ENCLOSURE

BELLEFONTE POSITION PAPER

REGARDING

CABLE PULLBY

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1.0 PURPOSE

This position paper describes TVA's evaluation of the potential for cable damage due to pullbys in conduits at TVA's Bellefonte Nuclear Plant (BLN) and defines our technical position on this issue. TVA requests NRC staff concurrence that there is reasonable assurance cable installation procedures and practices at BLN were adequate to prevent cable pullby damage, and that no further investigative effort is warranted to close this issue at BLN.

2.0 SUMMARY OF POSITION

The cable installation procedures and practices followed at BLN resulted in the installation of some cables into conduits that already contained cables. This process, referred to as cable "pullby", is used with success at numerous industrial facilities, including nuclear power plants. Because some cable damage due to pullbys was identified at TVA's Watts Bar Nuclear Plant (WBN), TVA has recently evaluated the potential for cable damage at BLN due to pullbys.

Based on its evaluation, it is TVA's position that there is reasonable assurance that the cable installation procedures and practices at BLN were adequate to prevent cable pullby damage and, therefore, no further investigative effort is warranted to close this issue at BLN.

TVA's position is based upon several factors. First, the practice of performing cable pullbys is not uncommon in the nuclear industry and problems with cable pullby damage in the industry are rare. Where pullby damage has been found, the damage was limited in scope. Second, the major contributor to the pullby damage at WBN was the use of small diameter braided nylon parachute cord. A thorough review has found no indication that this type of cord was used at BLN. Third, a review of the cable installation procedures and their implementation at BLN indicates that the procedures were adequate, that implementation of the procedures was thorough and professional, and that sufficient measures were in place throughout the period of cable installation to prevent pullby damage. This review included a comparison of the BLN design and installation with that at other TVA plants and an independent assessment of the BLN installation by a four member team of experienced electrical engineers. Finally, reviews of applicable BLN construction records found 32 conduits in which pullbys had occurred and whose cables had been reinspected as part of rework activities. In no case was pullby damage found.

3.0 BACKGROUND

3.1 <u>The Use of Pullbys in the Industry</u>

It is more efficient to install all cables in a conduit at one time (bulk or batch pulling) than to perform multiple pulls, which involve pullbys. As a result, there is an economic incentive to avoid pullbys whenever possible. However, pullbys are often necessitated to support system turnover from the construction organization to the startup test organization. Pullbys are also used when the number of cables to be installed in a conduit is too large for a batch pull, and when system modifications are installed. For these reasons pullbys are used commonly in the industry.

To perform a pullby, a pull rope is installed in the conduit by using an electrician's fish tape or by using a pilot line that was installed at the time of the previous cable pull. This latter method is often used when pullbys are anticipated. In these cases, the pilot line is left in place until it is needed. Sometimes the pilot line is used as a pull rope if its strength is sufficient.

3.2 Industry Standards Regarding Cable Pullbys

During the period of cable installation at BLN (1977-1988), the industry guides and standards which addressed the installation of cables in power plants and other industrial facilities provided no recommendations or guidance for performing cable pullbys. In fact, there are still no industry (e.g., IEEE and ICEA)* guides or standards which address cable pullbys, although an IEEE Committee report which provides guidance for performing pullbys was issued in 1989 (Ref. 1). There are no NRC regulatory requirements or guidance which address cable pullby practices.

3.3 Potential Causes of Pullby Damage

The potential concern with pullbys is that the fish tape, pilot line, pull rope or new cable being installed will rub too hard on the installed cables and damage them by cutting through the jacket and insulation. The potential for pullby damage is increased if the conduit is overfilled, the number of pullbys per conduit is large, or the pull tension required to make the pull is high. Required pull tension increases with increasing conduit length and increasing numbers of bends between pull points.

4.0 TECHNICAL JUSTIFICATION

TVA's position that cable pullby damage is not a concern at BLN is based upon our review and evaluation of: (1) industry experience with cable pullbys, (2) specific instances of pullby damage at TVA and non-TVA plants, (3) cable installation procedures and practices at BLN, and (4) the quality of the existing conduit and cable installation at BLN. The results of this review and evaluation are discussed in more detail in Sections 4.1 through 4.4, below. TVA's plans for the remaining cable installation at BLN are discussed in Section 4.5.

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* IEEE - Institute of Electrical and Electronics Engineers
ICEA - Insulated Cable Engineers Association

4.1 Industry Experience with Pullbys

Reported incidents of cable damage due to pullbys are rare and industry experience with cable system reliability is excellent. For example, Reference 2 documents the results of the NRC-sponsored Nuclear Plant Aging Research (NPAR) study on cables, connections, and containment electrical penetration assemblies (EPAs). The study consisted of evaluations of usage, operating experience, current inspection and surveillance methods, and normal and accident type stressors and aging mechanisms for electrical cables, connections, and EPAs.

Based on a review of operating experience of cable systems in nuclear power plants, the report states:

> "Cables, connections, and EPAs are much more reliable in normal service than the components that they are normally connected to (perhaps by several orders of magnitude). Thus, slight increases (several hundred percent) in random failure rates of this equipment will have little impact on overall plant risk. It is thus evident that under the current level of operating experience, the only possible aging threat is when increased component vulnerability (resulting from age-related degradation) is combined with a harsh environment exposure. These are the only conditions where the failure rate could become significant enough to impact overall plant risk." (Ref. 2, pg. 3)

This report suggests that, if pullby damage has occurred in the industry, it has not affected the reliability of cable systems.

Furthermore, our review of industry experience has shown that instances where pullbys are known to have caused damage are few in number. Conversations with individuals associated with cable installation at 7 utilities, 2 cable vendors, and 3 architect engineers and constructors confirmed that systematic damage due to pullbys is not known to exist in the industry (Ref. 26). The few documented instances of damage were cited as exceptions. Our review identified cable pullby issues at only three nuclear plants; Comanche Peak, Grand Gulf and Watts Bar.

At Comanche Peak, concerns were raised regarding the calculation of pull tension for cables installed in conduits with existing cables. The licensee evaluated conduit installations, including a review of Nonconformance Reports (NCR) associated with pullby damage which were previously closed. Tests were performed on the cables in six conduits of concern. A 500 volt DC megger test was used, as recommended by IEEE Standard 690 for post installation testing. No cable deficiencies were identified during the tests. After completing its evaluation, the licensee concluded, "in the event these issues had remained uncorrected, no condition adverse to the safety of plant operations would exist" (Ref. 3).

At Grand Gulf Nuclear Station, some pullby damage was detected. Extensive evaluations by the licensee, however, demonstrated that the damage was limited in scope. These evaluations consisted of a review of safety-related conduits for Unit 2 and inspections or high potential testing of the cables in 87 conduits. The inspections and tests found damage to a total of ten cables, only some of which had insulation damage (Ref. 4).

4.2 TVA Experience With Pullbys

TVA Experience at Watts Bar

In June 1989, TVA removed and inspected cables in some conduits at Watts Bar Unit 2 to address an employee concern that those cables might have been damaged by heat from welding activities. Although no heat damage was found, 5 instrumentation cables were found with exposed conductors. The insulation damage, which was attributed to pullbys, occurred in three conduits. In response, TVA removed 358 cables (approximately 30,000 feet of cable) from 28 additional conduits. These conduits were selected because they were considered to have the most credible chance of containing pullby damage. The conduits selected included Unit 1 conduits corresponding to the Unit 2 conduits in which damage was found and several other conduits selected based on conduit length and percent of conduit fill. Only two more cables were found with pullby damage (Ref. 5).

Subsequent evaluations of the pullby issue at WBN included the removal and inspection of approximately 2200 additional cables, and high potential tests of another 410 cables. These cables were considered to have the most credible chance of being damaged due to pullbys. Two additional damaged cables were found among those removed and inspected. Of the 2950 cables inspected and tested at WBN to date, 9 cables were found with pullby damage to the cable insulation. An additional 17 cables had pullby damage to the cable jacket only (Ref. 6). However, jacket damage to these cables is not considered significant since the jacket had fulfilled its function of protecting the cable insulation during installation. The pullby damage at WBN was limited to 7 conduits, each of which had large numbers of pullbys.

TVA has also performed a root cause analysis to identify the specific cause for the cable damage at WBN. This analysis determined that the use of small diameter braided nylon parachute cord was the primary cause of cable pullby damage at WBN.

At WBN, 1/8 inch parachute cord constructed of braided nylon was often installed in conduits along with the first cables pulled for use as a pilot line for pull ropes. Nylon parachute cord can still be seen at conduit ends and conduit bodies of many conduits at WBN. The parachute cord, although small in diameter, is very strong (335 lb. tensile strength - (Ref. 7, pg. 24)). Under high tensile loads, this small diameter cord is capable of applying local rubbing stresses on the cable sufficient to damage the insulation. The

Electrical Insulation Research Center (EIRC) at the University of Connecticut performed tests and evaluations for WBN cable damage, and concluded that "the cables were found to have been damaged in a manner consistent with pullby damage, resulting from contact with a parachute cord..." (Ref. 7, pg. 28). The EIRC also performed tests which simulated the pullby damage mechanism and stated in its report, "The pull rope was not used in the pullby simulations as it was determined by EIRC to be too large in cross section to have inflicted the type of localized damage found on the surfaces of the cable" (Ref. 7, pg. 12).

TVA Experience at Browns Ferry and Sequoyah

Pullbys were also performed during the construction of the TVA Browns Ferry and Sequoyah nuclear plants and TVA has previously evaluated the possibility of pullby damage at these two plants. Significantly, the investigations at Browns Ferry (BFN) and Sequoyah (SQN) found no damage due to pullbys (Ref. 8 and 9). Parachute cord was not used at BFN or SQN. Investigations at BFN and SQN, which have been previously reviewed with the NRC, are briefly discussed below.

At BFN, TVA identified the safety-related conduits required for Unit 2 operation containing more than one cable. This population of approximately 1330 conduits was screened further to identify the conduits having the greatest potential for containing cables with pullby damage. The screening identified 59 conduits. These 59 conduits were inspected to obtain detailed as-built geometries and 10 of these conduits were selected for high potential testing. In total, 137 cables in these 10 conduits were subjected to high potential tests at 4800 to 7200 volts direct current to determine if pullby damage existed. No cable damage due to pullbys was found (Ref. 8). The results of these tests showed that systematic damage due to pullby did not occur at BFN Unit 2.

At SQN, TVA also reviewed safety-related conduits in Units 1 and 2 (approximately 9,500 conduits) to identify a population of conduits having some potential for containing cables with pullby damage. TVA selected 15 conduits for high potential testing. In total, 298 cables in these 15 conduits were subjected to high potential tests at 4,800 to 7,200 volts direct current. No cable damage due to pullbys was found (Ref. 9).

Parachute Cord Not Used at Bellefonte

Because nylon parachute cord was identified as the cause of the pullby damage at WBN, TVA thoroughly investigated the potential for nylon parachute cord damage to have occurred at BLN. This investigation has found no indication that nylon parachute cord was used at BLN. A review of applicable warehouse records, including warehouse commodity ledgers, contract files, and material transfer and receiving records, concluded that BLN has not received or stocked nylon parachute cord (Ref. 10). To confirm that nylon parachute cord was a construction commodity recorded in TVA warehouse records, a check of the WBN construction warehouse records was made. These records showed that more than 490,000 feet of nylon parachute cord was received at WBN (Ref. 11).

Discussions with persons who were directly involved with the cable installation at BLN also confirmed that nylon parachute cord was not used at BLN. Instead, larger diameter ropes having a twisted construction were used at BLN. To further confirm the absence of parachute cord at BLN, a walkdown of safety-related conduits was conducted in 1991 of the Unit 1 and common areas of the BLN reactor, auxiliary, control, and diesel generator buildings. During the walkdown approximately 450 conduits were inspected at accessible points for the presence of parachute cord. No parachute cord was found and no cable damage was observed (Ref. 12).

4.3 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 the 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)."

In addition to QCP-3.4, additional requirements governing cable installation 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. 24 and 25).

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

Control of Pull Tension

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 a 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. 13).

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.

<u>Use of Lubricants</u>

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 and thereby reduce the potential for pullby damage. A review of BLN construction warehouse records was made to confirm the use of lubricants during cable pulling operations (Ref. 14). The results of the 1991 review indicate that 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.

<u>Training of BLN Personnel</u>

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 Bellefonte 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 Bellefonte 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." Similar 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. 15).

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 checklist to assist the inspectors in the field. These checklists were completed and signed by the inspectors and filed along with the cable pull card. A review of over 1,800 cable pull card records confirmed compliance with these procedural requirements.

4.4 BLN Cable Installation

Status of 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 9 million feet. The majority of the safety-related cable is installed in cable tray; of the 3.1 million feet, approximately 1.0 million feet (32 percent) is installed in conduit.

Comparison of BLN Installation to BFN and SQN

Evaluations of the BLN cable installation were made and the results compared to BFN, SQN and WBN where data were available. The comparison with WBN is discussed in the following section. The comparisons drawn indicate that the BLN cable installation, with respect to pullbys, is comparable to BFN and SQN and is better than the WBN installation.

As part of the pullby evaluations at BFN and SQN, safety-related conduits were screened initially to identify those conduits based on length and potentially having large numbers of pullbys. Comparable data for WBN was not available because a different approach was used for the pullby evaluations there.

At BFN, the screening criteria used were:

1) Conduits in voltage levels[1] V1, V2, and V3 having a length 20 feet or longer and containing 8 or more cables; and

2) Conduits in voltage level V4 having a length 20 feet or longer and containing 4 or more cables.

At SQN, the screening criterion used was:

1) Conduits in voltage levels V1, V2, V3 and V4 having a length 20 feet or longer and containing 7 or more cables.

The detailed results of the BFN and SQN screening are documented in References 16 and 17, respectively. The BLN installation was compared to the installations at SQN and BFN using the screening data available for those plants.

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1 VOLTAGE LEVEL DEFINITIONS

At Bellefonte, cable systems are divided into five categories dependent upon the voltage level of the electrical system and the nature of the service provided by the end device. Cable systems are designated as V1, V2, V3, V4, and V5. Similar designations are used at the other TVA plants. The following is a brief description of these cable designations:

V5 This category consists of shielded cables rated 8KV and 15KV that provide power at 6.9KV and 13.8KV AC to boards and large motors.

V4 This category consists of cables rated at 600V AC that provide low voltage power at service voltages from 277 to 480V AC. In addition, AC and DC control power cables with service voltages of 277V or less, that have a protective device rated greater than 30 amps, are also designated V4. These cables are not shielded.

V3 This category consists of non-shielded 600V cables used for AC or DC control application with service voltages of 277V or less. These cables are not shielded.

V2 This category is comprised predominantly of shielded cables rated 600V or 300V in medium-level signal applications such as transmitters, RTDs (greater than 100mV), rotor eccentricity and vibration detectors and annunciators.

V1 This category is comprised of shielded cables predominantly rated 600V or 300V AC in low-level instrumentation applications such as thermocouples, strain gauges, thermal converters, and RTDs that are 100mV or less.

For the purposes of comparison, BLN safety-related conduits were screened using the BFN criteria and the information in the ECM&D[2] computer database (Ref. 18). ECM&D was used as a construction status tool prior to construction deferral and is, therefore, believed to contain data which accurately reflect the cable installation status at BLN.

The pre-screening populations of conduits selected for each plant were different. At BFN, conduits from Units 1, 2, and 3 which contained safety-related cables required for Unit 2 operation were selected (approximately 1330 conduits). For SQN, safety-related conduits required for Unit 1 or Unit 2 operation were selected (approximately 9500 conduits). For BLN, safety-related conduits required for Unit 1 fuel load and having installed cables were selected (approximately 4800 conduits).

The BLN conduits which met the BFN screening criteria 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, the numbers of cables per conduit, and the number of pullbys per conduit. Table 1 contains the results of that comparison. The results indicate that the number of conduits which met the screening criteria at BLN and SQN are comparable on a percentage basis.

Comparisons of conduit lengths and sizes were made to determine whether the conduits selected by the screening process for each plant comprise a population of conduit configurations which is similar for all three plants. The tabulated values of median length and most common size indicate that these conduits are roughly of the same lengths and sizes. Comparisons of the numbers of cables per conduit were also made to determine if screened conduits for each plant fell within the same general population of conduit configurations. The median and average values indicate that the BLN conduits have slightly fewer cables, on average, than the BFN and SQN conduits. In terms of numbers of pullbys per conduit, the conduits for each plant are also comparable.

Overall, among the three plants, the conduit attributes within the sample selected are very similar. Conduit lengths, sizes, and the number of installed cables and pullbys per conduit are roughly the same, on average. This suggests that, based on the configuration of the installation, the potential for pullby damage at BLN is similar to that at SQN and BFN, where extensive investigations and tests have found no pullby damage.

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2 ECM&D - Engineering and Construction Monitoring and Documentation computer database.

Comparison of BLN Conduit Fill with WBN Conduit Fill
The most direct comparison which can be made between BLN and available WBN data related to the potential for pullby damage is on the basis of conduit fill. Conduit overfill increases the potential for pullby damage. Similar conduit fill results were not available for BFN or SQN.

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. 19). Safety-related conduits in Units 1 and 2 containing installed cables were included in the BLN calculation. The WBN calculation identified over 980 safety-related conduits which were overfilled (Ref 20). By contrast, the BLN calculation determined that only 64 conduits are overfilled at BLN. Many of these 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 TVA design criteria by approximately 5 percent.

Of the 64 overfilled safety-related conduits at BLN, 48 contain only one cable identifier and 16 contain multiple cable identifiers. The conduits with only one unique cable identifier contain three single conductor cables which comprise a single three phase circuit. These conductors were likely pulled together as a group and therefore were not subjected to pullbys. Four of the 16 conduits containing multiple cable identifiers had no pullbys, eight conduits had only one pullby, three conduits had only two pullbys, and the remaining conduit had seven pullbys. The conduit with seven pullbys is less than one percent overfilled (Ref. 21).

Based on this comparison of the conduits at BLN with those at WBN, the BLN installation is shown to be more favorable and therefore less likely to have problems with pullbys.

Assessment of Installation
The comparisons to the other TVA nuclear plants discussed above, showed that the BLN cable installation is generally comparable to or more favorable than the installations at these other plants. Extensive investigations at these other plants have found no indication of a problem with cable damage due to pullbys except for a few instances of damage caused by parachute cord at WBN. Nevertheless, to further assess the cable installation at BLN, a qualitative assessment of the safety-related cable tray and conduit installations at BLN was made in April of 1991 by a four-member team consisting of three senior electrical engineers and a senior electrical designer. The team was comprised of representatives from 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. 22).

The team reviewed applicable BLN site procedures and cable tray and conduit layout drawings and performed walkdowns of the BLN installation. All members of the team also visited Watts Bar to gain an understanding of the cable installation issues there and to conduct a plant walkdown. The objectives of the 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. The areas evaluated were selected to include a variety of equipment types, areas with heavy concentrations of cable, and harsh environments. These areas included:

- Cable spreading room

- Control room panel wireways

- Safety related Solid State Control System cabinet rooms

- Reactor building primary containment and annulus areas

- AC and DC power distribution switchgear, motor control centers and distribution panels

In addition to the general area walkdowns, 31 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 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 considers that these results confirm that the existing conduit installation at BLN is conducive to easy cable pulling and, therefore, there is reasonable assurance that systematic cable damage does not exist.

<u>Reinspection of Installed Cables</u>
During the period between 1985 and 1988, a number of conduits were reinspected as part of the corrective action to resolve nonconformance report NCR 4254 at BLN. The NCR was written to address nonconformances that were identified during final raceway verification inspections. A number of different specific nonconformances were identified in the NCR. These nonconformances included issues regarding the distances between conduit supports, the type, sizing and bolts for conduit straps and the status of pull tests for anchors. As a result of the reinspection effort some conduits were reworked. In a number of cases, the rework required the removal of cables installed within the conduit. In such cases, the cables were removed, inspected for damage and reinstalled in accordance with established BLN site procedures after the conduit rework was completed.

In 1991, construction records for the NCR 4254 reinspection effort were reviewed to identify those conduits at BLN which had had their installed cables removed and inspected. The records for these conduits were then reviewed to identify those containing cables which were involved in a pullby during initial installation. A total of 247 cable pull work packages were reviewed in 1991 as part of the evaluation of the conduit rework effort. These work packages covered the rework of approximately 590 conduits. The construction records show that the cables within 32 of these conduits were involved in pullbys during initial installation and were removed as part of the conduit rework effort. The records reviewed also show that the cables within these conduits were pulled out in a controlled manner and inspected for damage by BLN quality control inspectors. The 32 conduits ranged in diameter between 0.75 and 5.0 inches and length between 2 and 120 feet. A total of 110 cables, comprising roughly 1400 feet of V2 cable, 1700 feet of V3 cable, and 120 feet of V4 cable, were inspected and the construction records indicate that no pullby damage had occurred during the initial installation (Ref. 27).

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 TVA employee concern in 1985 regarding sidewall bearing pressure calculations for cable pulls in TVA plants.[3] 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. They found that the "Design of conduits for Bellefonte 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. 23). The NRC inspectors concluded that "no violations or deviations were identified within the areas examined" (Ref. 23).

4.5 Plans for Remaining Work at BLN

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 the conduit rework discussed above or modifications required by any new system design criteria. In performing this remaining cable installation work, the following requirements in TVA General Construction Specification G-38 will be implemented to further assure against pullby damage:

- In general, pullbys will be avoided.
- When pullbys are judged appropriate by BLN engineering, they will only be permitted under close engineering guidance and supervision.
- In no case will pull ropes already installed in conduits be used.

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. Preoperation testing includes closed loop 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.

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3 The question of sidewall bearing pressure calculations at BLN is being addressed by TVA in a separate position paper.

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 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; Volume 4, Number 3, July 1989

2. NUREG/CR-5461 SAND89-2369; "Aging of Cables, Connections, and Electrical Penetration Assemblies Used in Nuclear Power Plants"; published July 1990; prepared for US Nuclear Regulatory Commission by Sandia National Laboratories

3. Texas Utilities letter (W. G. Counsil) to US NRC; dated February 12, 1988; Comanche Peak Steam Electric Station (CPSES) 10CFR50.55(e); Potentially Reportable Items Deemed Not Reportable

4. Mississippi Power and Light Company letter to U.S. NRC (J. P. McGaughy, Jr. to J. P. O'Reilly); dated May 19, 1981; Grand Gulf Nuclear Station Units 1 and 2, Final Report, Cable Damage During Rope Pulling

5. TVA letter to NRC; dated December 20, 1989; Watts Bar Nuclear Plant Units 1 and 2 - Electrical Cable Damage - Assessment and Resolution Plan; (L44 891220 806).

6. TVA Watts Bar Nuclear Plant, Special Trend Analysis - Spare/Abandoned Cable Problems, Damaged Cable, Misrouted Cables and Undocumented Splices, Revision 1; November 1990; (B26 901121 403).

7. Analysis of Damage to Instrumentation Cables Removed from Watts Bar Nuclear Plant; Prepared by University of Connecticut, Electrical Insulation Research Center (EIRC) - Institute of Materials Science; dated December 11, 1989

8. TVA letter to NRC; dated October 4, 1990; Browns Ferry Nuclear Plant - Unit 2 - Revision to the Cable Installation Issues Supplemental Report - Cable Pullby (L44 901004 801)

9. TVA letter to NRC; dated October 23, 1990; Sequoyah Nuclear Plant (SQN) - Units 1 and 2 - Cable Test Program (CTP) Resolution Plan (TAC No. 77129/77130) (L44 901023 802)

10. TVA memorandum (J. L. Langston to R. C. Miles); dated February 5, 1991; Bellefonte Nuclear Plant, Electrical Cable Installation Pull Ropes, Nylon Parachute Cord

11. TVA memorandum (J. R. Borum to J. Langston); dated February 1, 1991; Watts Bar Nuclear Plant - Review of Construction Warehouse Records for Receipt of 1/8 Inch Nylon Parachute Cord (T68 910205 072)

12. Gilbert/Commonwealth letter to MPR Associates (R. A. McNabb to R. M. Carritte); dated February 25, 1991; Walkdown of BLN Safety Related Conduits for Nylon Parachute Cord

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

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

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

16. TVA Calculation ED-Q2999-900072; Calculation for Analysis of Cable Pullby Concerns at BFN; Revision 1; dated February 7, 1991; (B22 910211 101)

17. TVA Calculation SQN-CSS-033; Calculation for Analysis of Cable Pullby Concerns Sequoyah Nuclear Plant Units 1 and 2; Revision 0; dated October 5, 1990, (B87 901005 004)

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

19. United Engineers and Constructors letter to MPR Associates; dated April 25, 1991; Bellefonte Nuclear Plant Cables in Conduit - Percentage Fill (PE129AE-07)

20. Report for Overfilled Raceways For Watts Bar Units 1, 2, and Common Areas; Prepared by Stone and Webster Engineering Corporation for TVA; forwarding letter dated September 12, 1989; (B26 810918 523)

21. United Engineers & Constructors letter to MPR Associates (R. Bryans to H. Estrada); dated April 24, 1991; Bellefonte Nuclear Plant; Summary Report - Cable Pullbys in Overfilled Conduits

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

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

24. 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

25. 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

26. Gilbert/Commwealth letter to MPR Associates (J. Ioannidi to R. M. Carritte); dated April 25, 1991; Bellefonte Nuclear Plant - Cable Pullby Issue Study

27. Gilbert/Commonwealth letter to MPR Associates (R. A. McNabb) to R. M. Carritte); dated April 23, 1991; Bellefonte Nuclear Plant, OS Conduit Evaluation

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
d. NUMBER OF PULLBYS PER CONDUIT			
MAXIMUM	15	14	17
AVERAGE	4	4	5
MEDIAN	4	3	4
MINIMUM	0	0	0

TABLE 1

COMPARISON OF PULLBY 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 was not available for WBN because a different approach was used to evaluate pullby concerns.

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

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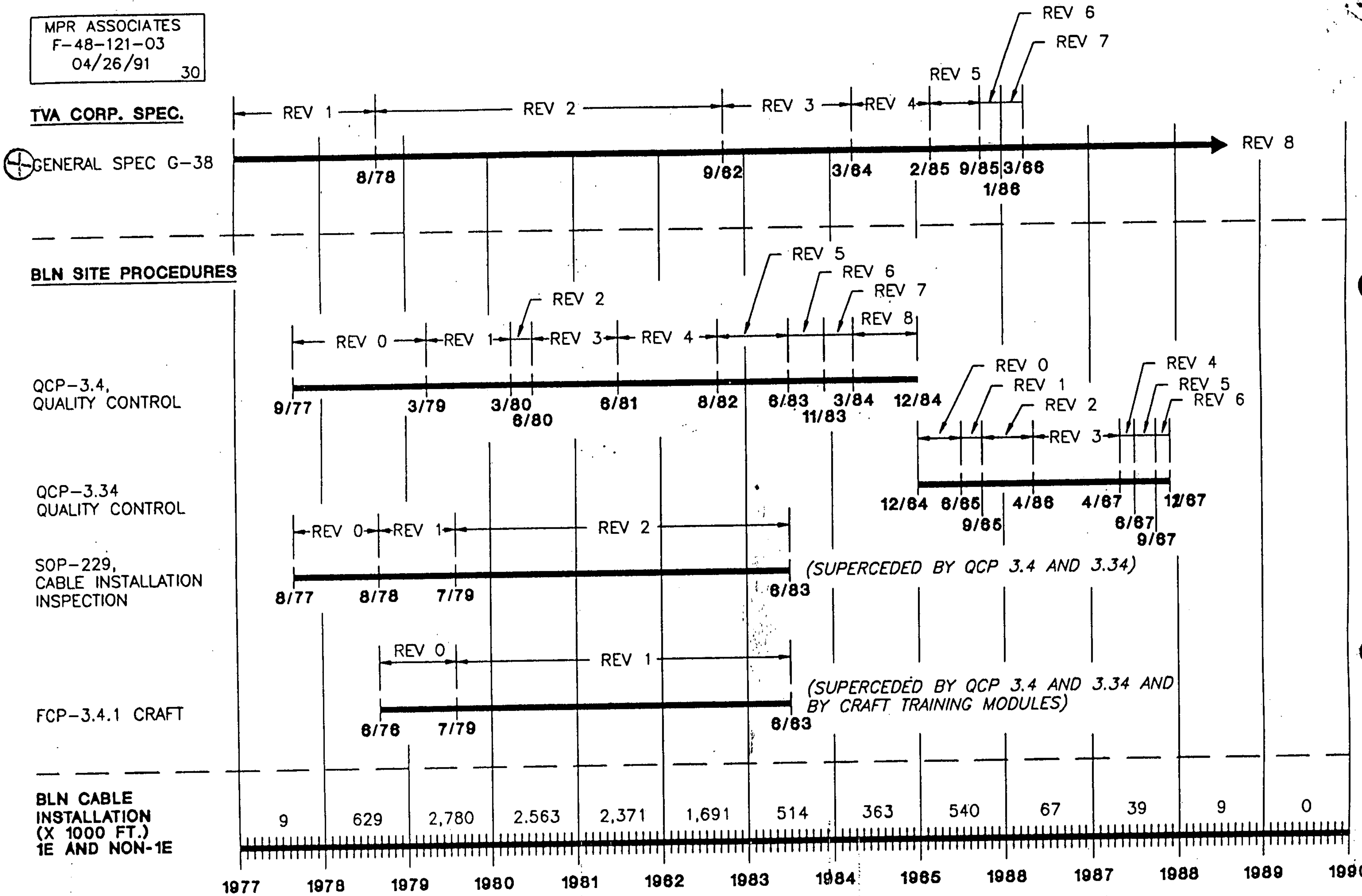

CABLE INSTALLATION PROCEDURES AND SPECIFICATIONS FOR BELLEFONTE NUCLEAR PLANT

FIGURE 1