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

JUL 22 1994

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

Gentlemen:

In the Matter of the Application of	)	Docket Nos. 50-390
Tennessee Valley Authority	)	50-391

WATTS BAR NUCLEAR PLANT (WBN) - TECHNICAL EVALUATION REPORT (TER) C5506-649

The purpose of this letter is to provide NRC with a response to the issues in the WBN Technical Evaluation Report issued on March 10, 1987, relative to the applicability of TVA's cable sidewall bearing pressure testing program to actual plant installation conditions. The enclosed response is in accordance with the commitment made in TVA's letter dated October 11, 1990. No new commitments are made in this letter.

If you should have any questions, contact P. L. Pace at (615)-365-1824.

Sincerely,

Dwight E. Nunn
Vice President
New Plant Completion
Watts Bar Nuclear Plant

Enclosure
cc: See page 2

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ENCLOSURE

TVA RESPONSE TO ISSUES IN
TECHNICAL EVALUATION REPORT (TER) C5506-649

On March 10, 1987, the NRC transmitted to TVA a Technical Evaluation Report (TER) titled, "Evaluation of Watts Bar Units 1 and 2 Cable Pulling and Bend Radii Concerns." The report dealt with a number of emerging cable related issues at Watts Bar and identified several additional concerns. In general, the report noted the lack of procedural control of the conduit and cable installation process. A number of the issues had already been identified through a variety of in-house programs. Many of the corrective action programs were under way at the time the TER was received.

One such corrective action program was undertaken in late 1985 as a result of a Nuclear Safety Review Staff report. Subsequent calculations by WBN showed that the allowable values of sidewall bearing pressure (SWBP), which were then current, may have been exceeded in a number of runs. In response to this condition, numerous cable specimens were collected, representative of the various constructions, materials and vendors who had supplied cable to TVA. These specimens were taken to the TVA laboratory at the Chickamauga Power Service Center in the spring of 1986 and were subjected to a series of tests to determine if new (increased) SWBP limits could be established.

In designing its test protocol, TVA drew heavily from the benchmark work by the Electric Power Research Institute (EPRI) which had been published in February 1984. The report of this work, EL-3333, "Maximum Safe Pulling Lengths for Solid Dielectric Insulated Cables," Volumes 1 and 2, details a series of closely controlled cable pulls which produced "high" values of SWBP. The pulls were then followed by visual inspection and a high voltage ac breakdown test. The results of the breakdown strength tests on the stressed cable were compared to the results of the same tests performed on virgin material. In general, the test program, which primarily focused on distribution style cables, demonstrated that the cables possessed a capacity to endure SWBPs six to ten times above the published values of 150 to 400 lbs/ft. Based on the tests, EPRI recommended new limits for 600 volt cables with cross linked polyethylene insulation (1200 lbs/ft) and ethylene propylene rubber (1000 lbs/ft). Even higher values were recommended for medium voltage cables (1200 - 2000 lbs/ft).

Though the EPRI results were not directly applicable to WBN due to the differences in cable construction, they provided an indication of the typical conservatism embodied in the existing limits and a clear methodology for performing additional evaluations. In order to ensure that the EPRI methodology was appropriately applied, D. A. Silver and Associates was engaged to perform an independent review of the TVA program. Silver, who had been the principal researcher for the EPRI work, concluded that the TVA tests could serve as a basis for consideration of higher permissible SWBPs.

When the NRC's consultants from Franklin Research Center (FRC) reviewed WBN's various programs related to electrical cables, they noted the existence of the TVA tests and offered numerous comments relative to the applicability of the results to the installations in the plant. In general, they expressed concern that the results obtained in the laboratory, under finely controlled

conditions, may not be reflective of those in the plant, given the lesser degree of control and the high dependence upon the skill of the craft. Those comments appeared in the TER on Pages 28, 29 and 30, in a section entitled, "Cable Sidewall Bearing Pressure Tests," and in the "Conclusions," section on Page 47.

It is the intent of this document to respond to the concerns raised by the FRC team in accordance with our commitment from the August 1-3, 1990, meetings held at WBN. It is acknowledged from the outset, that the numerous calculations, in situ dielectric tests and inspections performed over the intervening period, provide WBN with much data which was, of course, not available to TVA, the FRC team, or to the Staff in 1987. Thus, we believe that many of the issues have become somewhat more academic than they were in 1986. The integrity of the WBN cable systems has been established by the SWBP tests and the corresponding set of bounding calculations, as well as the programs described in the Cable Issues CAP.

During individual cable inspections, evidence of high SWBP was only noted in the powerhouse and duct banks on cables removed from conduits wherein kinks were noted to have been pulled and in duct banks where the cables were suspected to have slipped off their sheaves. In both of the above cases, the occurrence of the high SWBP was a secondary result of other phenomena, rather than the prime cause of the observed damage.

In the paragraphs that follow, the FRC team's comments have been reproduced and are then followed by the WBN response. For the sake of clarity, quotations from the TER are shown in bold type.

Section 8. CABLE SIDEWALL BEARING PRESSURE TESTS

The TVA test program for sidewall bearing pressure (SWBP), performed in April and May 1986, and its report [1] dated May 1986 represented ideal conditions and may have little direct applicability to the cables pulled during Watts Bar construction. Both situational and technical factors lead to this conclusion.

The situational differences between the station conditions and those simulated by the test are:

TER 1 **The method of applying lubricant and the probable effectiveness are totally different. The special flooding device, "Soaper" used in the test was not available for field installations and, more often than not, could not have been used because of the very difficult accessibility of cable feed and pull points during installation.**

WBN 1 In general WBN agrees with the comment. In the field, lubrication techniques and extent undoubtedly varied according to the craft's perception of the severity of the pull. Devices such as the "soaper" are not warranted for any but the worst of pulls and even then, alternate methodologies may be employed which will provide satisfactory lubrication. Thus, if the intent of the tests were to mirror field practices, many variants would be required. However, the intent of the TVA tests, as in the case of the EPRI tests and those performed by cable vendors, was not to replicate any given field practice but to evaluate a cable's

performance when exposed to a given force. In order for such materials tests to provide a meaningful comparison of the performance of the different cables, a consistent degree of lubrication from one test pull to the next must be provided. Thus, utilization of a device such as the "soaper" was required.

Once maximum allowable pull tensions have been established, the effectiveness of lubrication determines the relative ease of two identical pulls or the distance through which the craft can pull before reaching the limiting tension. However, the cable's response to the limiting sidewall bearing pressure will be the same regardless of the distance into the run where it occurs.

TER 2 **The Polywater lubricant specified for the test was not available at the time of most of the cable installation and is far superior to the lubricants that were actually used. The superiority involves both the low coefficient of friction attained and its resistance to being wiped off the cable surface during pulling. This superiority is significant because damage to cables from severe drag forces is much more common than from radial (SWBP) pressure alone.**

WBN 2 FRC team is correct regarding the use of lubricants other than Polywater during the greater part of the cable installation phase at WBN. As above, the intent of the tests was to evaluate the cable's response once the SWBP limit was reached rather than assessing the performance of various lubricants.

It is true that if the lubricants were to be wiped off during pulling, the coefficient of friction would increase greatly. However, Polywater has been shown to be superior in remaining with the cable and providing that lubrication. Numerous inspections performed during cable removal activities at WBN since these concerns were expressed have demonstrated the ability of the earlier lubricants to remain on the jackets through a variety of lengths and configurations. The result postulated by the FRC team may indeed occur in distribution applications where there are somewhat longer runs than are utilized in typical generating station pulls.

TER 3 **There is no indication that the test conduits were thoroughly cleaned of lubricant between tests. Therefore, lubricant from prior test pulls probably was present in subsequent tests and made lubrication nearly perfect for the tests - far different than pulling into virgin dry conduits as occurred at the Watts Bar plant site.**

WBN 3 As above, the intent of the tests was to determine the response to a known amount of SWBP. Therefore, in order for the results to be comparable from specimen-to-specimen, consistency in lubrication was desired. The use of the prelubricated (i.e., not thoroughly cleaned) duct likely resulted in a lower coefficient of friction and necessitated the use of more back tension in order to develop the desired SWBP, but would not affect the cable's response to that SWBP once it was reached. As noted

above, such variations in lubrication in the field will affect the distance through which one can pull before reaching the predetermined tension limit, but will not affect the response once that limit is reached.

EPRI reported coefficients of friction for both lubricated cable being pulled into a "clean, dry duct" and "when a cable is pulled into a pre-lubricated duct." The former coefficient is shown as μ_k^1 in tables 5-4 and 5-5 below, while the latter coefficient is shown as μ_k^2 in the same tables. A comparison of the results shows that the two values are very close, except for neoprene jacketed cable pulled into PVC duct. In the case of that combination, EPRI noted that under high normal pressure (greater than 150 lbs/ft) the coefficient of friction dropped to 0.12 (see EPRI Table 5-7). While WBN has not utilized Neoprene as a jacketing material, it is expected that chlorosulfonated polyethylene jackets would perform in a similar manner. The following table summarizes that data:

Table 1

Excerpts from Tables 5-4 and 5-5 of EL-3333

Jacket Material	Duct Material	Lubricant Type	μ_k^1	μ_k^2
PVC @ 25°C	PVC	1,3,5,6	0.5	0.38
	PVC	2,4	0.43	0.45
	Steel	3	0.58	0.49
N @ 25°C	PVC	1,3,6	1.11	0.7
	Steel	1,3,6	0.88	0.8
PVC @-7°C	PVC	1,3,6	0.23	0.19
	PVC	2,4	0.38	0.32
	Steel	2	0.34	0.3
N @-7°C	PVC	1,3	0.36	0.41
	PVC	6	0.11	0.15
	Steel	1,3,6	0.65	0.52

Lubricant Types:
1. Soap and water
2. Bentonite clay and water
3. Soap and water
4. Bentonite clay and water
5. Talc, stearyl alcohol, and stearate water
6. Soap and water

TER 4 **Careful monitoring of cable tensions as performed during the tests was seldom done at the Watts Bar plant and apparently**

was never recorded in the field. Therefore, neither the magnitude nor instability of tensions can be compared between the tests and the actual installations. "Monitor" is used in a quantitative (measurement) sense, not that of TVA standards where it implies only that some means is used to limit the tension.

WBN 4 WBN's practice was to establish the maximum tension and choose the appropriate breaklink. Documentation rarely indicated the size of that link and seldom, if ever, noted the actual tension. Tension monitoring during the tests was more elaborate than WBN typically utilizes during routine installation. Although such complexity is appropriate for laboratory testing, it is not generally warranted in the field. This is typical practice in the industry and is not unique to WBN.

TER 5 **Multicable pulls with cables of mixed sizes and construction as commonly found at the Watts Bar plant were not included in the tests.**

WBN 5 While the FRC team statement is true regarding the TVA test program, the other published SWBP tests results of which we are aware were conducted similarly. The purpose of all such tests is to expose a cable to a known value of SWBP and observe the effect. With single cable pulls, or multicable pulls where all cables are the same, the response of the most severely degraded cable can be taken to be the response of any cable in the bundle had it been adjacent to the conduit wall. In tests involving mixed sizes, one would need to confirm which cable was "on the bottom" and thus subject to the worst case forces from both compression and shear. Considering the complexity of determining which cable was on the bottom and the fact that this would yield no unique data, testing has traditionally exposed one construction at a time.

It is likely that the FRC team was concerned for the division of tension between cables of different sizes during such pulls rather than the effect of a given SWBP acting on the group. Inspections and tests performed since 1987 have produced many data points not originally available. Many conduits have been reworked which contained cables that would have been a part of multicable pulls involving mixed sizes. The inspection data has not indicated the presence of a unique problem for this family.

TER 6 **The pulling source of the test was especially engineered to provide as smooth (continuous) a tension as possible, which is in stark contrast to the field where such methods were apparently seldom, if ever, used.**

WBN 6 In keeping with the intent of the tests, smooth, continuous pulls were desirable to ensure repeatability. In order to achieve such conditions, a tugger was utilized for all tests. It is also true that, according to records, WBN seldom used

mechanical pulls. While hand pulls are not as smooth and tend to be far more variable, it is also true that hand pulls are chosen because the associated conduit runs are not as severe as those which lead to the use of the tugger.

TER 7 **Pullbys, recognized by the industry and by TVA in its recent change to G-38 as potentially damaging to in-place cables, were not evaluated or considered in the scope of the tests.**

WBN 7 In June of 1989, several instances of pullby damage were found in a single run of conduit. This led to an in-depth evaluation of the susceptibility of cables at WBN to pullby damage. Numerous circuits were removed for inspection, a ranking process was established, DC high potential tests were performed, and a large family of cables categorized as "high risk" for the issue of pullbys were replaced. Our analysis has shown that the pullby damage appeared to have been the result of the use of a nylon pull cord, known as "parachute cord," rather than cable-to-cable sidewall bearing pressure. The results of this work have been presented to the NRC Staff in numerous Rockville and WBN meetings and the subject of several submittals since the TER comment was made.

TER 8 **Swivels used during the tests were apparently not commonly used at the Watts Bar plant. There were no requirements for use of swivels and no requirement to record the use of swivels when they were used.**

WBN 8 The statement that swivels were seldom used is likely true. However, as noted in the TER, "controlled mechanical pulling was seldom the situation" at WBN. Instead, the majority of pulls were made by hand. This indicates that the runs were relatively benign such that limiting values of SWBP were not likely reached.

TVA's tests utilized swivels. Since this would have tended to expose the same surface to the high SWBP at each bend it would appear to make the TVA test conservative.

TER 9 **The mixing up, twisting, and crossing of cables fed in and out of many successive condulets or pull boxes, as probably occurred in Watts Bar cable pulls, was not evaluated during the test. As the number of random crossovers increases, the potential for damage at sidewall bearing points increases rapidly. It is one of the many reasons for conservatism in industry-recommended practices relating to the limits for SWBP but was absent in the tests.**

WBN 9 We are unable to locate any discussion of the mechanism postulated by the FRC team in the literature. The Station Cable Subcommittee of the Insulated Conductors Committee, Working Group 14-1 on "Station Cable Installation," has just successfully balloted P-1185. That Committee consists of numerous representatives from utilities, manufacturers and consultants. This document is being issued to address those

areas which were not covered by IEEE 422 or 690, yet makes no mention of the concern.

Aside from the current lack of consensus regarding this mechanism, the protocol was structured to ensure that the specimens were consistently subjected to the desired levels of SWBP rather than doing so in a random manner. In addition, the extensive tests and inspections have provided alternate assurance not available in 1987.

TER 10 **The steel conduits used in the tests develop low coefficients of friction with slight lubrication and are not damaged by cable or fiber pulling lines, whereas ducts of other materials (plastic, transite, fiber) are more readily damaged and, in turn, affect the friction and damage potential to cable. Duct materials other than steel were used in certain portions of the Watts Bar plant, but not evaluated in the test.**

WBN 10 At WBN, all conduits are rigid steel with the exception of a limited number, which are PVC, used in underground duct banks between the powerhouse and either the intake structure or the diesel generator building.

Cables in several ducts were removed as a part of our pullby program. Where cable damage was noted, the ducts were inspected. Several instances of fractured ducts were noted and several instances of ducts indented at rebar crossings were observed. Thus, it became standard practice to pass a mandrel through the ducts to ensure that they had not been damaged. No evidence of damage consistent with cables having been pulled through duct damaged by pull ropes was noted.

TER 11 **Several major technical issues also bring into question the applicability of the test results:**

The tension necessary to move the cable loop through the test rig was not measured so there is no means of determining or investigating the actual coefficients of friction. (The tension in the cable loop was monitored.)

WBN 11 The above statement is true. However, the intent of the program was to evaluate the effect of SWBP on cable rather than to evaluate the coefficient of friction.

TER 12 **There was no program to investigate the conditions necessary to damage cable, or what the mode of or symptoms of damage might be for the several cable constructions tested. Had such "fragility" tests been made, then it is likely that a reasonable engineering assessment could be made as to what actual cable pulling conditions and cable constructions represented the most limiting case that would be expected to lead to cable damage. As it is, it seems unfounded and illogical to assume that the test conditions represent the most adverse conditions in the plant.**

WBN 12 Since the intent of the program was to establish allowable values of SWBP for a variety of constructions rather than to find "the limit," fragility tests were not performed. This is consistent with those SWBP test programs conducted by Rockbestos and EPRI. Performance tests (as opposed to fragility tests) are frequently used in the cable industry. In particular, IEEE 383 and IEEE 1202 require demonstration of performance to a set of conditions rather than identification of ultimate capabilities.

TER 13 **The quick-rise ac breakdown tests used by TVA to evaluate possible damage during the SWBP program consisted of a rapid continuous rise in test voltage until breakdown occurred. However, ac stepped voltage tests having a 5- to 30-minute dwell time at successively higher steps in voltage until breakdown occurs are recognized in insulation science as well as cable engineering practice as much more effective in searching for either manufacturing defects or installation and service-incurred damage. That is why, for instance, such tests are used in AEIC cable qualification tests (not nuclear qualification tests) as cited in their CS5- and CS6-1982 specifications. The distortion or partial disruption of insulation or shield systems due to excessive SWBP would be best detected by extending the time of standard industry ac step tests. Using a quick-rise test will tend to miss evidence of damage observable by longer term ac overvoltage testing.**

WBN 13 The type of breakdown tests utilized by TVA is consistent with the "Short-Time Test" method specified in ASTM D149-1992, "Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies." As stated in section 5.4 of that standard, "Method A" (the short-time test) "is the most commonly used test for quality control tests." Section 12.1.1.1 notes that, "For many materials a rate of 500 V/s is used." The step-by-step test (Method B) is said to potentially, "provide more meaningful results when different materials are being compared." Since the breakdown tests were intended to evaluate the before and after characteristics of two or more specimens of exactly the same material, the use of the short-time tests is consistent with the intent of the standard. The TVA chosen rate of rise was 500 V/s, consistent with section 12.1.1.1. A review of published SWBP tests available to TVA indicates that a similar approach was often chosen by cable manufacturers when performing such evaluations.

TER 14 **The great majority of cable installation pulling damage seen by and reported to the FRC team members over the years has resulted from cable jamming, combined SWBP and drag around bends due to inadequate lubrication, scuffing and cutting of cable by the conduit after the pull line had grooved the inside of conduit bends, saw-through of cable jackets and insulation during pullbys, and pulling cables over sharp or**

rough edges at the end of a conduit. Direct SWBP damage to cables in well lubricated duct bends or over large sheaves has not been a source of problems in the FRC team's experience. However, direct SWBP damage has been experienced where several small rollers were used in place of a large sheave. Therefore, the TVA tests for damage to well lubricated cables passing straight over smooth conduit bends represent a search for a damage threshold seldom experienced in practice and that is not representative of the Watts Bar conditions that would likely have inflicted damage on cables being installed there.

While the test has yielded interesting information on the tolerance of cables to direct radial SWBP, the results are probably quite the same as would be found by running cables over sheaves of similar geometry to that of the conduit bends. However, shear forces parallel to the direction of travel in the jacket and insulating material induced by high SWBP coupled with significant friction coefficients (less than ideal lubrications as probably occurred under the conditions at the Watts Bar plant) can be expected to induce more and different damage effects than radial forces (SWBP) alone. These shear forces were not evaluated during the TVA test program.

WBN 14 As previously noted in the WBN 5 response, many data points have become available since the FRC team concerns were documented as a result of the many tests, inspections and replacements performed since 1986.

The EPRI tests took note of such shear forces, which led to the recommendation that SWBP be limited to 1500 lbs/ft for constructions where the jacket was not tightly applied to the cable core. Cables with tightly bonded jackets exhibited even higher allowables. The new TVA allowables are well below the 1500 lb/ft threshold.

TER 15 Section 14. CONCLUSIONS

4. Sidewall Bearing Pressure Damage

Based on the results of the TVA SWBP tests and those documented in EPRI EL-3333, SWBP damage is not considered to have been a significant concern except for the cases where cable was pulled around the corner of 90 condulets or through flexible conduits having tight bends. The number of 90 condulets and the described method of helping cables through pull points causes a concern to remain that some cables were pulled through 90 condulets and may have been damaged.

WBN 15 In accordance with the WBN Cable Issues CAP, the concern for pulling through 90 degree condulets was evaluated as a part of the Silicone Rubber Insulated Cable Program. Under that program, which was initiated as a result of the concern for impact damage to the silicone rubber insulated cables during shipping, storage, handling or installation, the selection

criteria used to identify the critical case circuits, required that as a minimum, the cable to be evaluated have two 90 degree condulets within its route. Since silicone rubber insulation is more susceptible to damage than other types of insulation, this enveloped all types of damage at WBN. In accordance with the cable CAP, the cables were removed and submitted to a program of thermal and radiation aging and a LOCA. The cables passed the test. For further details, refer to our submittal dated July 9, 1990 (L44 900629 801).