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

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October 10, 1984

WBRD-50-390/84-06
WBRD-50-391/84-06

U.S. Nuclear Regulatory Commission
Region II
Attn: Mr. James P. O'Reilly, Regional Administrator
101 Marietta Street, NW, Suite 2900
Atlanta, Georgia 30323

Dear Mr. O'Reilly:

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2 - IMPROPER DESIGN LOADS FOR BASE PLATES AND ANCHOR BOLTS - WBRD-50-390/84-06, WBRD-50-391/84-06 - REVISED FINAL REPORT

The subject deficiency was initially reported to NRC-OIE Inspector P. E. Fredrickson on January 31, 1984 in accordance with 10 CFR 50.55(e) as NCR WBN WBP 8402. The first interim report and a final report were submitted on February 28 and April 18, 1984 respectively. Enclosed is our revised final report.

If you have any questions, please get in touch with R. H. Shell at FTS 858-2688.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills, Manager
Nuclear Licensing

Enclosure
cc: Mr. Richard C. DeYoung, Director (Enclosure)
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Records Center (Enclosure)
Institute of Nuclear Power Operations
1100 Circle 75 Parkway, Suite 1500
Atlanta, Georgia 30339



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ENCLOSURE

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2
IMPROPER DESIGN LOADS FOR BASE PLATES AND ANCHOR BOLTS
NCR WBN WBP 8402
WBRD-50-390/84-06, WBRD-50-391/84-06
10 CFR 50.55(e)
REVISED FINAL REPORT

## Description of Deficiency

The design of the base plates and anchor bolts for supports 67-1ERCW-R337, revision 902, and 47A450-2-97, revision 4, used rigid plate theory without any consideration of the entire connection. Specifically, the configuration of the anchor bolt locations in relation to the attachment does not fulfill the requirements stipulated in Civil Design Standard DS-C1.7.1 to be classed and designed as a rigid plate; therefore, the tensile pullout load cannot be considered to be equally distributed. Due to this condition, the anchor bolts in the immediate proximity of the attachment will take a greater portion of the induced load and according to approximate hand calculations will not be within specified allowable limits.

A memorandum was issued which discussed the base plate design recommendations of NRC-OIE Bulletin 79-02. The memorandum stated that rigid plate analysis should be used for completion of Watts Bar Nuclear Plant (WBN). The memorandum was generally interpreted by designers to allow use of rigid plate analysis without evaluation of plate rigidity. This interpretation resulted in base plates being designed using rigid plate assumptions which would not be classified as rigid by IE Bulletin 79-02.

In 1983, Civil Design Standard DS-C6.1 was revised (new number C1.7.1). Section 5.1 of the standard gives limitations on the use of rigid plate analysis methods which must be applied unless documented justification is submitted for other limitations. Designers for WBN interpreted the memorandum discussed above to provide the required justification. However, the memorandum did not state any limitations and did not provide the justification required by DS-C1.7.1.

## Safety Implications

If the base plate of any affected pipe support is determined to be flexible, this could increase the tensile load on some of the concrete anchor bolts. If an anchor's load is increased above the design allowable, the margin of safety intended for the anchor and pipe support would be reduced. This could adversely affect the integrity of safety-related piping systems on which the affected supports are used.

## Corrective Action

TVA has evaluated the two deficient supports identified in the above "Description of Deficiency" and the 300 base plate random sample discussed in our first interim report on this condition. The details of the evaluation are as follows:

Method of Evaluation

Evaluate supports 67-1ERCW-R337, revision 902, and 47A450-2-97, revision 4, using flexible plate analysis to determine if rework is required on either support.

Select a random sample of 300 expansion-anchored pipe supports from unit 1. Review each support to determine if its base plate meets rigidity requirements of DS-C1.7.1. Evaluate supports which do not correctly account for base plate flexibility.

Results of the Evaluation

Support 67-1ERCW-R337, revision 902, was reevaluated using flexible plate analysis. The maximum anchor load by flexible plate analysis was 3.21 kips. The maximum anchor load by rigid plate analysis was 3.04 kips. The 3.21 kip load results in a factor of safety of 4.6 (6.5 when adjustments are made as discussed below). Therefore, support 67-1ERCW-R337 will be used-as-is.

Support 47A450-2-97, revision 4, was modified per a field change request. The support no longer uses expansion anchors. Therefore, this NCR no longer applies to support 47A450-2-97.

To obtain a sample of 300 expansion-anchored pipe supports, 260 supports were randomly selected and added to the 40 supports which were analyzed for NRC-OIE Bulletin 79-02. The sample was taken from the original drawing files and represents all supports designed by TVA, Bergen-Patterson, and EDS Nuclear. Although only unit 1 supports were selected, the sample also is representative of unit 2 designs. The sample of 40 plates was not random, but was biased in the direction of the more heavily loaded plates. However, for statistical evaluation of the results, the sample was conservatively assumed to consist of 300 random samples. The anchor loads and base plate stress for each support were calculated (if a support had more than one base plate the loads and stresses were calculated on each potentially controlling plate).

The base plates were analyzed using one of three methods. A rigid plate analysis was performed if the plate met the rigid plate requirements of Civil Design Standard DS-C1.7.1. A flexible plate analysis using manual approximations was used for simple base plates (generally, these calculations assumed the resultant compressive force between the base plate and concrete is located two plate thicknesses from the face of the support). A finite element flexible plate analysis was used for complicated base plates and for plates where the conservative results of manual methods were unacceptable. Approximately 5 percent of the plates were analyzed by rigid methods, 75 percent by manual flexible plate calculations, and 20 percent by the finite element flexible plate analysis.

The support design loads used for the reevaluation were those given on the support drawing. Normalized loads were unnormalized. Therefore, the factors of safety determined are for the maximum support loads obtained from any loading condition. If the expansion anchor factor of safety was less than 5.0, the results of the piping analysis were reviewed to determine if the calculated support loads are lower than the load given on the drawing. If reduced loads were available, they were used to calculate the factor of safety and plate stress.

Conclusions - Anchor Factor of Safety

The factors of safety reported here were calculated using ultimate anchor tensile loads which account for increased concrete strength and TVA qualification loads. A detailed discussion of this adjustment is given in TVA's revised response on Bulletin 79-02 dated June 20, 1984, and in TVA's response to unresolved item 390,391/84-05-01.

a. 296 of 300 (98.7 percent) supports have expansion anchor factors of safety greater than or equal to 5.0.

b. 299 of 300 (99.7 percent) have expansion anchor factors of safety greater than 4.0. The supports with factors of safety between 4.0 and 5.0 are listed below:

| Support | Factor of Safety Adjusted |
|---|---|
| 1. 67-1ERCW-R167 | 4.1 |
| 2. 1-87-80 | 4.1 |
| 3. 47A450-3-105 | 4.9 |

The supports with factors of safety less than 5.0 but greater than 4.0 are acceptable because the percentage of supports with factors of safety less than 5.0 is very low. Also, TVA has provided justification for a factor of safety less than 5.0 at WBN (see appendix H of Bulletin 79-02 revised response).

c. One support (47A435-18-12) had a factor of safety of 2.3 (adjusted for increased strength and TVA qualification loads). Review of the original calculation revealed a judgment error relative to the anchor loads. The baseplate meets the rigidity requirements of DS-C1.7.1, therefore, the low factor of safety is not related to plate flexibility. The support has been redesigned under engineering change notice (ECN) 4692. Rework of this support is complete.

Conclusion - Plate Stress

With respect to bending stress in the base plates, the allowable bending stress is 0.75 fy for service or normalized loads. TVA design criteria allows an increase for faulted conditions of either 33-percent (primary) or 60-percent (primary + secondary).

All supports but one had acceptable plate bending stress. Support 47A447-24-9B had a plate stress of 44 $k/in^2$. The calculated plate stress of 44 $k/in^2$ is conservative. The method of analysis did not consider the effect of the support on the stiffness of the base plate. Similar supports with multiple legs attached to one base plate have shown stress reductions of about 50 percent when the support frame is included as part of the base plate finite element model. The design loads were determined by alternate analysis (seismic plus dead load). Therefore, the allowable stress is 1.33 (0.75 fy) or 36 $k/in^2$ for A36 steel. The support is being modified under ECN 4728. Rework of this support is complete.

Summary

The evaluation of the sample results has shown that 2 of 300 supports are unacceptable (one low factor of safety, one high plate stress). The proportion of defects for this sample has shown with 95-percent confidence that for an infinite population less than 2.0 percent of the pipe supports at WBN do not meet design requirements with respect to expansion anchor factor of safety and base plate stress.

Therefore, the failure to properly consider base plate flexibility in the original design has not resulted in an excessive number of supports with unacceptable anchorage factors of safety or base plates with excessive steel stress. No further corrective action is required.

In order to prevent recurrence of this deficiency, TVA has revised the instructional memorandum discussed in the description of deficiency to refer designers to requirements of Civil Design Standard DS-C1.7.1 and has revised Civil Design Standard DS-C1.7.1 to clarify limitations and applicability of rigid plate analysis.

TVA has also conducted a training course to inform all attached support designers of the base plate design requirements of DS-C1.7.1.