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U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Gentlemen:

In the Matter of	)	Docket Nos. 50-259
Tennessee Valley Authority	)	50-260
	)	50-296

BROWNS FERRY NUCLEAR PLANT (BFN) - RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING MEDIUM VOLTAGE CABLE BEND RADIUS (TAC NOS. M86253, M86254, and M86255)

The purpose of this letter is to respond to NRC's "Request for Additional Information Regarding Medium Voltage Cable Bend Radius Browns Ferry Units 1, 2, and 3 (TAC Nos. M86253, M86254, and M86255)" dated August 23, 1993. Additionally, this letter responds to clarifications of the requested information and provides supplemental information requested by NRC staff personnel during a September 28,1993, telephone call. The enclosure to this letter provides TVA's response.

If you have any questions, please telephone me at (205)729-2636.

Sincerely,

Pedro Salas
Manager of Site Licensing

Enclosure
cc: See page 2

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1/1

JAN 10 1994

Enclosure
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Enclosure

Tennessee Valley Authority
Browns Ferry Nuclear Plant (BFN)
BFN Units 1, 2, and 3

Response to Request for Additional
Information Regarding Medium
Voltage Cable Bend Radius
(TAC NOS. M86253, M86254, and M86255)

PURPOSE AND BACKGROUND

This Enclosure provides TVA's reply to NRC's August 23, 1993, request for additional information (RAI) regarding changes to the corrective actions proposed by TVA to resolve medium voltage cable bend radius issues. TVA's bend radius corrective action program was developed to ensure that improper bends in safety-related electrical cables do not affect safe plant operations. The corrective actions for BFN Unit 2 for the bend radius program are described in Reference 1. The NRC reviewed these corrective actions and issued a Safety Evaluation Report on them in Reference 2. A similar plan was issued for Units 1 and 3. Reference 3 contains the plan for BFN Units 1 and 3 and Reference 4 contains a Safety Evaluation Report of the plans for Units 1 and 3. The action plans classified cables according to bend radius ratio (the ratio of bend radius to cable diameter).

TVA subsequently determined that some of the corrective actions should be modified. Based on these changes TVA submitted a letter dated March 17, 1993 to NRC describing the corrective action changes and the basis for making the changes. Additionally, TVA requested NRC to approve the corrective action changes by issuing a supplement to Reference 2, section 3.11.5. TVA also requested a supplement to Reference 4 for Units 1 and 3 to accept the revised cable testing plan.

By letter dated August 23, 1993, NRC requested additional information regarding TVA's proposed changes. On September 28, 1993, TVA held a teleconference with NRC to discuss the RAI. During the teleconference, further clarifications and information items were requested by NRC. The following is TVA's reply to the NRC's request. Included in each item where appropriate is a brief description of TVA's understanding of the supplemental information requested in the September 28, 1993, teleconference. A restatement of the NRC's RAI and supplemental requested items is followed by TVA's reply.

NRC Information Request Item 1

Replacement of Group 1 cables ES2550-II, ES75-I, ES88-I, and ES113-I was planned based upon the original BFN Unit 2 walkdowns. TVA claims subsequent constructability walkdowns found that these cables do not require replacement because the original walkdown data was incorrect. The NRC staff requests the following information for these cables:

NRC Information Request Item 1.a

Provide the number of bends involved and the remeasured bend radius values for these cables.

NRC Supplemental Request

Provide the total number of bends for each cable in Item 1 and expand the cable bend sample to determine if the original walkdown was on the proper cables.

TVA Response

There were 57 bends associated with cables ES2550-II, ES75-I, ES88-I, and ES113-I. The total number of bends for each cable is shown on the table below. During the original walkdowns, all 57 bends were evaluated. Subsequently, ten of the bends were selected for re-walkdown, either during the constructability phase or during random sampling walkdowns. Additionally, ten bends were walked down as a result of the NRC staff's request on September 28, 1993. The cable bends walked down as a result of NRC's request are denoted with an asterisk in the table. The remaining thirty-seven bends are inaccessible due to operational concerns (e.g., bends in the area of critical equipment for Unit 2 operation, ALARA) or are enclosed by Appendix R firewrap. A comparison of the bend radius (BR) from the original walkdown to the remeasured bend radius is also shown in the table.

CABLE NO.	TOTAL BENDS	BEND NO.		ORIGINAL BR	REMEASURED BR
ES113-I	16	PP-1	(At tray)	6.25"	10.5"
		B-1	(Pmp Sta)	3.54"	24.0"
		PP-1	(At board)	24.0"	No bend radius, Cable is straight
		*B-1	(SD BD B)	13.28"	13.28"
		*PP-2	(Pull Box)	15.69"	18.53"
		*PP-2	(Tray AY-I)	17.79"	22.1"
ES75-I	16	PP-1	(Tray AT-1)	6.77"	12.0"
		PP-2	(Tray AZ-1)	8.75"	20.0"
		*PP-2	(Pull Box)	24.4"	25.5"
ES88-I	14	PP1-1	(SD BD A)	7.06"	11.0"
		PP1-2	(SD BD A)	9.75"	14.0"
		*PP-1	(Tray AT-1)	11.47"	13.54"
		*PP-2	(Tray AZ-1)	19.94"	26.5"
ES2550-II	11	B-3	(El. 519)	4.05"	14.0"
		PP-1	(Tray AQ-II)	11.37"	11.37"
		B-2	(El. 565)	13.59"	14.8"
		*B-1	(El. 565)	13.89"	17.25"
		*B-4	(El. 519)	16.06"	18.5"
		*B-5	(El. 519)	13.26"	17.13"
		*PP-2	(Pull Box)	24"+	No bend radius, cable is straight

The followup walkdown was performed utilizing a sketch from the original walkdown delineating the bend locations. TVA's walkdown results indicate that the original walkdowns by Ebasco Services Inc. (ESI) were performed on the proper cables.

NRC Information Request - Item 1.b

Provide information on how the ratio of bend radius to cable outside diameter (OD) of 2.95 for cable ES113-I and 3.37 for ES2550-II per the original walkdown were remeasured to over six times the cable OD. Were the four cables retrained after the original walkdown?

TVA Response

The bend radius of 3.54 inches (2.95 ratio) for cable ES113-I occurred at conduit bend "B1" beneath a Residual Heat Removal Service Water (RHRSW) pump below the floor slab in the pumping station. The original walkdown data contains a sketch of this bend. The sketch indicates a 90 degree bend in conduit ES113-I. This conduit is a three inch rigid aluminum conduit. Subsequent walkdowns revealed a sweeping conduit configuration with an approximate 45 degree bend. The actual conduit configuration has a bend radius of 24.0 inches. Apparently, incorrect data were taken or errors in transcribing data occurred during the original walkdowns.

The cable ES2550-II bend radius value for bend "B3" was correctly recorded on the original walkdown sheets. However, the bend radius value for bend "B3" was incorrectly transcribed when the data were compiled. The correct value should have been the 14.05 inch bend radius, not the 4.05 inch bend radius (3.37 ratio) that was incorrectly recorded. The transcription error resulted from the grid paper that was used to perform the calculations. The number "1" aligned with the grid lines on the paper, and the bend radius appeared to be 4.05 inch.

TVA has no evidence that the referenced cables have been retrained. The same methods utilized during the original walkdowns were used to remeasure cable/conduit bends during subsequent walkdowns.

NRC Information Request - Item 1.c

Are there any cable bend concerns for the cables installed in BFN Units 1 and 3? Are there any changes in the cable group classifications of BFN Units 1 and 3?

TVA Response

The cables listed in the original walkdown data and corrective action report include those required for Unit 2 and common equipment required to support Unit 2 operation. Safety-related medium voltage cables and group classifications for Units 1 and 3 are addressed by Reference 3. These cables are to be dispositioned according to the same criteria used for Unit 2 as described in Reference 3.

NRC Information Request - Item 1.d

Justify that the sampling program used to validate the original walkdown results is sufficient to give a 95 percent confidence that 95 percent of the original walkdown bend data is adequate. The staff is concerned that a change in a cable group classification could be considered as a failed sample, and that some cable configurations may have changed after the initial walkdowns. Using an acceptance criterion based on a change in group classification would substantially increase sample size

requirements, because the four reclassified cables would be considered failures. Therefore, the staff requests additional discussion and justification of the sampling acceptance criterion.

NRC Supplemental Request

Provide historical information concerning medium voltage cable bend radius issues at BFN. Include data on the 54 bends that were selected for the sampling program and compare the bend radius documented by the original walkdowns to the results of the sampling walkdown.

TVA Response

In June of 1988, TVA began an evaluation of past cable installation practices to determine if there was reasonable assurance that cable damage had not occurred during installation. TVA contracted Ebasco Services Inc. (ESI) to perform field walkdowns, collect data, and to determine bend radius areas of concern. This work was performed under ESI's approved quality assurance program. Additionally, TVA personnel reviewed the data compiled by ESI and if acceptable, used it in the cable issues program.

Based on the ESI walkdown information, TVA submitted a corrective action plan to NRC by letter dated October 4, 1990 (Reference 1) to replace certain Group 1 cables and perform testing on others to resolve medium voltage cable bend radius issues. Group 1 cables are those having the smallest bend radius ratio. The proposed action plan required replacing five Group 1 cables by the Unit 2 cycle 6 refueling outage. The NRC staff reviewed this plan and concluded that it was acceptable (Reference 2).

During March 1992, constructability walkdowns in support of the replacement plans for Group 1 cables ES113-I, ES75-I, ES88-I, and ES2550-II were performed. These walkdowns consisted of an evaluation of the existing conduits for reuse, rework, and/or locating new conduits to be used for the replacement cables. During the walkdowns, cable bends were observed that had actual bend radii larger than those recorded in the original ESI walkdown data. As a result, TVA questioned the validity of the original ESI walkdown packages.

To determine if the original walkdown data were acceptable, TVA sampled the cable bend walkdown data based on NUREG/CP-0063, "1984 Statistical Symposium on National Energy Issues." This sampling program was designed to verify that with a 95 percent confidence that 95 percent of the population is acceptable. Bends greater than or equal to the bend radii documented in the original walkdown data were considered to be acceptable. The sample plan is illustrated in Reference 5, Table 2, page 219.

Walkdowns per the sampling plan were conducted based on a random sampling plan during the Summer and Fall of 1992. Fifty-four randomly chosen bends from a population derived from the original walkdown data were walked down and remeasured. The findings were then compared to the original data documented during ESI's walkdowns. All fifty-four bend radii remeasured were found to be greater than or equal to the original recorded data. Thirty-nine bends were found to have a larger bend radius (more conservative) and fifteen were the same as documented in the original walkdowns. Attachment A shows the walkdown comparison results. All measurements taken on subsequent walkdowns were based on the location of the bend as described in the original walkdown. A comparison to the original walkdown measurements was performed after completion of subsequent walkdowns. Based on the results, ESI's bend radius walkdown data was determined to be acceptable. There was no evidence that the cable configurations changed after the original walkdown.

NRC Information Request - Item 2

Provide objectives and details of the Load Cycle and Corona testing, including, as a minimum, purpose of the test, the test procedure, test apparatus required, place of the test, test voltage and its basis, parameters measured, and acceptance criteria.

NRC Supplemental Information

Provide specific references to the applicable portions of the load cycle and corona test report or give detailed explanation of requested information above.

TVA Response

The objective of the load cycle and corona testing was to address cable bend concerns by assessing the thermal/mechanical performance of the insulation/insulation shield interface due to tight bends. The testing was performed on medium voltage cable samples of the same vintage and type as those initially installed at BFN. TVA performed this testing to determine if medium voltage 5KV cables could be maintained in a six times (6X) their overall diameter configuration without degrading the design function of the cables.

The purpose of load cycle and corona test is to qualify cable construction. The test challenges cable construction interfaces by exposing the cable to a series of load cycles where the different polymers and layers undergo heat cycling resulting in expansion and contraction of materials. The testing is used as an assessment of the integrity of the cable interface. TVA used the standard AEIC load cycle and corona test on bent rather than unbent cable.

Based upon the results of the test, TVA determined that bending a cable to six times (6X) the overall cable diameter will not cause

the cable to display different characteristics (corona discharge) than that bent within Insulated Cable Engineers Association (ICEA) limitations. The Certified Engineering Test Report (Attachment B) furnished by Cable Technology Laboratories, Inc. contains detailed information associated with load cycle and corona testing. Additionally, TVA has included a copy of "Cable Bend Radius Corona and Load Cycle Testing Scope of Work Document" which discusses the basic test requirements (Attachment C).

The load cycle and corona testing showed that the 5KV cable samples would meet the test acceptance criteria. Based on satisfactory results, TVA concluded that the testing confirmed that the cables which had previously been committed to be hi-pot tested and trended each refueling outage due to bend radius issues should only be subject to routine scheduled maintenance tests.

The test procedure and test apparatus is addressed in section 4.0 and 5.0 of Attachment B.

Cable Technology Laboratories, Inc. performed the load cycle and corona testing at their facility in New Brunswick, New Jersey in December 1992. The test voltage used is listed in Section 5.0 of Attachment B. This voltage was as specified in table E1 of Association of Edison Illuminating Company (AEIC) specification CS5-87 for qualification testing of 5KV medium voltage cable.

The parameters measured are listed in Section 5.0 of Attachment B. The acceptance criteria for load cycle and corona testing was that the cable specimen pass the minimum partial-discharge extinction level of 5KV per ICEA S-66-524.

NRC Information Request - Item 2.a

Is this test applicable to all medium voltage power cables?

<u>TVA Response</u>

The testing is applicable to all safety-related medium voltage cables within the scope of the BFN cable issues program. Non-safety related medium voltage power cables are not addressed by this testing.

NRC Information Request - Item 2.b

Will installed cables be used for this test? If not, provide justification for applying the test results to installed cables. If installed cables are not used, how are aging effects accounted for?

<u>TVA Response</u>

Samples of installed cables were not used for this test, however, the cable samples used for the corona and load cycle testing were taken from a reel of cable of the same type and vintage as that

installed during construction of BFN. This cable type was manufactured by Triangle Wire and Cable Company Incorporated. The cable used in the testing is similar to the cable used in BFN such that the test results are applicable.

The standard AEIC load cycle and corona test is used on unbent specimens to qualify the design for the life of the cables. TVA applied this same test to qualify the cables for their design life in their bent configuration.

The samples of 5KV insulated cables passed all requirements of the corona and load cycle test. The samples were bent to a radii corresponding to six times (6X) the overall cable diameter. Dissection of the samples after testing indicated that the bent cable sections were undisturbed as a result of the testing and were similar to sections of cable that were straight during the test.

This testing did not place the cable in an advanced aged condition (e.g., 20 years). There are no postulated age phenomenon that causes a disruption of the cable materials interface. A condition that may degrade the interface is thermal expansion and contraction where the polymers are not compatible. A polymer with a high rate of expansion used for insulation and one with a low rate of thermal expansion used for shielding material, under cycling, could possibly cause a disruption at the interface. The load cycle and corona test evaluated the cable bend interface integrity, and determined that the expansion and contraction rates of the material were compatible.

NRC Information Request - Item 2.c

Provide references to any applicable Institute of Electrical and Electronic Engineers (IEEE), ANSI, or other standards which recognize Load Cycle and Corona testing for detection of cable damage due to excessive bends in installed cables.

TVA Response

The load cycle and corona test prescribed in specifications AEIC CS5-87 and CS6-87 are used by cable vendors to qualify new cables in straight runs. The same specifications were utilized to test BFN cable bent to a six times overall diameter. AEIC specifications are widely recognized in the industry as one of the most stringent in the United States. The AEIC is an organization of investor owned utilities. Standards such as AEIC CS5 and CS6 are prepared by the AEIC Cable Engineering Section Subcommittee. Manufacturers and their interests are not represented on the AEIC. Many other standards bodies recognize and endorse the AEIC documents. IEEE 383, which governs environmental qualification of cables at nuclear generating stations, acknowledges that cables which meet AEIC are qualified for normal service operation.

NRC Information Request - Item 2.d

Will Load Cycle and Corona testing be applied to all Group 2 cables?

TVA Response

Yes, those with bend radii between six times (6X) and eight times (8X) their diameter. Testing is complete. Refer to Attachment B, which provides information to show the acceptability of all Group 2 cables including any that were reclassified from subsequent walkdowns.

NRC Information Request - Item 2.e

Provide details about routine cable maintenance, including any testing.

TVA Response

Routine cable maintenance and testing refers to dc high potential "withstand" tests performed periodically (usually during outages) to assess the condition of 4KV motor windings. The tests are applied to the feeder cables and motor windings simultaneously and are useful in assessing age related degradation associated with cable installation practices. This testing was described in TVA's "Cable Issues Supplemental Report Cable Testing" submitted by Reference 6.

NRC Information Request - Item 3.a

TVA stated that a Load Cycle and Corona test program has been used in the disposition of similar issues for Watts Bar. What is meant by "similar issues"?

TVA Response

The term "similar issues" was only used to refer to the test methodology used in the BFN testing was the same as that used at Watts Bar. There is no intent to base the acceptability of the BFN test results on the acceptability of the Watts Bar program.

NRC Information Request - Item 3.b

Is TVA planning to retrain BFN Group 2 cables to a radius of eight times the cable OD as at Watts Bar?

TVA Response

No. BFN cables will not be retrained since they meet the 6 times (6X) overall diameter configuration which was determined to be acceptable as described in the Load Cycle and Corona Test Report.

NRC Information Request - Item 3.c

Provide the basis and rationale for the adequacy of this test for BFN cables.

TVA Response

The load cycle and corona test was specifically for medium voltage cables used at BFN. The basis and rational for the adequacy of the testing is discussed in TVA's response to NRC Information Request Item 2 and Attachment B.

NRC Information Request - Item 4

Provide the conduit bend radii for embedded cables.

NRC Supplemental Request

Provide the Safety Evaluation Report (SER) number for previous accepted cable issue supplemental reports for embedded cables.

TVA Response

Due to the lack of pictorial representation associated with Browns Ferry's physical conduit and grounding drawings, bend information on embedded conduits cannot be determined. As stated in section 2.2, page 2, paragraph 2 in the Cable Issues Supplemental Report - Corrective Actions (Reference 1) and accepted in the NRC's SER (NUREG-1232, Vol. 3, Supp. 2) (Reference 2), TVA committed to measure conduit bend radii for exposed conduits only. The embedded runs of conduit are assumed to have standard or greater bend radii commensurate with the conduit size.

REFERENCES

1. TVA letter to NRC dated October 4, 1990, Revision to the Cable Installation Issues Supplemental Report - Cable Pullby

2. NUREG-1232 Volume 3, Supplement 2 - Safety Evaluation Report on Tennessee Valley Authority Browns Ferry Nuclear Performance Plan, January 1991

3. TVA letter to NRC dated May 10, 1991, Action Plan to Disposition Concerns Related To Unit 1 and Unit 3 Cable Installation Issues Including Cable Separation

4. NRC letter to TVA dated April 8, 1992, Safety Evaluation of TVA Plans to Resolve Electrical Cable Installation and Separation Issues for the Browns Ferry Nuclear Plant Units 1 and 3 (TAC Nos. M80681 and M80682)

5. NUREG/CP-00 63, "1984 Statistical Symposium on National Energy Issues"

6. TVA letter to NRC dated September 29, 1988, Resolution of Cable Installation Issues - Cable Testing

7. TVA letter to NRC dated March 17, 1993, Medium Voltage Cable Bend Radius Issues

8. NRC letter to TVA dated August 23, 1993, Request for Additional Information Regarding Medium Voltage Cable Bend Radius BFN Units 1, 2, and 3 (TAC NOS. M86253, M86254, and M86255)

ATTACHMENT A

THE FOLLOWING SHOWS A COMPARISON OF AS FOUND BEND RADIUS TO THE ORIGINAL BEND RADIUS ASSOCIATED WITH THE 54 BENDS SELECTED BY THE SAMPLING PROGRAM.

CABLE NO.	BEND NO.	ORIGINAL BR	AS FOUND BR
PP495-I	B3	9.06"	33.52"
PP465-IE	B8	16.06"	16.71"
PP466-IB	B15	26.19"	26.76"
PP625-I	B1	12.07"	12.07"
PP625-I	B5	16.29"	16.29"
PP466-IB	B55	15.84"	15.84"
PP466-IB	B62	19.3"	19.3"
PP454-IID	B15	16.06"	17.52"
PP454-IID	B24	16.88"	17.08"
PP462-IE	B10	16.06"	21.25"
PP465-IB	B13	26.14"	28.25"
PP465-IB	B16	144.53"	144.53"
PP465-IB	B52	17.13"	17.13"
PP469-IE	B17	20.31"	20.31"
PP469-IE	B26	13.91"	15.69"
PP493-I	B24	32.13"	32.13"
PP493-I	BBB	32.13"	32.13"
PP493-I	BBB	14.28"	27.81"
PP629-II	B3	17.83"	18.42"
PP629-II	B10	31.88"	33.3"
PP493-I	PP5	NO BEND	NO BEND
PP495-I	B6	12.68"	13.58"
PP466-IB	B28	19.88"	20.7"
PP466-IB	B21	58.11"	61.56"
PP466-IB	B37	27.7"	30.8"
PP466-IB	B38	30.8"	30.8"
ES2550-II	B2	13.59"	14.8"
ES2641-II	B1	18.54"	19.14"
PP456-IE	B3	10.25"	11.04"
PP465-IE	B65	13.36"	14.26"
PP469-IE	B8	16.06"	16.51"
PP469-IE	B9	16.06"	16.51"
3PP734-II	B2	9.25"	10.11"
PP463-IE	B21	16.06"	16.25"
PP468-IE	B2	16.06"	16.25"
PP493-II	B15	12.69"	13.32"
ES113-I	PP1	24.0"	NO BEND
PP450-IE	PP1	24.0"+	NO BEND
PP462-IE	PP7	18.0"	20.32"
PP450-IE	B2	15.76"	16.54"

ATTACHMENT A (Continued)

CABLE NO.	BEND NO.	ORIGINAL BR	AS FOUND BR
PP454-IID	PP4	10.11"	10.11"
PP462-IE	B19	16.06"	18.5"
PP463-IE	B20	16.06"	18.5"
PP466-IB	B10	22.63"	24.01"
PP466-IB	B11	20.03"	21.25"
PP493-II	B23	24.58"	28.43"
PP493-II	B29	49.33"	52.00"
PP495-I	B8	20.31"	21.52"
PP495-I	B9	13.58"	13.58"
PP466-IB	B60	29.27"	30.83"
PP637-II	B5	14.20"	14.84"
ES2550-II	PP1	11.37"	11.37"
ES2641-II	PP1	24.0"+	NO BEND
ES2641-II	B5	112.76"	112.76"

ATTACHMENT B

Certified Engineering Test Report
Bend Radius
Corona and Load Cycle Testing