ENCLOSURE

BELLEFONTE POSITION PAPER

REGARDING

CABLE SIDEWALL BEARING PRESSURE AND JAMMING

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1.0 PURPOSE

This paper (1) describes TVA's evaluation of the potential for cable damage due to excessive sidewall bearing pressure (SWBP) or cable jamming during installation at TVA's Bellefonte Nuclear Plant (BLN) and (2) defines our technical position on this issue. TVA requests NRC staff concurrence that there is reasonable assurance the cable installation at BLN is adequate and that no further investigative effort is warranted to close these issues at BLN.

2.0 SUMMARY OF POSITION

During the time that the Browns Ferry (BFN), Sequoyah (SQN), Watts Bar (WBN) and BLN plants were constructed, TVA's installation specifications contained an approach to avoiding excessive sidewall bearing pressure commonly accepted in the industry. However, the specification also allowed maximum pull tension to be specified without consideration of sidewall bearing pressure. As a result, the calculation of sidewall bearing pressure was not specifically required or performed in all cases. Until 1984, the potential for cable jamming was not addressed in any industry standards. Nor was cable jamming addressed in TVA installation specifications during the construction phase at BLN. As a result, TVA conducted investigations at BFN, SQN, and WBN concerning potential cable damage due to sidewall bearing pressure and jamming. No damage from these mechanisms was found at any plant. Nonetheless, TVA has recently evaluated the potential for cable damage at BLN due to high sidewall bearing pressure and jamming during cable installation.

Based on its evaluation, it is TVA's position that the potential for cable damage due to high sidewall bearing pressure or jamming at BLN is extremely low. Accordingly, TVA considers there is reasonable assurance that the cable installation at BLN is adequate and that no further investigative effort is warranted to close these issues at BLN.

TVA's position is based upon several factors:

(1) The design of conduits and the cable pulling practices at BLN were sufficiently conservative to avoid this kind of damage.

(2) Values traditionally specified by manufacturers for limiting SWBP while pulling cables in conduit are highly conservative.

(3) Jamming conditions result in a sudden large resistance to pulling which is obvious to the installer; careful pulling practices and limitations on pull force prevent cable damage due to this mechanism.

(4) Extensive TVA reviews at the BFN, SQN, and WBN plants have not found damage due to excessive SWBP or jamming. Furthermore, these evaluations show that very few conduits are even susceptible to jamming.

(5) A review of the specific conduit design and cable installation practices used at BLN indicates that the conditions at BLN throughout the construction period were favorable to avoiding cable damage during installation.

(6) A walkdown by an independent team concluded that the BLN conduit and tray systems at BLN are, in general, well designed and installed, and are conducive to easy cable pulling.

(7) Reviews of applicable BLN construction and inspection records have revealed no indication of sidewall bearing pressure or jamming damage.

3.0 BACKGROUND

3.1 Definitions

Sidewall Bearing Pressure (SWBP) is the radial force exerted on a cable at a bend while being pulled through a conduit or around a sheave under tension. Excessive local bearing force (due to SWBP) and the frictional drag force on the cable as it slides around a bend in a conduit can damage the cable. SWBP increases directly with pulling force and inversely with conduit bend radii. Excessive SWBP can be avoided by proper conduit design and by cable pulling practices that limit cable pulling tension. Factors that influence sidewall bearing pressure during installation include:

- o Radius of the conduit bend
- o Cable pull tension, which in turn is dependent on the length of the pull, number and location of bends in a pull, cable weight, and coefficient of friction.

Jamming may occur when three single conductor cables of the same diameter are being pulled into a conduit and the ratio of the conduit inner diameter to the cable outer diameter (jam ratio) is between 2.8 and 3.1 (Ref. 1). If the jam ratio falls within this critical range and the three cables do not remain in a cradled or triangular configuration but rather move into a flat or single plane configuration, then the cables can "jam" in the conduit as they are pulled around a bend. When this occurs, the tension required to pull the cables increases dramatically. If jamming occurs and too much pull tension is applied, the cable could be damaged. Damage can be avoided by limiting pull tension.

3.2 Standards on SWBP and Jamming

During the period of construction at BLN, TVA's General Construction Specification G-38, "Installing Insulated Cables Rated Up to 15,000 Volts," stated "In the absence of specific instructions from the cable manufacturer, the maximum force in pounds on a cable shall not exceed 100 times the bend radius in feet for small instrumentation-type cables and shall not exceed 300 times the bend radius in feet for medium-voltage power cables." A relationship of this form was recognized as limiting the SWBP for single conductor cables in The Okonite Company's "Installation Practices for Cable Raceway Systems," published in August 1980. Okonite Company, however, allowed values of 300 times to 500 times the bend radius depending on cable type.

The TVA specification also allowed maximum pull tension to be specified without consideration of SWBP. As a result, the calculation of sidewall bearing pressure was not specifically required nor performed in all cases.

The potential for cable jamming was not addressed in any industry standards prior to 1984. Nor was cable jamming addressed in TVA installation specifications during the construction phase at BLN.

More specific requirements for SWBP and jamming were gradually incorporated in industry procedures over the intervening years. In 1985 the TVA General Construction Specification G-38 added the requirements for calculating SWBP prior to cable installation. Similar requirements for calculating jamming ratio were added to G-38 in 1988.

In 1985, an employee concern was documented regarding the calculation of sidewall bearing pressure in TVA plants. Technical Evaluation Reports on cable installation at WBN and SQN (Ref. 2 and 3), which were prepared for the NRC by Franklin Research Center in 1987, questioned whether cables installed prior to the initiation of these new requirements could have been damaged by high sidewall bearing pressure or jamming. Results of subsequent investigations at TVA nuclear plants, described below, show that these cables were not damaged by excessive SWBP or jamming (the WBN investigation of jamming is not complete as of the date of this paper).

3.3 Conservative SWBP Limits

Limits on SWBP specified by cable manufacturers (typically 100 lb/ft for instrumentation type cables and 300 lb/ft for medium voltage power cables) have been shown to be very conservative. An EPRI Program tested 23 types of cables up to load levels where cables were damaged and recommended maximum SWBP values of 1000-2000 lb/ft, depending on cable type (Ref. 4).

The "IEEE Insulated Conductor Committee Task Force 14-1" report on cable installation has also concluded that the limits of 100 lb/ft and 300 lb/ft are very conservative. The committee notes that IEEE-422-1986 recommends a 500 lb/ft limit for control cable and states that, "as a result of testing, SWBP limits of 800-1500 lb/ft for control and power cables and 400-1200 lb/ft for instrumentation cables have been reported" (Ref. 26).

TVA established an independent program which tested 16 types of cables, showing that the following SWBP values could safely be used (Ref. 5):

- 1000 lb/ft for power and control cables
- 500 lb/ft for medium and low-level signal cables
- 300 lb/ft for coaxial, twin-axial and tri-axial cables

3.4 Status of BLN Cable Installation

Cable installation at BLN began in 1977 for Unit 1 and in 1978 for Unit 2. Currently there are approximately 11,400 safety-related cables installed in Units 1 and 2. This represents about 75 percent of the safety-related cables required for Unit 1 fuel load and 40 percent of the safety-related cables required for Unit 2. The safety-related cables currently installed at BLN comprise roughly 3.1 million feet. Total installed footage, including nonsafety-related cables is roughly nine million feet. The majority of the safety-related cable is installed in cable trays; of the 3.1 million feet, approximately 1.0 million feet (32 percent) is installed in conduit.

4.0 TECHNICAL JUSTIFICATION

TVA's position that sidewall bearing pressure and jamming are not of concern at BLN is based upon our review and evaluation of: (1) the conservative conduit design and cable installation practice at BLN, (2) results of extensive reviews at BFN, SQN, and WBN which indicate no cable damage due to SWBP and jamming, and (3) the quality of the physical conduit and cable installation at BLN. The results of this review and evaluation are discussed in more detail in Sections 4.1 through 4.5, below. TVA's plans for remaining cable installation at BLN are discussed in Section 4.6.

4.1 BLN Procedures and Practices

A sound cable installation is the product of an integrated program, which includes procedures, training of personnel, good practices and implementation of procedural requirements, and inspection of the installation process. BLN had a sound program throughout the period of cable installation.

Procedural Requirements
The BLN cable pulling activities were controlled by TVA corporate and BLN site specific procedures which were in place throughout the period of cable installation. The period of applicability of these procedures is shown in Figure 1. General Construction Specification G-38, "Installing Insulated Cables Rated Up to 15,000 Volts," described material and procedures for installing, terminating and splicing cables. Revision 2 of G-38 was issued on August 3, 1978 and Revision 3 was issued on September 27, 1982. These revisions were in effect during the bulk of the cable installation at BLN. BLN Quality Control Procedure BNP-QCP-3.4 defined the methods used for inspection and documentation of safety-related cables. Revision 0 of QCP-3.4 was issued on September 30, 1977 under the title "Electrical Cables." QCP-3.4 was revised periodically and in 1984 the requirements for cable installation were incorporated into a new procedure BNP-QCP-3.34, "Electrical Cable Installation (Pulling)."

During the period of cable installation at BLN, these specifications and procedures contained a formula governing sidewall bearing pressure which was consistent with manufacturers' requirements. This formula was revised and eventually became a requirement instead of an alternative in G-38 in 1985. Requirements to perform calculations for jamming potential were incorporated into G-38 in 1988. These specific improvements are consistent with industry practice.

Additional requirements governing cable installation and inspection were contained in standard operating procedure EEU-SOP-229, "Cable Installation Inspection," and field construction procedure BNP-FCP-3.4.1. Revision 0 of SOP-229 was issued on August 22, 1977. This procedure describes the methods used by electrical quality control inspectors to verify that cables were installed properly. SOP-229 was cancelled in June of 1983 when its requirements were incorporated fully into QCP-3.4. Revision 0 of FCP-3.4.1 was issued on August 25, 1978. This procedure provides guidance to craft personnel for installing cables. FCP-3.4.1 was also cancelled in June of 1983 when its requirements were incorporated fully into QCP-3.4.

In July of 1977, prior to the initiation of cable installation, NRC inspectors reviewed the applicable BLN site procedures. At the time, these procedures were in the review process for issuance. QCP-3.4 Revision 0 was later reviewed by NRC inspectors in December of 1977. The NRC inspection reports covering these procedure reviews identified "no items of noncompliance" (Ref. 6 and 7).

These procedures contained the following requirements which represent good practice for producing a cable installation of high quality.

Control of Pull Tension

Limiting cable pull tension will limit SWBP and can prevent damage due to jamming. Applicable procedures required the control of pull tension for all mechanically assisted pulls throughout the period of cable installation at BLN. Site procedure SOP-229 Revision 0 stated that "a rope pull device, with a known breaking strength, shall be used on all mechanically assisted cable pulls, to assure that the maximum allowable pulling tension is not exceeded." A similar requirement was also included in FCP-3.4.1. Use of dynamometers by installation personnel during the period of cable installation activities was confirmed by an informal review of construction records.

Conversations with personnel involved with the cable pulling activities at BLN indicated that break ropes were also used for manual pulls throughout the period of cable installation. In December of 1984, Revision 0 of BNP-QCP-3.34 required the use of a rope or line pull device, with a known breaking strength, for mechanically assisted and manual pulls. Construction records confirm the calibration of break devices with break strengths as low as 10 pounds, which were used for manual pulls. During a 1985 review of quality assurance records for instrumentation cables at BLN, the NRC concluded, "the licensee uses a break rope on each conductor pulled, to assure that tension limits are not exceeded" (Ref. 8).

Conduit Design

Cable pull tension was also considered in the design and installation of the conduit system at BLN. Specifications and procedures placed requirements on conduit installation which reduce required cable pull tension. For example, General Construction Specification G-40, "Installing Electrical Conduit Systems and Conduit Boxes," describes materials and procedures for installing electrical conduit systems. Revision 0 of G-40 was issued on August 6, 1975. G-40 Revision 0 required conduit installation to be in accordance with the National Electric Code, which specifies a maximum of 360 degrees between pull points. This requirement was also explicitly stated in BLN site procedure SOP-231, which supplemented the requirements of G-40. G-40 also required that standard radius field bends or manufacturer's elbows be used for metal conduits and that field bends be made such that the internal conduit diameter did not change and the protective coating on the inside and outside of the conduit was not damaged. The specification also required that bends be free of kinks, indentations and flattened surfaces. After a conduit run was completed, G-40 required that it be inspected and cleaned out. Use of compressed air to blow out completed conduits was recommended. These requirements specify a conduit installation that eases cable installation and minimizes the potential for cable damage.

BLN site quality control procedure BNP-QCP-3.2, "Conduit Systems," defined the methods used for inspection and documentation of conduit runs at BLN. Revision 0 of QCP-3.2 was issued in September 1977. QCP-3.2 placed requirements on conduit inspection which enforced the requirements of G-40.

Use of Lubricants

TVA corporate and BLN site procedures required the use of lubricants throughout the period of cable installation at BLN. Lubricants further reduce required pull tension. A review of BLN construction warehouse records was made to confirm the use of lubricants during cable pulling operations (Ref. 9). The results of the 1991 review indicate that lubricants were used throughout the installation. Ideal Yellow 77 and Polywater were the principal lubricants used at BLN. Warehouse records show that 4500 gallons of Yellow 77 and 2200 gallons of Polywater were used in the installation of cables at BLN. These records also show that Yellow 77 was last issued for use in October 1982 and Polywater was first issued to construction in March 1981. The results of the review conducted indicate that lubricants were used throughout the cable installation period, thus reducing the coefficient of friction and required pull tension.

Training of BLN Personnel

The training of personnel, essential to translating procedural requirements into a cable installation of high quality, was thorough and complete at BLN. Training requirements for personnel who installed and inspected cables at BLN were documented in site Quality Control Procedures (QCPs). These training procedures, which were issued prior to the start of large scale cable installation, specified the training requirements for construction engineers, electrical craft supervisors and foremen responsible for installing cables and for the quality control inspectors responsible for verifying that safety-related cables were installed in accordance with site procedures.

The training included familiarization with the basic concepts of the BLN QA program and specific training sessions on the requirements of applicable site procedures. The specific training provided for construction engineers covered the applicable site procedures and the TVA General Construction Specifications, G-38, "Installing Insulated Cables Rated Up to 15,000 Volts," and G-40, "Installing Electrical Conduit Systems and Conduit Boxes." Training was also provided for electrical craft supervisors (superintendents and assistant superintendents), hourly foremen and dual rated hourly foremen. Craft personnel were trained in the content and requirements of the BLN QCPs and FCPs. In June of 1982, the site training procedure for craft personnel was revised to add provisions for craft superintendents to include journeymen in training sessions, as appropriate.

Formal training for quality control inspectors was also provided throughout the period of bulk cable installation at BLN. Site procedures required inspectors to be trained in the requirements of the applicable cable and conduit installation procedures and certified prior to performing any QA inspection activities. Inspectors were required to pass a written examination before receiving certification.

Samples of construction records from the period of cable installation at BLN were reviewed in 1991. This review confirmed that training in accordance with these procedures was implemented for personnel associated with the installation of cable at BLN. In addition, a sample consisting of 60 pull cards covering various years between 1979 and 1988 confirmed that the BLN inspectors were certified in the applicable revisions of the QCP at the time the cable was installed (Ref. 10).

Inspection of Process

Throughout the period of cable installation, site procedures required that certified quality control inspectors monitor safety-related cable installation and verify that cables were installed properly. The inspectors were responsible for ensuring that the conduit was cleaned out immediately prior to pulling cable, and water and debris were removed by using compressed air or pulling a swab through the conduit. The inspectors were also required to ensure that the cable reel was properly positioned, the cable was properly prepared for pulling, lubricant was used, and the cable was not damaged prior to or during installation.

Prior to 1984, the inspector's signature on the cable pull card signified the installation met the requirements of the site procedures. Cable pull cards are classified as a QA record. In 1984, Revision 0 of QCP-3.34 introduced a detailed check list to assist the inspectors in the field. These check lists were completed and signed by the inspectors and filed along with the cable pull card. A review of over 1800 cable pull card records confirmed compliance with these procedural requirements.

4.2 Assessment of SWBP Concern

The evaluation of the potential for SWBP problems at BLN included a review of TVA experience at its other nuclear plants, a comparison of the BLN conduit and cable installation with these other plants, and analyses of SWBP in BLN conduits found by reinspection to have large degrees of bends. The results of each of these efforts are described below.

TVA Experience With SWBP At BFN, SQN, and WBN

TVA conducted extensive investigations of the cable installations at BFN, SQN, and WBN to address the SWBP issue. These investigations have included walkdowns, calculations of SWBP, inspections, and laboratory tests. These reviews of SWBP have shown that these installations meet the TVA allowable SWBP criteria excepting only one conduit and have found no indication of cable damage due to this mechanism. The investigation for each plant has been reviewed with the NRC (Ref. 11, 25, and 13) and is summarized briefly below.

At BFN, a walkdown was performed to identify those conduits with the severe cable pulling geometry. The conduits selected were those in which the conduit length between pull points exceeded 80% of the values permitted by TVA specification G-38 or in which the total degrees of bends exceeded 360. It was found that the conduit configurations at BFN are similar to SQN and more favorable than those at WBN in that the length of conduit and the total degrees of bends between pull points are less than at WBN.

SWBP was calculated for the BFN conduits with the most severe cable pulling geometry. Significantly, in these cases the calculated SWBP was well within the allowable values (Ref. 15).

The SQN conduits were also screened in order to determine the worst-case population. SWBP calculations were performed for the worst-case and next-to-worst case conduits in each voltage level (a total of 16 conduits). Calculated SWBP values for these conduits were below the TVA allowable values (Ref. 24 and 25).

At WBN, the Class 1E conduits (approximately 10,000) were screened and 81 conduits were identified which had the highest potential of having exceeded the allowable SWBP values. Calculations of SWBP were made for the 81 conduits. One conduit out of the 81 exceeded the TVA allowable SWBP value in one direction only. TVA is planning to replace the cables within this conduit (Ref 13). To confirm that the sample of 81 conduits is representative of the worst-case population, an additional sample of 40 conduits was selected at random from the population of conduits located in harsh environments. SWBP was calculated for these installations and these 40 conduits met the TVA allowable SWBP value (Ref. 23).

Comparison of BLN Conduit and Cable Installation With BFN, SQN, and WBN

Evaluations of the BLN conduit and cable installation were made and the results compared to BFN, SQN and WBN where data were available. The comparisons indicate that the general configuration of the BLN installation, particularly with respect to ease of cable installation, is comparable to BFN and SQN, and is better than WBN.

The comparison to BFN and SQN used the results of the pullby evaluations made at those plants. As part of those pullby evaluations at BFN and SQN, safety-related conduits were initially screened to identify those conduits long in length and having large numbers of cables. These parameters were used to identify populations of conduits with more difficult cable pulls. Similar screening data is not available for WBN because a different approach was used for the pullby evaluations there. A comparison with WBN on the basis of conduit fill is described later in this section. The BFN and SQN databases do not contain data on degrees of conduit bends, which also affects difficulty of pulls. This parameter is also discussed later in this section of the report.

The BLN conduits were screened using criteria similar to BFN (Ref. 16). The results were compared with the BFN and SQN conduits which met the respective criteria used at those plants. The specific attributes chosen for comparison were the numbers of conduits, the conduit lengths and sizes, and the numbers of cables per conduit. These attributes affect the potential for excessive SWBP. Table 1 contains the results of that comparison. The screening and comparison study are discussed in more detail in the BLN Position Paper Regarding Cable Pullby, dated May 16, 1991.

The results of the comparison indicate that the number of conduits which met the screening criteria at BLN and SQN are comparable on a percentage basis. Overall, among the three plants, the conduit lengths, sizes, and the number of installed cables per conduit are roughly the same, on average.

The most direct comparison which can be made between BLN and WBN data related to the ease of cable installation is based on percent of conduit fill. Similar conduit fill results were not available for BFN or SQN. Conduit overfill, whether in a large conduit with many cables or a small conduit with few cables, increases the potential for the excessive pull tensions which can cause cable damage.

Evaluations of conduit fill were performed in 1989 for WBN safety-related conduits. A similar calculation of conduit fill was performed in 1991 for BLN safety-related conduits (Ref. 18). Safety related conduits in Units 1 and 2 containing installed cables were included in this BLN calculation. The WBN calculation identified over 980 safety-related conduits which were overfilled based on TVA design criteria (Ref. 17). By contrast, the BLN calculation identified only 64 conduits which are overfilled based on TVA design criteria. Many of the WBN conduits were filled to more than one and one half times the allowable fill values. By contrast, the overfilled safety-related conduits at BLN exceeded allowable values by a very small amount (a few percent). The worst case BLN conduit exceeds the TVA design criteria by approximately five percent (Ref. 18).

These comparisons with SQN, BFN, and WBN suggest that, based on the configuration of the installation, the ease of cable installation at BLN is similar to that at SQN and BFN, and better than at WBN; extensive investigations and tests have found no damage at any of these plants due to excessive SWBP.

Analysis of SWBP

Assessment of SWBP conditions at BLN took advantage of the results of a major conduit reinspection effort. Specifically, over 5500 installed conduits at BLN have been reinspected due to a nonconformance report (NCR) written against conduit at BLN. NCR 4254 was written to address a number of minor nonconformances with conduit that were identified during final raceway verification inspections (the nonconformances were primarily related to conduit supports). In the process of resolving NCR 4254, five conduits exceeding 360 degrees of bends between pull points were identified. These five conduits were analyzed for SWBP and were shown to be within the TVA limits for SWBP, even though the 360 degree bend criterion was exceeded (Ref. 20). This extensive reinspection and the associated analysis results support the position that excessive SWBP is not a concern at BLN. A 1991 walkdown identified one conduit embedded in concrete which exceeded the 360 degrees of bend limit. This conduit will be evaluated for SWBP and other embedded conduits will be reviewed as needed to assure that the installation is satisfactory.

4.3 Assessment of Jamming Concern

The evaluation of the potential for jamming problems at BLN included a review of TVA experience at its other nuclear plants, a comparison of the BLN conduit and cable installation with these other plants, and a walkdown and evaluation of the conduits with critical jam ratios.

TVA Experience With Jamming

TVA conducted extensive investigations at SQN, BFN and WBN to address the potential for cable jamming. These investigations have included walkdowns, analyses, inspections, and tests. The results have shown no indication of cable damage due to this mechanism. The investigation for each plant has been reviewed with the NRC (Ref. 11, 12, and 13) and is summarized briefly below.

At SQN, the total population of conduits (approximately 9500) containing safety-related cables was screened to identify the conduits possibly containing jammed cables. Forty-eight conduits met the following criteria: the conduits contained three single conductor cables of the same size, the cable and conduit configuration fell within the critical jam ratio of 2.8 to 3.1 and the number of conduit bends between adjacent pull points exceeded the requirements of G-38. Cables within 15 selected conduits were subjected to a 5-minute DC high voltage test. No cable damage due to jamming was detected during these tests (Ref. 14).

As part of the jamming investigation at BFN, TVA identified the three-inch conduits containing three 600V 400 MCM power cables. This category of conduits had been identified in the SQN investigation as having the highest potential for jamming. A walkdown team inspected five of these conduits at accessible terminations and pullpoints. No damage was found (Ref. 15). TVA concluded and the NRC concurred that the worst-case group of conduit runs at BFN are bounded by those tested at SQN (Ref. 11).

At WBN, TVA again investigated the total population of Class 1E conduits (approximately 10,000) to identify those conduits with some potential for jamming. This evaluation identified only 87 conduits which met the screening criteria. TVA is planning to visually inspect the cables in 25 of these 87 conduits for jamming damage because the cables are being removed to resolve other cable issues (Ref. 13).

Comparison of Jamming Potential at BLN, SQN, WBN, and BFN

At BLN, TVA recently evaluated the class 1E conduits required for Unit 1 fuel load (approximately 4800) to identify conduits with some potential for cable jamming (Ref. 19). Twelve hundred seventy-five conduits were identified which contained three single conductors. This population was then screened for conduits containing three single conductor cables of the same diameter and a jam ratio of 2.8 to 3.1; 90 conduits met these criteria. Evaluations at SQN and WBN identified comparable small numbers of conduits with critical jam ratios (see Table 2). (Similar data is not available for BFN.) The small numbers of conduits with critical jam ratios at BLN and at the other plants and the absence of jamming damage at these other plants suggests that the potential for damage at BLN due to jamming is not a concern.

Walkdown and Evaluation of Conduits at BLN

Fifty-seven of the 90 BLN conduits identified as having critical jam ratios were further evaluated by walking down each one and determining their length, size, and total degrees of bends. Fourteen of the 57 were found to be 25 feet long or shorter, or to contain 180 degrees or less in bends. The remaining 43 were inspected at accessible points (conduit ends, intermediate pull boxes, and intermediate condulets) and no cable damage was found (Ref. 19). The results of the evaluation showed that few conduits had the potential to jam and inspections found no problems.

4.4 Independent Assessment of Installation at BLN

The comparisons to the other TVA nuclear plant installations, discussed above, showed that the BLN cable installation is generally comparable to or more favorable than these other installations. Further, extensive investigations at these other plants have found no indication of a problem with cable damage due to SWBP or jamming. Nevertheless, to obtain an additional assessment of the cable installation at BLN, an independent team of experienced engineers was organized and tasked to walkdown and evaluate the BLN installation in April 1991.

This qualitative assessment of the safety-related cable tray and conduit installations at BLN was made by a four member team consisting of three senior electrical engineers and a senior electrical designer. The team was comprised of representatives of Gilbert/Commonwealth, Fluor Daniel and an independent consultant. Each of the team members has over 20 years of experience related to the design and installation of cable, conduit, and cable tray for a variety of industrial facilities, including nuclear power plants (Ref. 21).

The team reviewed applicable BLN site procedures and cable tray and conduit layout drawings and performed walkdowns of the BLN installation. The members of the team also visited WBN to gain an understanding of the cable installation issues there and to conduct a plant walkdown. The objectives of the BLN walkdowns were to:

- Assess the overall quality of the installation of safety-related cable trays and conduit.
- Assess the reliance on cable tray versus conduit as a means of conveyance.
- Assess the design and installation of the safety-related cable tray and conduit system with respect to how it lends itself to installing cables without damage; particular emphasis was placed on the conduit system.
- Compare the overall installation of safety-related cables in tray and conduit with installations in other nuclear plants.

The walkdown team evaluated specific plant areas, as well as specific conduit runs which were selected by the team. Areas were selected to include a variety of equipment types, heavy concentration of cable, and harsh environments. These areas included:

- Cable spreading room
- Control room panel wire ways
- Safety related Solid State Control System cabinet rooms

- Reactor building primary containment and annulus areas

- AC and DC power distribution switch gear, motor control centers and distribution panels

In addition to the general area walkdowns, thirty-one conduit runs were inspected in detail by the team. Those conduits were selected by the team members because they were long and contained large numbers of installed cables.

Based on the results of the walkdown, the team concluded that the conduit and tray systems at BLN are, in general, well designed and installed, and are conducive to easy cable pulling. The overall conclusions of the team were based on the following observations of the BLN tray and conduit system:

- There is a greater reliance on cable tray rather than conduit as a means of conveyance for cables, including significant use of cable trays for both safety divisions within the reactor building primary containment and annulus areas.

- Cable trays and conduits are currently lightly loaded with cables.

- Quality workmanship and attention to detail is evident by the orderly arrangement of cables in trays, smooth conduit bends and gradual transitions at conduit offsets.

- Intermediate pull points were provided to limit conduit bends to a maximum of 360 degrees between pull points.

- Cable tray and conduit installation compares favorably with other nuclear plants and, in general, meets or exceeds industry standards.

TVA believes that these results confirm that the existing conduit installation at BLN is conducive to easy cable pulling and that there is reasonable assurance that systematic cable damage does not exist.

4.5 NRC Inspections

The favorable characteristics of the BLN cable and raceway installation were also recognized by NRC inspectors during their 1986 review and inspection of the design and installation of the conduit and cable system. This NRC review was conducted in response to a 1985 TVA employee concern regarding sidewall bearing pressure calculations for cable pulls in TVA plants. The NRC inspectors examined site programmatic controls to develop an understanding of the methods used to control conduit and cable installation activities. The NRC inspectors also "examined conduit installations in various areas above and below power distribution boards and motor control centers. These conduits have been found at other sites to pose the most SWP problems (Ref. 22)." They found that the "Design of conduits for BLN site restricted the lengths of conduit runs, used cable trays above electrical boards instead of conduit, incorporated larger conduit sizes and larger fittings at directional transition points" (Ref. 22). The NRC inspectors concluded that "no violations or deviations were identified within the areas examined" (Ref. 22).

4.6 Plans for Remaining Work

The cable installation work remaining at BLN involves rework of some cables and installation of the remaining cables. The cable rework will be required for such reasons as conduit rework from NCR 4254, discussed previously, or modifications required by any new system design criteria. In performing this remaining cable installation work at BLN, the following requirements in TVA General Construction Specification G-38 will be implemented to assure against sidewall bearing pressure and jamming concerns:

- o Sidewall bearing pressure will be evaluated and the lesser of the SWBP tension and cable maximum straight line tension will be utilized for the pull.
- o Jam ratio will be calculated when three single conductor cables of the same conductor size are being pulled into a conduit, and the pull will not be made if the jam ratio is in the critical range.

Following construction completion, BLN will undergo an extensive start-up test program. This program will verify the construction and functionally test plant systems and components, including the cables associated with each component. Construction verification testing involves detailed tests of plant components over approximately an eighteen month period. Preoperational functional testing of systems will follow construction verification testing.

Preoperational testing includes individual system functional tests and integrated systems functional tests. During these tests, plants systems will be operated over a wide range of plant conditions and thus will exercise power, control and instrumentation cabling for these conditions.

This start-up test program is consistent with industry practice for verifying the adequacy of the installation of plant systems, components, and associated cables.

5.0 REFERENCES

1. IEEE 690, "IEEE Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations"; dated 1984

2. Technical Evaluation Report, "Evaluation of Watts Bar Units 1 and 2 Cable Pulling and Cable Bend Radii Concerns, TER-C5506-649 prepared for Nuclear Regulatory Commission by Franklin Research Center"; dated January 30, 1987

3. Technical Evaluation Report, "Evaluation of Sequoyah Units 1 and 2, Cable Pulling and Cable Bend Radii Concerns, TER-C5506-649 Sequoyah"; dated February 19, 1987

4. Electric Power Research Institute Project 1519-1, Project Report No. EPRI EL-3333, "Maximum Safe Pulling Length for Solid Dielectric Insulated Cables"; dated February 1984

5. David A. Silver & Associates Final Report, "Review and Analysis of TVA's Cable Sidewall Pressure Tests"; dated November 21, 1986

6. NRC letter to TVA (C. E. Murphy to G. Williams, Jr.); dated July 8, 1977; Inspection Reports Nos. 50-438/77-8 and 50-439/77-8

7. NRC letter to TVA (C. E. Murphy to G. Williams, Jr.); dated December 12, 1977; Inspection Reports Nos. 50-438/77-17 and 50-439/77-17

8. NRC letter to TVA (R. D. Walker to H. A. Parris); dated February 27, 1985; Inspection Report Nos. 52-438/85-04 and 50-439/85-04

9. TVA Memorandum (J. L. Langston to R. M. Carritte); dated March 26, 1991; Bellefonte Nuclear Plant - Electrical Cable Inspection - Cable and Wire Pulling Lubricants (U02 910326 600)

10. Bellefonte Reactivation Project Report, "Confirmation of Training of Personnel Associated with the Installation of Cables at Bellefonte Prior to Construction Deferral"; dated April 1991

11. NUREG 1232, Volume 3, Supplement 2; Safety Evaluation Report on TVA's Brown's Ferry Nuclear Performance Plan - Brown's Ferry Unit 2 Restart

12. TVA letter to NRC (from Mark O. Medford); dated October 23, 1990; Sequoyah Nuclear Plant - Units 1 and 2 - Cable Test Program (CTP) Resolution Plan (TAC No. 77129/77130)

13. TVA letter to NRC (from E. G. Wallace); dated October 11, 1990; Watts Bar Nuclear Plant - TVA Responses to NRC Comments Resulting from 8/1-3/90 Meeting

14. TVA letter to NRC (from R. L. Gridley); dated April 8, 1987; Sequoyah Nuclear Plant (SQN) - Cable Test Program

15. Cable Issues Walkdown Report, Revision 2, March 22, 1989 - Browns Ferry Nuclear Plant (B22 89 0322 011)

16. Gilbert Commonwealth letter to MPR (K. E. Shuman to R. M. Carritte); dated May 2, 1991; BLN Cable Pullby Calculation BLN-GC-CBL-01

17. Stone and Webster Engineering Corporation Report, "Report For Overfilled Raceways For Watts Bar Unit 2 and Common Areas"; dated September 12, 1989 (B26 810918 523)

18. United Engineers and Constructors letter to MPR Associates (R. Bryans to H. Estrada); dated April 25, 1991; Bellefonte Nuclear Plant Cables in Conduit, Percentage Fill (PE 129 AE-07)

19. Gilbert/Commonwealth letter to MPR Associates (B. S. Kohout to R. M. Carritte); Bellefonte Nuclear Plant - Evaluation of Conduits With Critical Jamming Ratio; dated May 10, 1991

20. Gilbert Commonwealth letter to MPR Associates (G. D. Tupper to R. M. Carritte); BLN Conduits with Over 360° Bends, Pull Tension Calculations, AWRS EE128-01; dated April 9, 1991

21. Bellefonte Reactivation Project Report; Qualitative Assessment of the Cable and Raceway Installation at Bellefonte Nuclear Plant; April 1991

22. NRC letter to TVA (J. A. Olinski to S. A. White); dated March 11, 1986; Inspection Reports Nos. 50-438/86-01 and 50-439/86-01

23. TVA Calculation, WBPEVAR 9010001, "Cable Issues SWBP in Harsh Environments"; RMS# B18901030504 dated October 1990

24. TVA Memorandum (D. W. Wilson to M. R. Harding); dated December 4, 1986; Sequoyah Nuclear Plant Units 1 and 2 - Response to Cable Issues (B25 861204 016)

25. TVA letter to NRC (R. L. Gridley to B. J. Youngblood); dated December 8, 1986; Sequoyah Nuclear Plant (SQN) - Cable Pulling Questions: Supplemental Responses (L44 861208 800)

26. IEEE Task Force 14-1; Station Cable Installation; Insulated Conductors Committee Report; Recommended Practice on Specific Aspects of Cable Installation in Power Generating Stations; IEEE Transactions on Power Delivery; Vol. 4, Number 3, July 1989

TABLE 1

COMPARISON OF PULLBY DATA

FOR BELLEFONTE, BROWNS FERRY AND SEQUOYAH

(Sheet 1 of 2)

		BELLEFONTE	BROWNS FERRY	SEQUOYAH
1.	INITIAL POPULATION OF CLASS IE CONDUITS EVALUATED (SEE NOTE 1)	4880	1330	9500
2.	NUMBER AND PERCENT OF CONDUITS WHICH MEET SCREENING CRITERIA (SEE NOTE 2)	135 (2.8%)	110 (8.3%)	269 (2.8%) (SEE NOTE 3)
3.	FOR CONDUITS MEETING THE SCREENING CRITERIA:			
a.	CONDUIT LENGTHS - FEET (SEE NOTE 4)			
	MAXIMUM	270	475	193
	AVERAGE	57	77	44
	MEDIAN	43	40	37
	MINIMUM	20	20	20
b.	CONDUIT SIZES - INCHES			
	MAXIMUM	5	4	5
	MOST COMMON	3	3	3
	MINIMUM	1.5	1.5	1.5
c.	NUMBER OF CABLES PER CONDUIT			
	MAXIMUM	46	76	31
	AVERAGE	13	17	14
	MEDIAN	9	13	11
	MINIMUM	4	4	7

TABLE 1

COMPARISON OF CONDUIT DATA

FOR BELLEFONTE, BROWNS FERRY AND SEQUOYAH

NOTES:

1. At BLN, conduits selected for the initial population were those required for Unit 1 fuel load having installed safety-related cables; some conduits are Unit 2 conduits which are required for Unit 1 fuel load but not for Unit 1 operation.

   At BFN, conduits selected for initial population were those conduits having installed safety-related cables required for Unit 2 operation (voltage level V1-V4 only). This population included Units 1 and 3 conduits required for Unit 2 operation.

   At SQN, conduits selected for the initial population were those conduits which were safety-related conduits for both Units 1 and 2.

   Comparable data were not available for WBN because a different approach was used to evaluate pullby concerns there.

2. Screening criteria:

   At both BLN and BFN, for voltage levels V1-V3, safety-related conduits having a length of 20 feet or greater and containing 8 or more cables were included.

   At both BLN and BFN, for voltage level V4, safety-related conduits having a length of 20 feet or greater and containing 4 or more cables were included.

   At SQN, for voltage levels V1-V4, safety-related conduits having a length of 20 feet or greater and containing 7 cables or more were included.

3. At SQN, 269 conduits met the screening criteria. The conduit length and size data included these 269 conduits. The number of cables per conduit and number of pullbys per conduit data were only available for 101 of the 269 conduits meeting the screening criteria. Therefore, the values for the number of cables per conduit and the number of pullbys per conduit at SQN are based on 101 conduits.

4. At BLN, 4 conduits were not included in the conduit sample due to their excessive length (approximately 4900 feet) which would have skewed the conduit length comparison. These conduits are in the ductbank to the intake structure and have numerous intermediate pull points.

   At BFN, 1 conduit was not included in the sample due to its excessive length (803 feet) which would have skewed the conduit length comparison.

TABLE 2

NUMBER OF CLASS 1E CONDUITS
WITH CRITICAL JAMMING RATIO CABLE CONFIGURATION

PLANT	NUMBERS OF CONDUITS	POPULATION EVALUATED
BELLEFONTE	90	1E CONDUITS REQUIRED FOR UNIT 1 FUEL LOAD
WATTS BAR	87	1E CONDUITS REQUIRED FOR UNIT 1
SEQUOYAH	48	1E CONDUITS REQUIRED FOR UNITS 1 AND 2
BROWNS FERRY	[Not Available]	[Not Available]

MPR ASSOCIATES
F-48-121-03
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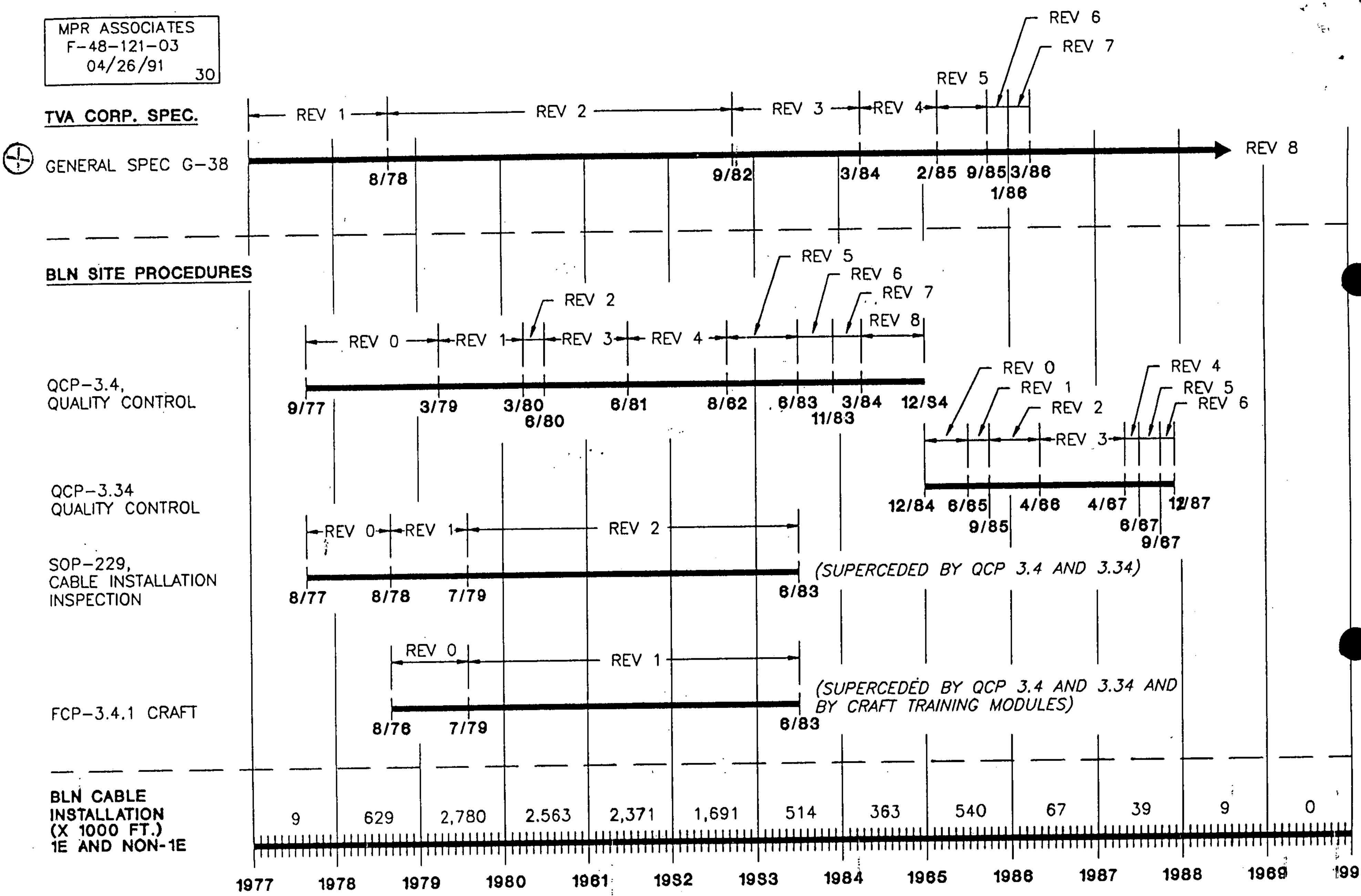

CABLE INSTALLATION PROCEDURES AND SPECIFICATIONS FOR BELLEFONTE NUCLEAR PLANT
FIGURE 1