TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE 37401
400 Chestnut Street Tower II

August 22, 1985

Director of Nuclear Reactor Regulation
Attention: Ms. E. Adensam, Chief
Licensing Branch No. 4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Ms. Adensam:

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

Please refer to your letter to H. G. Parris dated June 28, 1985 which requested additional information concerning flexibility requirements in pipe support base plate design using concrete expansion anchors at the Watts Bar Nuclear Plant units 1 and 2.

Enclosed is the requested additional information. The timeliness of this response has been previously discussed with your staff.

If you have any questions concerning this matter, please get in touch with K. P. Parr at FTS 858-2682.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

J. A. Domer

J. A. Domer, Chief
Nuclear Licensing Branch

Sworn to and subscribed before me
this 22nd day of Aug. 1985
Paulette H. White
Notary Public
My Commission Expires 8-24-88

Enclosure
cc: U.S. Nuclear Regulatory Commission (Enclosure)
Region II
Attn: Dr. J. Nelson Grace, Regional Administrator
101 Marietta Street, NW, Suite 2900
Atlanta, Georgia 30323

B001
1/1

ENCLOSURE

WATTS BAR NUCLEAR PLANT
UNITS 1 AND 2

RESPONSE TO NRC QUESTIONS ON FLEXIBILITY REQUIREMENT
FOR PIPE SUPPORT BASEPLATES USING CONCRETE EXPANSION ANCHORS

References:

1. Your letter to H. G. Parris dated June 28, 1985 (L44 850705 763)

2. TVA CEB Report 84-05 - "NRC-OIE Bulletin 79-02 - Pipe Support Baseplate Designs Using Concrete Expansion Anchors - Final Report - Revision 2" (CEB 841210 002)

   a. Appendix B - TVA Civil Design Standard DS-C1.7.1 for General Anchorage to Concrete

   b. Appendix D - Justification for Use of 4t Criteria for Determining Applicability of Rigid Plate Analysis

QUESTION 1A

In section B, page 24 (reference 2a), the method used for analyzing baseplates with four bolts subjected to a uniaxial bending moment appears to be applied to both rigid and flexible baseplates. Justification for this approach should be presented by comparison with BASEPLATE II calculations. Clarification is also needed when this approach is used for biaxial bending (presumably it is not used for combined bending plus axial tension).

RESPONSE

The baseplate analysis methods given in Civil Design Standard DS-C1.7.1 are based on the fact that all baseplates are flexible since they will exhibit deformations under load. However, some baseplates will exhibit such small deformations that rigid baseplate analysis provides adequate estimation of anchor loads. The conservative methods provided for rectangular plates with a single attachment located at the centroid of the bolt group are intended for use in analysis of flexible baseplates. If the methods were applied to a plate meeting rigid plate criteria, the resulting anchor size would be conservative provided the same anchor size was used for all anchor sizes in the plate. The use of the same anchor size and type for all anchors in the plate is standard TVA practice. (Field changes sometimes result in different sizes and types of anchors on the same plate; however, the replacement anchor is required to have a capacity greater than the replaced anchor.)

The attached calculations (attachment 1) provide the justification for use of the method for a baseplate which meets the rigid plate criteria. The results show that hand calculations using this method will result in higher anchor loads than obtained using BASEPLATE II. We use BASEPLATE II as the reference method for evaluating other methods for calculating anchor loads. BASEPLATE II is a finite element method for calculation of anchor loads. However, the calculated loads are only approximations of the actual loads which would develop since the method is approximate (element size, element properties, etc.), and since actual anchor stiffness, variations in anchor stiffness, installed location of the anchors, and anchor tightness all affect the actual inplace anchor loads.

QUESTION 1B

In the same section and page, clarification is needed on the basis for distributing anchor loads by inverse proportion for plates loaded primarily in tension, where the baseplate is apparently considered rigid. In addition, the rigidity requirement should be stated as conforming to IE Bulletin 79-02.

RESPONSE

This method is intended for flexible baseplates but may be used for baseplates which meet criteria for use of rigid baseplate analysis. To our knowledge, this method has not been applied to baseplates which meet rigid plate criteria since analysis for tension using rigid plate methods is much more simple. Rigid plate analysis would result in equal loads in all anchors.

The method was developed to conservatively envelope the results of a BASEPLATE II analysis. This method will result in a large percentage of the tension load on the support being applied to anchors closest to the support. If used for a plate that meets rigid plate criteria, the anchor size selected for the whole group would be based on the loading on the anchors adjacent to the support and would, therefore, be a conservative design. An unconservative design could be obtained if smaller anchors were used for the anchors farthest from the support, but we know of no pipe support designs which called for different anchor sizes on the same plate (see question 1a).

QUESTION 2

Appendix C of section b (reference 2a) states a set of anchor stiffnesses to use with the computer program BASEPLATE II. However, in the response by TVA to Black and Veatch (B&V) inquiry of January 13, 1984, it was stated that the stiffness properties of the anchor bolts are nonlinear and are input into the program in the form of a curve. The specified basis for these stiffnesses or stiffness curves has not been located in the report and should be provided.

RESPONSE

TVA Civil Design Standard DS-C1.7.1 specifies constant stiffnesses for anchors. A question was received from B&V because some of the BASEPLATE II calculations which they reviewed did not have the bolt stiffness input in the same form as other calculations. Also, the value used for the stiffness was not readily apparent. The concern was resolved by explaining that the calculations were performed before Appendix C was added to DS-C1.7.1. For the analysis in question, the designer input the entire stiffness curve from the test data instead of just the linear portion in the working load range. The load deflection curves for expansion anchors are nonlinear; however, the secant stiffness in the working load range can be assumed to be linear.

The stiffness values in Appendix C of DS-C1.7.1 were originally based on several sets of data from tests performed prior to 1980 on 1/2- and 3/4-inch self-drilling and wedge bolt anchors. None of the tests were specifically intended for determination of anchor stiffness, but deflection reading had been taken. The tests for 1/2-inch self-drilling anchors showed deflections at the maximum allowable anchor load from 0.001 inch to 0.02 inch. This corresponds to apparent stiffnesses from about 80 to 1600 kips/inch. The tests for 3/4-inch-anchors showed deflections from 0.003 to 0.03. This corresponds to stiffnesses from about 100 to 1000 kips/inch.

This data and other data that we have reviewed have shown that the variability of observed stiffnesses of expansion anchors is extreme and that any method for calculation of anchor loads will not have great accuracy. The apparent stiffness of the anchor is primarily a function of whether the anchor exhibits a minute slip at the level of the applied load. If some slip occurs, the apparent stiffness will be in the lower range of the values given above.

Tests were recently performed for TVA at the University of Tennessee to simulate actual baseplate installations. One of the primary reasons for the tests was to determine if the results obtained from BASEPLATE II analyses adequately estimated the anchor loads in actual installations. Tests were performed on 16-inch-square plates of various thicknesses with 4-, 6-, and 8-bolt patterns (3/4-inch self-drilling anchors). BASEPLATE II analysis were compared to the test results.

The variability shown in the pre-1980 tests was also exhibited in these tests. However, the anchor loads generally compared to BASEPLATE II analyses using an anchor stiffness of 100 kips/inch. For eight bolt patterns, for which some anchors are closer to the attachment than other anchors, the ratio of the maximum loaded anchor to the minimum loaded tensile anchor was best approximated for most tests using 100 kips/inch.

The full-scale baseplate tests also provided some indication of prying forces since strain gauges were placed between the anchor and the corner of the plate. The strain gages indicated that prying forces were not developed except for 1/2-inch-thick grouted plates with 8 anchors. For this condition, the indicated prying force was less than 5 percent of the anchor load.

Attachments 2 and 3 are plots of the measured elongation of some of the bolts from the full scale tests. Again, significant variability occurred, however, the stiffness are generally in the range used in DS-C1.7.1.

To provide additional information on anchor stiffness, TVA has recently performed a series of tests on single anchors of all types (self-drilling, wedge bolts, undercut, cast-in-place, and embedded). Preliminary evaluation of those tests indicate that the stiffnesses for expansion anchors are variable and are not strongly size dependent. Based on those tests and the full-scale baseplate tests, consideration is being given to revising the stiffness values in Appendix C to specify use of 150 to 200 kips/inch for all expansion anchor sizes and types. Other anchor types do not appear to be size dependent.

In summary, we believe that the stiffness values in Appendix C provide BASEPLATE II results which adequately estimate expansion anchor loads.

QUESTION 3

In section D (reference 2b), "Justifiction of the 4t Criterion," the information required under item 2 (question 2) above is also needed here, since the justification is based on the stiffness of the anchor bolts. The applicant's results show that for plates under pure axial loading the rigid plate approach (8 bolts) underestimates the maximum bolt loads from 5 to 13 percent. Therefore, 4t does not appear conservative under primarily axial tension. The effect of combined biaxial bending and axial tension should also be addressed.

RESPONSE

IE Bulletin 79-02 states that rigid plate analysis may be used if the extension of the plate beyond the attachment is no more than 2 plate thicknesses. It further states that justification may be provided for other criteria. TVA chose to present justification a 4t extension since this criteria, if technically justified, would allow a reduction in the number of baseplates requiring flexible plate analysis. For moment connections, a rigid plate analysis with a 4t extension was known to give approximately the same results as for a BASEPLATE II flexible plate analysis. For tension connections, the 4t extension was expected to give the same anchor loads for most expansion anchored baseplates (4 bolts). For a worst-case condition (8 bolts), the 4t extension was expected to provide results within the accuracy of a BASEPLATE II analysis.

An 8-bolt connection was selected as the worst case for the evaluation because for both bending and tension loadings, at least one anchor is located closer to the attachment than other tension anchors. The bending stiffness of the plate at the closest anchor is higher because the span between the attachment and the anchor is smaller than for the other anchors. Therefore, the closest anchor will pick up more load.

As stated in the calculations, the study was intended for a 3/4-inch self-drilling anchor (stiffness approximately 100 kips/inch). The higher stiffness was investigated to provide information on how stiffness could affect the results. The plate and attachment sizes used for the study are not representative of anchors with stiffnesses of 300 kips/inch or greater. The anchors with those stiffnesses would require larger plates to obtain required minimum spacings.

For moment connections, the calculations in Appendix D (reference 2a) of the final report show that a rigid plate analysis gives a higher maximum anchor load than a BASEPLATE II analysis for an anchor stiffness of 100 kips/inch. For axial loading, the rigid plate analysis gives an anchor load 5-percent less than BASEPLATE II. We believe that this underestimation is acceptable since the accuracy of the reference analysis method (BASEPLATE II) does not provide this level of accuracy, the condition analyzed is a worst-case condition used for less than 10 percent of the supports, anchors are rarely loaded to their maximum allowable, the 2t criteria will underestimate the anchor load by a few percent, and a large factor-of-safety is being applied to the results. The 13-percent underestimation is for a stiffness of 300 kips/inch and is not intended for evaluation of the 3/4-inch self-drilling anchors for reasons mentioned above.

Revised calculations for the justification of the 4t criteria are attached (attachment 4). The revision was made as requested to include combined bending and axial load. The results are approximately the same as for the axial load only condition.

QUESTION 4

The correspondence or relation of the material properties in the program CASDBAP and BASEPLATE II should be provided. Justification is also required for using a value of 0.334 inch as the cross-sectional area of a 3/4-inch bolt. Indicate if the minimum distance from the bolt centerline to the plate edge as shown is the minimum which was used in all analyses using the 4t criterion.

RESPONSE

CASDBAP is a rigid baseplate analysis program based on the transformed area method commonly used for working stress concrete design. For this method, the area of steel (or anchor in this case) is multiplied by the modular ratio (modulus of elasticity of the steel/modulus of concrete) and the section analyzed as an elastic section with the tensile area of the concrete neglected.

BASEPLATE II is a finite element program specifically for approximating anchor loads for flexible baseplates. BASEPLATE II considers deformations of the plate, the anchors, and the underlying concrete. The use of the finite element method allows evaluation of complicated plates, plates with multiple attachments, and baseplates where prying forces may develop (thin plates with stiff anchors).

The material properties required for baseplate analysis using CASDBAP are the compressive strength of the concrete and the modular ratio. The material properties required for baseplate analysis using BASEPLATE II are the compressive strength of the concrete and the stiffness of the anchors. BASEPLATE II uses the compressive strength for determination of compressive spring constants for the concrete. The value used has only minimal effect on the results.

CASDBAP also requires the area of the anchor. This area is multipled by the modular ratio to obtain the transformed area for the elastic analysis. For all anchors, we have used the net tensile stress area (0.334 inch for 3/4 inch). This is the area used for stress analysis of the bolt. The 8th Edition of the AISC Manual allows use of the gross area, but we purposely continued to use the more conservative areas for stress from the 7th Edition since we believe that anchorage connections should have a higher factor-of-safety than typical steel to steel structural joints.

The value of the bolt area used for CASDBAP has some effect on calculated anchor loads since the moment on inertia of the transformed area will change. However, like all baseplate analysis loads, CASDBAP is only intended to approximate the anchor loads. For conditions to which the program is restricted, we believe that use of the net tensile area and a modular ratio of 9 provides adequate approximations of the anchor loads. Actual anchor loads will be affected by actual anchor stiffness, variation in stiffness, installed location of anchors, and anchor tightness.

For the 4t evaluation, the edge distance from the anchor to the edge of the plate was assumed to be 1-1/2 inches. Our sampling program for expansion anchor factor-of-safety for IE Bulletin 79-02 indicated that 1-1/2 is the most commonly used edge distance for all anchor sizes. However, a 1-inch-edge distance was used occasionally. This would not affect the results of the 4t analysis since studies indicate that for 3/4 inch and thicker plates, no prying occurs even for an anchor stiffness of 300 kips/inch.

QUESTION 5

Indicate the minimum required distance from the bolt centerline to the edge of the plate. Show that this minimizes or eliminates any prying effects.

RESPONSE

The minimum edge distance called for on pipe suport drawings is 1 inch. However, the most common edge distance is 1-1/2 inches.

Civil Design Standard DS-C1.7.1 requires consideration of prying for baseplates with ductile anchors, but does not require prying to be considered for expansion anchored baseplates. This was based on:

1. The results of numerous BASEPLATE II analysis that showed that no prying forces were being developed, and

2. The results of the testing on full-scale expansion anchored plates which showed prying only for 1/2-inch plates with 8 anchors. The prying force in this case was less than 5 percent of the anchor load.

To address the above question, an additional series of BASEPLATE II analyses were performed. The following parameters were used:

1. Bolt edge distance - 1, 1-1/2, and 2 inches.
2. Bolt stiffnesses - 100 and 300 kips/inch.
3. Plate thickness - 1/2 and 3/4 inch.
4. Load cases - Tension, bending, and tension plus bending
5. Bolt patterns - 4 and 8 bolt

The results of the study indicate that:

1. Maximum prying occurs for tension loading with no bending.
2. No prying for bolt stiffness of 100 kips/inch.
3. No prying for 3/4-inch plate even with anchor stiffness of 300 kips/inch.
4. For 4-bolt pattern with anchor stiffness of 300, prying adds about 4 percent to the anchor load for 1-inch-edge distance (1 percent for 1-1/2-inch-edge distance.
5. For 8-bolt pattern with anchor stiffness of 300, prying adds about 9 percent to anchor load for 1-inch-edge distance (4 percent for 1-1/2-edge distance.

We believe this additional study provides additional justification for not requiring consideration of prying for expansion anchored baseplates.

ATTACHMENT

1