "tensile failure" as a result of this latter condition but the concern is for the load on the equipment termination as a result of the ratcheting and not any tensile load on the insulation itself.

May 1992.

[22]"Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations", Draft Report, April 28, 1995, prepared by Ogden Environmental and Energy Services Company for the Department of Energy.

Industry Survey

During the period from 1989 to 1992, TVA's Corporate Cable Specialist contacted several of the leading engineers and chemists in the industry to discuss the WBN cable bend radius program. The contacts were of an informal nature and little documentation of the discussions exists. The intent of the contacts was to ensure that all known effects had been evaluated and to identify the appropriate protocols when laboratory work was required. The listing of course does not imply that those individuals ever reviewed or approved of the WBN program, only that they were surveyed as a part of its development.

<u>Name</u>	<u>1995 Affiliation</u>
Jack Lasky	Okonite

Lasky, the chief engineer at Okonite, suggested that bird caging of the copper was a greater concern than any synergism at the stress levels under consideration. Lasky also had a concern for plastic deformation of certain multiconductor cables under tight bend conditions. He proposed a bend-and-AC-hipot test and believed that there would not be any synergism unless an ozone environment was present.

Bob Gehm — Rockbestos

Gehm, the chief engineer at Rockbestos, believed that one could readily bend cables to one-half of the ICEA limits without degradation. He noted that ICEA limits were typically fabricated with power cables in mind. Thus, when evaluating instrumentation and control applications, considerable margin exists. Suggested a bend test where the exposed copper was evaluated for deformation.

Keith Petty — SWEC

Petty, the SWEC Corporate Cable Specialist, participated in a bend radius test program with Rockbestos in the late 1970s to assist Palo Verde, Limerick and Perry Nuclear Stations. The programs included bending followed by visual inspection, assessment of conductor deformation, insulation resistance and dielectric breakdown. Petty also noted that ICEA was considering establishing the bend radius of multiconductor cables as a function of the OD of the singles, rather than as a function of the completed cable.

Larry Bustard Sandia

Bustard, one of the key researchers in the cable arena, had a particular concern for CPE jacketed cables due to that materials tendency to shrink at elevated temperature. He noted that Ken Gillen of Sandia had observed some synergism between stress and aging in an ozone environment. Suggested that the brute force approach would be to measure elongation post-LOCA on bent and unbent samples.

R. Arhart DuPont

Arhart, the chief cable polymer chemist for DuPont, noted that there were some known synergisms as a result of testing of plastics by the automotive industry, but that these always involved flexural stressing rather than a fixed stress.

Gary Toman NUS

Toman, an engineer with ERC International at the time and a consultant to the NRC on TVA issues, suggested a LOCA on bent cables. He noted that no mandrel rebend would be necessary. He foresaw no problems except in the harshest of areas unless the bend was against a sharp corner.

Chris Diglio Consultant

Diglio, who was the chief chemist for Brand Rex at the time, suggested that a program of aging unbent cables, bending a portion of them and then dielectrically breaking them all down would provide a basis for comparison.

R. Luther Consultant

Luther, former Cable Specialist for Northeast Utilities, restricted his comments to medium voltage, where he proposed an adaptation of the AEIC load cycle and corona test to assess the effect of bending on the insulation/shield system.

Morton Brown Consultant

Brown, the former chief cable polymer chemist for DuPont and now a consultant for A. Schulman, noted the existence of synergisms for certain plastics used in the automotive industry. He stated that the automotive industry frequently used a "bent loop" test where the specimen is wound on a form and then exposed to the desired stressor (frequently UV). Following this test, they optically check the plastic for the existence of stress cracks.

Joe Groeger Altran Materials Engineering

Groeger, the former Assistant Director of the University of Connecticut's Electrical Research Center, had been involved in numerous programs which had evaluated cables aged under tight bend conditions. As was typical of many of the programs noted above, the second aging stress applied was voltage rather than thermal. In contrast to the work by Ilstad cited above, Groeger had observed no increase in the rate of treeing due to the presence of a mechanical stress unless the cable had residual axial stresses (from the extrusion process). In this case, the compression of the insulation on the inner radius may have been the source of the observed difference rather than the existence of the additional stress on the outer radius. Groeger noted that the protocol should have relieved those stresses before commencing the aging cycle in order to avoid the uncertainty.

The TVA bend radius plan was also discussed in that time frame with other vendors/consultants who had no particular recommendations but provided feedback on the TVA plan. Those individuals were as follows:

Name	1995 Affiliation
Bob Fleming	Kerite
Steve Sandberg	Delta Surprenant
Paul Cardello	Consultant

Table 2 (Table 1 of Ilstad et. al.)
Measured number of vented water trees from the insulation screen of the sharply coiled cable per 5 mm long section (equal to an area of 230 mm²)

Radius of curvature (mm)	Aging time (years)	Number per circumference position					
		tension			compression		
		1	2	3	4	5	6
50	0.3	32	32	32	13	14	9
	0.5	68	72	58	10	4	6
70	0.3	21	25	42	14	11	5
	0.5	26	71	71	17	10	2
100	0.3	33	16	32	8	8	12
	0.5	51	90	91	19	2	10

Testing to Establish "Lower Bound":

In order to assess the parameters discussed above, tests were initiated by TVA at its Central Laboratories Services Department[23] (CLSD) in Chattanooga and at The Okonite Company[24] in Ramsey, NJ. These evaluations, which are type test in nature, were conducted in accordance with each lab's quality assurance program.

The first CLSD program consisted of the bending of single conductor cables, ranging in size from 16 AWG to 500 MCM, (low and medium voltage) on specially constructed forms. The "lower bound" for such a specimen was tentatively regarded as the radius at which significant deformation occurred plus one cable diameter (lx) or the minimum practical bend, if no deformation was noted. An additional specimen was then bent to this "lower bound" and subsequently retrained to a larger radius (typically the ICEA radius). This step was intended to demonstrate that the nonelastic components (conductor, tape shield, etc.) would not deform during the retraining. In order to simulate conditions in "mid-run", the strands of the conductor were soldered together so that they could not move past one another to relieve the bending stress. This was deemed a conservative factor, since many of the tight bends actually occur in the near vicinity of the termination where such movements are indeed possible.

In the case of the medium-voltage test program, if the tape shield integrity was still present (no separation, no gouging or pinching, etc.) and excessive conductor deformation (i.e., birdcaging) had not occurred, the "lower bound" value was confirmed. In all cases, the lower bound for medium voltage cables turned out to be a function of the theoretical loss of overlap of the metallic tape shield rather than conductor deformation or interfacial disruptions. The postulated separation was determined by comparing the minimum permissible tape overlap (10%) as directed by ICEA requirements or TVA procurement specifications with the bend factor which results in that degree of stress. Since the tape

[23] CLSD Report 90-1014, "Test to Document Cable Bend Radius Damage", June 1990. CLSD Report 90-1817, "Multi-Conductor Cable Bend Radius Damage Tests", January 1992. Additional tests were also performed for TVA's Bellefonte Nuclear Plant and reported in 92-0459. Those results were consistent with the WBN programs.

[24] The Okonite Company Report 02-6451, "Final Test Report for Cable Bend Radius, Corona and Load Cycle Testing of 8Kv Medium Voltage Cables", 1992.

does not stretch, the bend was assumed to have produced a loss of overlap corresponding to the stress. Thus, for medium voltage the lower bound[25] was determined to be four[26].

As noted above, WBN's target training radius for its medium voltage (8 kV rated) cables used in Class 1E applications is 8 times the cable's outer diameter which produces less than two percent additional elongating stress than the ICEA recommended value of twelve times. Compared to the ultimate capability of these insulations, this increase is insignificant. The critical issue for these cables is the insulation-to-shield integrity. Using the same method used by the industry to qualify a cable system design (Load Cycling and Corona Testing), WBN developed and performed a series of tests to address this issue. However, in contrast to the protocol in AEIC Specifications CS5 and CS6[27], WBN's tests were performed on cable bent to a four times (4x) multiplier and retrained to 8x. The cables tested met the AEIC requirements and thus established the integrity of the insulation-to-shield systems even when subjected to a moderate bending stress.

For low voltage cables, the lower bound was reached when the non-standard bend produced a 3% conductor deformation[28] or at the minimum practical bend when that did not occur (the 3% criteria was established following discussions with various cable vendors). The lower bound for low-voltage cables 10 AWG and smaller was set at a bend radius factor of one and was set at two for cables 8 AWG and larger.

In order to ensure that the guidance provided in Rockbestos Technical Bulletin 28 was adequate for multiconductor cables which had been previously bent down to, but not below the lower bound and then retrained, additional testing was performed on ten specimens. Since the concern for this construction type is for insulation deformation (as opposed to the conductor), the test plan called for the measurement of insulation thickness at the point of greatest deformation. The cables were deemed to be acceptable as long as the wall thickness measured at that point exceeded the ICEA minimum (ie 90% of the nominal wall thickness). All specimens met the above criteria.

Development of Inspection/Acceptance Criteria:

Having thus defined the mechanisms of concern and having established lower bound values, a review was initiated to correlate this information with industry standards, vendor letters, voltage and current loading requirements, cable construction, and environmental parameters.

Given the severity of the environmental conditions postulated in certain areas (and its regulatory environment), WBN decided to take a conservative approach in primary containment and the main steam valve vault and utilize less restrictive criteria elsewhere based on test results and analysis. Results are summarized in Table 4. Several comments regarding the table are warranted:

- Class 1E 10 CFR 50.49[29] cables located inside of primary containment and the main steam

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[25]As noted above, the "lower bound" values defined the onset of damage and were not used to establish permissible training radii in the field.

[26]Additional tests were performed for TVA's Browns Ferry Nuclear Plant on 5kV cables bent to 6x. Those tests were conducted at Cable Technologies Laboratories in New Brunswick, NJ. The results, documented in Report 93-007, were consistent with the Okonite findings.

[27]Association of Edison Illuminating Companies Specifications, CS5, "Thermoplastic and Cross-Linked Polyethylene Insulated Shielded Power Cables Rated 5 through 35 KV" and CS6, "Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 through 69 KV"

[28]Percent conductor deformation was determined by dividing its post-bend diameter by the pre-bend diameter and subtracting 1 from the result.

[29]10 CFR 50.49, Title 10 of the Code of Federal Regulations, Part 50 (Domestic Licensing of Production and Utilization Facilities), section 49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants".

valve vault will comply with industry standard bend radius factors. This is in recognition of the severity of the accident environmental transient in these areas. Cables found to be bent below the lower bound will be replaced.

- Medium-voltage Class 1E cables required to support Unit 1 operation have been inspected to ensure at least an 8 times bend radius factor. This training radius factor is consistent with recommendations based on independent testing performed by some TVA vendors. None of these cables are located in primary containment or the valve vault. Environmental transients in the remainder of the plant are significantly lower with respect to both magnitude and duration.

  Cables which were above the lower bound (4 times) but less than 8 times will receive a high-potential withstand test at maintenance levels[30] prior to Unit 1 startup subsequent to their retraining. Cables found to be bent below the lower bound will be replaced.

- Low-voltage single conductor power cables in 10 CFR 50.49 service but installed in areas other than the primary containment and the main steam valve vault will be accepted "as-is", provided that they are not bent below their lower bound. Cables found to be bent below the lower bound will be replaced[31].

- Low-voltage single conductor cables which are in 10 CFR 50.49 control applications and are located outside of the primary containment and the main steam valve vault may be accepted "as-is" without a reduction in qualified life. Cables found to be bent below the lower bound will be replaced. Control cables are generally accepted to operate at or near ambient temperature because of the minimal current loading within this voltage level. Elimination of this factor significantly reduces concerns for this age-related phenomenon. Figure 1 is a typical plot for EPR Type II when used in control applications. Assuming values of 1.1 eV for activation energy and 60°C for conductor temperature results in a "qualified life" of in excess of 900 years for this 90°C material. Reducing the initial elongation by the differential stress imposed by the tight bend is shown to be of no effect for the plant's 40-year life.

- Low-voltage multiconductor power, control, and signal cables which are in 10 CFR 50.49 service outside of primary containment and the main steam valve vault and multiconductor power cables which are not in 10 CFR 50.49 circuits but are in containment or the valve vault may be retrained and used without

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[30] Institute of Electrical and Electronics Engineers (IEEE) 400-1980, "Guide for Making High-Direct-Voltage Tests on Power Cable Systems in the Field."

[31] It was originally intended that those 10 CFR 50.49, single conductor, low voltage power cables which were found to be above the lower bound but below the ICEA radius would be accepted based on a reduction in life directly proportional to the additional stress. That method would have entailed an assumption that no synergistic effect existed between the additional physical stress and aging and required laboratory confirmation of that assumption as was described in revision 0 of this plan. However, subsequent walkdowns and inspections showed that all single conductor, low voltage power cables within the scope of 10 CFR 50.49 were trained at or above the ICEA limit, obviating the need for further research in this area. The scope of the inspections was identified in WBPEVAR9007015 (section 7) and carried out under DCNs M-09484-A, M-10189-A, M-10464-D, M-10823-A, M-10950-A and M-10951-A). As was noted in the NE response to action item 712 of the WBN Independent Design Review Assessment, "No data sheets were received per the above DCN requirements, thus no cables remained installed at a radius which requires a reduction in qualified life" (see attachment 7.0, item 3). Additional confirmation that this assumption was not used was obtained by a review of Tabs B and G of the EQ binders containing PXJ and CPJ cables (WBN EQ CABL-002, 008, 021, 032, 043, 044, 050, 051, 052, 053).

reduction in life provided they are not bent to less than the lower bound for their individual conductors. Cables found to be bent below the lower bound will be replaced. The training radius factor applied to this family (see Table 3[32]) gives consideration to both the size and number of individual conductors. Restricting the bends in this manner limits the forces produced between the constituent components of a multiconductor cable. By eliminating this issue of concern, the 10 CFR 50.49 cables may now be regarded as qualified for their full life since the smallest bend allowable per this bulletin is 4x the diameter of a single conductor. This value corresponds to ICEA guidance.

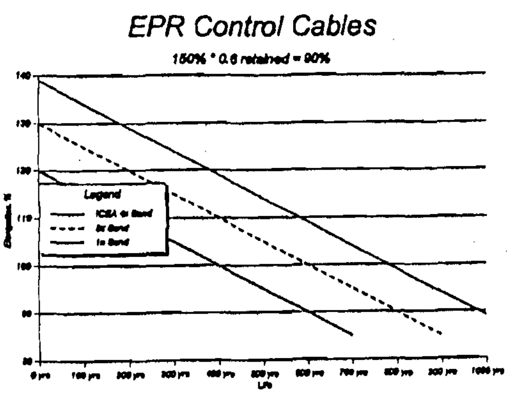

Figure 1

Table 3
Multiconductor Training Radius

Factor	No. of Conductors
4	9 or less
8	10 - 19
12	more than 19

[32]Table I, column A of Rockbestos Technical Bulletin No. 28, "Bending Radii and Installation Practices"

- Low-voltage Class 1E single conductor power cables in non-10 CFR 50.49 service inside of containment or the main steam valve vault will be accepted "as-is" provided that they are not bent less than the lower bound. Cables found to be bent below the lower bound will be replaced. Since these cables have no accident service requirements, the pre-LOCA end-of-life criterion previously discussed is not applicable. However, a typical "projected life" analysis, as shown in Figure 2, indicates a minimum of 40-year service life for bends at the lower bound and above[33].

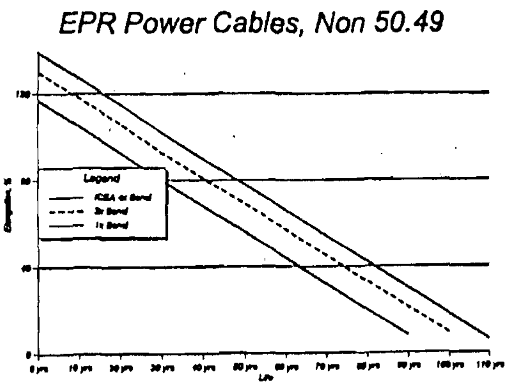

Figure 2

- All 10 CFR 50.49 and RG 1.97[34] single-jacketed coax cable in harsh environment (much of which had been installed under

[33]These non-50.49 power cables have no accident service requirements, thus no common mode failure mechanism exists even if aging/physical stress synergism were identifie. Any resulting failures during their required normal environment operation would be random in time.

[34]Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following and Accident", May 1993.

relaxed requirements, Attachments 2 and 5) has been replaced as a result of a concern for jacket integrity following the installation process. While jackets are generally considered sacrificial for most other cable types, a breach in a coaxial cable's jacket could lead to moisture wicking up the braid and shorting out the connector. To ensure the integrity of this moisture barrier, TVA adopted a new design for its harsh environment coaxial cables. The new design incorporates a second jacket, which serves as the "sacrificial layer", while the inner jacket acts as the moisture barrier. The new double-jacketed cables will be installed to meet ICEA requirements.

- The remaining cables will be used "as-is." These cables either are not exposed to accident service conditions or are not required to mitigate the consequences of such an accident. As such, the margins associated with the remaining cables exceed even those described above.

Long-Term Program:

In order to ensure the mechanisms pertinent to cable performance under small bend radius conditions have been properly evaluated for age-related consequences of such bends on normal and accident service, a long-term cable bend radius program plan has been established. It's key components include a condition monitoring, inspections, failure trending, ongoing upgrades and industry participation.

Cable Condition Monitoring

TVA has initiated a cable monitoring and trending program for WBN. The program invokes a combination of meggering, high-potential testing and visual inspection to ensure the continued integrity of cables in safety-related systems. WBN's cable condition monitoring program has been developed to comply with the recommendations set forth in IEN 86-49[35].

Since the scope of IEN 86-49 is much broader than bend radius, the cable condition monitoring aspect of TVA's long-term bend radius program addresses medium voltage power, control voltage, and instrumentation voltage as well as the previously mentioned low voltage power cables. However, the program does emphasize monitoring of feeder cables to large motors (100 hp or larger), because of their consequent higher rate of aging due to their thermal loading and cycling. This results in the routine dielectric examination of the very circuits expected to first display signs of postulated degradation when overbent.

Additional confidence is provided by implementation of a program that merges the following test and inspection data to ensure the early identification of undesirable trends.

Periodic Testing

Periodic insulation resistance testing on a random selection of 80 percent of 100 horsepower and larger Class 1E motors will be performed on an interval not to exceed 2 refueling outages for WBN. This testing will be governed by the plant preventive maintenance program[36]. The specific details of the test and acceptance criteria are addressed on a case by case basis by the governing maintenance instruction[37].

Testing of Class 1E 6.9kV and 480V motors 100 hp and larger is initially done from the breaker cubicles, with motor connected, and therefore, includes verification of the motor power cables. If results indicate degraded or questionable insulation, and cleaning or drying of the motor windings, etc. is unsuccessful in bringing the motor/cable into compliance with the acceptance criteria, the motor leads are then disconnected from the power feeder cables and each is tested separately. A general description of the test is provided below but may

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[35]USNRC IE Information Notice (IEN) 86-49, "Age/Environment Induced Electrical Cable Failures."

[36]Site Standard Practice (SSP)-6.02, "Maintenance Management System."

[37]Maintenance Instruction (MI)-57.108, "Insulation Resistance and Continuity Tests for Rotating Machinery, Cables, and Transformers."

vary, as previously mentioned, depending on the specific load:

1. A megger test to ground using 2,500V direct current (DC) on 6.9kV circuits and lkV DC on 480V circuits is performed.

2. Insulation resistance readings are recorded at 1 and 10 minutes after initiation of megger testing for 6.9kV and 1 minute for 480V circuits. The minimum acceptable insulation resistance for the 6.9kV circuits is 8 megohms and 1.5 megohms for the 480V circuits. In addition, Polarization Index (PI) is calculated for 6.9 kV motors in accordance with site procedures using the following formula:

$$PolarizationIndex = \frac{TenMinuteReading}{OneMinuteReading}$$

   With motor and cable connected the acceptable PI is 2. When testing the cable by itself, the minimum acceptable PI is 1. The lower minimum acceptable PI for the cable by itself is due to station cables having low charging times because of their relatively short lengths.

3. A DC step voltage test is performed on the 6.9kV circuits with the phases (cable conductors) connected together. The test voltage is slowly increased in lkV DC increments up to and including 13kV. Leakage current readings are taken after 3 minutes at each interval. The test results are then plotted on a graph of voltage versus leakage current. A cable is adequate if the plot is an approximately straight line without a "knee."

The above acceptance criteria are consistent with those recommended by industry standards (e.g., IEEE 141 and IEEE 400)[38]. It is noted that consistent with industry thinking, WBN no longer performs routine DC hipot test on cables which have been subject to long-term submergence[39].

Inspection

Each time devices required to mitigate 10CFR50.49 events (which are located in harsh environments) are entered, low voltage control, instrument level, medium voltage, or low voltage power field cables are visually inspected. This inspection provides visible indication of premature cable deterioration inside equipment and is accomplished through the Environmental Qualification and Preventive Maintenance Programs.

Failure Analysis and Trending

In order to identify potential adverse conditions, trending of maintenance history is performed. When an adverse trend is substantiated[40], a corrective action program document is initiated in accordance with site procedures[41]. Thus, via the corrective action program, the extent of condition and cause (e.g., bend-radius splice, submergence, etc.) are determined and appropriate actions taken.

Ongoing Upgrades

New installations involving Class 1E cables are required

[38]IEEE 141-1993, "Recommended Practice for Electrical Power Distribution for Industrial Plants" and IEEE 400-1990, "Guide for Making High-Direct-Voltage Tests on Power Cable Systems in the Field."

[39]EPRI TR-101245, "Effect of DC Testing on Extruded Cross-Linked Polyethylene Insulated Cables," January 1993 and "Effect of D.C. Testing Water Tree Deteriorated Cable and A Preliminary Evaluation of V. L. F. as Alternate," G. S. Eager, B. Fryszczyn, C. Katz, H. A. Elbadaly and A. R. Jean, IEEE Transactions on Power Delivery, Volume 7, Number 3, July 1992, Pages 1582-1591.

[40]SSP-6.04 - "Equipment History and Failure Trending."

[41]SSP-3.04 - "Corrective Action Program."

to meet the current Corporate[42] and Site procedures[43], which were revised to reflect industry standards. These procedures also require that during maintenance and modification activities an attempt is to be made to bring the portion(s) of previously installed Class 1E cable being disturbed into compliance with current requirements.

Industry Participation

TVA is currently actively participating in the development of standards and test methodologies relating to cable installation issues. TVA personnel are participating in IEEE working groups responsible for IEEE-422, 690, and 1185 and are members of 383 and 1186[44]. Furthermore, TVA is one of the major sponsors of EPRI Cable Life Program and a member of the peer review group for EPRI Cable Diagnostics Project. As a result, TVA will be cognizant of developments within the industry concerning condition monitoring and bend radius and will incorporate them as appropriate.

Vendor Feedback

In July 1995, Corporate Cable Specialist, Kent W. Brown visited Brand Rex, Rockbestos and The Okonite Company for the purpose of reviewing Revision 0[45] of the plan that WBN had undertaken to resolve the issue of tight cable bend radius.

Prior to the meetings an overview of this issue was prepared and provided to the three companies. Because of the detail provided in the white paper, no formal presentation of the issue was made. Mr. Brown gave a general overview of the key points and provided clarifications as requested. Per our agreement with the NRC, the vendors were not requested to "approve" the plan, but to only provide a verbal assessment. A general review of the vendor response is as follows:

July 20, 1995
BICC Brand Rex, Willimantic, CT 860-456-8000

John L. Macchia	President
Jerry Liskom	Market Manager
Ed Aberbach	Product Engineer
Richard Metz	QA Engineer
Chris Durland	Senior Applications Engineer, BICC, West Nyack, NY

Following the discussions, Mr. Macchia stated that Brand Rex believed that the bends in question should pose no problems for the subject cables. He stated that industry bend radii were known to be conservative but acknowledged that the degree of conservatism has not been established. While he did not believe that such a program should have been necessary, he noted that BICC Brand Rex was in agreement with the actions to date, as well as those

[42]TVA Design Standard, DS-E12.1.5, Revision 4, dated June 22, 1994, "Minimum Radius for Field-Installed Insulated Cables Rated 15,000 Volts and Less and "General Construction Specification G-38, "Installation, Modification, Maintenance of Insulated Cables Rated Up to 15,000 Volts".

[43]MI-57.113 - "Cable Bend Radius", Instrument Maintenance Instruction (IMI)-101 - "Instrument Maintenance Planning and Work Activity Guidelines", IMI-200 - "Periodic Calibration of Plant Instrumentation and Control Equipment", "Cable Pulling for Modification/Addition Instruction (MAI) - 3.3 - "Cable Terminating, Splicing, and Testing for Cables Rated Up To 15,000 Volts" and Modification/Addition Instruction (MAI) - 3.2 - "Cable Pulling for Insulated Cables Rated Up to 15,000 Volts."

[44]IEEE 383-1992, "Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations", IEEE 422-1986, "Guide for the Design and Installation of Cable Systems in Power Generating Stations", IEEE 690-1984, "Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations", IEEE 1185-1994, "Guidelines for Installation Methods for Generating Station Cables" and IEEE-P 1186, "Recommended Practices for the Evaluation of Installed Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations."

[45]Memo from R. C. Willimas to M. C. Brickey dated July 28, 1996 (B43 950728 005).

remaining to be completed.

July 24 and 25, 1995
Rockbestos, East Granby, CT 860-653-8300
Robert Gehm, Sr. Chief Engineer
Robert Konnick, Jr. Product Engineer

As at Brand Rex, Mr. Brown provided a general overview of the history of cable problems at WBN relating to the issue of bend radius. Mr. Gehm, who had been one of those originally surveyed, believed that the proposed program was sound, though beyond that which should have been required of TVA. In support of that position he cited three considerations beyond his original comments.

First, he noted that most of the ICEA limits were developed in support of paper-lead cables. The helically wound paper tapes have practically no elasticity and required conservative measures to ensure that the layers did not tear or buckle. When extruded dielectrics came into wide usage, Mr. Gehm stated that there simply was no compelling reason to change the then current bend radius factors.

Second[46], he noted that nuclear grade Raychem products (typically cross-linked polyolefins) function by ensuring that there is a residual recovery force present after heat-shrinking. Extensive testing of these products for nuclear service has failed to identify any synergism between that stress and thermal aging. Third, Mr. Gehm noted that it did not appear that WBN had taken full credit for the fact that even power cables do not run at or near 90°C. He observed that the reduction of the stressor certainly results in a corresponding reduction of any potential synergism.

Regarding ICEA bend radius limits, TVA agrees with Gehm's position but note that the basis for selection of the appropriate multiplier (paper-lead or polymeric) has not been published and thus it is difficult to take credit for when bending the latter type tighter than the standards based on the earlier materials permitted.

With respect to the residual stress in Raychem products, Gehm is correct. However, the concerns expressed for the thermal annealing of other semi-crystalline materials would likewise apply to the previous Raychem testing. It is for that reason that Raychem products are tested in both the aged and unaged condition since the unaged product would have a higher residual stress and therefore have a higher for potential for splitting. Raychem takes great pains in choosing its application ranges to limit those forces. Gehm conceded that Raychem had thus not been aged in such a manner as to fully retain the stress but noted that this had elicited no regulatory concern and could see no reason why the WBN cables under similar conditions should be of any more concern. Thus, while the parallel is true, the successful testing of one material applied within its design limit (Raychem) does not automatically cover the use of another material stressed beyond its design limit (cable).

We agree that there is substantial margin in our cable sizing process given the use of load multipliers, the assumption of no load or time diversity, the assumption of filled raceways and the use of maximum normal ambients. As with other conservatisms, the great difficulty lies in the quantification of those margins. Furthermore, this approach assumes that the affect of aging and stress is small and can thus be offset by the application of margin, but this involves assuming that which we have been asked to prove.

July 26 and 27, 1995
The Okonite Company, Ramsey, NJ 201-825-0300
John Cancelosi Mgr. of Application Eng

Following the customary review and discussion, Mr. Cancelosi stated that Okonite had no problem with WBN's program as described. It was their opinion that much of the work was well beyond that which should have been necessary but that the program as described was logical and comprehensive. It was his opinion that the results of the work would be of general interest to the industry and that TVA should consider publication or presentation of the data.

[46]Comments two and three pertain to the postulated synergism between physical stress and aging and have thus been made moot (along with the TVA responses) given the absence of bends below ICEA allowables for single conductor power cables in 10 CFR 50.49 service.

The changes to the long term bend radius plan which necessitated revision 1 of this document were discussed with each of the above vendors by K. W. Brown in February and March 1996 following their review of a draft of that revision (B43 960321 003). The purpose of that review was to ensure that the vendors still agreed that the plan would achieve the desired objective. The results of those discussions were as follows:

Brand Rex reviewed the draft plan and in a letter to K. W. Brown dated February 29, 1996 (B43 960321 001) noted that they concurred that the plan would ensure early identification of adverse trends and could not identify any deficiencies in the TVA approach in addressing bend radius concerns.

Robert Gehm, Sr of Rockbestos discussed his review of the draft plan with K. W. Brown on February 27, 1996. Gehm noted that Rockbestos had no technical objections to the revised plan.

John Cancelosi of Okonite discussed his review of the draft plan with K. W. Brown on March 13, 1996. Cancelosi noted that Okonite had no technical objections to the revised plan.

Conclusions

As a result of the actions undertaken by TVA, including testing, field inspection, and rework; 10 CFR 50.49 cables inside containment and main steam valve vaults meet industry standard bend radius criteria. For the remaining cable population, TVA will utilize less restrictive bend radius criteria with corresponding adjustment of qualified life, where appropriate. Ongoing condition monitoring, inspections and failure analysis, will provide TVA the necessary confirmation of the foregoing evaluations.

Attachments

1.0 Okonite, letters dated June 7, 1983 (EEB 830610014), September 29, 1983 (EEB 831004003) and August 19, 1986 (B43 860821003).

2.0 TVA Design Standard, DS-E12.1.5, Revision 0, dated September 20, 1983, "Minimum Radius for Field-Installed Insulated Cables Rated 15,000 Volts and Less".

3.0 Rockbestos, letters dated September 8, 1983 (EEB 830913008) and July 25, 1986 (B43 860729003).

4.0 Rockbestos Technical Bulletin No. 28, revision 3, dated April 25, 1979.

5.0 Brand Rex, letters dated August 29, 1983 (EEB 830906006), September 26, 1983 (EEB 830930009) and July 29, 1986 (B43 860820004).

6.0 TVA Design Standard, DS-E12.1.5, Revision 4, dated June 21, 1994, "Minimum Radius for Field-Installed Insulated Cables Rated 15,000 Volts and Less".

7.0 NE response to action item 712, WBN Unit 1, Independent Design Review Assessment, 12/27/1994 (see item 3).

Table 4
Watts Bar - Cable Bend Radius Summary

		MV Power	1/c LV Power	m/c LV Power	1/c Control	m/c Control	Signal	Coax
50.49	I/C or MSVV	n/a	b	b	b	b	b	h
	Other Harsh	a	d	c	e	c	c	h
Non 50.49	I/C or MSVV	n/a	f	c	g	g	g	h,g
	Other Harsh	a	g	g				
1E Mild		a	g	g	g	g	g	g

(a) if < LB, replace*
if ≥ LB, retrain to ≥ 8x
(b) if < LB replace*
if ≥ LB, retrain to ICEA
(c) if < LB replace*
if ≥ LB based on the OD of the singles, retrain to Rockbestos Technical No. Bulletin 28.
(d) if < LB replace*
if ≥ ICEA use-as-is (inspections revealed no cables with a bend radius ≥ LB and < ICEA)
(e) if < LB replace*
if ≥ LB use-as-is based on margin analysis and long-term programs
(f) if < LB replace*
if ≥ LB use-as-is based on projected life
(g) use-as-is based on margin analysis and long-term programs
(h) 10CFR50.49 and RG 1.97 cables to be replaced in harsh areas with new double-jacketed construction

*Replace In some cases the entire cable will not be replaced. Where possible, only the portion of the cable where the training radius is less than acceptable will be replaced. For example, cables or portions of cable reworked or replaced under the new site cable installation procedures may be excluded from the reinspection/rework design change notices.

Table Abbreviations:

LB	lower bound (4x for MV cables, 2x for LV cables 8 AWG and larger and 1x for LV cables 10 AWG and smaller)
1/c	single conductor cable
m/c	multiconductor cable
I/C	inside containment
MSVV	main steam valve vault
LV	low voltage (typically 480vac)
MV	medium voltage (6.9 kVac phase-to-phase)

FRONT SIDE OF SPECIFICATION REVISION NOTICE (SRN)
FOR A GENERAL ENGINEERING SPECIFICATION

June 23, 2004

QA RECORD

Holders of G-40

TVA GENERAL ENGINEERING SPECIFICATION G-40 (R15) FOR " INSTALLATION, MODIFICATION AND MAINTENANCE OF ELECTRICAL CONDUIT, CABLE TRAYS, BOXES, CONTAINMENT ELECTRICAL PENETRATIONS, ELECTRIC CONDUCTOR SEAL ASSEMBLIES, LIGHTING AND MISCELLANEOUS SYSTEMS"
SPECIFICATION REVISION NOTICE SRN-G-40-79

AFFECTS: All Plants; section 3.12.10, 3.12.11 and 3.12.12.

INSTRUCTIONS: The attached pages constitute an advance revision to the subject specification. Insert these pages in that specification in accordance with the instructions on the reverse side of this memo and then file the memo in the front of each controlled copy of the specification.

SIGNATURES/APPROVAL:

Kent W Brown — 6/23/2004
PREPARED — DATE

W. Karl Nesmith — 6/23/04
DESIGN VERIFICATION — DATE

Craig R Butcher — 6/23/04
APPROVED — DATE

The effective date of this SRN is 90 days from the date of issue or sooner upon incorporation into site procedures.

The requirements of this SRN are not retroactive. The RIMS number of the SA/SE for this SRN is B43 040623 002.

C. R. Butcher
Manager, Electrical Engineering
Corporate Engineering (LP 4H-C)

kwb
Attachment
cc (Attachment):

EDMS,	WR4Q-C	
K.W. Brown	LP 4H-C	
DCRM,	LP 4D-C	Attached is the SIGNED ORIGINAL; please distribute copies of this memo and its attachment(s) to all holders of controlled copies of this general engineering specification and release the RIMS copy.

BACK SIDE OF SPECIFICATION REVISION NOTICE (SRN)

SRN-G-40-79, FILING INSTRUCTIONS	
REMOVE AND DESTROY	REPLACE WITH
General Engineering Specification G-40 INDEX dated August 25, 2004 Pages: 75 From G40 R15	General Engineering Specification G-40 INDEX dated June 23, 2004 Pages: 75 From SRN-G-40-79

TENNESSEE VALLEY AUTHORITY

NUCLEAR POWER

ELECTRICAL ENGINEERING

GENERAL ENGINEERING SPECIFICATION

G-40

INSTALLATION. MODIFICATION AND MAINTENANCE OF ELECTRICAL CONDUIT, CABLE TRAYS. BOXES, CONTAINMENT ELECTRICAL PENETRATIONS. ELECTRIC CONDUCTOR SEAL ASSEMBLIES, LIGHTING AND MISCELLANEOUS SYSTEMS

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Revision Log

Rev. No.	DESCRIPTION OF CHANGE	Date
14	This revision incorporates the following SRNs: • SRN-G-40-74 (B43 950614 001) - Revised section 3.2.1.12.B for Browns Ferry Nuclear Plant. • SRN-G-40-75 (B43 950709001) - Revised sections 3.2.1.15.A and 3.2.2.9 for Watts Bar Nuclear Plant. • SRN-G-40-76 (B43 950713 007) - Removed Appendices W, X Y and Z for All Plants. • Duplicate notes for Figure 3.2.6.3-1 were deleted from the end of section 3.2.6.3. the font size of the notes was reduced to distinguish them from the body of the Gspec and allow them to be on the same page as the formula. The page reference in the definition of FL was therefore eliminated. No Safety Assessment was performed for this revision since one had been performed on June 14, 1997 (B43 970614 001) on G40 rev. 13 along with SRNs 74, 75 and 76. The effective date and retroactivity of any SRN included in this revision is as noted in the SRN.	01/20/1999
15	This revision incorporates the following SRNs: • SRN-G-40-77 (B43 990721 001) - Revised section 3.2.2.9 on internal conduit sealing. An SA/SE was performed for this SRN (T25 990721 957). • SRN-G-40-78 (B43 991116 001) - Revised sections 1.1.2, 3.2.1.15.A, 3.2.2.4, 3.2.6.1.G.4, 3.3.5 and 6 as a result of the Triennial Review of the Gspec. An SA/SE was performed for this SRN (B43 991115 001). The following editorial changes were also made during this revision: • Re-added the heading to section 3.2.6, "Flexible Conduit" which had been inadvertently dropped during earlier revisions • Corrected the spelling of "Patel" in Table 3.2.6.3-2. • In note 2 for Table 3.2.6.3-2 and reference 6.19 changed the calculation identifier to CD-Q0999-000001. In order to maintain the tie to its original identifier, included the following: "(previously CEB-CQS-449, B41 940620 001)". No Safety Assessment was performed for this revision since one had been performed for revision 13 along with all subsequent SRNs as noted above. The effective date and retroactivity of any SRN included in this revision is as noted in the SRN.	08/25/2000

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PREFACE

This General Engineering Specification supersedes TVA General Construction Specification No. G-3 for Browns Ferry Nuclear Plant and all future nuclear plants. It also supersedes Sequoyah Nuclear Plant Project Construction Specification No. N2E-860.

This specification is intended to be a general guide; therefore, it does not define installation procedures for all possible configurations.

The materials used in the construction of nuclear plants (and other projects) are continually reviewed by the Division of Occupational Health and Safety (OC H&S), Policy and Coordination Branch, for their acceptability to the health and safety of personnel. Should a material specified herein become restricted from use, an equivalent material approved by the OC H&S, Policy and Coordination Branch, shall be used.

Since this specification applies to more than one plant, generic wording must be used to express the requirements. Interpretations or specific applications for each plant which differ from the wording in this specification shall be addressed by the Nuclear Engineering group at the site. This shall be accomplished by obtaining NE review and concurrence with revisions to site procedures which implement the specification interpretations. Changes which incorporate wording in this specification verbatim or are outside the scope of this specification do not require NE review.

1.0 GENERAL

1.1 Scope

1.1.1 This general engineering specification describes the minimum engineering requirements for materials receiving, storage and handling, and installation, modifications and maintenance of electrical conduit, cable trays, boxes, containment electric penetrations, electric conductor seal assemblies, lighting and miscellaneous systems for all nuclear plants, with the exception of those portions of the design under separate contract. Procedures or instructions provided by the contractor shall be followed for those portions of the design under separate contract. This specification supplements and amplifies the instructions given on the design drawings.

1.1.2 Preapproved (prior to construction) variances / exceptions, which have been dispositioned by engineering, but do not constitute a generic change to the requirements of this specification are issued in Exception Manuals which are issued and distributed by the applicable site in accordance with NEDP 10. Distribution of these manuals shall be made to all holders of controlled copies of this specification (G-40).

1.1.3 Browns Ferry Nuclear Plant:

1.1.3.1 During maintenance activities, only that portion of the TVA field-installed conduit raceway system being disturbed is required to meet G-40 requirements. Restoration maintenance are those conditions where electrical equipment requires a disconnection of its externally connected conduit system so that maintenance or rework can be performed. Examples of restoration maintenance are:

A. When a failed electrical component, such as a solenoid valve, has to be replaced (via a work request).

B. Equipment rework, such as the need to rewind a motor, which requires moving the equipment to a service center.

C. When conduit is temporarily moved to facilitate the removal/addition of equipment such as a tank, piping, or ventilation duct.

1.0 GENERAL (Continued)

1.1.3.2 Restoration maintenance to flexible conduit that does not meet G-40 requirements at BFN can be made, provided the following conditions are met:

A. When specified, the flexible conduit shall be reconnected as defined on design drawings.

B. When not defined on design drawings, flexible conduit containing cables listed as safety-related on the Q-list should be reconnected to meet the requirements of Section 3.2.6 unless an approved variance is provided in Appendix W.

C. Flexible conduits which do not contain Q-list cables may be installed or replaced to the best available configuration.

1.1.3.3 When conduit systems that are part of the vendor furnished equipment (such as panels, racks, skid-mounted assemblies, motors, etc.) are required to be removed or replaced for maintenance, it may be returned to the as-found length. The removal and reconnection of vendor conduit does not constitute restoration maintenance. The replacement of vendor installed conduit is considered restoration maintenance. The repair or replacement of vendor supplied conduit systems shall be in accordance with established plant procedures/instructions.

1.0 GENERAL(Continued)

1.2 Drawings and Other Documents

1.2.1 It is the responsibility of engineering to prepare detailed design drawings and standards for the installation of conduit systems and conduit boxes. The latest revision of the documents or a site-specific document with the same number listed below, in effect at the time of installation, shall be followed.

- DS-E1.2.1 - Electrical Nameplates (Browns Ferry Nuclear Plant and all hydroelectric and fossil-fuel plants)
- DS-E1.2.2 - Electrical Equipment Nameplates - Sequoyah and Subsequent Nuclear Plants
- DS-E13.1.4 - Conduit - Maximum Cable Diameter for Various Rigid Steel Conduits
- DS-E13.1.6 - Spacing of Locknuts on Steel Conduit
- DS-E13.1.7 - Dimensions of Rigid and Flexible Metal Conduit Bends
- DS-E13.1.11 - PVC Conduit
- DS-E13.6.1 - Raceways, Conduit Box Design - Minimum Requirements
- DS-E13.6.2 - Raceways, Use of Conduit Bodies in Conduit Systems
- SD-E13.1.1 - Expansion/Contraction Joint for Embedded Aluminum, Intermediate Metal, and Steel Conduit
- SD-E13.1.2 - Expansion and Deflection Fitting for Embedded Aluminum, Intermediate Metal, and Steel Conduit
- SD-E13.4.1 - Concrete Reinforcement Bar Insulation to Reduce Induction Heating

1.0 GENERAL (Continued)

1.2.1 (Continued)

- SD-E13.6.3 - Conduit Boxes, Frames, and Covers
- SD-E13.6.5 - Conduit Box Connection (Watertight)
- SD-E15.3.3 - Conduit, Cable and Wire Identification Tags (Browns Ferry Nuclear Plant and all non-nuclear projects)
- SD-E15.3.4 - Raceways, Cable and Wire Identification Tags (Sequoyah Nuclear Plant and All Subsequent Nuclear Projects)
- N3C-944 - Watts Bar Nuclear Plant - Engineering Requirements Specification, "Conduit and Conduit Support Installations"
- G-14 - TVA General Engineering Specification, "Selecting, Specifying, Applying, and Inspecting Paint and Coatings"
- G-29 - TVA General Engineering Specification (Volume VII), "Process Specification for Welding, Heat Treatment, Nondestructive Examination, and Allied Field Fabrication Operations"
- G-34 - TVA General Engineering Specification, "Repair of Concrete"
- G-55 - TVA General Engineering Specification, "Surface Preparation, Application, and Inspection of Special Protective Coatings for Nuclear Plants"

1.0 GENERAL (Continued)

1.2.2 Where specific instructions are lacking on design documents, engineering shall be requested to provide the necessary information on a case-by-case basis.

1.2.3 It shall be the joint responsibility of engineering, construction and modifications/maintenance to record changes on the design drawings that were made during construction, modification or maintenance for the as-built record in accordance with established administrative and quality assurance procedures.

1.3 Responsibilities

Corporate Engineering Electrical (CE-E) is responsible for the contents of this document. The respective site construction manager, engineering manager, modifications manager or maintenance manager, acting directly or through properly authorized agents, is responsible for enforcing the requirements of this general engineering specification.

The Lead Engineer in the site engineering organization is responsible for enforcing the requirements of this specification.

1.4 Definitions

1.4.1 Class 1E. The safety classification of electrical equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling and containment and reactor heat removal or otherwise are essential in preventing significant release of radioactive material to the environment.

1.4.2 Compatible. A material suitable for use with adjoining materials and the environment (i.e., proper size, similar materials, such that no adverse reaction occurs, able to withstand temperature, radiation and other harmful parameters for the area, as recommended for use by the respective manufacturer).

1.0 GENERAL (Continued)

1.4.3 Seismic Category I (Class I at BFN). Those structures, systems or components which perform primary safety functions. They are designed and constructed to assure achievement of their primary safety functions at all times including a concurrent Safe Shutdown Earthquake (SSE).

1.4.4 Seismic Category I(L) (Class II at BFN). Those portions of structures, systems or components which perform secondary safety functions to the extent that only limited structural integrity is required. They are designed and constructed to assure achievement of their limited structural integrity at all times including a concurrent SSE.

1.4.5 Safe Shutdown Earthquake (SSE). An earthquake which produces the maximum vibratory ground motion for which structures, systems and components which perform a primary safety function are designed to remain functional.

1.4.6 Verify. An act of confirming, substantiating and assuring that an activity or condition has been implemented in conformance with the specified requirements. Observation of each activity (event) is required.

1.4.7 Wet Location. Installation underground or in concrete slabs or masonry in direct contact with the earth, and locations subject to saturation with water or liquids, and locations exposed to weather and unprotected.

2.0 MATERIALS

2.1 General

2.1.1 Materials used in the installation of electrical raceway systems shall be in accordance with TVA standard specifications; otherwise, they shall meet the requirements of recognized industry standards (i.e., Underwriter's Laboratories [UL]; National Electrical Manufacturer's Association [NEMA]) for the class of service for which they are intended or shall be approved by engineering. The materials shall be compatible with the environment and configuration in which they are to be located.

2.0 MATERIALS (Continued)

2.1.2 Standard specifications applicable to the procurement of electrical conduit and fittings are:

- SS-E21.000 - Rigid Aluminum Conduit
- SS-E21.001 - Rigid Steel Conduit (Zinc Coated)
- SS-E21.002 - Fittings for Conduit and Outlet Boxes

2.1.3 Throughout this specification materials are referenced as "similar to" or "equal to" a specific vendor or manufacturer. Where this occurs, engineering shall be consulted for an approved "similar" or "equal" material.

2.2 Major or Special Materials

Major materials and those of a special nature used in the installation shall be designated on detailed design drawings or standard drawings, described in the electrical bill of material.

2.0 MATERIALS (Continued)

2.3 Miscellaneous Materials

These materials are of a standard nature and shall be purchased directly by construction, modifications or maintenance. Included are conduit bodies and covers, conduit fittings, joints and terminations, flexible conduit and other minor materials necessary for installation. Refer to General Engineering Specification G-38 for requirements for cable ties, tags and markers.

2.3.1. a. Conduit accessories such as metallic conduit bodies, fittings, joints, standard couplings, and terminations (except for slip joints as permitted in Sections 3.2.3.7 and 3.2.3.8 and as noted below) shall be of the threaded type and approved for use with conduit systems which serve as the equipment grounding conductor.

b. Die cast zinc conduit fittings and connectors shall not be used inside the reactor building primary containment which has a boric acid containment spray system.

c. Only malleable iron or steel fittings shall be used.

d. Nonmalleable cast iron fittings and bodies may be used with aluminum conduit, only when approved by Nuclear Engineering on a case basis.

2.0 MATERIALS (Continued)

2.3.2 In certain embedded conduit applications, it may be impractical or very costly to use threaded couplings. When these situations are encountered, threadless couplings (such as manufactured by Thomas and Betts or equivalent) may be used if the following conditions are satisfied:

2.3.2.1 The manufacturer's instructions regarding installation of threadless couplings shall be followed.

2.3.2.2 Threadless couplings shall be concrete tight.

2.3.2.3 Threadless couplings shall be made watertight and rustproof in accordance with Section 3.2.4.2.

2.3.2.4 The conduit systems shall be adequately braced or supported on each side of the threadless coupling to maintain the integrity of the fitting during concrete pours.

2.3.2.5 The threadless couplings shall be electrically continuous or shall be made electrically continuous by means of a bonding strap or ground cable attached to the conduit system on each side of the fitting.

2.3.4 Split couplings shall not be used in new installations inside category 1 structures. Engineering approval for their use as a replacement of existing split couplings is contingent upon the following:

2.3.4.1 The manufacturer's instructions concerning installation of the split couplings (such as tightening of bolts) shall be carefully observed.

2.3.4.2 Where grounding of the conduit system is required and to be accomplished by brazing a ground wire to the top of the split coupling, the neoprene gasket shall be temporarily removed before the brazing process. Brazing shall be done in accordance with General Engineering Specification G-29 (Volume VII).

2.3.4.3 The joint shall be made watertight and rustproof in accordance with Section 3.2.4.2.

2.0 MATERIALS (Continued)

2.3.5 Threads on conduit or conduit stubups, which have been damaged to the extent of preventing the installation of couplings, shall be rethreaded using conventional threading equipment. Where this repair method is impractical, Threadmaker Conduit Fittings (Crouse-Hinds), or equivalent, may be used for extending the conduit system.

Copper-silicon alloy, brass, or plastic conduit plugs shall be used where spare conduits are terminated in wet places, except for conduits penetrating fire barrier (see Section 3.2.1.9).

If additional restrictions or limitations are required on miscellaneous materials to be purchased by construction, modifications or maintenance, these restrictions shall be so stated on the design drawings.

2.3.6 Bellefonte Nuclear Plant

2.3.6.1 Stainless steel flexible conduit shall be used inside primary containment. The following types of stainless steel flexible conduit are acceptable for these application:

A. ServicAir Company SS60, SS63 or SS63C series, or

B. American Boa, Inc., type NB1-0 or NB1-1 series, or equal.

Connector fittings of compatible material available from the respectable manufacturer shall be used. The stainless steel flexible conduit and appropriate connector fittings shall be installed in accordance with the manufacturer's instructions; however, no pressure test of the stainless steel flexible conduit is required, unless required as a part of equipment seal.

2.3.6.2 Pressure-tight stainless steel flexible conduit (ServicAir SS63C extra flexible stainless steel), as defined on design drawings and as approved for use by engineering, shall be used for installations where an equipment seal is required.

2.0 MATERIALS (Continued)

2.3.6.3 In areas outside primary containment/drywell, liquid-tight flexible metal conduit with a synthetic jacket (similar to the Anaconda Company. Brass Division. "Sealtite type UA" for available sizes, or equal) and connectors (similar to Ideal Industries, Incorporated, "Vap-Oil-Tight" series, or equal) shall be used for flexible conduit applications, unless otherwise noted on design drawings. Stainless steel flexible conduit described above may be used in these areas.

2.3.7 Sequoyah Nuclear Plant

2.3.7.1 The following flexible conduit shall be used for applications inside primary containment and may be used outside primary containment. Liquid-tight flexible metal conduit with a synthetic jacket in trade sizes through 4 inches shall meet the requirements of UL 360, and liquid-tight connector fittings shall be used which meet the requirements of UL 514B. Anemet Inc, Type EF with compatible connector fittings shall be used for 5-inch and 6-inch trade sizes.

2.3.7.2 Stainless steel flexible conduit with a convolute core structure (similar to ServicAir Company type SS60, SS63 or SS63C; or American Boa, Incorporated, type NB1-0 or NB1-1 series) and connector fittings or compatible material (available from the respective supplier) may be used in other areas, except inside primary containment. The stainless steel flexible conduit and appropriate connector fittings shall be installed in accordance with the manufacturer's instructions; however, no pressure test of the stainless steel flexible conduit is required, unless required as part of the equipment seal. Stainless steel flexible conduit installations for Class 1E applications shall be analyzed by Civil Engineering for seismic qualification.

2.3.7.3 Flexible conduit connector fittings shall be of the type approved for providing continuous ground continuity.

2.0 MATERIALS (Continued)

2.3.8 Watts Bar Nuclear Plant

2.3.8.1 American Boa. Incorporated. Type NB1-0 stainless steel flexible conduit and connector fittings of compatible material (available from the supplier) shall be used inside primary containment and the main steam valve vaults. The stainless steel flexible conduit and appropriate connector fittings shall be installed in accordance with the manufacturer's instructions.

The manufacturer instructions requiring the application of the primer to the inside of the conduit and the threaded portion of the seal and the instruction to apply RTV compound to the threaded portion of the conduit seal is not required.

Liquid-tight flexible conduit installed inside containment prior to April 1, 1994, is acceptable.[WBN-10] After April 1, 1994, if rework involving replacement of liquid-tight flexible conduit inside containment occurs, American BOA shall be used and installed in accordance with the requirements of this section.

2.3.8.2 Liquid-tight flexible metal conduit with a synthetic jacket and liquid-tight connector fittings may be used in all other areas. Trade sizes through 4 inches shall meet the requirements of UL standards. Anemet Inc., Type EF with compatible connector fittings shall be used for 5-inch and 6-inch trade sizes.

Note: Unless otherwise restricted by design drawings, American BOA, Inc flexible metal conduit as specified in section 2.3.8.1 may be used in any location where use of liquid-tight flexible metal conduit with a synthetic jacket is permitted.

2.0 MATERIALS (Continued)

2.3.8.3 Replacement of ServicAir Company stainless steel flexible conduit shall be as follows:

A. The replacement of TVA installed, ServicAir Company stainless steel flexible conduits utilized in Class 1E applications inside primary containment and the main steam valve vaults shall comply with Section 2.3.8.1. Replacement of TVA installed ServicAir stainless steel flexible conduit in the Turbine Building is not required unless the flexible conduit is subsequently reworked. If rework does occur in the future, the Service Air Company stainless steel flexible conduit shall be replaced in accordance with Section 2.3.8.2. In all other plant areas, the replacement of TVA installed Service Air Company stainless steel flexible conduits utilized in Class 1E applications shall comply with Section 2.3.8.2.

B. Replacement of TVA installed Service Air Company stainless steel flexible conduits utilized in non-Class 1E applications is not required unless the flexible conduit is subsequently reworked. If rework does occur in the future, the Service Air Company stainless steel flexible conduit shall be replaced in accordance with Section 2.3.8.1 or 2.3.8.2, as applicable.

C. Vendor installed Service Air Company stainless steel flexible conduits on a vendor qualified (Class 1E) packaged unit does not require replacement except as follows. If TVA has modified the vendor's configuration in the past or if TVA modifies the vendors configuration in the future (relocate components, add components, etc), then change out of the vendor installed Service Air Company stainless steel flexible conduits shall also be performed: replacement shall be the same as described for TVA Class 1E installations in section 2.3.8.3.A above. Change out of vendor installed Service Air Company stainless steel flexible conduits on a vendor's packaged unit which is unqualified shall be the same as for TVA non-Class 1E installations described in Section 2.3.8.3.B above. [WBN-7]

2.0 MATERIALS (Continued)

2.3.9 Browns Ferry Nuclear Plant

2.3.9.1 Liquid-tight flexible metal conduit with a synthetic jacket and liquid-tight connector fittings may be used in all areas. Trade sizes through 4-inch shall meet the requirements of UL standards. Anemet Incorporated, Type EF or Electric-flex type LT with compatible connector fittings shall be used for 5-inch trade sizes.

2.3.9.2 When shown on design drawings, it shall be permissible to use pressure-tight stainless steel flexible conduit with a convolute core structure (similar to Service Air Company Type SS60, SS63, or SS63C; American Boa Incorporated, Type NB1-0 or NB1-1 series or Patel/EGS) and connector fittings of compatible material (available from the respective supplier) at BFN.

Pressure-tight stainless steel flexible conduit (ServicAir SS63C extra flexible stainless steel), as defined on the design drawings and as approved for use by engineering, shall be used for installations where an equipment seal is required.

2.3.9.3 Liquid-tight flexible metal conduit with a synthetic jacket (similar to the Anaconda Company, Brass Division, "Sealtite type UA" for available sizes or equal) and connectors (similar to Ideal Industries, Incorporated, "Vap-Oil-Tight" series or equal) shall be used for flexible conduit applications, unless otherwise noted on design drawings. Stainless steel flexible conduit described above may be used in these areas.

2.0 MATERIALS (Continued)

2.4 Material Storage and Handling

2.4.1 External threaded ends of conduit and fittings shall be protected during shipment, storage, and handling to prevent damage and exclude dirt, moisture, and other foreign substances.

2.4.2 Conduit shall not be stored on end, but must be sloped for drainage when stored in an ANSI N45.2.2 Class D environment.

2.4.3 Conduit, conduit fittings and conduit boxes may be stored to ANSI N45.2.2 Class D requirements.

2.4.4 To prevent warping during storage, plastic conduit shall be stacked on a smooth, flat surface in an area not directly exposed to the rays of the sun. Spacers of 1-inch soft wood, approximately 2 feet apart, should be used between layers of conduit. Manufacturer's shipping bundles may also be used for direct storage.

3.0 INSTALLATION

3.1 General

3.1.1 Installation of conduit, boxes, fittings and accessories shall conform to the latest design drawings, standards and specifications described in Section 1.2 and manufacturer's instructions provided in the vendor catalog for the particular part number or instructions provided with the contract. In the event of a conflict between design drawings, standards or this specification, this specification shall govern; however, for Watts Bar, conflicts between these documents and N3C-944, the N3C-944 shall govern.

3.1.2 Unless specifically called for on the detailed design drawings or otherwise permitted (see Section 3.2.2.4) by site specific procedures, structural steel or reinforcing bars shall not be cut or drilled in category 1 structures.

3.2 Conduit

3.2.1 General

3.2.1.1 Conduit exposed to the weather, embedded in concrete or in wet locations shall be sloped for drainage. If it is not possible to slope or if the slope causes interferences, the installation shall be analyzed by engineering and resolved prior to completion. Embedded conduit systems shall be rigidly supported and braced in position to avoid settling or floating and to prevent the formation of air pockets if heavy batches of concrete are placed on the conduit.

3.0 INSTALLATION (Continued)

3.2.1.2 To protect the cables during installation, a bushing, chase nipple or conduit bodies (such as a condulet) shall be used at the end of a conduit run where it terminates at a piece of equipment or cable tray. Where equipment design prohibits their use due to space limitations, these conduit accessories may be omitted provided the end of the conduit is deburred and one of the following options exercised:

A. The end of the conduit shall be beveled or rounded to at least a 1/16-inch radius, or

B. The end of the conduit shall be fitted with a collar (i.e., a plastic protective end cap for protecting cable during installation).

NOTE: Conduit bushings may be eliminated at Watts Bar Nuclear Plant (WBN) equipment for flexible conduit fittings and other connectors if all the following conditions apply: (1) there are no sharp edges or burrs which could contact the cable, (2) the edge of the fitting or connector is rounded by the manufacturer to a minimum 1/16-inch or contains an insulated sleeve to preclude any damage, (3) the cable jacket has not been removed, and (4) the cables are not pulled tightly across the edge of the fitting.

3.2.1.3 The total sum of all bends in a conduit run shall not exceed 360° between pullpoints. [WBN-2]

3.0 INSTALLATION (Continued)

3.2.1.4 Field-installed pullpoints, such as conduit bodies, shall be adequately sized to accommodate the required splices or terminations (e.g., interfaces with devices with pigtails) as applicable, or in accordance with Design Standard DS-E13.6.2, and to accommodate the minimum training radius of the cable (see Section 3.2.1.3 of General Engineering Specification G-38). Conduit bodies shall be inspected for sharp edges or burrs which could contact the cables, and if present, ground smooth prior to installation.

A. Conduit bodies shall not be installed as pull points in conduit systems to be used for the installation of medium voltage (5 to 15KV) power cables.

B. Standard conduit bodies shall not be installed as pull points for 300 kcmil and larger low voltage power cables; however, mogul fittings may be used if they allow the cable to maintain minimum training radius requirements at all times (G-38 Section 3.2.1.3). WBN-5 Straight conduit bodies may be installed for injecting lubricant.

3.2.1.5 Provisions shall be made for supporting cables in vertical conduit runs if required by General Engineering Specification G-38, Section 3.2.1.9. Conduit bodies (ELLS, TEES) shall not be installed at the top of vertical conduit sections that exceed:

- 25 feet in length for conduit sizes 1-1/2" and smaller,
- 20 feet in length for 2" and 2-1/2" conduit,
- 15 feet in length for 3" conduit,
- 12.5 feet in length for 4" conduit, and
- 10 feet in length for 5" conduit, unless otherwise authorized by engineering.

If a pullpoint is required at the top of a vertical section exceeding the lengths above, a conduit box shall be installed. For vertical runs less than the lengths above, standard conduit bends are preferred at the top of the vertical run in lieu of conduit bodies. The minimum cable training radius shall not be violated (see Section 3.2.1.3, General Engineering Specification G-38). WBN-1

3.0 INSTALLATION (Continued)

3.2.1.6 After a conduit run is completed, it shall be examined and cleaned out. Any accumulation of trapped liquids shall be removed.

3.2.1.7 Conduit identification tagging shall accompany the conduit installation. The tagging and identification shall be as designated on the conduit design drawings and/or conduit schedule and in accordance with Standard Drawing SD-E15.3.3 or SD-E15.3.4. Unscheduled lighting conduits are exempted from this requirement.

In yard areas where conduits are exposed to the natural environment, the conduit tag may be of 1/2-inch minimum width stainless steel or aluminum ribbon material with the designation made using a Dymo tapewriter (or equivalent). For additional identification requirements of exposed conduits see Section 3.2.6.

3.2.1.8 Reducers (or enlargers) may be used in the following applications:

A. To mate up the incoming conduit (rigid or flexible) to a device supplied with hubs or knockouts which do not match the size of the incoming conduit (reduction in conduit size, unless specified on design drawings, must be approved by engineering and documented on appropriate drawings) or

B. To mate up rigid conduit to flexible conduit where mismatched conduit sizes are specified on design drawings, or to oversized conduit fittings.

Coat male threads as defined on design drawings; where not defined, coat per Section 3.2.4.2 or Section 3.2.4.3.

3.2.1.9 Where design drawings do not specify otherwise, spare conduits and wall sleeves which penetrate fire barriers shall be sealed and end capped with steel conduit plugs. If conduit/sleeve configurations do not permit steel conduit plugs or caps to be used, refer to design drawings for alternate methods of sealing.

3.0 INSTALLATION (Continued)

3.2.1.10 Rigid conduit fittings shall be installed wrench tight using commonly available tools: wrench tight shall be defined as "not being able to rotate or remove by hand at the joint or fitting". Rigid conduit fittings may be backed off up to a maximum of one full turn for alignment purposes. When this occurs, a lock nut or a Right Angle K-Clamp (by Appleton Electric Co.) shall be installed at the fitting to ensure electrical continuity.

3.2.1.11 Sequoyah Nuclear Plant

A. Separation of Conduit From Pipes

1. Rigid and flexible conduits shall be separated from hot pipes and their insulation (system numbers 01, 03, 05, 06, 12, 15, 43, 44, 62, 68, 74, and all branch lines two inches and larger connecting to these systems up to the first normally closed isolation or check valve) as noted below (valve stems and bonnets are considered part of the pipe):

a. Conduits and Vertical Hot Pipes

Conduits running adjacent to hot pipes (both parallel and nonparallel) shall have a minimum separation of six inches.

b. Conduit and Horizontal Hot Pipes

Conduits running parallel to and above hot pipes shall be separated from the pipe a minimum of 1.5 times the diameter of the pipe including the insulation. The zone of influence shall also include the area six inches outside the pipe insulation (see Figure 3.2.1.11-1). Conduits running adjacent to and below hot pipes (both parallel and nonparallel) shall be separated by a minimum of six inches. Conduits in nonparallel configurations located above hot pipes shall be separated by a minimum of six inches.

3.0 INSTALLATION (Continued)

3.2.1.11 (Continued)

NOTES:

(1) Flexible conduits connecting to end devices attached to hot pipes should be oriented perpendicular to the pipe and shall not be routed above the hot pipe, unless approved by engineering.

(2) If the pipe insulation has been removed, an insulation thickness of four and one-half inches shall be used for determining separation distances or the design insulation thickness shall be obtained from the drawings.

(3) No conduit separation from instrument sensing lines is required for temperature considerations.

(4) Conduits and pipes are considered to be parallel if they form an angle of less than 20° to each other.

3.0 INSTALLATION (Continued)

3.2.1.11 (Continued)

B. Appendix R Conduit Separation

1. Compliance with the intent of 10CFR50 Appendix R is based on physical separation between cables for redundant functions. Essential Appendix R Fire Safe Shut Down (FSSD) conduits identified in CCRS shall be installed within the areas identified on the Appendix R separation sketches and instructions provided in the design change notice (DCN) or engineering change notice (ECN)-Mod package.

2. As-installed location of essential Appendix R conduits shall be field verified. Nuclear Construction (NC) shall notify the Nuclear Engineering (NE) lead electrical engineer upon completion of essential Appendix R conduit installation.

3. Essential Appendix R (FSSD) conduits shall not be relocated (more than 6 inches horizontal) without NE notification and written concurrence.

3.0 INSTALLATION (Continued)

3.2.1.12 Browns Ferry Nuclear Plant

A. Separation of Conduit from Pipes

New installations of rigid and flexible conduits shall be separated from hot pipes and their insulation as noted below:

1. Conduits and Vertical Hot Pipes

Conduits running adjacent to insulated hot pipes (both parallel and nonparallel) shall have a minimum separation of six inches.

2. Conduit and Horizontal Hot Pipes

Conduits running parallel to and above insulated hot pipes shall be separated from the pipe a minimum of 1.5 times the diameter of the pipe including the insulation. The zone of influence shall also include the area six inches outside the pipe insulation (see Figure 3.2.1.11-1). Conduits running adjacent to and below hot pipes (both parallel and nonparallel) shall be separated by a minimum of six inches. Conduits in nonparallel configurations located above hot pipes shall be separated by a minimum of six inches.

3.0 INSTALLATION (Continued)

3.2.1.11 (continued)

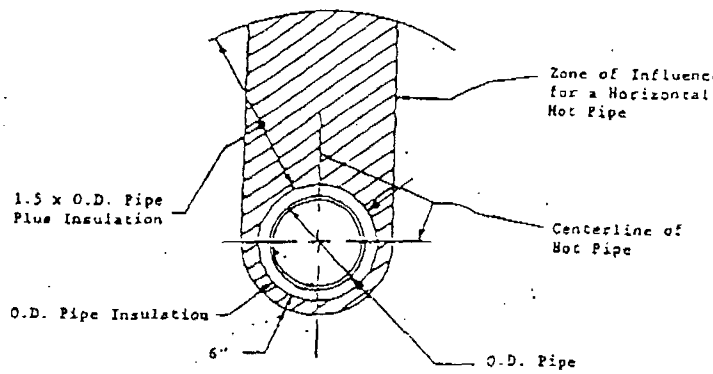

Figure 3.2.1.11-1
Hot Pipe Zone Of Influence for Browns Ferry

3.0 INSTALLATION (Continued)

3.2.1.12 (Continued)

NOTES:

(1) Flexible conduits connecting to end devices attached to hot pipes should be oriented perpendicular to the pipe and shall not be routed above the hot pipe, unless approved by engineering.

(2) If the pipe insulation has been removed, an insulation thickness of three inches shall be used for determining separation distances or the design insulation thickness shall be obtained from the drawings.

(3) No conduit separation from instrument sensing lines is required for temperature considerations.

(4) Conduits and pipes are considered to be parallel if they form an angle of less than 20° to each other.

3.0 INSTALLATION (Continued)

3.2.1.13 Conduit, conduit fittings and conduit bodies shall be sealed as required by design output documents.

3.2.1.14 Conduits greater than six feet in length containing medium voltage (V5) and low voltage (V4) power cables shall be separated from other conduits by a minimum of one fourth the diameter of the larger conduit.

3.0 INSTALLATION (Continued)

3.2.1.15 Watts Bar Nuclear Plant

A. Separation of Conduits From Pipes [WBN-5]

The following table identifies the walkdown inspections of existing conduit installations and the associated calculations that provide evaluations and dispositions. All future installations shall meet the requirements established in the paragraphs following the table.

PIPING SIZE	TEMPERATURE	WALKDOWN NUMBER	DISPOSITION CALCULATION
> 2"	> 250°F	WD-11	WBN-OSG4-139 WBN-OSG4-221
All	140°F - 250°F	WD-38	WBN-OSG4-139 WBN-OSG4-221
< 2"	> 250°F	WD-38	WBN-OSG4-139 WBN-OSG4-221

The criteria established in the following paragraphs is for installations (after 10-21-91) at Watts Bar Nuclear Plant based on bounding cases as established in calculation WBN-OSG4-138. This calculation is based on all insulated hot piping having an operating temperature of 650°F and an insulation surface temperature range of approximately 176°F to 224°F and all uninsulated hot piping having a surface temperature of 600°F. Calculation WBN-OSG4-138 also establishes that no thermal clearance requirements apply for piping with a surface temperature of 135°F or less as specified in WBN-OSG4-170 or the operating mode calculations for the piping system.

The following separations are for conduits containing power cables, i.e., medium voltage power, V5, low voltage power, V4, and those control power cables classified as, V3. For separation requirements for conduits containing non power cables, ie., low level signal, V1, medium level signal, V2, and control, V3 which are not control power see Section 3.2.1.15.A.6.

1. Conduits shall be separated from pipes and pipe components by the minimum distances specified in Watts Bar Nuclear Plant Engineering Specification N3C-941. The separation distances described below shall be added to the thermal growth separations specified in N3C-941.

3.0 INSTALLATION (Continued)

3.2.1.15 (Continued)

2. Where running parallel, rigid and flexible conduits shall be separated from insulated hot piping up to 39" O.D. (including insulation) as noted below. Hot piping includes piping for systems 01, 02, 03A, 03B, 05, 06, 15, 43, 62, 63, 68, 74, and all branch lines two inches and larger connecting to these systems up to the first normally closed isolation or check valve. Valve stems and bonnets are considered part of the pipe. WBN-8

a. Conduits adjacent to or below insulated hot piping (horizontal and vertical)

Conduits running parallel to hot piping and located adjacent to or below this piping shall have a minimum separation of six inches from the pipe.

b. Conduit above insulated hot piping (horizontal and vertical)

Conduits running parallel to and above insulated hot piping shall be located outside the zone of influence for the hot pipe. The zone of influence is as shown in Figure 3.2.1.15-1 where "X" is equal to 1.5 except for those pipes in rooms identified in Table "A". For the rooms identified in Table "A", use the specific distance or the value of "X" shown in Table "A", as applicable.

3.0 INSTALLATION (Continued)

3.2.1.15 (Continued)

3. Where running parallel, rigid and flexible conduits shall be separated from uninsulated hot piping and tubing 2" and smaller as noted below. Hot piping includes piping, tubing, valve stems, and bonnets for systems 01, 02, 03A, 03B, 05, 06, 7, 12, 15, 43, 44, 62, 63, 68, 74, and 77. WBN

a. Conduits, adjacent to or below 2" and smaller uninsulated hot piping and tubing (horizontal and vertical).

Conduits running parallel to uninsulated hot piping and located adjacent to or below that piping shall have a minimum separation of 1'-10" from the pipe.

b. Conduits running above uninsulated hot piping and tubing (2" and smaller, horizontal and vertical).

Conduits running parallel to and above hot pipes shall be located outside the zone of influence for the hot pipe. The zone of influence is as shown in Figure 3.2.1.15-2, using the distances of 1'-11" for 1/2" or less piping and tubing, 3'-2" for piping and tubing greater than 1/2" up to 1", and 4'-4" for piping and tubing greater than 1" up to 2".

3.0 INSTALLATION(Continued)

3.2.1.15 (Continued)

4. Where running non-parallel (see note 3), rigid and flexible conduits shall be separated from insulated and uninsulated hot piping and tubing (horizontal or vertical) as noted below for systems 01, 02, 03A, 03B, 06, 15, 43, 62, 63, 68, 74, and branch lines two inches and larger connecting to these systems up to the first normally closed isolation or check valve. These separation requirements also apply to uninsulated piping and tubing for systems 7, 12, 44, and 77. Valve stems and bonnets are considered part of the pipe: WBN-8

   a. For conduits running non-parallel to hot piping and tubing insulated or uninsulated and located adjacent to or below that piping and tubing; the minimum separations distance shall be six inches from the pipe.

   b. Conduits running above and non-parallel to insulated hot piping and tubing shall be located outside the zone of influence for the hot pipe. The zone of influence is as shown in Figure 3.2.1.15-1 using a distance of 10" for piping 4-3/8" O.D. and smaller 3'-5" for piping with an O.D. greater than 4-3/8" up to 39". Piping O.D. includes insulation.

   c. Conduits running above and non-parallel to uninsulated hot pipes and tubing shall be located outside the zone of influence for the hot pipe. The zone of influence is as shown in Figure 3.2.1.15-2 using a distance of 1'-3" for tubing less than 1/2" O.D. and 2'-9" for 2" O.D. down to 1/2" O.D. pipe and tubing.

5. Piping for systems other than those identified in paragraphs 2, 3 and 4 have no thermal clearance requirements. Separation distances shall satisfy the requirements of Engineering Specification N3C-941 in all cases.

3.0 INSTALLATION (Continued)

3.2.1.15 (Continued)

6. Conduits shall be separated from pipes and pipe components by minimum distances specified in N3C-941. The separation distances described below shall be added to the thermal growth separations specified in N3C-941. Conduits containing non power cables, i.e., low voltage signal, V1, medium voltage signal, V2 and control, V3, which are not control power shall be separated from hot piping by distances specified in Table B. These clearances apply to hot piping and all branch lines connecting to this piping up to the first normally closed isolation or check valve. Valve stems and bonnets are considered part of the pipe.

3.0 INSTALLATION (Continued)

3.2.1.15 (Continued)

NOTES (For paragraphs 2, 3, 4, 5, and 6)

(1) Flexible conduits connecting to end devices attached to hot pipes shall be routed to minimize intrusion into the zone of influence. Flexible conduit shall be restrained as necessary to assure that separation requirements are maintained for normal operating conditions.

(2) If the pipe insulation has been removed, an insulation thickness of four and one-half inches shall be used for determining separation distances or the design insulation thickness shall be obtained from the drawings.

(3) Conduits and pipes are considered to be parallel if they form an angle of less than 20° to each other.

(4) For vertical conduit that runs parallel with vertical hot piping for more than ten feet, Engineering shall be contacted to provide the necessary clearances.

(5) For conduits (1E only) being installed in the RB-SG1, 2, 3, and 4 rooms and Titration, Radio Chemlab and Counting rooms, Engineering shall be contacted to provide the necessary clearances required to any hot piping.

(6) The separation of conduits from hot piping is based on cables with a rating of 90°C or above qualification temperature (see 3.2.1.15A).

(7) The conduit separation requirements are based on insulated pipe maximum O.D. (including insulation) of 39" (for all voltage levels), uninsulated hot pipe maximum O.D. of 2" (for NV3 control power, NV4, and NV5 levels) and uninsulated pipe maximum O.D. of 39" (for NV1, NV2, and V3 control levels). Engineering shall be contacted to provide the necessary clearances for larger hot pipe O.D.

(8) An existing conduit may be removed and replaced with a conduit of the same size or smaller in the same location without verification of separation distances, except in those cases where the original installation required the modification (e.g. notching) of piping insulation. In such cases, NE approval must be obtained prior to reinstallation of the conduit.

(9) No conduit separation from instrument sensing lines is required for temperature considerations.

3.0 INSTALLATION (Continued)

3.2.1.15 (Continued)

B. Appendix R Conduit Separation

1. Compliance with the intent of 10CFR50 Appendix R is based on physical separation between cables for redundant functions. Essential Appendix R Fire Safe Shut Down (FSSD) conduits identified in CCRS shall be installed within the areas identified on the Appendix R separation sketches and instructions provided in the design change notice (DCN) or engineering change notice (ECN)-Mod package.

2. As-installed location of essential Appendix R conduits shall be field verified. Nuclear Construction (NC) shall notify the Nuclear Engineering (NE) lead electrical engineer upon completion of essential Appendix R conduit installation.

3. Essential Appendix R (FSSD) conduits shall not be relocated (more than 6 inches horizontal) without NE notification and written concurrence.

3.0 INSTALLATION (Continued)

3.2.1.15 (Continued)

TABLE "A" **
CLEARANCE VALUES BY ROOM NUMBERS FOR PARALLEL CONDUITS INSTALLED ABOVE HOT INSULATED PIPING

ROOM NO'S *	ELEVATION		DISTANCE OR "X" FOR FIGURE 3.2.1.15-1 OUTSIDE DIAMETER OF INSULATED PIPE		
			PIPING LESS THAN 4-3/8" (DISTANCE)	4-3/8" UP TO 23" (VALUE OF "X" in inches)	23" UP TO 39" (VALUE OF "X" in inches)
A1, A2, A11, A10, A12, A13	729.0		1'-4"	3.55	1.70
RB ANNULUS	ALL				
RB-LOWER COMPT, RACEWAY & PRESS RMS	ALL				
RB-INSTR. ROOM	716.0		1'-4"	2.90	1.50
A1, A2, A3, A4, A7, A10, A13, A14, A15, A16	772.0				
A1, A2, A3, A4, A5, A9, A17, A21, A22, A23, A24, A25, A26, A27, A28	757.0				
A2	737.0				
C3, C4, C5, C6, C7, C8, C9	692.0				
C6, C12, C13, C15	755.0				
C1, C4	708.0				
RB UPPER COMPT.	ALL		1'-4"	1.87	1.50
A1	786.5				
A1, A2	763.5				
A1	775.25				
A14, A15	729.0				
C1, C2, C10	692.0				
C1	755.0				
RB-ACCUM & FAN RMS	ALL		0'-6"	1.50	1.50
A8	772.0				
4, 5	742.0				
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14.	760.5				
A1, A2, A3, A4	782.0				

* Room descriptions and location drawings are shown on 47E235-00 drawing series.
** This table applies to insulated piping systems 01, 02, 03A, 03B, 05, 06, 15, 43, 62, 68, and 74.

3.0 INSTALLATION (Continued)

3.2.1.15 Watts Bar Nuclear Plant (Continued)

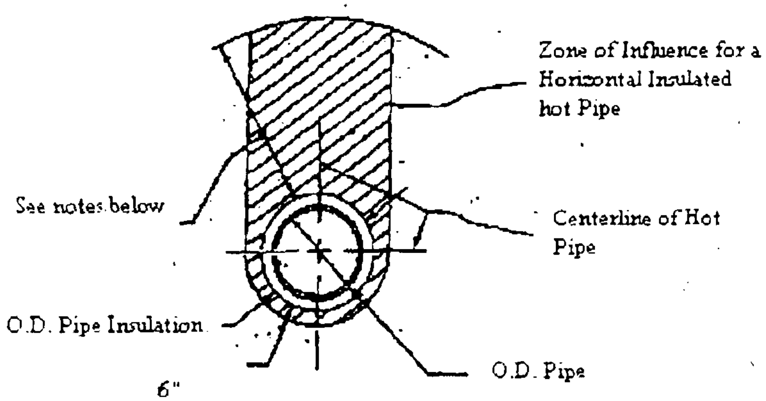

Figure 3.2.1.15-1 (For Watts Bar only)

Notes:

A) For separation of insulated piping in systems 01, 02, 03A, 03b, 05, 06, 15, 43,62, 63, 68 and 74 from conduits containing NV3-control power, NV4, or NV5 cables.

1) For rooms listed in Table "A", this dimension equals the specific distance provided or "X" x O.D. pipe insulation, where a value of "X" is provided.

2) For rooms not listed in Table "A", this dimension equals the specific distance provided in the applicable paragraph for conduits located above pipe, or 1.5 x O.D. pipe insulation, where no specific distance is provided.

3) The minimum distance in all cases is 6".

3.0 INSTALLATION

3.2.1.15 (continued)

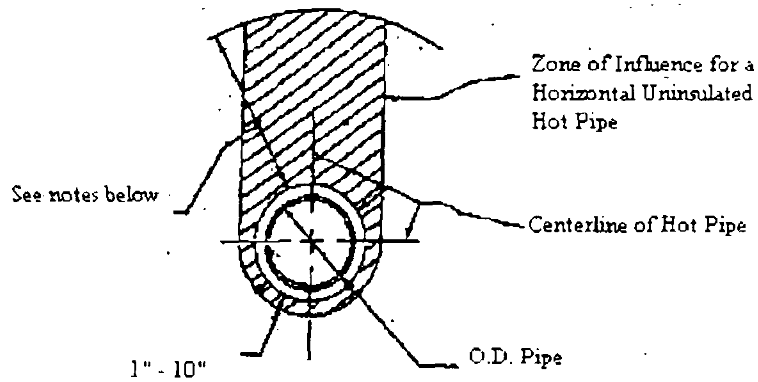

Figure 3.2.1.15
Zone Of Influence For Horizontal Uninsulated Hot Pipes (For Watts Bar Only)

NOTES:

A) For separation of uninsulated piping in systems 01,02, 03A, 03B, 05, 06, 07, 12, 15, 43, 44, 62, 63, 68, 74, and 77 from conduits containing NV3-control power, NV4, or NV5 cables.

1) This dimension equals the specific distance provided in the applicable paragraph (see 3.2.1.15.3.b. and 3.2.1.15.4.c) for conduits running above pipe.

2) The minimum dimension is 1'- 10" in all cases.

3.0 INSTALLATION

3.2.1.15 (Continued)

TABLE B*

CLEARANCE VALUES FOR CONDUITS CONTAINING CONTROL LEVEL, V3, MEDIUM LEVEL SIGNAL, V2, AND LOW LEVEL SIGNAL V1 CABLES FROM HOT PIPES

	Conduits above and parallel to pipe	All other conduits to pipe orientations
Insulated Pipes		
Systems 01, 03A, 03B, 15, 43, 62, 63, 68, and 74	5 inches	1 inch
All other systems	See Section 3.2.1.15.A.5	See Section 3.2.1.15.A.5
Uninsulated Pipes		
Piping diameter 2" and less in Systems 01, 02, 03A, 03B, 05, 06, 07, 12, 15, 43, 44, 62, 63, 68, 74, and 77	8 inches	2 inches
Piping diameter greater than 2" in System 01, 02, 03A, 03B, 05, 06, 07, 12, 14, 43, 44, 62, 63, 68, 74, and 77	36 inches	6 inches
All other uninsulated piping	See Section 3.2.1.15.A.5	See Section 3.2.1.15.A.5

* QIR MNMWBN93007 RO (T31 930408 986)

3.0 INSTALLATION (Continued)

3.2.2 Exposed Conduit

3.2.2.1 Exposed conduits shall be run in straight lines parallel to column lines, walls or beams. Where conduits are grouped, the bends and fittings shall be installed to present an orderly appearance. Unnecessary bending or crossing shall be avoided.

3.2.2.2 In seismic Category I structures (Class I at BFNP), exposed conduits shall be supported as defined by design drawings.

Rigid conduit attachments to end devices (i.e., all conduit bodies for making splices, oversized conduit bodies for accommodating minimum training radius requirements, rigid conduit for installing equipment seals, etc.) shall be installed in accordance to design drawings to ensure that the end device will not be damaged due to stress created by excessive weight.[WBN-9]

3.2.2.3 Malleable iron 1-hole pipe straps, clamps, U-bolts, hangers or close bracket-type pipe supports may be used. Pipe backspacers should be used for the 1-hole malleable iron pipe supports where it is desired to hold a conduit run away from the surface to eliminate offsetting the conduit at the fittings.

3.2.2.4 In nonseismic (non category I) structures, galvanized steel members may be drilled or punched for conduit supporting bolts provided the holes are immediately coated with zinc-dust zinc-oxide paint (in accordance with ASTM A780, Annex A2) and galvanized or rust-resisting bolts are used. Threaded stud bolts, Nelson stud anchors or equivalent may be used instead of drilling or punching steel members.

3.2.2.5 In moist locations and in locations where appearance is of importance, precautions shall be taken, such as by use of strap-type wrenches or equivalent means, to avoid injuring the galvanized coating of steel conduits or surface of stainless steel conduit.

3.0 INSTALLATION (Continued)

3.2.2.6 Beginning with the Watts Bar Nuclear Plant, exposed conduit containing Class 1E wiring shall have its division of separation identified (by marking, tagging, or taping) with the respective background color code at intervals not to exceed 15 feet in accordance with Electrical Standard Drawing SD-E15.3.4.

3.2.2.7 When in the vicinity of piping which must be insulated, the conduit shall be adequately spaced away from the pipe to avoid interferences when the pipe is insulated.

3.2.2.8 Two conduit bodies having three conduit openings each (e.g., two "Tee" condulets) may be used where one conduit body having four conduit openings (e.g., an "X" condulet) is specified on design drawings. The conduit interconnecting the two conduit bodies shall be sized in accordance with Design Standard DS-E13.1.4.

This configuration is treated as a single conduit body, and the conduit interconnection is not required to be uniquely identified if it is 12 inches or less in length. Contact engineering when the interconnecting conduit is greater than 12 inches in length.

3.2.2.9 Watts Bar Nuclear Plant.

Conduits containing 10 CFR 50.49 cables shall not have threaded portions (i.e., condulets, junction boxes, couplings or unions, etc.) and flexible sections located below postulated HELB flood levels identified on the Environmental Data Drawings 47E235 series. When more than one applicable flood level is provided, the highest level shall be used. When a conduit passes through a wall/floor, the conduit shall be evaluated based on the new conduit location. If it becomes necessary to route conduits below the HELB flood levels identified in 47E235 series drawings, contact Site Engineering to determine if they contain 10 CFR 50.49 cables.

After 7/7/95, installation of conduits containing 10 CFR 50.49 cables below the postulated MELB flood levels identified on the Environmental Data Drawings shall require specific approval on design output documents.

Unless otherwise stated on Design Output Drawing, any conduit which exits a room below the postulated MELB flood level for that room shall be sealed in accordance with drawing 45W883 Sheet 6 to prevent water egress to other areas.[WBN-4]

3.0 INSTALLATION (Continued)

Conduit sealing to prevent water accumulation in conduit or entering equipment, on a case-by-case basis with prior SE approval on the Work Instruction Document at a location specified by SE, is permitted. Sealing shall be accomplished by packing approximately 1" depth of ceramic fiber damming around cables and in voids between cables/conduits (damming shall be used on either side of silicone foam) and injecting 3" minimum Dow Corning 3-6548 Silicone RTV Foam. **CAUTION**: The above seal is not to be used as a firestop, nor as a 50.49 pressure / moisture seal.

3.2.3 Embedded Conduit

3.2.3.1 A minimum 2-inch clearance shall be maintained between conduits embedded in poured concrete walls or floor slabs, except that detailed design dimensions shall be adhered to adjacent to conduit terminations, etc., where area is restricted.

Conduits and conduit sleeves, when located in a bank or group form in a wall pour, may be adjusted as required to line up the bottom outside edge of the smaller sized conduit with the bottom outside edge of the largest conduit in the group in order to continue the group run on a common exposed support.

Likewise, grouped conduits in a floor or ceiling slab may be shifted enough to take advantage of a common exposed wall or column support. For tolerances for embedded conduit runs, see Section 3.13.2.

Conduits embedded in switchyards and transformer yards shall maintain a 1-inch minimum clearance between conduits.

3.2.3.2 In switchyards and transformer yards all single conduit or groups of conduits shall be encased in concrete with the outer coverage a minimum of 2-1/2 inches.

3.2.3.3 Where embedded in concrete, extreme care shall be taken to anchor aluminum and nonmetallic conduit so that it will not be floated when the concrete is placed.

3.2.3.4 Embedded conduit shall be rigidly supported to withstand concrete vibrators or batches of mass concrete placements.

3.2.3.5 In supporting embedded steel, aluminum or plastic conduit, extreme care shall be taken to avoid damage to the surface of the conduit if welding or brazing is used near the conduit. In no case shall the conduit be welded or brazed to the support. Plastic conduit in duct runs shall not be supported by reinforcing steel forming closed magnetic loops; preformed plastic spacers shall be used. See Electrical Standard Drawing SD-E13.4.1.

3.0 INSTALLATION (Continued)

3.2.3.6 Concrete curbs shall be provided where specified on design drawings.

3.2.3.7 Slip joints shall be installed in accordance with Electrical Standard Drawing SD-E13.1.1, where embedded conduits cross expansion or contraction joints, as defined and located on design drawings.

3.2.3.8 Wherever slip joints are used, suitable bonding in accordance with Electrical Standard Drawing SD-E13.1.1 shall be provided around the joint to ensure a continuous ground circuit. Where use of expansion and deflection-type fittings (see Standard Drawing SD-E13.1.2) are defined in design drawings, the manufacturer's instructions shall be followed in making ground connections.

3.2.3.9 Except as noted below or unless otherwise specified on design drawings, all embedded conduits turning out of poured concrete shall terminate with a standard coupling flush with the surface of the concrete. Where the thickness of the concrete is not adequate to accommodate the minimum bending radius of the conduit (see DS-E13.1.7), one of the following options may be exercised:

A. A short radius elbow may be used where approval has been obtained from engineering. (Short radius elbows must also be shown on design drawings. See Section 3.2.4.1 Item G).

B. Where terminating into surface of floor-mounted boxes or equipment, a standard radius field bend or manufacturer's bend may be used and extended beyond the concrete surface as needed to complete the 90-degree bend. If necessary to avoid interferences or to accommodate the minimum bending radius of the cables, the end of the 90-degree bend projecting beyond the concrete surface may be cut, if the cut end is deburred and handled in accordance with Section 3.2.1.2 Items A or B.

3.0 INSTALLATION (Continued)

3.2.3.9 (Continued)

C. Where the conduit bend must be terminated in a coupling to allow the conduit system to be extended beyond the wall or floor surface, the coupling may extend beyond the surface as needed to complete the 90-degree bend.

D. Where the difference in being able to comply with Section 3.2.3.9 and DS-E13.1.7 is small, the straight portion of the bend may be cut as required, if the minimum bending radius (dimension A, DS-E13.1.7) is not altered and the bend is rethreaded to the original specifications.

3.2.3.10 In duct runs the metallic conduit shall be grounded at each manhole or handhole by brazing the ground wire to the top of the conduit coupling or by using grounding bushings.

3.2.3.11 Holes for conduits may be drilled in hardened concrete; however, no reinforcing steel will be cut or damaged during the drilling operation. The reinforcing steel may be located by removing the cover concrete. Holes may be relocated up to 8 inches in any direction from the dimensions specified on design drawings and may be canted from one face to the other to avoid the reinforcing steel. After installation of the conduit, the damaged concrete shall be repaired in accordance with TVA General Engineering Specification No. G-34.

3.2.3.12 The conduits shall be identified in such a manner that permanent tag identification can be made at a later date.

3.2.3.13 The conduits shall be swabbed immediately (before any concrete which may have sipped inside the conduit has had a chance to harden) after the concrete pour is complete.

3.0 INSTALLATION (Continued)

3.2.4 Rigid Metal Conduit

3.2.4.1 General

A. Metallic conduit systems, whether embedded or exposed, shall be installed in accordance with those portions of the NEC which ensure that the systems will be adequately grounded and electrically continuous to function as the equipment grounding conductor.

B. When necessary to achieve electrical continuity (per NEC), bonding jumpers shall be installed between the rigid metal conduit and the enclosure (i.e., box, cabinet, switchgear cable tray). This shall be accomplished by using UL-listed ground clamps or fittings approved for grounding. These bonding jumpers shall be sized in accordance with conduit size as listed in Table 3.2.4.1-1.

C. When boxes do not have threaded hubs or bosses (or as in Section 3.3.1.3), conduits shall be securely fastened to boxes and cabinets, each with a locknut and a bushing inside the box and a locknut outside. (See Electrical Design Standard DS-E13.1.6 for locknut spacing requirements.) The conduits shall be of such length that when the bushings are screwed tight against the ends of the conduits, no appreciable space will be left between the bushings and the locknuts.

D. To avoid hotspots or sparking during fault conditions, locknuts shall be firmly tightened against the box. Care shall be taken to prevent deforming the box. As an alternative, a coupling may be used on the end of the conduit system and a chase nipple inside the enclosure (box or cabinet) to connect the enclosure and conduit together. To ensure that the enclosure and conduit are electrically continuous, the T&B grounding wedge having the UL label shall be used. Unless otherwise specified by the manufacturer, the wedge may be installed inside or outside (preferred) the enclosure.

3.0 INSTALLATION (Continued)

3.2.4.1 (Continued)

Table 3.2.4.1-1
Bonding Jumpers for Ensuring
Electrical Continuity of Electrical Conduit System

Conduit Size	Copper Jumper Size (AWG) for Power Conduits	Copper Jumper Size (AWG) for Control, Medium-Level Signal and Low-Level Signal Conduits*
1/2	#6	#6
3/4	#6	#6
1	#6	#6
1-1/2	#4	#4
2	#2	#2
2-1/2	#2/0	#2
3	#2/0	#2
4	#2/0	#2
5	#2/0	#2

* These AWG sizes may be reduced to match the largest available ground cable in the vicinity when it is not practical or possible to extend the bonding jumper to a larger ground cable. Engineering must review and approve such deviations on a case by case basis. If required to match existing ground cables, cable sizes may be increased without engineering approval.

NOTE: Bonding jumpers for ensuring electrical continuity of electrical conduit systems shall be installed such that the ground cable is held firmly in place. Torquing is not required. Compound 'Kopr-Shield' shall be applied to the mating surfaces of the connections.

3.0 INSTALLATION (Continued)

3.2.4.1 (Continued)

E. Running threads on field threaded conduits shall not be used on metal conduits except for short nipples which are used to extend the conduit systems.

F. Welded or brazed grounds on conduit runs shall be done on the top of couplings only, and extreme care shall be taken to avoid injury to the inner surface of the conduit by excessive heating. The welded or brazed joint shall be coated with asphaltum, RTV sealants or equivalent.

G. Unless otherwise noted, standard radius field bends (see Electrical Design Standard DS-E13.1.7) or manufacturer's bends (bending radius as specified in NEC) shall be used where needed in metal conduit systems. Special, long radius bends (bending radius greater than Electrical Design Standard DS-E13.1.7 or NEC requirements) shall be used where specifically called for on design drawings or where otherwise needed to complete the installation of the conduit system. Short radius elbows (bending radius less than Electrical Design Standard DS-E13.1.7 or NEC requirements) shall <u>not</u> be used unless specified on design drawings.

3.0 INSTALLATION (Continued)

3.2.4.1 (Continued)

H. Field Bends

1. Field bends for metal conduit shall be made such that the internal diameter of the conduit is not materially changed and the protective coating on the inside and outside of the conduit is not significantly damaged.

2. When making field bends, a certain amount of necking, flattening, nicks, kinks, splits, dents and/or damage to the protective coating can be expected to occur.

3. Field bends which result in a kink or split in the conduit shall be abandoned. Likewise, if a nick should occur which actually penetrates the wall of the conduit, the bend shall not be used.

4. Nicks and abrasions resulting in significant damage to the protective coating should be repaired by spraying or painting galvanize on the damaged areas.

3.0 INSTALLATION (Continued)

3.2.4.1 (Continued)

5. When the following conditions are satisfied, less severe necking, flattening, dents, and nicks which could not result in damage to the cable insulation during pulling are acceptable:

   a. The bending equipment being used is correct for the application.

   b. The manufacturer's instructions and recommendations pertaining to the use of the bending equipment are being followed.

   c. The bending equipment is functioning properly (i.e., making bends which do not result in kinks, splits, or damage to the conduit coating).

   Heat shall not be applied in making any metal conduit bend. (See Section 3.2.5.4 for field bends for nonmetallic conduit.)

I. Die cast zinc conduit fittings and connectors shall not be used inside the reactor building primary containments which have a boric acid containment spray system.

J. Except for conduits containing battery board supply cables, sections of existing aluminum conduit runs may be replaced with rigid steel conduit without requiring revision to drawings.

3.0 INSTALLATION (Continued)

3.2.4.1 (Continued)

K. Conduit fittings and conduit bodies (tees, LBs) installed within the rigid conduit system shall be compatible to the strength requirements of the conduit.

1. For rigid conduit, the bodies and fittings shall be malleable iron or steel. See Standard Specifications referenced in 2.1.2.

2. Nonmalleable cast iron fittings and bodies may be used with aluminum conduit only when approved by TVA Nuclear Engineering on a case by case basis.

3.2.4.2 Steel Conduit and Intermediate Metal Conduit

Steel and intermediate metal conduit joints and connections shall be made weathertight and rustproof by means of the application of a thread compound which will not insulate the joint. Each field-cut thread shall be cleaned to remove the cutting oil before the compound is applied. An electrically conductive antiseize compound for metal surfaces (Thomas and Betts Company "Kopr-Shield"; Jet-Lube, Incorporated, "SS-30"; Burndy "Penetrox E"; or equivalent) shall be applied to the male conduit threads.

3.2.4.3 Aluminum Conduit

A. Rigid aluminum conduit installed outdoors or in wet locations shall be provided with aluminum fittings. The use of aluminum conduit in areas containing corrosive materials should be avoided. Galvanized fittings (such as type EYS) may be used in special cases as designated by engineering. Care must be taken to prevent the contact of aluminum conduit with corrosive materials in places where moisture can accumulate.

B. Strap-type wrenches should be used to avoid scratching and gouging the aluminum conduit.

3.0 INSTALLATION (Continued)

3.2.4.3 (Continued)

C. Aluminum conduit joints at couplings or fittings shall be made weathertight by application of an electrically conductive, antiseize compound for metal surfaces (Thomas & Betts Company "Kopr-Shield" or "Aluma-Shield;" Jet-Lube, Incorporated, "SS-30;" Burndy Corporation "Penetrox E." or equivalent).

Satisfactory mixtures such as zinc dust and vaseline (50-50 by weight), or a heavy cup grease containing 25-percent graphite may be used. Aluminum threads shall not be coated with red lead or other lead compounds. Each field cut thread shall be cleaned to remove the cutting oil before the compound is applied.

D. Standard benders may be used for aluminum conduit except that electrical metallic tubing (EMT) benders shall be used for conduit 1 inch in diameter and below. Use an EMT bender 1/4-inch larger than the conduit size, i.e., 1-1/4 inches for 1-inch rigid, 1 inch for 3/4-inch rigid.

E. In addition to the methods described in Section 3.2.4.1, aluminum conduit may be grounded by inserting a galvanized steel coupling in the run, brazing the ground wire to the top of the coupling and carefully coating the joint with asphaltum, RTV sealant or equivalent.

F. Aluminum conduit, conduit fittings or components shall not be used inside reactor, building primary containments that have a boric acid spray system that would react with aluminum to produce excessive hydrogen.

3.0 . INSTALLATION (Continued)

3.2.4.4 Electrical Metallic Tubing (EMT)

EMT, a threadless, thin-wall steel conduit requiring special threadless fittings for couplings and terminations may be used in exposed and embedded applications in office and service buildings. Installation shall be in accordance with Article 348 of the National Electrical Code, latest edition.

3.2.5 Plastic Conduit (PVC)

3.2.5.1 To prevent warping during storage, plastic conduit shall be stacked on smooth, flat surface in an area not directly exposed to the rays of the sun. Spacers of 1-inch soft wood, approximately 2 feet apart, should be used between layers of conduit. Manufacturer's shipping bundles may also be used for direct storage.

3.2.5.2 Refer to DS-E13.1.11 for applications of embedded PVC conduit. Where plastic conduits are encased in concrete (such as in duct banks between buildings), the conduits shall be anchored with preformed plastic spacers before concrete placement. The conduits and spacers shall be located as shown on design drawings.

3.2.5.3 Plastic conduit may be cut with a hacksaw. After cutting, ends shall be trimmed and rough edges smoothed. The area to be solvent welded (outside of conduit and inside of coupling or fitting) shall be free from dust, dirt, grease, and moisture. Use PVC cleaner for cleaning. Polyvinyl chloride (PVC) solvent shall be brushed liberally on the and of the conduit and inside the fitting or coupling when making a joint. After fitting has been pushed on, it should be twisted one-fourth turn to spread the solvent evenly. Continue to hold joint for 15 seconds so that conduit does not push out of fitting.

3.2.5.4 Bends for nonmetallic conduit are usually purchased as required for the conduit system, but for special cases may be made in the field. Extreme caution should be observed when any source of heat is near plastic conduit. Field bending can be accomplished by the use of a "hot air-cold air" blower: a hand-type hair dryer is recommended by the manufacturers.

3.0 INSTALLATION (Continued)

3.2.6 Flexible Conduit

3.2.6.1 General

A. Flexible conduit shall be used to interface the rigid conduit system with electric equipment and devices that rotate, vibrate, are subject to thermal movement, or where seismic considerations must be taken into account.[WBN-3] It shall also be used for connecting flush and recessed lighting fixtures to rigid conduit systems when so indicated on design drawings.

B. Flexible conduit installed in straight lengths (reference Section 3.2.1.1 Item J of G-38) may be used within a rigid, exposed conduit run to:

1. Avoid interferences.

2. Cross an expansion-contraction joint where the rigid conduit is attached to the structure on each side of the joint.

3. It may also be used to interface between cable trays and/or equipment. Attachment of flexible conduit to cable trays shall require site engineering approval prior to installation.

C. Flexible conduit secured with P2558 series unistrut 2-hole straps, instead of connecting to equipment with standard flexible conduit fittings, may utilize ferrules supplied by approved flexible conduit connector vendors on the end(s) of the flexible conduit to protect the cables. Ferrules must have rounded ends and be of the screw-in type to ensure position retention.

3.0 INSTALLATION (Continued)

3.2.6.1 (Continued)

D. The electrical continuity of the conduit system shall be preserved.

1. This electrical continuity shall be achieved by installing a bonding strap or ground cable across stainless steel or liquid-tight flexible conduit by connecting to the raceway and/or equipment/end device. This shall be accomplished by using UL-listed ground clamps or fittings approved for grounding. Bonding jumpers shall be sized in accordance with conduit size as listed in Table 3.2.4.1-1. For support purposes, cable ties shall be adequate to secure the grounding conductor to the flexible conduit.

This bonding jumper is not required on 1/2", 3/4", and 1" liquid-tight flexible metal conduit if a, b, and c below are met:

a. The installed length of flexible conduit is 6 foot or less and the rigid conduit section or the end component are adequately grounded and provides a ground return path (NEC 350-5, and 351-9).

b. All fittings are UL-listed, and

c. The conduit is used only for control, medium-level, or low-level signal cables or low voltage power (20 amps or lower).

For conditions where the bonding jumper is presently not installed, any future rework of existing stainless steel or liquid-tight flexible conduits will require the installation of the above required bonding jumpers concurrent with the rework activities.

3.0 INSTALLATION (Continued)

3.2.6.1 (Continued)

2. For equipment with more than one flexible conduit connection (i.e., MCC's, switchgear, valves, R-panels, etc.), which have common end points, it is acceptable to provide only one ground jumper from the rigid conduits/cable tray to the equipment as long as:

   a. All conduits are jumpered together either at the common support or at the equipment.

   b. The ground cable is sized for the largest conduit, and

   c. The flexible conduits are attached to a common point at the equipment.

   d. For flexible conduits which are not physically/electrically attached to the equipment and/or raceway, the ground jumper shall extend from the equipment to the raceway.

   Flexible conduits routed from different supports will require separate ground jumpers, sized as indicated in Table 3.2.4.1-1.

3.0 INSTALLATION (Continued)

3.2.6.1 (Continued)

E. Flexible conduit shall be installed between conduit fittings in exposed lengths not exceeding 72 inches, except as noted on design output documents. Rigid conduit should be located as near the equipment and device as practical. The flexible conduit shall be prepared, assembled, and installed in accordance with manufacturer's instructions provided in the vendor catalog for the particular part number or instructions provided with the contract. If the flexible conduit fitting vendor requires the compression nut to be torqued, the vendor supplied valves shall be used. If torquing is not required by the flexible conduit fitting vendor, the compression nut shall be installed wrench tight using commonly available tools. Wrench tight shall be defined as "not being able to rotate or remove by hand at the joint or fitting."[WBN-12]

NOTE: Based on the justification provided in Appendix Y variance 4 for WBN and Letter from T&B (A) torquing of T&B flex conduit fittings to a numerical value other than wrench tight is not required. This applies to all sites.

NOTE: Flexible conduit connector bodies should be installed and tightened into the end device prior to installing the flexible conduit. When compression nuts are torqued or tightened, care shall be taken not to exceed the maximum torque value for the end device.

F. The minimum recommended bend radii listed in Table 3.2.6.3-2 shall not be violated.[WBN-11] (Other types of flexible conduit may be acceptable; however, engineering approval shall be required prior to installation.) Flexible conduit should be installed without twist and oriented away from heat radiating sources, such as a hot pipe and its insulation (see Section 3.2.1.11 for separation distances for Watts Bar and Sequoyah Nuclear Plants and Section 3.2.1.12 for Browns Ferry Nuclear Plants). After installation, the flexible conduit shall not be stretched tight between flexible conduit fittings.

3.0 INSTALLATION (Continued)

3.2.6.1 (Continued)

G. Flexible conduit entering the top or side of boxes, equipment, and devices requiring external sealing in accordance with Engineering design documents shall be installed utilizing a vendor supplied or vendor recommended O-ring seal between the box, equipment, or device and the flexible conduit fitting. This is not a requirement if:

1. The box, equipment, or device has a threaded hub.

2. Welded hub is provided as part of the enclosure, or

3. No open terminations exist inside the enclosure.

4. This is not a requirement for BFN if it is sealed in accordance with drawing 0-45B891-1.

5. For BLN, the joint between the installed conduit connector and the outside of the electrical enclosure is coated with a minimum of a 1/8" bead of RTV 738 sealant or approved equal.

Where design output documents for Watts Bar Nuclear Plant show flexible conduits, short sections of rigid conduit of equal size or larger, may be substituted for a portion of the flexible conduit where the conduit enters a fitting, provided the rigid section is for seismic support anchoring, has been approved by Civil Engineering, and the remaining length of flexible conduit meets all requirements of this specification.

3.0 INSTALLATION (Continued)

3.2.6.1 (Continued)

H. Where liquid tight (synthetic jacket) flexible metal conduit has damage which penetrates the PVC jacket, it shall be replaced, or repaired as noted below:

a. Liquid Tight PVC Jacket Flex Conduit

1. Ensure there is no significant damage to the metallic core of the conduit (no sharp edges inside the conduit). If the metallic core has been penetrated or is broken, the flexible conduit should be replaced.

2. Clean the area where the damage has occurred using a clean rag and denatured alcohol, or equivalent.

3. Wrap at least one half-lapped layer of 3M Company Scotch 22 Electrical Tape or equivalent for a minimum 2-inch distance on each side of the damaged synthetic jacket, or to the end of the conduit such that it extends under the gland nut.

NOTE: Where the above flexible conduit exists inside drywell at Browns Ferry Nuclear Plant and inside primary containment or in the main steam valve vault at other nuclear plants, it shall not be repaired but replaced.

3.0 INSTALLATION (Continued)

3.2.6.1 (Continued)

b. <u>ServicAir Stainless Steel Conduit</u>

ServicAir flexible conduit is considered damaged and shall be replaced if any core damage, any broken strands of the braid or any burn marks exist prior to installing the cable, since there is no repair method. If conditions exist to the extent described below after cable installation the conduit shall also be replaced. If the damage has been caused due to a bend radius violation, the more restrictive requirements contained in the notes for Table 3.2.6.3-2 apply instead of those listed below:

1. Core (metallic bellows) is visibly damaged (e.g. flattening/ distortion of cross section or kinks).

2. For conduits which serve as a pressure boundary (environmental seal), greater than 10% of the braid strands are visibly broken. For conduits which do not serve as a pressure boundary, greater than 20% of the braid strands are visibly broken.

3. Burn marks in outer braid, which occurred from an outside source (i.e. not from a fault inside the conduit) are acceptable provided that there are no burn marks or discoloration on the core and burn does not result in broken strands in excess of item 2 above.

4. Conduit is pulled loose from end connectors and the flexible conduit or connector parts are visibly damaged (bent or broken). Reassembly is acceptable if the parts are not visibly damaged and the flex conduit can be reconnected as originally installed. The cable shall be inspected by Nuclear Engineering for damage at the exposed location in accordance with G-38 section 3.7, prior to reconnection.

3.0 INSTALLATION (Continued)

3.2.6.1 (Continued)

c. American Boa Stainless Steel Conduit

American Boa flexible conduit is considered damaged and shall be replaced if any core damage, or any burn marks exist prior to installing the cable, since there are no repair methods. If conditions exist to the extent described below after cable installation the flexible conduit shall also be replaced. If the damage has been caused due to a bend radius violation, the more restrictive requirements contained in the notes for Table 3.2.6.3-2 apply instead of those listed below:

1. Flattening/distortion, kinks or excessive indentation of core (metallic bellows). Indentations in the outer surface of the bellows not exceeding 1/8 inch in depth on no more than 10% of the bellows are acceptable provided the wall is not broken or torn.

2. Conduit is pulled loose from end connectors and the flexible conduit or connector parts are visibly damaged (bent or broken). Reassembly is acceptable if the parts are not visibly damaged and the flexible conduit can be reconnected as originally installed. The cable shall be inspected by Nuclear Engineering for damage at the exposed location in accordance with G-38 Section 3.7, prior to reconnection.

3. Burn marks on the core.

3.0 INSTALLATION (Continued)

3.2.6.1 (Continued)

I. Flexible conduits at the end devices may be increased by one standard size above the design specified size without engineering approval or revision of design drawings, provided the last two rigid conduit supports are sized to accommodate the larger flexible conduit.

J. For Watts Bar Nuclear Plant rework or maintenance of installed flexible conduits in Category I structures after May 26, 1989, shall comply with the following criteria to ensure conformance with the critical case evaluation by Civil engineering.

1. Flexible conduit may be removed and reinstalled or replaced without increasing the length of the flexible conduit or changing the length of the cantilevered section of rigid conduit, including couplings and fittings.

2. Flexible conduit may be removed and reinstalled or replaced meeting the requirements of this specification, except as defined on WBEP design output documents.

3. Flexible conduit removed and reinstalled or replaced not meeting the requirements of Section 3.2.6.1 Item J.1 or J.2 shall be approved by engineering.

K. Wire mesh grips may be installed at the Flex conduit connector in order to prevent pull out of the flex conduit from the connector. The wire mesh grip may be installed as a new installation or for repair of existing installations.

Approved Manufacturers of these devices are Crouse-Hinds, Thomas & Betts, Appleton, Kellems. The wire mesh grip shall be installed in accordance with the manufacturers instructions.

3.0 INSTALLATION (Continued)

3.2.6.2 Floor-Mounted Equipment and Devices. Seismic Thermal Movement Considerations in Seismic Category I (Class I at BFN) Structures [WBN-3]

During a seismic event, flexible conduit will allow for relative displacement of equipment or devices and a rigid conduit system. To ensure that movement of the rigid conduit system and movement of floor mounted equipment (such as motors, electrical boards, and panels) are independent during a seismic event, the following installation procedures shall be observed unless otherwise noted on design drawings:

A. When conduits connect to seismic Category I (L) floor-mounted equipment, an 18-inch minimum exposed length of flexible conduit shall be installed between the flexible conduit fittings at the rigid conduit coupling and the equipment. The actual minimum conduit length required for a particular installation shall be as specified on design drawings or as calculated using the equation in Figure 3.2.6.3-1. This minimum length of flexible conduit will ensure that floor-mounted, Class 1E equipment is capable of sufficient movement (i.e., combined thermal/seismic movements) in any direction. The minimum bend radii for flexible conduit given in Table 3.2.6.3-2 shall not be violated.

B. Where physical limitations prevent the installation of flexible conduits in accordance with Section 3.2.6.2 Item A minimum requirements, the construction, modifications, or maintenance electrical engineer shall be notified for resolution (by established procedures) with site engineering.

C. In cases where flexible conduit is used for alignment purposes only and both ends of the flexible conduit are rigidly attached to the same seismic structure, the relative displacement between ends is zero and therefore exempt from thermal/seismic considerations.

D. Conduit connections to cable trays should be avoided; however, if conduits are connected to seismic Category I cable trays, an 18-inch minimum length of flexible conduit shall be installed as indicated in Section 3.2.6.2 Item A.

3.0 INSTALLATION (Continued)

3.2.6.3 Pipe-Mounted Devices, Thermal Seismic Movement Considerations [WBN-3]

A. Where electrical connections must be made to devices (such as motor-operated valves, solenoid-operated valves and temperature switches) which are attached to a mechanical flow system designed for thermal movements, flexible conduit shall be used to compensate for any expansion/contraction and seismic movement.

B. Typically, flexible conduit connected to pipe-mounted electrical devices which are subject to thermal movements are in the 1/2-inch through 1-1/2-inch range. Excessive lengths in smaller flexible conduit sizes should be avoided to decrease stress and prevent pull-out at flexible conduit fittings.

C. Seismic Category I (Class I at BFN) Structures

Flexible conduit to pipe-mounted devices in seismic Category I structures shall be installed to compensate for combined thermal/seismic movements. The minimum length of flexible conduit shall be as specified on design drawings or as calculated using the equation in Figure 3.2.6.3-1. This minimum length of flexible conduit will ensure that pipe-mounted devices are capable of sufficient movement in any direction. The minimum bend radii for flexible conduit given in Table 3.2.6.3-2 shall not be violated.

D. Nonseismic Structures

Flexible conduit to pipe-mounted devices in nonseismic structures shall be installed to compensate for thermal movements only. However, installing conduit per the equation given for seismic Category I structures will provide adequate compensation for nonseismic thermal movements.

3.0 INSTALLATION (Continued)

3.2.6.3 (Continued)

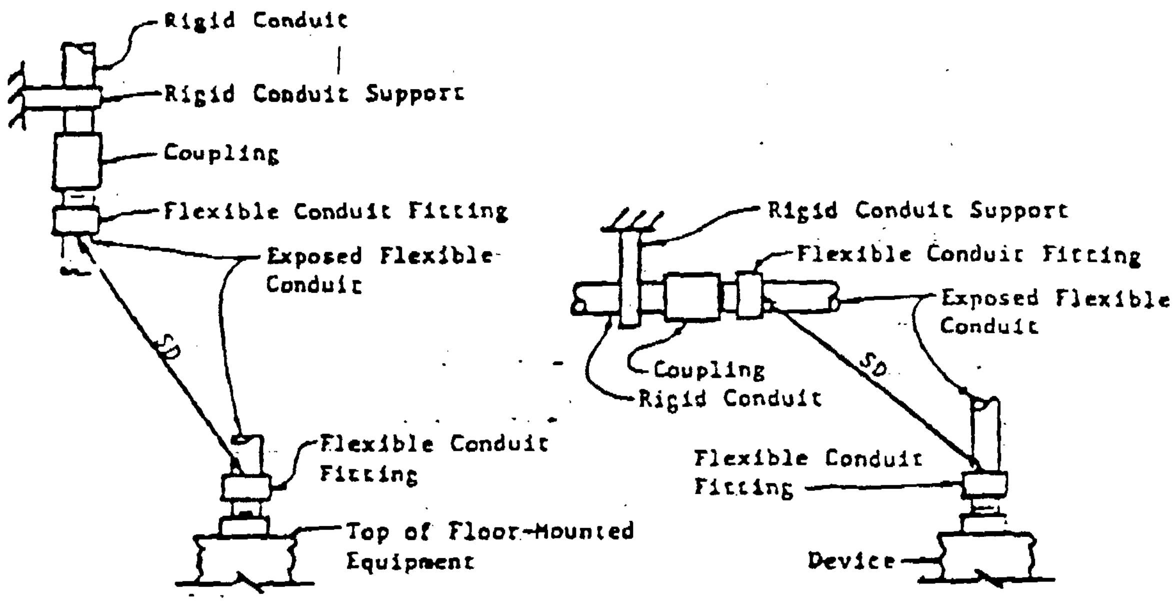

Figure 3.2.6.3-1

Typical Arrangement of Floor-Mounted Equipment or Pipe-Mounted Devices

The equation for calculating the minimum length of exposed flexible conduit required between flexible conduit fittings, between flexible conduit fitting and an intermediate support point or between intermediate support points, is as follows:

3.0 INSTALLATION (Continued)

3.2.6.3. (Continued)

FL= SD + K

Where.

FL = Minimum, exposed flexible conduit length between flexible conduit fittings. (See Notes 1 and 2 page 65.)

SD= Field measured straight-line distance between the center line points of the flexible conduit fittings. (if the straight-line distance is obstructed such that an exact measurement cannot be made, the field engineer shall conservatively estimate the distance using a combination of measurements if required.)

K = (WBN)

- 1 inch for floor-mounted equipment and for conduits crossing seismic interface boundaries for maximum seismic movement;
- 3-1/4 inches for connections to the steel containment vessel for maximum combined seismic thermal/DBA movement;
- 4 inches for conduits attached to cable trays or cable tray supports for maximum seismic movement; or
- 4 inches for pipe mounted devices for maximum combined seismic/thermal movements, except as noted on design drawings.

(Movements are in any direction.) (Note that for items attached to the steel containment vessel, the movements must be added i.e., for a cable tray attached to the steel containment vessel, the maximum total movement would be 7-1/4 inches.)

K = (all other nuclear plants)

- 1 inch for floor-mounted equipment or
- 4 inches for pipe-mounted devices

(1 inch flexible conduit length is required for maximum seismic movement in any direction; 4-inch flexible conduit length is required for maximum combined seismic/thermal movement in any direction at all nuclear plants).

Note 1: For flexible conduit cut length, the field shall add to the minimum calculated length (FL), the flexible conduit length required for conduit fittings and any additional length required for bend radii. The minimum bend radii for flexible conduit given in Table 3.2.6.3-2 shall not be violated. Any exceptions to minimum calculated lengths (FL) and/or minimum bend radii shall be approved by engineering.

Note 2: Exposed flexible conduit lengths shall not exceed 72 inches or be less than 18 inches (28 inches for ServicAir SS63C), except as noted on design output documents. For exceptions not noted on design output documents including conduit support drawings or an approved variance in Appendices W, X, Y or Z, contact engineering for resolution.

3.0 INSTALLATION (Continued)
3.2.6.3. (Continued)

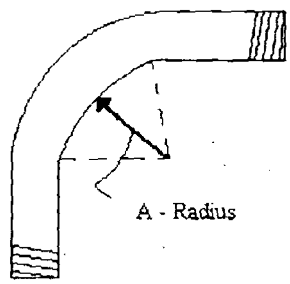

Table 3.2.6.3-2

Minimum Bend Radii for Flexible Metal Conduit										
All Dimensions are in inches										
Conduit Trade Size	1/2	3/4	1	1-1/2	2	2-1/2	3	4	5	6
Flexible Conduit Manufacturer and Type	**A - Radius to inside of conduit as shown in figure above** SEE NOTES ON FOLLOWING PAGE									
Anaconda Seal Tite Type UA	3.5	5.0	6.0	5.5	7.0	9.5	15.0	17.0	20.0	30.0
O-Z Gedney Flexi-Guard Type UAG	3.0	3.5	6.0	5.0	7.0	9.5	11.5	14.0	—	—
Liquatite Electric-Flex Type LA (Type LT)	3.0 —	4.2 —	5.5 —	4.5 —	6.0 —	8.0 —	10.0 —	12.0 —	— (17.5)	— (22.5)
American Flexible Conduit Ameri-Tite Type UL	3.25	4.25	6.5	9.0	11.13	14.63	17.5	24.0	—	—
American Boa Type NBI-0 and NBI-1 see note 1	—	1.23	1.38	2.55	3.81	4.54 see note 1	5.27 see note 1	8.74 see note 1	12.20 see note 1	14.71 see note 1
ServicAir SS60, SS63 and SS63C	2.5	3.8	5.0	7.5	10.0	12.0	15.0	20.0	25.0	30.0
Anemet, Inc.	—	—	—	—	—	—	—	—	22.0	30.0
Patel/EGS	—	7.5	—	—	—	—	—	—	—	—

3.0 INSTALLATION (Continued)

3.2.6.3 (Continued)

NOTES FOR TABLE 3.2.6.3-2:

1. American Boa (Type NBI-0 and NBI-1) flexible metal conduit larger than 2 inch (trade size) shall not be used for attachments to pipe-mounted devices.

2. The values contained in this table are based on manufacturers information and TVA calculation CD-Q0999-000001 (previously CEB-CQS-449, B41 940620 001).

3. Once flexible conduit has been installed per the requirements of this specification, the as-found bend radius configuration of the flex is acceptable as long as no damage has occurred including:

   a. Kinking of flexible conduit so that the minimum bend radius (listed above) is obviously violated.

   b. Obvious surface damage of flexible conduit from denting, weld arc strikes, tearing of stainless steel or pvc jacket as applicable, or fatigue cracks (See Section 3.2.6.1).

   c. Pullout of flexible conduit from its end connections (See Section 3.2.6.1).

   When detected, bend radius damage shall be evaluated by engineering and corrected accordingly.

4. The flexible conduit types which have numerical bend radius values provided in this table are the only types which are approved by this specification for installation (i.e. those sizes with "—" are not approved and have not been approved unless justified in an exception contained in this specification). Additional types must be approved by listing the required bend radius values in this specification prior to procurement or installation. This will be accomplished by an engineering analysis of the materials, engineering data and construction of the conduit. Other brands even though similar are not to be assumed to be equal.

3.0 INSTALLATION (Continued)

3.3 Conduit Boxes

3.3.1 General

3.3.1.1 Boxes shall be of the type and size as specified on design drawings. They shall be located as shown on design drawings and shall not be installed if damaged. Where large boxes are embedded, they shall be properly braced on the inside so that concrete placement will not deflect them. Threaded holes in box frames shall be protected from damage.

3.3.1.2 Outlet boxes in architectural tile or masonry unit walls shall be installed strictly in accordance with design drawings and for best appearance.

3.3.1.3 Where watertight conduit connections to junction boxes without threaded hubs or bosses are required (see Electrical Standard Drawing SD-E13.6.5), Appleton type HUB conduit hubs, or equivalent, may be used in place of welded hubs.

3.3.1.4 Exposed noncurrent-carrying metal parts of fixed equipment and boxes shall be grounded. Equipment not secured to, and in metallic contact with, grounded structural steel shall be connected to the grounding system by brazing the grounding cable to the equipment and then carefully coating the joint with asphaltum, RTV sealant, or equivalent; or by bolted-connections to the box, or equipment.

3.3.1.5 For general information concerning field fabricated boxes, see Electrical Standard Drawing SD-E13.6.3-1.

3.3.1.6 Appleton type "PTC" threaded pull boxes may be used as cable pull boxes or to install splices in order to achieve cable or splice bend radius. All such installations in Category I structures shall be installed in accordance to approved design output documents.

3.0 INSTALLATION (Continued)

3.3.2 Painting

Field-fabricated surface-mounted boxes shall be painted, inside and outside, immediately after fabrication. Field-fabricated flush-mounted boxes shall be painted on the inside and the exposed parts only. Primer paints shall be lead free. Boxes outside the primary containment shall be primed in accordance with General Engineering Specification G-14, Part No. 1-310 and finish coated the same color and type of coating as the surrounding area. Boxes located inside the primary containments shall be coated in accordance with General Engineering Specification G-55 and the plant-specific coating specification as follows:

- BFN Project Engineering Specification N1A-930 BFNP-N-955
- SQN Project Engineering Specification N2A-931 SNP-N-971
- WBN Project Engineering Specification N3A-932 WBNP-N-9711
- BLN Project Engineering Specification N4A-933 BLN-N-971

Boxes that are purchased may be touched up if paint is nicked using the above requirements.

3.3.3 Seismic Mounting

Surface-mounted conduit boxes located in seismic Category I structures shall be seismically mounted. Where the mounting surface is poured concrete, boxes shall be attached to embedded steel plates or mounted to the concrete with bolt anchors as shown on equipment seismic support design drawings. Seismic mounting of flush or surface boxes to masonry walls shall be in accordance with specific design details.

3.0 INSTALLATION (Continued)

3.3.4 Identification Marking

Junction boxes and/or pull boxes shall be labeled in accordance with the applicable design drawings with the applicable color scheme defined for the respective nuclear plant (see applicable Electrical Design Standard DS-E1.2.1 or DS-E1.2.2). For those not shown on design drawings, the size lettering shall be determined by construction, modifications, or maintenance, depending on the box size. The use of self-sticking mylar markers (e.g., AMP Special Industries or LEM Products, Incorporated), self-adhesive polyester markers (e.g., W. H. Brady Company), or equivalent, is a suitable means for box identification markings.

For future work at Bellefonte only beginning after 07/01/93 Junction boxes and/or fabricated pull boxes as shown on design drawings shall be labeled in accordance with the Design Standard drawing DS-E1.2.2. Fittings (i.e. TEE's & X's) that are shown on design drawings and are utilized as pull boxes shall be considered an extension of the conduit system and identified in accordance with Electrical Standard drawing SD-E15.3.4. Box identification shall be as shown on design drawings.

3.3.5 Internal Protection Against Rust and Corrosion

In most instances, boxes are installed well in advance of actual cable terminations. Many boxes or panels may also have electrical components installed therein. To provide protection against rust or corrosion until the cables are terminated and the installation completed, one of the following methods may be used. For the first and second methods, the applicable portions of the TVAN Safety and Health Manual shall be observed during the applications of coating and subsequent preparation of terminal blocks for permanent cable connections. Section 3.3.5 Item C is the preferred method.

A. Use of CRC No. 2-26 for 1-2 year storage period. Before terminating cables, clean terminal blocks by brushing (using linseed oil if necessary) and then burnishing.

B. Use of CRC Lectra Shield coating on terminal blocks for 2-5 year storage (or even for 1-5 year storage). Use Exxon's Stoddard Solvent No. 627, or an equivalent, to remove the coating from terminal blocks and then burnish them before making final electrical connections.

3.0 INSTALLATION (Continued)

3.3.5 (Continued)

C. Use of Zerust vapor capsules or Cortec VCI-160 tape. Inspection and/or replacement shall be in accordance with manufacturer's specifications.

3.3.6 On a case-by-case basis, with prior Nuclear Engineering approval on the Work Instruction Document, weep holes up to 1/4" in diameter may be drilled in the low points of non-safety junction/pull boxes, as required, to prevent water accumulation.

3.4 Cable Trays

3.4.1 Cable trays and accessories shall be installed in accordance with design drawings and engineering approved instructions.

3.4.2 Tray segments, fittings, connectors and hold down clips should be aligned before fasteners are installed. Bolt holes shall not be enlarged unless approved by engineering.

3.4.3 Bolted fasteners shall be torqued in accordance with design approved documents. Bolts through a tray side rail shall be drawn up flush with the tray siderail's interior surface with the bolt head inside the tray and the lockwasher (if required) and nut outside. Rivets shall be installed in accordance with engineering output documents.

3.4.4 Vendor supplied hex head bolts may be substituted when too short to pass through multiple thicknesses of tray side rails and connector fittings. Bolt substitution shall be in accordance with the following:

- Minimum ASTM A307
- Same diameter as the vendor-supplied bolt
- Free of sharp edges or burrs
- Of sufficient length to ensure adequate thread engagement

3.0 INSTALLATION (Continued)

3.4.5 Sharp edges shall be avoided at splice-connector joints, expansion joints, dividers and tray cover cutouts. Tray dropouts shall be installed where cables exit downward, at tray end points or through the tray bottom. Cables resting on divider edges end plate edges and exiting tray covers shall have chafe protection provided by applying a 6" + or - 1/2" length of Hypalon cable jacket material (PXJ, PXMJ or EPSJ) which has been slit to allow it to fit around the cable(s)/cable tray hardware (e.g. siderails, rungs, end plates, etc.), or the cover opening or divider shall be lined with rubber or weather resistant polyethylene grommeting material. The width shall be sufficient to insure protection of the cable surface and the edge. The jacket covering material shall be fastened to the cable/cable tray hardware by use of nylon or tefzel tie wraps which meet the requirements of G-38 Sections 2.2.8.1 and 2.2.8.2 (Reference G-38 Section 3.2.1.8 Item B for other requirements on placing cables in trays). The requirements of this paragraph are not intended to replace requirements for vertical cable support contained in G-38 Section 3.2.1.8.6.

3.4.6 Provisions for attaching vertical cable supports (such as Kellums grips) to seismic structures such as walls, ceilings, etc., other than the cable tray itself shall be provided at the time of tray installation. This may be a structural steel support mounted on a wall or floor or to the tray support structure as specified by design output documentation. To identify when this is required see G-38 section 2.2.8.1 and 2.2.8.2.

3.4.7 Cut edges of trays shall be smooth and clean. The cut surface shall be coated with zinc-rich paint immediately after the cut. Bent or dented trays or fittings shall not be installed without approval by engineering.

3.0 INSTALLATION (Continued)

3.4.7 The tray system shall be electrically continuous and grounded in accordance with design drawing details and General Engineering Specification G-47.

3.4.8 Outside trays of vertical stacks penetrating any floor or platform shall have covers extending 6 feet above the floor or platform to provide physical protection of the enclosed cable unless design drawings dictate otherwise. Additional tray covers shall be installed in accordance with design drawings.

3.4.9 At expansion joints, tray shall be installed in accordance with dimensions, edge details, cable support distances, and special fitting details shown on design drawings.

3.4.10 Vertical spacing between cable trays within the same tier or stack shall be 12 inches bottom-to-bottom of trays unless otherwise specified on design drawings.

3.5 Manholes and Handholes

3.5.1 Manholes and handholes shall be constructed in accordance with approved engineering output documents. Precast manholes shall be free of damage and installed according to engineering-approved instructions.

3.5.2 Concrete inserts for cable rack or tray supports shall be installed on manhole and handhole walls in accordance with design drawings. Cable supports shall be installed as designated on design drawings.

3.5.3 Manhole and handhole excavation, backfill and concrete materials shall be in accordance with design output documents.

3.5.4 End bells shall be used to terminate nonmetallic conduits inside manholes. All metallic conduit shall be terminated with appropriate insulated grounding bushings or chase nipples.

3.5.5 All exposed metallic parts within the manhole/handhole, including conduit bushings shall be grounded to an internal loop and connected to the ground grid in accordance with General Engineering Specification G-47.

3.5.6 Any space remaining where ductbanks do not fully occupy the space for the conduits at the wall shall be sealed with concrete grout.

3.0 INSTALLATION (Continued)

3.5.7 Manholes and handholes shall be maintained free of standing water to the extent practical. Provisions (i.e., sump pumps or drains) shall be made to remove standing water. Standing water as a result of low areas, uneven surfaces or surfaces designed to drain to other sumps, or surfaces designed for minimal water levels (i.e., handholes or french drains) is acceptable as long as the water level in the manholes and handholes containing safety related cables is below all cables and electrical devices. Also see section 3.2.1.1.

3.5.8 Manholes and handholes shall be identified as shown on design output documents.

3.6 Cable Trenches and Underfloor Ducts

3.6.1 Underfloor duct systems and cable trenches shall be free of damage and installed in sizes and locations as shown on design drawings and in accordance with engineering-approved instructions.

3.6.2 Excavation, backfill and concrete materials shall be in accordance with design output documents.

3.6.3 Underfloor duct systems and cable trenches shall be identified as shown on design output documents.

3.7 Electric Conductor Seal Assemblies (ECSAs)

3.7.1 ECSAs for conduit shall be installed at instruments and at end devices as specified on design drawings.

3.7.2 ECSAs shall be free of damage and installed and terminated in accordance with engineering-approved instructions and supported in accordance with design drawings.

3.7.3 ECSAs shall be identified as shown on design output documents.

3.0 INSTALLATION (Continued)

3.8 Containment Electrical Penetrations

3.8.1 Containment electrical penetrations shall be free of damage and installed in accordance with design drawings and engineering-approved instructions.

3.8.2 Cables at containment electrical penetrations shall be terminated in accordance with General Engineering Specification G-38.

3.8.3 Fit-up, welding, verification and testing of penetration connection to containment vessel shall be done in accordance with ASME B&PV, Division 1, Section III, Subsection NE for Class MC components.

3.8.4 Containment electrical penetrations shall be identified in accordance with design output documents.

3.9 Lighting System

3.9.1 Installation of the lighting system, including lighting transformers, lighting panels, fixtures, switches, contactors, eight-hour battery packs, unscheduled lighting conduits, branch circuits and associated supports, shall be performed in accordance with design drawings.

3.9.2 Fixture assemblies shall be installed with all lamps and appurtenances (i.e., starters/ballasts, individual lighting transformers, and fixture wiring). Bent, dented or broken fixtures shall not be installed without engineering approval.

3.9.3 Lighting fixtures in Seismic Category I (Class I at BFN) areas shall be mounted/secured as shown on design output documents.

3.9.4 Lighting cable and terminations shall be installed in accordance with General Engineering Specification G-38.

3.9.5 Components (i.e., boxes) which make up the lighting system shall be grounded in accordance with this specification.

3.9.6 Lighting conduits, fixtures and components shall be identified as shown on the drawings.

3.0 INSTALLATION (Continued)

3.10 Communication System

3.10.1 Installation of the communication systems, including low-level intraplant paging and communications, telephone, sound-powered phone jacks, radio communications, alarm equipment, fire/emergency communications, unscheduled conduits and support systems shall be located and installed in accordance with design drawings and engineering-approved instructions.

3.10.2 Communication system equipment in seismic Category I areas shall be mounted/secured in accordance with design output documents.

3.10.3 Communication cable and terminations shall be installed in accordance with General Engineering Specification G-38.

3.10.4 Conduits and components (i.e., boxes) which make up the communications system shall be grounded in accordance with this specification.

3.10.5 Communication fixtures and components shall be identified as shown on the drawings.

3.11 Security System

Security system hardware and components of an electrical nature shall be installed in accordance with design drawings and engineering-approved instructions. Wiring shall be in accordance with design drawings and General Engineering Specification G-38.

3.12 Marking and Identification

3.12.1 Exposed Class 1E and associated circuit raceway systems shall be permanently marked in accordance with Electrical Standard Drawing SD-E15.3.3 or SD-E15.3.4 at end points and should be marked at points of entry and exit from enclosed areas.

3.12.2 Cable tray marking shall normally be done when the cable tray installations are completed and before cable installation. The cable tray identification markings shall be as defined on the respective engineering project cable tray drawings.

3.0 INSTALLATION (Continued)

3.12.3 Beginning with Watts Bar Nuclear Plant and subsequent nuclear plants, the respective voltage level markers shall be located on at least one exterior side surface of cable trays designated for Class 1E circuits (train or channel) at intervals not to exceed 15 feet and at points of entry to and exit from enclosed areas.

3.12.4 Each cable tray system (by voltage level) shall be identified with node numbers (for computer routing of cables) at intermediate points as shown on design drawings (cable tray node diagrams). These markers shall conform with the color code scheme defined for each respective nuclear plant (see Table A, B, or C on Electrical Standard Drawing SD-E15.3.4). Markers for trays designated for nondivisional cables shall be white background with black lettering. The markers shall be of the self-sticking Mylar type or self-adhesive polyester type (Brady's B-361 or Electrotag's T-1002-R) installed per manufacturer's instructions.

3.12.5 All exposed non-Class 1E raceway systems except lighting systems shall be permanently and distinctively marked to identify the system as non-Class 1E in accordance with SD-E15.3.3 or SD-E15.3.4.

3.12.6 Boxes, ECSAs and containment electrical penetrations shall be identified in accordance with engineering approved output documents.

3.12.7 All conduit at the faces of manholes and handholes shall have permanent identification tags or markers in accordance with Section 3.2.1.7.

3.12.8 Manholes and handholes shall be permanently identified in accordance with design drawings.

3.12.9 Lighting, communications equipment and security equipment shall be tagged or marked where required by design drawings.

3.12.10 When cables are directly buried, a 4" wide (minimum) red warning tape (Seton Identification Products or equal) shall be placed approximately 6" above the cables to alert personnel to their presence. [SRN 79]

3.12.11 When conduits are directly buried (with or without a protective concrete cap) a 4" wide (minimum) red warning tape (Seton Identification Products or equal) shall be placed approximately 6" above the conduits (or protective concrete cap) to alert personnel to their presence. Where a group of conduits is so routed and its width exceeds twice that of the tape, additional tapes shall be placed on 12"-18" centers. [SRN 79]

3.12.12 Duct banks shall be overlaid with a 4" wide (minimum) red warning tape (Seton Identification Products or equal) shall be placed approximately 6" above the top of the concrete to alert personnel to its presence. Where the width of the duct bank exceeds twice that of the tape, additional tapes shall be placed on 12"-18" centers. [SRN 79]

3.0 INSTALLATION (Continued)

3.13 Tolerances

Horizontal and vertical spacing between trays and conduit of different divisions of separation shall be maintained as shown on design drawings within tolerances of minus 0 inch for horizontal spacing, and minus 0 inch for vertical.

3.13.1 Cable tray installation tolerances shall be in accordance with design drawings or engineering approved instructions. For installation tolerances not covered by design drawings or instructions, use:

A. Horizontal locations shall be ±2 inches of specified dimensions in both lateral and longitudinal directions, except as noted above.

B. Vertical locations shall be ±1/2-inch of specified dimensions except as noted above.

3.13.2 Embedded conduit terminations shall be located within 1/2-diameter of the conduit or 1-inch, whichever is greater unless greater accuracy is required to avoid interference, to allow spacing and clearance for fittings, or to permit insertion into terminating devices.

3.13.3 The maximum variance for elevations of ductbanks at manhole faces shall not exceed +6 inches to -1 inch. Also see section 3.2.1.1.

3.13.4 On pre-engineered designs, the conduit and box location tolerance shall be ± 6 inches. For field-routed and located equipment, tolerance limits are not applicable.

3.0 INSTALLATION (Continued)

3.13.5 Lighting fixtures shall be located in accordance with the following:

A. Lighting fixtures, except for emergency and standby lighting units, may be relocated up to ± 12 inches of design location as long as no unlighted areas are created.

B. Standby and emergency lighting unit locations may be adjusted as long as all areas needed for operation of safe shutdown equipment and access and egress routes remain illuminated.

C. Fixtures in grid systems or suspended ceilings shall be installed as located on design drawings with tolerances to accommodate grid location.

4.0 VERIFICATION REQUIREMENTS

This paragraph shall define the activities and physical attributes that must be verified to assure that the installed or restored condition conforms to design requirements. These requirements apply to new installation and modifications. For maintenance activities, only those attributes being affected by the activity are applicable. The context of "verification" as used in this paragraph does not define a specific organization's responsibility.

4.1 Conduit

4.1.1 Verify that conduit is of the correct type and size. (Section 3.1.1)

4.1.2 Verify that conduit utilizes acceptable fittings/hardware and that all couplings/fittings are wrench tight (i.e., cannot be loosened by hand). (Sections 3.2.1.4, 3.2.1.10, 3.2.2.8 and 3.2.4.1 Item K)

4.1.3 Verify that conduit (routing dimensioned on drawings) is installed in accordance with drawings. (Section 3.1.1)

4.1.4 Verify that conduit terminates at correct equipment/devices and correctly utilizes any designated routing such as embedded sleeves, penetrations, etc. (Section 3.1.1)

4.1.5 Verify by visual examination that conduit and fittings are not damaged. (Section 3.1.1)

4.0 VERIFICATION REQUIREMENTS (Continued)

4.1.6 Verify that conduit is correctly identified.

4.1.7 Verify that provisions for cable supports in vertical conduit are installed where required. (Section 3.2.1.5)

4.1.8 Verify the use of thread compounds and that conduit is touched up with zinc-rich paint when galvanization is damaged.

4.1.9 Verify that the number of bends between pullpoints does not exceed 360°. (Section 3.2.1.3)

4.1.10 Verify that conduit is grounded as required (grounding bushings, expansion joints jumped, flexible conduit jumped). (Section 3.2.4.1 Item A)

4.1.11 Verify that conduit is installed in accordance to design drawings to maintain required physical separations between redundant safety divisions.

4.1.12 Verify conduit attachments to end devices. (Section 3.2.2.2)

4.1.13 Verify that flexible conduit lengths meet the requirements of Section 3.2.6.

4.1.14 Verify that flexible conduit bend radius is in accordance to Table 3.2.6.3-2.

4.1.15 Verify correct span distance between supports (Section 3.2.2.2).

4.1.16 Verify proper distances from piping (Section 3.2.1.11, 3.2.1.12 and 3.2.2.7).

4.2 Embedded Conduit

4.2.1 Verify that conduit is the correct type and size. (Section 3.1.1)

4.2.2 Verify that conduit utilizes acceptable fittings/hardware and that all couplings/fittings are wrench tight such that they cannot be loosened by hand. (Sections 3.2.1.4, 3.2.1.10, 3.2.2.8 and 3.2.4.1 Item K)

4.2.3 Verify that conduit end points or points where conduit exits concrete are installed in accordance with design drawings.

4.2.4 Verify by visual examination that conduit and fittings are not damaged.

4.0 VERIFICATION REQUIREMENTS (Continued)

4.2.5 Verify correct use of thread compounds for metallic conduit and verify that conduit is touched up with zinc-rich paint when galvanized coating is damaged. (Sections 3.2.4.2 and 3.2.4.3 Item C)

4.2.6 Verify that conduit is supported and secured to avoid movement during concrete placement. (Section 3.2.3.3)

4.2.7 Verify the required spacing between adjacent conduits. (Section 3.2.3.1)

4.2.8 Verify that conduits have minimum concrete cover as specified on design drawings. (Section 3.2.3.2)

4.2.9 Verify that conduit terminations at walls, floors and ceilings are capped and that spare sleeves are sealed and capped. (Section 3.2.1.9)

4.2.10 Verify that conduit exits the concrete perpendicular to the surface (± 10 degrees). (Section 3.2.3.9)

4.2.11 Verify that bonding for continuous ground across expansion joints has been installed. (Sections 3.2.4.1 Item A and 3.2.3.8)

4.2.12 Verify that PVC joint compound is applied in accordance with PVC manufacturer recommendations. (Section 3.2.5)

4.2.13 Verify that conduit slopes towards manholes and handholes. (Section 3.2.1.1)

4.2.14 Verify that ductbank plastic spacers are adequately installed. (Section 3.2.3.5)

4.2.15 Verify conduits to be embedded are positioned correctly before concrete is placed. (Section 3.2.3.1)

4.2.16 Verify all embedded conduit bends before concrete placement. (Section 3.2.3.9)

4.2.17 Verify that conduit is properly identified after concrete placement. (Section 3.2.1.7, and 3.12.7)

4.2.18 Verify that conduits are swabbed immediately after concrete placement. (Section 3.2.3.13)

4.0 VERIFICATION REQUIREMENTS (Continued)

4.2.19 Verify that conduit caps/plugs are installed where required and that plastic or aluminum conduit plugs are not used in fire barriers. (Section 3.2.1.9)

4.3 Boxes

4.3.1 Verify that the box is type specified on drawings. (Section 3.3.1)

4.3.2 Verify that the box is of the correct size. (Section 3.3.1)

4.3.3 Verify that the box is installed in accordance with design drawings. (Section 3.3.1)

4.3.4 Verify by visual examination that the box is not damaged. (Section 3.3.1)

4.3.5 Verify that damaged paint or finish is touched up. (Section 3.3.2)

4.3.6 Verify that exposed metal parts of boxes are grounded. (Section 3.3.1.4)

4.3.7 Verify that embedded boxes are attached to the forms before concrete is placed. (Section 3.3.1.1)

4.3.8 Verify boxes are labeled properly. (Section 3.3.4)

4.3.9 Verify that weepholes are provided where required. (Section 3.3.1)

4.0 VERIFICATION REQUIREMENTS (Continued)

4.4 Cable Tray

4.4.1 Verify that all cable trays are located, installed and identified in accordance with design output documents and applicable site procedures. (Section 3.4.1)

4.4.2 Verify that cable tray identification is in accordance with the following:

4.4.2.1 Browns Ferry:

A. Drywell trays

Self-sticking mylar markers (e.g., LEM Products, Inc.) shall be used to identify tray designations. Letter sizes and background color are the same as those described in Section 4.4.2 Item B.

B. Trays outside primary containment

1. Nondivisional trays are identified by a white rectangle 3-1/2 inches high by 12 inches long painted on the side of the tray. The tray designation is painted on the white background in black, block letters 3 inches high.

2. Trays used for ESS cables are identified by a yellow rectangle 3-1/2 inches high, with lengths required, painted on the side of the tray. The tray designation is painted on the yellow background in black, block letters 3 inches high, followed by ES-I or ES-II in black, block letters 2 inches high.

Painting material shall be in accordance with General Engineering Specification G-14.

4.4.2.2 Sequoyah, Watts Bar and Bellefonte:

In accordance with design output documents.

4.0 VERIFICATION REQUIREMENTS (Continued)

4.4.3 Verify that cable tray components are in good condition, free from handling or installation damage, and without burrs or protrusions caused by field cutting. (Section 3.4.6)

4.4.4 Verify that cut edges and other bare metal tray surfaces are coated, and all damaged protective coatings repaired in accordance with General Engineering Specification G-14 and applicable site procedures. (Section 3.4.6)

4.4.5 Verify that all cable tray covers are installed when required as shown on design output documents with the fasteners attaching covers to tray properly torqued or secured in accordance with design output documents. (Section 3.4.8)

4.4.6 Verify that cable trays are grounded in accordance with design output documents and General Engineering Specification G-47. (Section 3.4.7)

4.4.7 In accordance with design output documents, and applicable site procedures, verify that tray fasteners: (Section 3.4.4)

A. Are the proper size and type

B. Have the proper thread engagement (minimum thread engagement shall be the thickness of one nominal bolt diameter).

C. Have lockwashers, where applicable, properly installed and visibly seated.

D. Have spline bolt heads, where applicable, properly installed and visibly seated.

E. Have proper torque where applicable

F. Have protrusions oriented toward the outside of the tray.

4.0 VERIFICATION REQUIREMENTS (Continued)

4.5 Manholes, Handholes, Trenches, and Underfloor Ducts

4.5.1 Verify that manholes, handholes, trenches, and underfloor ducts are of the correct types as specified by design drawings. (Section 3.5.1)

4.5.2 Verify that manholes, handholes, trenches, and underfloor ducts are installed in accordance with design drawings. (Section 3.5.1)

4.5.3 Verify by visual examination that manholes, handholes, trenches, and underfloor ducts are not damaged. (Sections 3.5.1 and 3.6.1)

4.5.4 Verify that manholes, handholes, trenches, and underfloor ducts are identified and marked. (Sections 3.5.8 and 3.6.3)

4.5.5 Verify that end bells for nonmetallic conduit are installed in manholes and handholes where required. (Section 3.5.4)

4.5.7 Verify that metallic conduit ends in manholes and handholes are terminated with appropriate insulated grounding bushings or chase nipples. (Section 3.5.4)

4.5.8 Verify ductbank entry into manholes and handholes for complete sealing. (Section 3.5.6)

4.5.9 Verify that grounding is installed in accordance with design drawings. (Section 3.5.5)

4.5.10 Periodically verify that manholes and handholes containing safety related cables are free of standing water as defined in Section 3.5.7. (Section 3.5.7)

4.0 VERIFICATION REQUIREMENTS (Continued)

4.6 Electric Conductor Seal Assemblies (ECSAs)

4.6.1 Verify that each ECSA is the correct type as specified on design drawings. (Section 3.7.1)

4.6.2 Verify that ECSA is installed in accordance with design drawings, engineering-approved instructions, and site procedures. Verify that ECSA terminates at the correct equipment. (Section 3.7.2)

4.6.3 Verify by visual examination that ECSAs are not damaged. (Section 3.7.2)

4.6.4 Verify that ECSA is properly identified. (Section 3.7.3)

4.7 Containment Electrical Penetrations

4.7.1 Verify that each containment electrical penetration is the correct type as specified and located on drawings. (Section 3.8.1)

4.7.2 Verify that containment electrical penetrations are properly installed in accordance with design drawings and engineering-approved instructions. (Section 3.8.1)

4.7.3 Verify by visual examination that containment electrical penetrations are not damaged. (Section 3.8.1)

4.7.4 Review containment test records to ensure that all tests were performed and recorded for plant records. (Section 3.8.3)

4.7.5 Verify that containment electrical penetrations are identified correctly. (Section 3.8.4)

4.0 VERIFICATION REQUIREMENTS (Continued)

4.8 Lighting System

4.8.1 Verify lighting system installation to ensure that components are as specified on the design drawings. (Section 3.9.1)

4.8.2 Verify that lighting system components are installed in accordance with design drawings and that any specified lighting levels are achieved. (Sections 3.9.1, 3.9.2 and 3.9.6)

4.8.3 Verify that lighting system components are not damaged. (Section 3.9.2)

4.8.4 Verify that components are identified as required by design drawings. (Section 3.9.6)

4.9 Communication and Security Systems

4.9.1 Verify that components are as specified on design drawings. (Section 3.10.1)

4.9.2 Verify that components are installed in accordance with design drawings. (Sections 3.10.1 and 3.10.2)

4.9.3 Verify that components are not damaged. (Section 3.10.1)

4.9.4 Verify that components are identified as required by design drawings. (Section 3.10.5)

4.9.5 Watts Bar Nuclear Plant

Verify that the essential Appendix R Fire Safety Shut Down (FSSD) conduits are installed within the boundaries identified on the Appendix R separation sketches and instructions provided in the DCN or ECN-Mod package. Verification is not required for DCNs/ECN-Mod packages which do not include Appendix R separation sketches or instructions.

5.0 TESTING/ACCEPTANCE REQUIREMENTS

Testing and acceptance criteria are delineated below. Site procedures shall provide detailed implementing instructions including documentation methods and forms. Tests specified in this section are installation acceptance tests unless otherwise stated.

5.1 General

Tests and checks shall be made in accordance with engineering-approved test equipment instructions or engineering instructions.

5.2 Containment Electrical Penetrations

5.2.1 Gas leak-rate test shall be performed on each electrical penetration assembly, including the aperture seal(s). The test shall be performed with the equivalent leak-rate of dry nitrogen at design pressure and at ambient temperature. The total leak-rate shall not exceed a value equivalent to $(1)10^{-2}$ std cm^3/s of dry nitrogen or less as specified by engineering-approved instructions.

NOTE: When the method of penetration attachment is by welding, the aperture seals (the welds) should be tested as part of the containment integrated leak-rate test (ILRT).

5.2.2 Electrical Tests

After the penetration assembly is installed, each conductor shall be tested in accordance with the following:

5.2.2.1 Cables shall be tested for continuity and insulation resistance tested at 500V dc. Medium-voltage power cables shall have a minimum resistance of 100 megohm between conductors and between conductor and ground. Other cables shall have a minimum resistance of 10 megohm.

5.2.2.2 High-voltage dielectric strength tests shall not be performed on penetration cables unless directed by engineering.

5.0 TESTING/ACCEPTANCE REQUIREMENTS (Continued)

5.2.2 (Continued)

5.2.2.3 The preceding electrical tests may be performed before or after external (field) cables are connected to the penetration assembly. In either case, the lesser of allowable test voltages for external cables or penetration cables shall be utilized. (External field cables shall be tested in accordance with General Engineering Specification G-38).

5.3 Electric Conductor Seal Assemblies

Electric conductor seal assemblies with integral cables and requiring in-line splices shall be tested prior to termination for continuity and insulation resistance in accordance with manufacturer's instructions. In the absence of manufacturer's instructions, testing shall be in accordance with General Engineering Specification G-38. After termination, no special testing of electric conductor seal assemblies is required. This section does not preclude or eliminate the requirement for the performance of post-pulling tests on the external cable.

5.4 Lighting System

5.4.1 Cable shall be installed and tested in accordance with General Engineering Specification G-38.

5.4.2 Fixtures and lamps shall be functionally tested.

5.4.3 Areas designated for preoperational testing shall be tested for adequate illumination in accordance with test instructions.

6.0 REFERENCES

6.1 **General**

6.1.1 TVAN Standard Drawings, Design Standards, Design Guides and General Engineering Specifications listed in section 1.2.1

6.1.2 ANSI N45.2.4-1972, *Installation, Inspection, and Testing Requirements for Instrumentation and Electric Equipment During the Construction of Nuclear Power Generating Stations* - Section 4, first paragraph, second sentence to end of section.

6.1.3 TVAN Standard Specification, SS-E21.000, *Rigid Aluminum Conduit*

6.1.4 TVAN Standard Specification, SS-E21.001, *Rigid Steel Conduit (Zinc Coated)*

6.1.5 TVAN Standard Specification, SS-E21.002, *Fittings for Conduit and Outlet Boxes*

6.1.6 General Engineering Specification G-38, *Installation; Modification and Maintenance of Insulated Cables Rated Up to 15,000 Volts*

6.1.7 NEDP-10, *Design Output*

6.1.8 UL 360, *UL Standard for Safety Liquid-Tight Flexible Steel Conduit*

6.1.9 Calculation CD-Q0999-000001 (previously CEB-CQS-449, B41 940620 001), *G-40 Bend Radii for American Boa Flexible Conduit*

6.1.10 UL 514B, *UL Standard for Safety Fittings for Conduit and Outlet Boxes*

6.1.11 General Engineering Specification G-47, *Installation, Modification and Maintenance of Electrical Grounding Systems and Lightning Protection Systems*

6.1.12 General Engineering Specification G-29, *Welding, Materials and Nondestructive Examination*

6.1.13 General Engineering Specification G-34, *Requirements for Repair of Concrete During Construction, Modifications and Maintenance*

6.1.14 General Engineering Specification G-55, *Technical and Programmatic Requirements for the Protective Coating Program for TVA Nuclear Plants*

6.1.15 General Engineering Specification G-14, *Selecting, Specifying, Applying and Inspecting Paint and Coatings*

6.1.16 Code of Federal Regulations, 10CFR50 Appendix R

6.1.17 Code of Federal Regulations, 10CFR50.49

6.1.18 NFPA 70, *National Electric Code*

6.1.19 *TVAN Safety and Health Manual*

6.1.20 ASTM A307, *Standard Specification for Carbon Steels Bolts and Studs, 60,000 psi Tensile Strength*

6.1.21 ASME B&PV, Division 1, Section III, Subsection NE, *Rules for Construction of Nuclear Power Plant Components, Class MC Components, Non-Interfiled*

6.2 **Browns Ferry**

6.2.1 No. G-3, *Construction Specification for Browns Ferry Nuclear Plant and all Future Nuclear Plants* (withdrawn, included as historical reference only)

6.2.2 Drawing 0-45B891-1, *Conduit and Grounding, Details of Electrical Equipment Waterproofing and Sealing.*

6.2.3 N1A-930, BFNP-N-955, BFN Project Engineering Specification, *Special Protective Coating Systems Approved for Use in Coating Service Levels I and II and Corrosive Environments*

6.3 **Sequoyah**

6.3.1 N2E-860, *Sequoyah Nuclear Plant Project Construction Specification.* (withdrawn, included as historical reference only)

6.3.2 SQN Project Engineering Specification, N2A-931, SNP-N-971, *Special Protective Coating Systems Approved for Use in Coating Service Levels I and II and Corrosive Environments*

6.4 **Watts Bar**

6.4.1 WBN-OSG4-139, *Walkdown of Electrical Raceways within Close Proximity to Hot Pipes, Data Tabulation and Violation Evaluation.*

6.4.2 WBN-OSG4-221, *Class 1E Electrical Cable Hot Pipe Requirements for Special Cases*

6.4.3 WBN-OSG4-138, *Class 1E Electrical Cable Hot Pipe Clearance Requirements*

6.4.4 WBN-OSG4-170, *Mechanical Systems Operating at 135F or Greater*

6.4.5 Watts Bar Nuclear Plant Engineering Specification, N3C-944, *Conduit and Conduit Support Installations*

6.4.6 Watts Bar Nuclear Plant Engineering Specification, N3C-941, *Commodity Clearance Requirements*

6.4.7 Environmental Data Drawings 47E235 series, *Environmental Data, Environment - Mild and Harsh*

6.4.8 QIR MNMWBN93007 RO (T31 930408 986), *Separation Requirements for Non-Power Cables in Proximity to Hot Pipes for Incorporation Into G-40*

6.4.9 ASTM A780, *Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings*

6.4.10 45W883, Sheet 6, *Conduit and Grounding, Penetration Sealing and Fire Stop Details*

6.4.11 WBN Project Engineering Specification. N3A-932. WBNP- N-9711. *Special Protective Coating Systems Approved for Use in Coating Service Levels I and II and Corrosive Environments*

6.5 **Bellefonte**

6.5.1 BLN Project Engineering Specification, N4A-933, BLN-N-971, *Special Protective Coating Systems Approved for Use in Coating Service Levels I and II and Corrosive Environments.*

APPENDIX J

SOURCE NOTES

SOURCE NOTE NUMBERS	SOURCE NOTE TRACKING DOCUMENT	APPLICABLE SECTION
BLN-1	NCO850468001 & NCO850468002	3.2.6.1 G
WBN-1	L44851003807	3.2.1.5
WBN-2	L44860128806, MSC-00991, NCO920042754, MC851220804001	3.2.1.3
WBN-3	L44860819807, WBRD 50-390/86-27, NCO860099003, WBRD 50-391/86-23, MSC-03978, NCO890048003	3.2.6.1.A, 3.2.6.2, 3.2.6.3
WBN-4	L44900305802, NCO900020006, WBP890421	3.2.2.9
WBN-5	L44901011801, NRC CDR 390/90-03, WBP900264SCA, NCO880283004	3.2.1.15.A
WBN-6	L44900615802, NCO900002020, WBP900256PER	3.2.1.4.B
WBN-7	WBSCA930163	2.3.8.3.C
WBN-8	NCO880283056	3.2.1.15.A
WBN-9	L44870316805	3.2.2.2
WBN-10	SCRWBNEEB8548 R2	2.3.8.1
WBN-11	MSC-03979, NCO890048004, L44890215801, Watts Bar Electrical Issues CAP	3.2.6.1.F
WBN-12	MSC-03980, NCO890048005, L44890215801, Watts Bar Electrical Issues CAP	3.2.6.1.F