TVA 22036A (DNE 9-87)

TENNESSEE VALLEY AUTHORITY
Division of Nuclear Engineering

BROWNS FERRY NUCLEAR PLANT

CABLE ISSUES SUPPLEMENTAL REPORT

CORRECTIVE ACTIONS

September 1990

Revision 3

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1.0 INTRODUCTION

In June 1988, TVA began an evaluation to determine if past practices were adequate to ensure that damage did not occur during cable installation at Browns Ferry Nuclear Plant (BFN). The Evaluation of Browns Ferry Nuclear Plant Cable Installation Concerns Summary Report, (Reference 1) was issued documenting this evaluation including conclusions and recommendations for resolution of each of the concerns. The Summary Report made recommendations for the resolution of four of the issues; Vertical Cable Supports, Cable Bend Radii, Pullbys, and Use of Condulets for Pull Points for Large 600V Cables.

This report provides an overview of the work performed to satisfy the recommendations made in the Summary Report for these issues. Details of the walkdowns and analysis are contained in the documents referenced in this report.

2.0 CABLE BEND RADIUS

2.1 Walkdown Inspection Results

The action recommended in the Summary Report, Section 5.5 (Reference 1) for closure of the bend radius issue was the performance of a walkdown and inspection of Class 1E medium voltage cables, using TVA's General Construction Specification G-38 as acceptance criteria. Cables not meeting the acceptance criteria would be technically justified or replaced.

An inspection was performed and documented in Reference 2 and the results are summarized in Table 1.

Upon evaluation of the walkdown data, it was noted that 52 of 54 class 1E cables violated the allowable bend radius requirements. Fifteen of the worst case cables were tested as described in Section 2.2.

2.2 Testing Results

To determine the acceptability of these cables, TVA proposed and the NRC concurred that High Potential (Hi-Pot) testing should verify that the cables were capable of performing their intended safety function.

The methodology for selection of the 15 worst case cables to be tested was discussed in a letter to the NRC on December 9, 1988 (Reference 3), and requires ranking them by using the following ratio.

$$\frac{\text{Actual Bend Radius}}{\text{Allowable Bend Radius}} = \text{Bend Radius Ratio}$$

2.2 Testing Results (Continued)

The bend radius ratio is then indexed from lowest to highest values. Certain categories were excluded from the test sample. These categories are identified below and the Category 1 and 2 cables excluded from the test sample are noted in the last column of Table 1.

1. Cables which were identified by other programs for replacement before U2C6 restart.

2. Cables which are in diesel generator neutral ground circuits and are not subjected to rated voltage and current on a normal operating basis.

3. Cables which are nonsafety related.

The conduit bend radii were measured for exposed conduits. Inspection of the actual bend radii conditions of cables in embedded conduit (Table 1) was not possible. These conduits are short embedded runs (less than 30 feet). The embedded runs are assumed to have standard or greater bend radii commensurate with the conduit size. Conduit configurations with standard bend radii have bend radius values well above the worst 15.

The test and acceptance criteria are in accordance with Reference 3. The worst 15 cables were Hi-Pot tested at 20,000 volts DC for a duration of 15 minutes. The voltage level was the maintenance test voltage recommended by IEEE 400-1980. The acceptance criteria for the test was a polarization index of one or greater. This test was performed following Special Electrical Maintenance Instruction SEMI-65 (Reference 4). Test results are tabulated in Table 1.

Table 1

WALKDOWN INSPECTION CLASS 1E 5kV CABLES - CABLE BEND RADIUS RESULTS

Cable Number	Bend Radius Ratio	Max. Leakage During 20 kV Hi-Pot Test	Polarization Index	Reason for Not Testing
Group 1				
ES113-I	.246	3 microamp	1	Tested
ES2550-II	.281	1 microamp	1	Tested
ES50-I *	.281	1 microamp	1	Tested
PP453-IID	.305	1 microamp	1	Tested
ES4379-IIC	.317	----------	--	Dsl Neutral Gr
ES13-I	.325	----------	--	Replaced
PP633-I	.334	----------	--	Replaced
3ES4102-IIC	.340	1 microamp	1	Tested
3ES4101-IIC	.374	1 microamp	1	Tested
ES2689-II *	.401	1 microamp	1	Tested
ES2588-II	.405	----------	--	Replaced
3ES4104-IIC	.466	----------	--	Dsl Neutral Gr
ES75-I	.470	2 microamp	1	Tested
ES2575-II	.479	----------	--	Replaced
ES88-I	.490	2 microamp	1	Tested
Group 2		----------	--	
PP493-II	.534	1 microamp	1	Tested
ES4404-IID	.514	----------	--	Dsl Neutral Gr
3ES4090-II	.590	----------	--	Replaced
3ES4080-II	.593	----------	--	Replaced
PP637-II	.613	1 microamp	1	Tested
PP625-I	.620	1 microamp	1	Tested
PP456-IE	.631	1 microamp	1	Tested
PP462-IE	.637	1 microamp	1	Tested
PP463-IE	.637	1 microamp	1	Tested
3PP734	.639	----------	--	---
PP454-IID	.663	----------	--	---
Group 3		----------	--	---
PP451-IE	.703	----------	--	---
PP457-IE	.703	----------	--	---
ES4375-IIC	.717	----------	--	---
ES141-I	.719	----------	--	Replaced
ES1900-IB	.721	----------	--	---
PP629-II	.729	----------	--	---
ES1875-IA	.749	----------	--	---
ES100-I	.781	----------	--	---
PP465-IB	.789	----------	--	---
PP466-IB	.789	----------	--	---
PP468-IE	.827	----------	--	---
PP469-IE	.827	----------	--	---
PP450-IE	.836	----------	--	---
PP497-I	.949	----------	--	---
ES189-I	.991	----------	--	Replaced
ES2513-II	1.58	----------	--	---
ES2641-II	1.21	----------	--	---
ES1876-IA	Embedded Conduit	----------	--	---
ES1877-IA	Embedded Conduit	----------	--	---
ES1879-IA	Embedded Conduit	----------	--	Dsl Neutral Gr
ES1901-IB	Embedded Conduit	----------	--	---
ES1902-IB	Embedded Conduit	----------	--	---
ES1904-IB	Embedded Conduit	----------	--	Dsl Neutral Gr
ES4376-IIC	Embedded Conduit	----------	--	---
ES4377-IIC	Embedded Conduit	----------	--	---
ES4400-IID	Embedded Conduit	----------	--	---
ES4401-IID	Embedded Conduit	----------	--	---
ES4402-IID	Embedded Conduit	----------	--	---

Nonsafety related cables are not included in Table 1.

*These cables were selected for replacement by the environmental qualification program after this test was complete.

2.3 Disposition of [illegible]isting Bend Radius Conditions

The cables having a bend radius less than the allowable (twelve times the cable OD) were classified in three groups as shown below.

Group 1 (2.95 - 5.88) x Cable OD

Group 2 (6.50 - 7.95) x Cable OD

Group 3 (8.43 - 11.42) x Cable OD

Based on the satisfactory results of the tests, the existing bend radii of the cables listed in Table 1 are acceptable as installed for Unit 2 restart. Five cables (ES113-I, ES2550-II, PP453-IID, ES75-I, and ES88-I) in Group 1 operate at full system voltage. These cables are approximately 15 years old. Since the Hi-Pot tests produced satisfactory results for these cables, engineering judgment supports continued operation for at least another fuel cycle. However, in view of the severity of the bend radius conditions and the age of the cable, these cables will be replaced during the next scheduled U2 refueling outage. The remaining four cables (ES4379-IIC, 3ES4102-IIC, 3ES4104-IIC, and 3ES4101-IIC) in Group 1 are diesel Generator Neutrals which carry a reduced voltage or near zero voltage except for small voltage caused by phase imbalance or short duration voltages caused by fault conditions. These cables are also located in a mild environment. Therefore their installed condition is acceptable without modification or further testing.

Group 2 cables are in the bend radius range of 6.5 to 8 times the cable OD. This radius is significantly less than the allowable 12 times. However, separation of the shield tape would not occur at these radii. The test results support these cables remaining in service. Reference 5 requires all cables in Group 2 to be tested to the requirements of SEMI-65 during the next scheduled U2 outage and subsequent outages to facilitate a trend analysis. BFN plans to evaluate the trend analysis at the end of the third refueling outage following restart of unit 2 to assess the need for continued trending of these cables.

TVA will further support its conclusions for the Group 2 cables by application of data to be obtained through WBN's long-term bend radius program. In the WBN tests, medium voltage cables will be bent to a radius of 4 times the cable OD and then retrained to 8 times. The specimens will then be subjected to a period of load-cycling followed by a corona test to assess the effects of the excessive bend. TVA believes that such testing will encompass the less severe Group 2 bends. Per NRC's request, TVA will confirm this latter judgement in discussions with its major suppliers.

The cables in Group 3 have installed bend radii ranging from 8 times the OD to near 12 times. None of the cables are located inside of the drywell. The environmental transients in the remainder of the plant are less severe. While the Insulated Cable Engineers Association (ICEA) recommends a 12 times factor for training this type of cable, the worst Group 3 bend can be shown to produce only about a 7 percent elongating stress which is negligible when contrasted with the materials' capabilities. Therefore, these cables will remain in service without retraining and will be subjected only to the normal maintenance testing.

3.0 SUPPORT OF VERTICAL CABLES

3.1 Walkdown Results

The action recommended in the Summary Report (Reference 1) for closure of the Vertical Cable Support issue was the performance of a walkdown of class 1E medium voltage cables, using G-38 as acceptance criteria. Any vertical sections of cable not properly supported would be Hi-Pot tested at the maintenance voltage levels specified in IEEE Standard 400-1980 and supports added if the cable passed the test.

An inspection was performed as recommended. Thirteen class 1E cables had an unsupported vertical length greater than allowed by G-38. Since there were only 13 class 1E cables which did not meet the vertical drop criteria, the methodology identified in Reference 3 for selecting the worst 15 conditions, was not utilized.

3.2 Testing Results

Five of the 13 cables (ES2689-II, ES189-I, ES141-I, ES13-I, and ES2641-II) are being replaced by other issues prior to Unit 2 restart and therefore were excluded from the testing program. The remaining eight were HVDC tested as previously discussed. All eight cables met the acceptance criteria of SEMI-65 (Reference 4).

3.3 Disposition of Existing Vertical Support Conditions

Evaluations were performed on those eight cables to determine if the static sidewall bearing pressures resulting from the vertical drops in excess of that recommended by the National Electrical Code were within the acceptable range as defined by available vendor guidance (Reference 6 and 7). This methodology is consistent with that successfully applied in resolution of these issues at SQN. The recommendations provided by these references are generic rather than restricted to certain materials. These vendors have offered a wide range of insulating materials of differing durabilities with respect to static sidewall bearing pressures (crosslinked polyethylene, ethylene propylene rubber, silicone rubber, chlorosulfonated polyethylene, fluoropolymers, etc.) for Class 1E service. These crosslinked polyethylene insulated cables, applied at loading stresses well below the recommended maximums, will perform equal to or better than many of the referenced polymers. Utilizing this approach seven cables were technically justified (Reference 8) and are shown in Table 2. A support has been added to the final cable (ES2513-II) to bring it in compliance with the requirements of G-38.

A program for evaluating the support of low voltage cable vertical drops will be implemented with scheduled completion by Cycle 7 startup.

Table 2
STATIC SIDEWALL BEARING PRESSURE VALUES FOR
EVALUATION OF VERTICAL CABLE DROP

CABLE	MARK NO.	OD (Inches) DS E12.1.13	CABLE LB/FT	VERT DROP FT.	COND SIZE/ BEND RAD IN.	KERITE P	OKONITE SWP
PP453-IID	WNC	1.136	1.215	28.08	3"/12.07	14.9	101.76
3PP734-II	WNB	1.04	.899	30.42	3"/12.75	12.4	77.42
ES50-I	WNB	1.04	.899	28.58	3"/13.27	11.27	69.70
ES2550-II	WNB	1.04	.899	23.83	3"/11.47	10.78	67.24
PP451-IE	WNC	1.136	1.215	25.17	3"/15.76	10.25	69.86
PP450-IE	WNC	1.136	1.215	25.17	3"/15.76	10.25	69.86
PP497-I	WNB	1.04	.899	26.00	3"/15.76	8.56	53.39

Okonite maximum recommended SWP (lb/ft) = 120 lbs/ft
Kerite maximum recommended P (lb/in^2) = 50 lbs/in^2

4.0 USE OF CONDULETS FOR PULL POINTS FOR LARGE 600V CABLES

4.1 Corrective Actions

As recommended in the Summary Report (Reference 1), all eight of the circuits identified as 3-400 MCM cables which are installed in three inch conduit and utilizing standard format condulets as pull points will be replaced prior to Unit 2 restart. These raceways are being reworked to increase the conduit size to four inch and incorporate junction boxes or large format, mogul-type condulets as pull points. Additionally, TVA Electrical Design Standard E13.6.2 R2 (Reference 9), Construction Specifications and BFN Site Procedures were revised to prohibit the use of standard condulet bodies as pull points for 300-MCM and larger low voltage power cables.

5.0 FURTHER REVIEW OF CABLE JAMMING

BFN's program (as described in Reference 1) for evaluation and inspection for the potential of damage due to jamming has been implemented. No evidence of damage was observed. Subsequent to this evaluation, numerous circuits were replaced as a part of on-going modifications to address other electrical issues (ampacity, Appendix R, EQ, large 600V cables in condulets, etc). In accordance with an NRC request in a telecon on August 8, 1990, a review was performed of those circuits which were initially identified as being in the critical jam ratio range in order to assess their current status. This review, the results of which were discussed in a September 5, 1990, telecon, identified that only one such conduit remains with cables in the critical jam ratio range; conduit ES1400-I. The three 600V, 400 MCM cables in this conduit feed the control bay water chiller A. It was noted that the cables feeding control bay water chiller B (the redundant chiller) have been replaced during this outage. It was agreed in the latter telecon that no further action was required by BFN for this issue.

6.0 CABLE PULLBY

6.1 Introduction

The walkdowns of potential pullby conduits identified in Reference 1 established a high degree of confidence that the installed safety-related systems at BFN will perform their required function and that cable pullby damage was not present. Subsequent to the completion of the reviews and to the submittal of the above referenced documentation, damage to cables was discovered at Watts Bar Nuclear Plant (WBN). Analysis indicated that the damage was attributed to pullbys.

Even though no pullby damage was identified at BFN, the findings at WBN warrant additional evaluations. This effort included further analysis of installed conduits and cables at BFN and a program of high-potential testing of cables which may have experienced high sidewall bearing pressures during the pullby process.

TVA met with the NRC on December 18, 1989, January 18, 1990, and February 13, 1990, to discuss the plan for resolution of cable pullby concerns at BFN. This plan (Reference 10, Enclosure 1) included the selection criteria to define and identify a group of ten "worst" conduits and the test program criteria. The NRC staff concurred with TVA's test program after the February 13, 1990 meeting (Reference 11).

6.2 Selection of Test Conduits

Since the initial screening process did not include direct consideration for raceway configuration (this could only be known as the result of field walkdowns), TVA's plan was to compare those results with the SWBP ranking process to confirm adequate correlation between the two methodologies. This comparison was made and it was noted that several conduits were ranked much higher using the SWBP values than with the initial screening process.

The selection criteria submitted to the NRC stated that if ranking of the top 30 conduits produced by these two methods did not adequately correlate, the remaining conduits would be walked down to obtain values for SWBP calculations. Upon application of the above process, a review of the remaining 64 conduits identified that 35 were 50 feet or less in length. These short conduits are not considered likely to contain sufficient complexity to be considered worst case when compared to the longer, highly-filled conduits identified by the screening parameters. This observation lead to a decision to expand the walkdown and SWBP calculation process to include conduits which are greater than 50 feet long. This expansion provided walkdown data on a total of 59 conduits. This methodology was discussed with the NRC during their inspection in April 1990.

These 59 conduits were ranked according to the percent of their allowable SWBP. Ten conduits were selected for testing. These conduits consist of the top seven V3, the top two V4, and the top V2.

As was discussed in a September 13, 1990, telecon with the NRC, several differences exist between the final rankings (and the associated forces) and the preliminary rankings (and forces). This latter data had been shared with the NRC during the course of its development and during the test program. As the cable test program has neared a close, two efforts have been undertaken which have resulted in the above changes.

First, BFN's QC organization performed an independent review of the walkdown sketches of conduits ES4508-IIC, 3ES1676-IB, and ES1539-I used to obtain the configuration data necessary to perform sidewall bearing pressure calculations. This review found errors in bend angles and conduit lengths. The QC data was reverified and entered into the SWBP calculation. The revised data lowered the SWBP and swapped the sixth and seventh ranked conduits (3ES1676-IB and ES1540-I). Four additional walkdown sketches were reviewed (ES4035-II, 2ES3106-II, ES4028-II, and ES2835-II) and the changes entered into the SWBP calculation. Although, differences were found in three of the conduits, most of the changes were within the tolerance of the walkdown procedure and the changes to the SWBP calculation were not significant. To ensure that the calculated SWBP were correct for the tested conduits, TVA decided to verify the sketches for the remainder of these conduits (3ES4177-IID, ES2052-IB, ES337-I, 3ES3677-II, ES1540, ES2051, ES335-I, ES359-I, and 2ES904-I). The revised SWBP calculation based on this data made no other changes to the ranking order for this group. Walkdown sketches for two additional conduits (ES223-I and 3ES4538-IIC) were verified as requested by the NRC on September 5, 1990, to confirm that any discrepancies would not increase SWBP and move these conduits into the population requiring testing. The revised calculation based on this data resulted in lower SWBP for these two conduits.

Based on the results of the walkdowns of these 18 conduits, it was concluded that although discrepancies were found, they would not significantly impact the SWBP conduit rankings and that no further action was required. The above was discussed with the NRC on September 3, 1990.

The second effort was the normal process of checking and review of the test-conduit selection calculation. In the course of this review, it was determined that the computer program which evaluated pullslip data to establish pull-groupings did not properly consider multiple pullslips having the same cable number. Multiple pullslips may exist as the result of cable replacement for any of a variety of programs. The initial version of the program recognized only the first pull-date associated with a given cable number. Following the discovery of this oversight, the computer code was modified so as to include the additional pullslips in its conduit's database prior to establishing the individual pull groups. Approximately 140 records were added to the existing database of 34,000 pullslips. Using the same 30 day window for establishing pull groups (Reference 12), conduits 3ES3677-II, ES4508-IIC, ES1676-IB, and ES2051-IB were unaffected by the above changes. The calculated SWBPs for conduits ES335-I, ES359-I, 3ES4177-IID, and ES337-I increased since the consideration of the addtional records resulted in significantly heavier worst case pull groups.

Review of the calculation for conduit ES2052-IB shows that the number of cables in t worst case pull group also inc ased (from 6 to 9). In general the expression for SWBP is T/R, where 'T' is the tension developed and 'R' is the radius of the conduit. However, for pulls of 4 or more cables the expression becomes (x * T)/R, where 'x' is used to account for the distribution of the SWBP across the various cables. TVA's G-38, using methodology developed by T. A. Kommers of the Okonite Company, requires the use of an 'x' of .7 and .44 for pulls of 6 and 9 cables, respectively. In this case, the increased tension resulting from the slightly heavier pull was more than offset by the change in the distribution factor 'x', and resulted in a small decrease in the calculated SWBP.

The forces and rankings shown in the test conduit selection calculation (Reference 12) include consideration for both of the above efforts.

In addition to the worst segment of the ten conduits selected for testing (top seven V3, top 2 V4, and top V2) all additional segments in those conduits which had expected SWBPs greater than the maximum allowed by G-38 were tested. The applied test voltage was 240V dc per mil of insulation thickness (minimum required insulation thickness for qualified cables or nominal thickness for nonqualified cables) with a maximum test voltage of 7200V dc and not exceeding 80% of industry standard test values.

6.3 Testing

The voltage was applied for a duration of five minutes. A polarization index of one or greater at the applied voltage was the acceptance criteria for the test. Testing was performed with V3 and V4 conduits filled with water. All V2 cables involved in this program are constructed with an overall shield. This shield provided the required ground plane for testing, therefore water was not used for conduits which contained only V2 cables. These ten conduits contained 137 cables which were comprised of 520 conductors.

6.4 Test Results

The ten conduits were tested in accordance with Special Test 90-01 (ST 90-01) (Reference 13). The cables tested passed the acceptance requirements except for the following anomalies:

1. Cable ES327-I in conduit ES337-I had a high leakage current during the Hi-Pot test. Additional meggering was performed and a cut was observed in the jacket and insulation of this multi-conductor cable at a conduit pressure boundary seal. The NRC staff inspected this cable and concurred with TVA that the damage was not caused by pullbys and probably occurred during a previous removal of the seal. A large number of conduit seals are being replaced during the current outage for Appendix R and additional seals are replaced during modifications for other electrical issues. BFN procedures that control the installation of the fire seals require QC inspection of the cables prior to the installation of the new seal. Mindful of this high level of activity in seal replacement with no evidence of a negative trend and of the presence of seals in other tested conduits, TVA determined and the NRC concurred that this damage was an isolated case. The damaged area was repaired and the cable was successfully re-tested.

6.4 Test Results (Continued)

2. Six conductors routed in conduit ES2051-I and ES2052-I exhibited high leakage currents and the test was stopped. Additional testing was performed to locate the anomalies. It was noted that the segment in which the anomaly had been isolated had a disconnected conduit bushing at a mid-point pull box. Cables were removed from that segment and carefully inspected by TVA engineers and NRC resident inspectors. Small tears were found in the jacket and insulation. The cables in the remaining segments of these conduit runs were successfully tested.

6.5 Resolution of Damage Caused by Missing Conduit Bushings

The damage found in conduits ES2051-I and ES2052-I was postulated to have been the result of pulling the cables over a conduit with a missing bushing. In an effort to confirm this hypothesis, simulated pulls were performed across a conduit without a bushing. The resulting damage was similar to the damage found on the test cables. This simulation was witnessed by the NRC. It was agreed that the damage to the test cables closely resembled that created by the simulated pull and that it was not caused by a pullby. The damaged cables were single conductor TVA type PN which have 30 mils of polyethylene insulation covered by a 4 mil nylon jacket. Other cable types in use at TVA have substantially thicker jackets.

A program was established for identifying conduits with missing bushings. Boxes containing Unit 2 10CFR50.49 circuits were inspected, either by reviewing existing photos taken during previous inspections or by plant walkdown inspections. Those boxes covered with fire barrier material for Appendix R were excluded from the inspection program since removal of the fire barrier material is costly and the conduits entering these boxes do not contain PN type cables. Nine conduits were identified with missing bushings by reviewing 627 photos. Nine additional missing bushings were identified during the plant walkdown inspection of 313 boxes. Of these 17 missing bushings, ten were located at end device enclosures and it was evident that the cable was not pulled over the exposed conduit edge. On conduit 2ES922-I the bushing was missing from a part of the conduit segment which was less than two feet in length to the next pull point (a condulet). Three to four feet of flex conduit is installed between that fitting and the panel. Given the short length of straight conduit involved it is likely that the cable was pushed or hand-fed through this segment. Therefore, testing was not warranted. This was discussed and agreed upon with the NRC on August 2, 1990 and August 6, 1990.

On conduit ES4070-II the bushing was missing from a conduit sleeve which penetrates the wall between Units 1 and 2 and terminates in a box on each side of the wall. As above the cables would likely have been hand-fed through the sleeve and testing was not warranted. This conduit was discussed in the above telecon. The remaining five conduits with missing bushings were Hi-Pot tested following ST 90-01.

6.5 Resolution of Damage Caused by Missing Conduit Bushings (Continued)

Consistent with the testing performed for the pullby program, shielded cables were tested dry, whereas unshielded cables were tested wet in order to obtain an acceptable ground plane. A non-bushing related failure occurred in 2RP1917-IB, as described below. All other tests were successful.

Conduit	Junction Box	Remarks
2ES1313-I	2474	Wet
2ES905-I	6541	Dry
2RP1919-IB	6541	Dry
ES2226-1B	3301	Wet
2RP1917-IB	2476	Dry

As noted above, during testing of conduit 2RP1917-IB a failure occurred. At approximately 2-1/2 minutes into the test at 4.9 kVDC the leakage current on the black conductor of cable 2RP1945 rose to approximately 1 mA. When the problem could not be cleared by additional cleaning and taping of the terminal ends the cable was cut at various intermediate pull points. By this process the failure was isolated to a segment approximately 22 feet in length. The cables in the suspect segment were carefully removed and inspected. No damage was observed. It was decided to send this cable, a TVA mark letter WVA, type MS, manufactured by Brand Rex on contract 80K6-825419 to the University of Connecticut's (UCONN) Electrical Insulation Research Center for further analysis. This approach was discussed with the NRC on August 2 and August 6, 1990.

Analysis of the failed cable concluded that no damage had been inflicted at the box with the missing bushing and that the test failure resulted from the presence of a large number of atypically large contaminant particles concentrated in the region of the fault.

In order to determine whether or not the contaminant in the insulation was isolated, it was decided to subject additional segments of the same cable to a dielectric breakdown test. Both segments, one from each end of the faulted section, broke down at 12kVAC (approximately 36 kVDC). UCONN therefore concluded that the contamination was isolated in nature.

Further review by TVA determined that at least 17 cables of the same mark number and contract had been successfully tested as a part of the pullby program. This further supports the conclusions drawn by UCONN.

Existing procedures require the installation of conduit bushings at each conduit end.

6.6 Conclusion of Pullby Issue

Approximately 1330 conduits were identified as possible candidates for pullby during cable installation. Using the screening process of this program, the population was reduced to 94. Of this number, 59 were walked down and 10 were tested.

Although anomalies were identified by the testing, no pullby damage was identified at BFN by this extensive review and testing program. Therefore, the program serves to confirm that the cable installation practices at BFN were adequate to ensure that pullby damage does not exist.

7.0 CONCLUSIONS

For the issues above, TVA has completed an aggressive program of walkdowns, inspections, testing, and recurrence control to ensure that safety related cables will perform their required function.

8.0 REFERENCES

1. Browns Ferry Nuclear Plant - Evaluation of Browns Ferry Nuclear Plant Cable Installation Concerns Summary Report (B22 890322 012)

2. TSD E180 Cable Pulling Issues, Cable Bend Radius and Vertical Drop Analysis (B22 881111 243)

3. Letter to U. S. Nuclear Regulatory Commission - Browns Ferry Nuclear Plant - Response to Request for Additional Information on Electrical Issues (TAC62260) (L44 881209 806)

4. Special Electrical Maintenance Instruction SEMI-65 R3

5. General Construction Specification G-38 SRN-83 (B22 900607 012) "Variance Number 16-5kV Bend Radius Violations"

6. Installation Practices for Cable Raceway Systems, The Okonite Company, May 1982 (B43 880617 708)

7. Kerite Installation Data, The Kerite Company, March 1979 (B43 880617 709)

8. G-38 SRN 32 (B22890112002) "Variance Number 5-5kV Vertical Support Violations"

9. TVA Electrical Design Standard E13.6.2 R2 "Raceways - Use of Conduit Bodies in Conduit Systems" (B43 890725 908)

10. Letter to U.S. Nuclear Regulatory Commission from Tennessee Valley Authority dated February 5, 1990 (L44 900205 801) - Resolution of Cable Installation Concerns (TAC No. 62260)

6.0 <u>REFERENCES</u> (Continued)

11. Letter to Tennessee Valley Authority from the U.S. Nuclear Regulatory Commission dated February 16, 1990 - Summary of Meeting with Tennessee Valley Authority held on February 13, 1990 to discuss the Browns Ferry Nuclear Plant Unit 2 Cable Installation Program (TAC No. 00421)

12. Calculation for Analysis of Cable Pullby Concerns at BFN (B22 90 0917 113)

13. Special Test Procedure for High Potential Testing of Low Voltage Cables ST-90-01