WATTS BAR UNITS 1 AND 2

SPECIAL CALCULATION AUDIT RELATING TO THE

CIVIL CALCULATION PROGRAM AND IMPLEMENTATION

September 9-13, 1991

by the

OFFICE OF NUCLEAR REACTOR REGULATION

Sang Bo Kim, Team Leader
Yong S. Kim
Carl Costantino (consultant)
N. C. Tsai (consultant)
Ahmed I. Unsal (consultant)

Watts Bar Units 1 and 2

Special Calculation Audit Relating to the

Civil Calculation Program and Implementation
(September 9-13, 1991)

1. BACKGROUND

The elements of the civil calculation program for Watts Bar Nuclear Plant (WBN) include the evaluation for reinforced concrete elements, masonry wall, embedded plates, steel containment vessel, geotechnical issues, steel platform structures, thermal analysis and above ground vertical steel tank.

Initial concerns were identified in 1984 relative to the availability of adequate design basis calculations for these features. These findings were common to reviews performed by both INPO and the TVA quality engineering staff.

A. Calculations were not always well documented

B. Justification of Results which differed from the design criteria requirements were not always documented.

TVA instituted the design baseline and verification program (DBVP) to address these identified concerns. As excerpted from Volume 4 of the WBN Nuclear Performance Plan:

> "The calculation activity was initiated to ensure that technically adequate design calculations exist for primary and secondary safety-related plant features. The activity involves development of the list of required calculations by each engineering discipline. The existence of each calculation on the list is then determined and those not found are regenerated. The technical adequacy of existing calculations is

determined through review, which is scoped by one of two means: (1) calculations of a given type are reviewed if problem indicators at WBN or other TVA plants demonstrate the need; (2) a selected review of calculations is performed of calculation type for which no problem indicators exist with expansion of the review occurring based on a root cause determination of any problem found. Deficient calculation are regenerated as appropriate. The technical adequacy review of existing calculations will include assurance that the calculations are consistent with current plant design."

In the process of implementing these programs the applicant is addressing other existing issues such as employee concern, Conditions Adversed to Quality (CAC) resolutions, and vertical slice review finding closure.

The purpose of this audit is to review the adequacy of the civil calculation program implementation and the calculations completed as part of the program implementation. This report also discusses open items discussed during the April 15-19 audit.

2 REVIEW FINDINGS

During September 9-13, 1991, a NRC team (the team) conducted a site audit of TVA's civil calculation program for WBN at the plant site in Spring City, Tennessee. The enstrance meeting was held on September 9, 1991, and the list of attendees is contained in Cnclosure 1. The exit meeting was held on September 13, 1991, and the attendees were listed in Enclosure 2. The sections that follow document the audit findings and the teams's conclusions on each of the above mentioned design areas.

2.1 Reinforced Concrete Elements

TVA is performing evaluations on Category 1 reinforced concrete structures at Watts Bar Unit 1 (WBN 1). These evaluations are performed on the selected worst cases for various concrete features including slabs, beams, columns and walls. The team reviewed TVA Calculation WGC-1-585 (RIMS No. B18 910412 273) which develops worst case selection approach for the various concrete features. The team could not review the analysis performed on these worst case features since this tasks has not been completed by TVA at the time of this audit.

Certain Category 1 concrete structures including the reactor building were not included within the scope of TVA Calculation WCG-1-585. Evaluation of the reinforced concrete features in the reactor building would be performed under a separate program. The team met with TVA to discuss this evaluation program for the reactor building. However, at the time of this audit, TVA was still in the process of developing this program. The staff will review the evaluation of the reactor building concrete when it is available.

2.1 Reinforced Concrete Elements

2.1.1 Introduction

TVA is performing evaluations of Category 1 reinforced concrete structures at Watts Bar Nuclear Plant Unit 1. These evaluations are performed on selected worst case concrete element including slabs, beams, columns and walls. The selection process of the worst case elements were reviewed by the staff during an audit performed on April 15-19, 1991.

During the current audit held on September 9-13, 1991, the staff reviewed all the open issues from the previous audit, as well as the calculations for the evaluation of the worst case concrete elements. Although the evaluations of the worst case concrete elements were mostly completed, due to time limitations, the staff could only review a limited sample of these calculation. The samples selected by the staff included the evaluations of slabs and exterior load carrying walls.

TVA is also evaluating the crane wall, fill slab and the base mat of the reactor building. However, at the time of this audit, this effort was still not completed, and therefore, was not reviewed by the staff.

2.1.2 Review of Open Items From Previous Audit (April 15-19, 1991)

2.1.2.1 Item No: CAN-1 (Closed)

During the previous audit, the review of calculation WCG-1-585 showed that worst case concrete features were selected through an elimination process. An initial screening on the total population of a concrete element (slabs, walls, columns, etc.) was made after field walkthroughs and drawing reviews. However, the calculation was not clear as to whether loads on the various elements were also considered in this initial stage of screening.

To resolve this staff concern, TVA has revised calculations WCG-1-585 and WCG-1-739 to clarify that loads were considered at this initial stage of screening. During this audit (September 9-13, 1991), the staff reviewed calculation WCG-1-585 Rev. 2 and WCG-1-739 Rev. 1 and verified that loads were considered during the initial stage of screening. Therefore, the staff considers this item to be closed.

2.1.2.2 Item No: CAN-2 (Closed)

During the previous audit, the review of calculation WCG-1-585 showed that worst case selection of concrete elements were made through an elimination process with various stages. However, this elimination process and the criteria used for eliminating elements were not explicit and clear.

To resolve this staff concern, TVA has revised calculations WCG-1-585 and the related concrete element calculations WCG-1-738, WCG-1-739, WCG-1-740, WCG-1-741, and WCG-1-742 to clarify the elimination process for each stage. The staff reviewed calculations WCG-1-585 Rev. 2 and WCG-1-739 Rev. 1 and found the elimination process and the criteria for this process to be acceptable. Therefore, the staff considers this item to be closed.

2.1.2.3 Item No: CAN-4 (Closed)

During the previous audit, the review of calculations WCG-1-757 and WCG-1-585 showed that there were discrepancies between these two calculations as to the type of evaluations to be performed on the intake pumping station. Specifically, calculation WCG-1-757 required that shear walls in both the longitudinal and transverse directions, as well as, the floors be evaluated for increased seismic loads. However, calculation WCG-1-585 only required the evaluation of shear walls in one direction.

TVA has revised calculation WCG-1-585 Rev. 2 to resolve this staff concern. During this audit, the staff reviewed this calculation and verified that the evaluations as stated in calculation WCG-1-757 would be performed for the intake pumping station. The staff considers this item to be closed.

2.1.3 Review of Worst Case Evaluations

2.1.3.1 Review of Worst Case Slab Evaluations

The staff reviewed portions of TVA calculation WCG-1-923 Rev. 0, which includes the evaluation of worst case concrete slabs. TVA selected 22 slab panels as worst case slab elements to be evaluated. These 22 panels corresponded to approximately 8 areas with multiple slab panels. Five (5) of these 8 areas were evaluated by finite element analysis and the remaining 3 by hand computations. The staff reviewed two areas; one evaluated by finite element analysis and the other by hand computations.

TVA performed a finite element analysis of the panels located at elevation 737.0' of the auxiliary control building between column lines A4, A12, r, and t. The thickness of the slab in this area was 1'-0", and it was heavily loaded due to the location of various heat exchangers. The staff performed a detailed review of the TVA evaluation. The loads and load combinations, finite element model, boundary conditions, adherence to ACI 318-77 code and FSAR requirements were all reviewed. TVA drawings specifying the reinforcing bar requirements for this area were also reviewed.

The review of the finite element analysis showed that TVA used different live loads for this same slab areas corresponding to plant operation and outage conditions. The staff questioned as to how these different live loads would be controlled, especially during plant operation where certain slabs have zero live load associated with them. In response to this staff concern, TVA provided design change notice DCN S-16590-A which will revise and document all permissible floor design live loads during plant operational and outage. The revised drawings would then become the control room drawings. This documentation of tracking the permissible live loads for the selected worst case slabs is acceptable to the staff. Since the worst case slabs represent the total population of slabs, the limitation of live loads on these worst case slabs have to be applied to the total population of slabs. The TVA program to limit live loads on the total population of the slabs was not clear. Therefore, this item will be left open pending additional information from TVA as to the methodology of determining the permissible live loads on the total population of slabs (Item No. AU-1)

TVA determined the punching shear around columns from the finite element analysis by averaging the reaction forces at the nodes representing the four corners of the column. Instead, the staff stated that the punching shear should be the total summation of the column reaction forces. TVA revised calculation WCG-1-923 to recalculate the punching shears around various columns and to show that they were still within the ACI 318-77 code allowables. Although, this revised calculation is acceptable to the staff, TVA should evaluate the other slab areas analyzed by finite element models to determine whether the staff concern about punching shear calculations around columns is generic or not. Therefore, this item will be left open pending TVA evaluation of the other slab area (Item No. AU-5).

The finite element analysis results also showed erroneous reaction forces along column line t, which is the north boundary of the finite element model. The large variation of the magnitude and the change of direction of adjacent reaction forces along this edge were not explainable, and therefore, could be the result of an inadequate finite element model representing the actual physical situation. The erroneous reaction forces along this edge might have an effect on the punching shear forces around columns along column line s. Therefore, TVA should evaluate the adequacy of the finite element model to determine whether it represents the actual structure and loading distribution. This evaluation should also be extended to other finite element models used for the evaluation of other slab areas. This item will be left open pending further TVA evaluation (Item No. AU-10).

TVA performed manual computations to evaluate the panels located at elevation 713.0, of the auxiliary control building between column lines A1, A3, s, and u. The staff performed a review of this evaluation to determine whether the slab met the requirements of the Watts Bar Unit 1 FSAR. Again, this areas was loaded with heavy equipment and the slab thickness was 1'-0".

During this review, the staff had one concern relating to openings that were located in this area. The calculations did not specifically address the effect of these openings on the structural adequacy of the slab. However, TVA responded to this staff concern by providing drawing 41N316-1 R14, which includes detail A1 showing that the reinforcing bars that were cut around the openings were replaced by an equal amount of reinforcing. This method is in accordance with ACI 318-77 code for openings located in low stressed areas of slabs. This response by TVA was acceptable to the staff and therefore, considers this item to be closed (Item No. AU-7). The staff did not have any other concerns from the review of this manual computation.

2.1.3.2 Review of Worst Case Exterior Wall Evaluations

The staff reviewed TVA calculation WCG-1-950 Rev. 0, which included the evaluation of worst case concrete exterior load bearing walls. TVA has selected seven exterior walls to be the worst cases. The staff reviewed the evaluation of one wall located in the auxiliary control building. The wall was located on column line A1 and extended form elevation 713.0' to 736.0' and column line s to u. This wall had a thickness of 3'-0".

TVA performed manual computations to evaluate this wall. The staff, similar to the slab evaluations, reviewed the loads and load combinations, FSAR and ACI 318-77 code requirements and the related reinforced concrete drawings showing reinforcing requirements. The local effect including the penetration of tornado generated missiles into the concrete wall was not a part of this calculation. However, it is covered in calculation WCG-1-608 Rev. 1. The staff did not review this calculation.

The review of calculation WCG-1-950 showed that tornado wind loads were the governing loads for the evaluation of the wall. Both the tornado wind velocity and pressure drop effects were considered separately. However, these two effects were not combined as required by section 3.3.2.2 of the FSAR. TVA responded to this staff concern by performing additional calculations to show that the total pressure on the wall would be less than 3 psi, which was used in the TVA evaluation. This response was acceptable to the staff and considers this item to be closed (ITEM No. AU-8).

The staff did not have any other concerns from the review of the evaluation of this wall.

2.1.4 Conclusion

In the reinforced concrete area, the staff reviewed limited samples of the evaluations performed by TVA. Most of the worst cases representing various concrete areas have been evaluated by TVA. These evaluations have not led to any modifications to the existing concrete structures. The evaluations of the concrete elements (crane wall, fill slab, base mat), included in the reactor building concrete program, have not yet been completed. Therefore, these areas were not reviewed by the staff.

Overall, the staff found the TVA evaluations to be comprehensive and in accordance with the FSAR requirements. These evaluations are acceptable to the staff pending the resolution of the open items.

2.1.5 List of Open Items

AU-1: Additional information from TVA as to how permissible lived loads would be determined for the total population of slabs.

AU-5: Generic review by TVA of the finite element analyses for calculating punching shear around columns.

AU-10: Validity of reaction forces and adequacy of the finite element model at boundary of slab.

2.1.6 List of Documents and Calculations Reviewed

1. TVA Calculation WCG-1-585 RIMS No. B18 910502 267, Worst Case Concrete Feature Selction, Rev. 2, 4/26/91.

2. TVA Calcualtion WCG-1-739 RIMS No. B18 910502, Worst Case Concrete Feature Selection for Slabs, Rev. 1, 4/26/91.

3. TVA Calculation WCG-1-923 RIMS No. B18 910907 265, Evalution of Worst Case Slabs, Rev. 0, 9/5/91.

4. TVA Calcualtion WCG-1-950 RIMS No. B18 910907 288, Evaluation of Worst Case Concrete Exterior Load Bearing Walls, REv. 0, 9/5/91.

5. TVA Design Criter WB-DC-20-1 RIMS No. B26 900423 078, Concrete Structures - General, Rev. 6, 4/18/90.

6. TVA Design Criteria WB-DC-20-8 RIMS No. B26 900423 080, Auxiliary Control Building Concrete Structures, Rev. 6, 4/19/90.

7. TVA Drawing 41N318-1, Auxiliary Building Units 1 & 2 Concrete El 729.0 & 737.0 Floor Outline, Rev. 14 12/2/86.

8. TVA Drawing 41N318-2, Auxiliary Building Units 1 & 2 Concre El 729.0 & 737.0 Floor Outline, Rev. 6, 4/9/83.

9. TVA Drawing 41N319-1, Auxiliary Building Units 1 & 2 Concrete El 729.0 & El 737.0 Floor Reinforcement, Rev. 14, 3/15/91.

10. TVA Drawing 41N319-2, Auxiliary Building Units 1 & 2 Concrete El 729.0 & El 737.0 Floor Reinforcement, Rev. 11, 3/1/5/91.

11. TVA Drawing 41N319-3, Auxiliary Building Units 1 & 2 Concrete El 729.0 & El 737.0 Floor Reinforcement, Rev. 18, 3/15/91.

12. TVA Drawing 41N319-4, Auxiliary Building Units 1 & 2 Concrete El 729.0 & El 737.0 Floor Reinforcement, Rev. 9, 3/15/91.

13. TVA Drawing 41N315-2, Auxiliary Building Units 1 & 2 Concrete El 713.0 Floor Outline, Rev. 6, 12/30/82.

14. TVA Drawing 41N316-1, Auxiliary Building Units 1 & 2 Concrete Floor Slab El 713.0 Reinforcement, Rev. 14.

15. TVA Drawing 41N316-2, Auxiliary Building Units 1 & 2 Concrete Floor Slab El 713.0 Reinforcement, Rev. 9, 3/27/86.

16. TVA Drawing 41N316-3, Auxiliary Building Units 1 & 2 Concrete Floor Slab El 713.0 Reinforcement, Rev. 3, 3/18/75.

2.2 Masonry Walls

2.2.1 Introduction

TVA is performing a evaluation of the masonry block walls at Watts Bar to determine whether their designs are in accordance with the FSAR and TVA design criteria requirements. During the previous NRC audit (April 15-19, 1991), the staff reviewed TVA evaluations for various worst case masonry walls, as well as the selection of these worst cases. At the conclusion of this audit, certain staff concerns were left opern pending further TVA actions.

During this current audit, the staff only reviewed the TVA actions taken to resolve the open items. The staff did not review any additional items relating to masony walls.

2.2.2 Review of Open Items From Previous Audit (April 15-19, 1991)

2.2.2.1 item No. CAK-3 (Closed)

During the previous audit, the review of calculation WCG-1-767 showed that the determination of the frequencies of the masonry walls did not consider a cracked section. This was in contrary to the requirements of TVA design criteria WB-DC-20-23 section 3.3.2 where it is stated that both a cracked and uncracked section should be considered for frequency analysis. At that time, TVA's responde to this staff concern was that an effective moment of inertia as calculated in accordance with ACI 318-71 section 9.5.2.2 would be used to calculate frequency. This methodology was acceptable to the staff, however this item was left open pending a revision to calculation WCG-1-767 to incorporate the calculations of these effective moment of inertias.

During this audit, the staff reviewed Revision 1 of calculation WCG-1-767, which included the calculation of the effective moment of inertias. The calculations showed that the gross moment of inertias were greater than the effective moment of inertias, leading to the conclusion that the frequencies calculated previously were still valid. Therefore, the staff considers this item to be closed.

2.2.2.2 Item No. CAK-4 (Closed)

During the previous audit, the review of calculation WCG-1-767 showed that frequencies of the masonry walls in the in-plane direction were calculated using only the bending stiffness. However, in this direction, the shear stiffness of the walls have a major contribution to the frequency calculations.

During this audit, the staff reviewed Revision 1 of calculation WCG-1-767, which included the revised frequency calculations. By considering the shear stiffness, the wall frequencies in the in-plane direction have been lowered. However, they were still greater than 33 Hz and therefore, the lower frequency values did not effect the seismic loads on the walls. TVA has also issued Problem Evaluation Report (PER No. WBPER910247) to identify, evaluate and dispose this issue for other masonry walls. The actions taken by TVA to resolve this item were adequate and therefore, the staff considers this item to be closed.

2.2.2.3 Item No. CAK-7 (Closed)

During the previous audit, the review of calculation WCG-1-767 for the unreinforced mortared walls revealed that a factor of 1.5 was used to increase the allowable masonry tension perpendicular to the bed joint for extreme and abnormal loads. This was not in accordance with TVA design criteria WB-DC-20-30 section 3.4.8, where a factory of only 1.3 is allowed.

In response to this staff finding, TVA revised calculation WCG-1-767 to determine whether the allowable masonry tension stresses were exceeded due to a lower allowable stress. The staff reviewed revision 1 of this calculation which showed that the lower allowable stress did not impact the final conclusions reached by this calculation. TVA has also initiated Problem Evaluation Report (PER No. WBPER910247) to identify, evaluate and dispose this item for other masonry walls. The actions taken by TVA were adequate, and therefore, the staff considers this item to be closed.

2.2.2.4 Item No. CAK-10 (Closed)

During the previous audit, the staff found that determination of the maximum compressive stress in the masonry block and the tensile stress in the steel for reinforced masonry walls did not consider a cracked-section. This was not acceptable to the staff since SRP Appendix A section 3(c) requires that, for reinforced masonry walls, all the tensile stresses would be resisted by reinforcement.

To resolve this staff concern, TVA has revised calculation WCG-1-767 to evaluate all reinforced masonry walls as cracked sections. The review of these revisions by the staff showed that the masonry and the reinforcing steel stresses were within the allowable stresses. Therefore, the staff considers this item closed.

2.2.2.5 Item No. CAK-11 (Closed)

During the previous audit, the review of calculation WCG-1-767 for the unreinforced unmortared block walls showed that the shear forces on the top and bottom faces of some blocks exceeded the allowable shear forces. This was not in accordance with TVA design criteria WB-DC-20-30 section 4.2.2 where an exceedance of these shear forces is not allowed.

To resolve this NRC concern, TVA has revised calculation WCG-1-767 to recalculate the seismic loads on these walls as described in TVA design criteria WB-DC-20-30. This revised calculation showed that the masonry walls were stable and the shears calculated were within the allowables. Therefore, the staff found the revised calculations acceptable and considers this item closed.

2.2.3 Conclusion

During this audit, the staff reviewed the actions taken by TVA to resolve the open items from the previous audit. The revised calculations showed that modifications to masonry block walls were not necessary, except for certain unreinforced unmortared masonry walls which were painted with a epoxy paint. The evaluation concluded that the paint from these walls have to be stripped to increase their ability to resist shear forces. Overall, the staff found Revision 1 of calculation WCG-1-767 to be adequate.

2.2.4 List of Open Items

There are no open items relating to the review of masonry walls.

2.2.5 List of Documents and Calculations Reviewed

1. TVA Calculation WCG-1-767, Masonry Block Wall Evaluation, Rev. 1.

2. TVA Design Criteria WB-DC-20-23 RIMS No. B26 880617 006, Reinforced Concrete Block Walls, Rev. 2, 6/17/88.

3. TVA Design Criteria WB-DC-20-30 RIMS No. B26 900423 083, Evaluation of Unreinforced Masonry Walls Constructed from Solid Concrete Blocks, Rev. 3, 4/18/90.

2.3 Embedded Plates

2.3.1 Introduction

TVA is in the process of evaluating the design adequacy of embedded plates at Watts Bar Unit 1. This evaluation is performed under two groups of programs.

Both groups of programs include the selection of worst cases to represent the total population of embedded plates.

The first group of embedded plates include those that are associated with the hanger analysis and update program (HAAUP), CAQ 8623 and CAQR WBP890450. The second group of embedded plates include embedded plates for the supports of HVAC, cable tray, conduit, instrumentation and control (I&C) systems and small bore piping. The selection of the worst cases for the second group has been scheduled TVA. However, documentation has not been finalized for staff review. Therefore, the staff was not able to review this portion of the program.

During the previous audit, the staff had reviewed samples of TVA calculations for embedded plates associated with steel platforms. During the current audit (September 9-13, 1991), the staff reviewed TVA methodology for worst case selection of embedded plates associated with HAAUP. Also, the staff reviewed calculations relating to cable tray support embedded pates which were a part of CAQ 8623 and CAQR WBP890450.

2.3.2 Audit Review

2.3.2.1 Worst Case Selection for HAAUP Embedded Plates

The staff reviewed TVA calculation WCG-1-873 Rev. 2, which includes the worst case selection of HAAUP embedded plates for evaluation. The HAAUP piping support loads were obtained recently by the TVA piping group. TVA performed a preliminary evaluation of the embedded plate by comparing these loads to embedded plate capacities developed for the various types of embedded plates. All embedded plates where the actual applied loads were close to the capacity of the embedded plate were selected for detailed evaluation. TVA would perform a walkdown for these embedded plates and use this information for the final evaluation. The worst case embedded plate for different types would be analyzed to determine it's adequacy.

The staff had two concerns relating to the worst case selection methodology. First, the capacities developed for various types of embedded plates did not consider the location of the attachment to the embedded plate. This is important because the capacity of the embedded plate could be effected depending on the location of the attachment. To resolve this staff concern, TVA stated that they would evaluate additional cases for each type of embedded plate to account for the effects of attachment location. This methodology was satisfactory to the staff, however, this item will be left open pending a revision to calculation WCG-1-873 stating the selection of additional samples to account for attachment location effects (Item No. AU-11a).

The second staff concern was also related to the worst case selection methodology. The capacities of various embedded plates did not account for shear in the stud anchors. The capacities of the embedded plates were based on only tensile forces in the stud anchors. However, the total capacity should have been a combination of tensile and shear forces. To address this staff concern, TVA proposed the additional samples of embedded plates with high shear forces would be evaluated to account for shear effects. This is acceptable to the staff, however, this item will be left open pending a revision to calculation WCG-1-873 documenting this additional samples process (Item No. AU-11b).

2.3.2.2 Review of Evaluations for Cable Tray Embedded Plates

The staff reviewed TVA calculations with RIMS nos. B26 910905 110, B26 910906 114, and B26 910906 102 which were performed to evaluate unique embedded plates for cable tray supports. These embedded plates were analyzed by computer program BASEPLATE II for the geometry obtained from walkdowns. TVA computer program CONAN was used to obtain stud anchor capacities. The evaluations were performed in accordance with TVA design standard DS-C1.7.1. The staff did not have any open items relating to the review of these evaluations.

2.3.3 Conclusion

The review of the methodology to determine worst cases for HAAUP embedded plates showed that TVA has to include additional worst case embedded plates to include the effects of attachment location and shear. The review of evaluations of embedded plates relating to cable tray supports did not yield to any staff concerns. The methodology used in these evaluations were acceptable to the staff. However, TVA was still in the process of selecting worst cases for HAAUP embedded plates, and embedded plates associated with HVAC, cable tray, conduit small bore piping and I&C supports. The staff needs to review these evaluations to reach a decision on the adequacy of the embedded plates associated with these systems.

2.3.4 List of Open Items

2.3.4.1 Open Items From Previous Audit (April 15-19, 1991)

Item No. AU-12:

TVA calculations WCG-1-848 and WCG-1-841 (RIMS Nos. B18 910413 273 & B18 910413 265) used an elliptical formula for calculating the interaction of tension and shear in the stud anchors. However, calculations WCG-1-845 and WCG-1-837 (RIMS Nos. B18 910413 281 & B18 910413 257) used a straight line formula for the same interaction. TVA should justify the use for the elliptical formula used in calculations WCG-1-848 and WCG-1-841.

Item No. AU-13:

In calculation WCG-1-841 (RIMS No. B18 910413 265), TVA should justify why the vertical force (Fy) obtained from the STRUDL computer analysis is lower for SSE than for OBE.

2.3.4.2 Open Items From Current Audit (September 9-13, 1991)

AU-11a: TVA to revise calculation WCG-1-873 to include the consideration of attachment location in worst case embedded plate determination.

AU-11b: TVA to revise calculation WCG-1-873 to include the consideration of shear in calculating the capacity of stud anchors.

2.3.5 List of Documents and Calculations Reviewed

1. TVA Calculation WCG-1-873 RIMS No. B18 910910 261, Selection of HAAUP Embedded Plates for Evaluation, Rev. 2, 9/10/91.

2. TVA Calculation 48N133402A043 RIMS No. B26 910905 110, Calculations for Unique Embedded Plate Number 48N1334-2A 43, Rev. 0, 8/29/91.

3. TVA Calculation 48N094601B131 RIMS No. B26 910906 114, Calculations for Unique Embedded Plate Number 58N946-1B 131, Rev. 0, 8/29/91.

4. TVA Calculation 18N030904A001 RIMS No. B26 910906 102, Calculations for Unique Embedded Plate Number 18N309-4A-1, Rev. 0, 9/5/91.

5. TVA Civil Design Standard DS-C1.7.1 RIMS No. B41 910506 002, General Anchorage to Concrete, Rev. 5, 5/6/91.

LIST OF PERSONS CONTACTED

Name	Organization
R. Hernandez	TVA
R. Alexander	TVA
R. Rowell	TVA
E. Perry	TVA
E. Cole	EBASCO
K. Lanham	EBASCO
H. Toturgul	EBASCO
M. Sueki	EBASCO
E. Odar	EBASCO
D. Phipps	EBASCO

2.4 Steel Containment Vessel (SCV)

2.4.1 Introduction

The staff identified three open items during the inspection previously conducted in April, 1991, for which TVA agreed to provide resolutions. They are Item CAE-2, CAE-4(a) and CAE-5 as documented in Enclosure 1 of the June 7, 1991 TVA letter to NRC. During this inspection, the staff and consultants reviewed the TVA resolutions for these open items. Results of TVA evaluation for the pad plates and Phase II evaluation for four HVAC penetrations were also reviewed on a sample basis. Review findings are discussed in the following.

2.4.2 Audit Review Findings

2.4.2.1 Open Items from April, 1991 Inspection

Open item CAE-2 identified the staff concern with minor discrepancies in as-built pad plate location between the SCV stretch out composite drawings (DCA-15752-01-0 to DCA-15752-10-0) and the walkdown package information. TVA resolved this concern by revising the composite drawings in accordance with the walkdown information package, which were reissued per Design Change Notice DCN/S-16031-A. The staff and consultants reviewed the revised drawings and found them adequate. In addition, to prevent recurrence of problem similar to this open item, TVA stated in their June 7, 1991 letter to NRC that a formal training was provided to the WBN civil engineering staff on May 10 and 13, 1991, to increase individual awareness in the areas of calculation quality and attention to detail. The staff conclude that the TVA corrective actions are adequate and item CAE-2 is closed. Open item CAE-4(a) is related to the inconsistency in boundary conditions between the ANSYS and STARDYNE finite element models which TVA used to develop generic stress influence lines for the SCV dome and cylindrical shell, respectively. The influence line provides a convenient tool for determining the stress at a given location on the shell when an attachment load exists within a specified interaction distance from the location under consideration. The staff concern was with the increase in stress of up to about 15% at the edge of the original ANSYS analysis model, which is axisymmetric with a radius of about 89", when the original non-fully fixed boundary condition was revised to full fixity for consistency with the STARDYNE model. TVA resolved this staff concern with a study in which the radius of the ANSYS model was extended to 120" while maintaining full fixity at the boundary. The results, documented in TVA calculation WCG-1-606, R2, show that the stress in the extended ANSYS model at a radius of 89" exceeded the corresponding stress at the edge of the original ANSYS model (non-fully fixed boundary) by only 4%. The staff found it reasonable to use the study results for the extended ANSYS model to justify the boundary stresses in the original 89"-radius model having the non-fully fixed boundary. Based on the study, the staff concludes the use of the original ANSYS model for generating the stress influence lines for the SCV dome is acceptable although the non-fully boundary condition is not consistent with the fully fixed boundary condition of the STARDYNE model. This item is closed.

Open item CAE-5 is related to the comparison of thermal movements of the SCV shell at a pad plate locations between the main steam line break (MSLB) accident and hot leg break accident, the latter being the original design basis accident (DBA) for WBN. This item request TVA to (a) formally document the criteria for determining when the thermal movement due to the MSLB accident constitutes a significant change from the movement due to the hot leg break accident and (b) revise the thermal movement comparison report (WCG-1-814, R0) for full compliance with the comparison criteria. To resolve the staff concern, TVA (a) documented the thermal movement comparison criteria in calculation WCG-1-721, R1, and (b) revised calculation WCG-1-814 to ensure all thermal movement comparisons are in compliance with the documented comparison criteria. In addition, TVA issued a QIR-EBA-WBN-91-424, R0, summarizing all MSLB induced thermal movements that are identified in calculation WCG-1-814 to be significantly different from the original DBA induced thermal movements. The staff found the TVA corrective action to be adequate, and this item is closed.

2.4.2.2 Pad Plate Evaluation

According to TVA, there are a total of 516 pad plates on the SCV shell. The evaluation of pad plates includes two phases. The Phase I evaluation employed a simple yet conservative approach. For each pad plate location, a load ratio, defined as the ratio of the new attachment load resulting from Set B SSE + DBA to the original attachment load resulting from Set A SSE + DBA, was first computed. The original design stresses for the pad, pad-to-shell weld, and shell were scaled by this load ratio and compared to the ASME code allowables for normal condition. When all three elements passed this quick screening the shell was then further evaluated for the combined effect of the scaled shell stress and the stress resulting from adjacent new attachment loads. A pad plate was considered qualified for the new attachment loads due to the Set B SSE and DBA when it passed the further SCV shell stress checking. Otherwise, the particular pad plate would be subjected to the Phase II evaluation with a more rigorous analysis. TVA calculation WCG-1-862 documents the methodology and results for the Phase I evaluation. It shows that a total of 80 pad plates passed the Phase I screening. The staff and consultants reviewed a sample of about 30 out of a total 971 pages contained in TVA calculation WCG-1-862. Based on this sample review, the staff found the methodology and results for the Phase I screening evaluation of pad plates to be acceptable.

For those pad plates requiring the Phase II evaluation, the evaluation for 249 pads was completed at the time of the inspection, and results are documented in five TVA calculations. The staff and consultants reviewed two calculations, i.e., WCG-1-924, R0, for the residual heat removal (RHR) support footprint loads and WCG-1-926, R0, for the conduit support footprint loads. For the RHR support system, the footprint loads on pad plates due to the Set B SSE and DBA inertia loads of the support system were obtained with the equivalent static analysis of a space frame model for the system, using TVA computer code FAPPS. A static analysis of the same space frame model was also performed to obtain footprint loads due to dead weight of the RHR support and pipe support reactions acting on the support system. For the conduit supports, the footprint loads were provided by the conduit support analysis program. In the evaluation of pad plates, the stress in the plate was obtained either with hand calculations based on Roark's formula or with TVA code BASEPLATE II. In the evaluation of SCV shell, TVA code WERCO was typically used to compute the shell stress. Interaction effect from the adjacent attachment loads was taken into account. Calculated stresses in the pad plate, pad-to-shell weld, and shell were evaluated against the ADME normal condition allowables. According to TVA, all 249 pad plates passed the Phase II evaluation and no modification is required.

Based on staff review of two TVA calculations, the staff concludes that the methodology and results of the Phase II pad plate evaluation is acceptable. Since TVA has not competed the Phase II evaluation of all pad plates at the time of inspection, a full staff acceptance of the pad plate evaluation is conditional upon TVA adequately completing Phase II evaluation of the remaining pad plates.

2.4.2.3 Phase II Evaluation of HVAC Penetrations

According to the previous audit conducted in April, 1991, TVA identified four HVAC penetrations as requiring the Phase II evaluation with a more rigorous analysis. They are penetration X-6, X-9A, X-9B, and X-10A. The staff and consultants reviewed two out of four TVA calculations, i.e., WCG-1-870, R0, and WCG-1-872, R0, for penetration X-9A and X-10A, respectively. At both locations, an equivalent static analysis of the HVAC system was performed with GTSTRUDL to determine the new footprint loads due to the dead weight, Set B OBE, Set B SSE, and DBA. Stresses in the SCV shell and nozzle were computed using WERCO code for penetration X-9A and STARDYNE code for penetration X-10A, and then compared to the respective ADME code allowables. Effects from the adjacent attachment loads were taken into account in the evaluation of shell. The staff and consultants found the methodology and results for the Phase II evaluation of penetration X-9A and X-10A to be acceptable. According to TVA, none of the four HVAC penetrations requires modification for the new attachment loads as a result of the Phase II evaluation. On the basis of the sample review of two out of four calculations, the staff concludes that the Phase II evaluation of the HVAC penetrations is acceptable.

2.4.3 Conclusions

Based on findings from staff review of the sample TVA calculations, the staff concludes that the TVA evaluation of the SCV for new attachment loads resulting from the Set B seismic and DBA conditions is acceptable provided that TVA adequately complete the required Phase II evaluation of pad plates. During the inspection, the staff found the quality of TVA calculations and the qualifications of TVA and EBASCO engineers interviewed to be excellent.

2.4.5 List of Open Items

No open items were identified from this inspection.

2.4.5 TVA Documents Reviewed

During the inspection, the staff and consultants reviewed approximately a total of 20% of all pages contained in the follwoing TVA documents:

(1) Design Change Notice DCN/DCA-S-16031-A (B26 910614 820)

(2) TVA Calculation WCG-1-606, R2 (B18 910904 263)

(3) TVA Calculation WCG-1-721, R1 (B18 910430 253)

(4) TVA Calcualtion WCG-1-814, R1 (B18 910430 255)

(5) QIR-EBA-WBN-91-424, R0 (B18 910522 405)

(6) TVA Calculation WCG-1-862, R0 (B18 910502 281)

(7) TVA Calculation WCG-1-924, R0 (B18 910903 253)

(8) TVA Calcualtion WCG-1-926, R0 (B18 910903 257)

(9) TVA Calculation WCG-1-879, R0 (B18 910815 257)

(10) TVA Calcualtion WCG-1-872, R0 (B18 910905 252) 3231

(11) TVA letter to NRC, dated June 7, 1991.

2.5 GEOTECHNICAL ISSUES

2.5.1 Introduction

During the period of April 15th through 19th, 1991, an inspection was conducted of the seismic analysis calculations performed for the Watts Bar Nuclear power Plant. The primary areas involved with that review were concerned with the following evaluations:

a. stability analyses performed for the slopes alongside the Intake Channel adjacent to the Intake Pumping Station (IPS), the slopes along the ERCW/HPFP pipeline and the slopes adjacent to the Diesel Generator Building (DGB) and the Additional Diesel Generator Building (ADGB);

b. seismic stresses induced by potential liquefaction-induced settlements that may develop along the ERCW/HPFP pipeline;

c. seismic stress analyses performed for the sheetpile walls immediately adjacent to the IPS.

The criteria documents used during that review which served as bases of evaluation include the plant FSAR (Ref. 5), the Standard Review Plan of the USNRC (Ref. 6) and a number of design criteria documents (Refs. 7 through 12) used by TVA in their various design and analysis calculations and reviewed during previous inspections at the site.

Based on this inspection, the following items remained for further assessment, and were considered open or pending:

a. Stability of slopes adjacent to the Intake Channel;

b. Shear stress analyses for soils within sheetpile walls at the IPS;

c. Bearing pressures under Category I structures;

d. Settlement and wave passage effects along the buried piping;

The documents recently received and reviewed are associated with items a and d above and the results of their evaluation provided below.

2.5.2 Slope Stability Analyses Along The Intake Channel

The stability of a number of different slopes at the plant were previously reviewed and evaluated to ensure safety against both static and seismic loadings. The specific slopes evaluated during the inspection are the slopes adjacent to the DGB and the ADGB, the slopes alongside the length of the ERCW/HPFP pipeline, and those alongside the Intake Channel. The slopes near the DGB/ADGB are relatively flat slopes (approximately 1 on 3) through which safety related piping passes. Based on an evaluation of stability analyses of these slopes, it was concluded that the slopes in the vicinity of the DGB and the ADGB are stable. The slopes along the ERCW/HPFP pipeline were similarly evaluated for conditions both during and following a seismic event. These slopes similarly found to be adequately stable against the design seismic loadings.

To evaluate the stability of the slopes immediately adjacent to the Intake Channel, TVA performed a stability analysis using the REAME Computer Code for assumed conditions both during and following an earthquake. This code treats the pseudo-static response of the slope using the simplified Bishop method of analysis. The computed results indicated a relatively low safety factor nearing a value 1.0 for loading conditions during the earthquake. However, for this case, rather arbitrary definitions of soil strength parameters were made. In addition, no vertical component of earthquake loading was considered in these evaluations. Although the analyses performed are relatively conservative, it is difficult to assess the impact of these assumptions on the stability of these slopes. Therefore, it was requested that TVA reanalyze these slopes using the actual slope configurations and selecting soil strength properties based either on conservative assumptions or specific laboratory data. In addition, it was suggested that TVA consider the impact of coincident vertical and horizontal ground motions in the reanalysis. The purpose, of course, is to ensure that adequate margin exists in the stability of these critical slopes.

In the document supplied (Ref. 2), the TVA summarized numerical results for stability calculations using actual soil configurations appropriate for the Channel sections. However, the soil properties assumed for the potentially liquefiable materials at these locations were again assumed values, with no justification for their selection provided. Again, the resulting safety factors were still found to be close to unity for these cases. It is concluded from these calculations that the stability of these slopes remains an open issue.

2.5.3 Safety Related Buried Piping

Two additional documents (Refs. 3 and 4) were recently provided for review which are concerned with the evaluation of deflections and stresses induced in the safety related buried piping due to either over burden loads, wave passage effects or settlements induced by potential soil liquefication effects from the design based earthquake. In reviewing these calculations, several concerns mentioned in the previous review (Ref. 1) were adequately addressed and are no longer considered open.

However, two issues remain for further explanation and documentation. Firstly, the stress acceptance criteria presented in Ref. 4 indicates that all piping is qualified under ASME Code Equation 10A. It is the staff's understanding that this ASME criteria may not be appropriate for buried piping. Therefore, it is recommended that the appropriateness of the acceptance criteria used should be fully qualified.

Secondly, several questions remain for the stress calculations of the section of pipe located at the pipe cradle near the Intake Pumping Station which can be summarized as follows:

- The effects of surface overburden (soil, protective slab, surface loads, etc.) have not been incorporated into this calculation even though the pipe is not directly supported by either the ground or the cradle.

- The length of unsupported piping is assumed in this calculation, even though the length can be calculated using standard strength of materials approaches.

- The effects of lift-off of the pipe from the cradle has not been considered.

- The effects of the concentrated force developed by the cradle at its end point on the pipe stresses (stress concentration effects, local buckling, etc.) has not been considered.

2.5.4 Summary of Open Issues and Concerns

Of the open issues summarized above, it is believed that only two have been addressed by these recent documents. Of those issues addressed by these documents, the questions associated with the stability of the slopes adjacent to the Intake Channel are still considered open as no support has been provided for the range of strengths used in the calculations. Of the calculations provided for the buried piping, the evaluations of the stresses induced in the piping at the cradle are considered incomplete. In addition, the acceptance criteria used for all buried piping must be supported.

2.5.5 References

1. "Trip Report for Inspection at The Watts Bar Nuclear Plant on April 15 through 19, 1991," from C. J. Constantino to Dr. Thomas Cheng, USNRC, dated 14 May, 1991.

2. "Response to NRC Audit Items - Seismic Analysis Corrective Action Program (CAP) Implementation Audit - April 15-19, 1991," TVA to USNRC, Docket Nos. 50-390 and 391, dated June 7, 1991.

3. "Evaluation of Potential Settlement," WCG-1-868, RIMS B18-910503-269, 3 May, 1991

4. "Buried ERCW and HPFP Piping/Settlement Evaluation," WCG-1-867, RIMS B18-910429-253, 29 April, 1991

5. Watts Bar Nuclear Plant, "Final Safety Analysis Report" including Amendments 1 through 59, TVA, August 1986.

6. "Standard Review Plan," Revision 2, USNRC NUREG-0800, August 1989

7. "Concrete Structures - General," Design Criteria No. WB-DC-20-1, Rev. 6, Watts Bar NPP, April 11, 1989, RIMS B26-90-0423-078, 18 April 1990.

8. "Intake Pumping Station Concrete Structure, Intake Channel and Retaining Walls," Design Criteria No. WB-DC-20-19, Rev. 8, Watts Bar NPP, RIMS B26-90-0423-082, 18 April, 1990.

9. "Dynamic Earthquake Analysis of Category I Structures and Earth Embankments," Design Criteria No. WB-DC-20-24, Rev. 6, Watts Bar NPP, RIMS B26-91-0305-076, 5 Mar 1991.

10. "Analysis of Safety-Related Buried Piping Systems," Design Criteria No. WB-DC-40-31.5, Rev. 3, Watts Bar NPP, RIMS B26-90-0305-077, 28 Feb. 1990

11. Analysis of Category I and 1(L) Piping Systems, Design Criteria No. WB-DC-40-31.7, Rev. 12, Watts Bar NPP, RIMS B26-90-0511-100, 5 May 1990

12. "Dynamic Soil and Backfill Parameters," Appendix O, Seismic Assessment Report for the Watts Bar Nuclear Plant, Letter from TVA to NRC dated 29 June, 1989.

13. "Stability Analysis for Category I Buildings for NRC Audit on Seismic Cap," TVA-WCG-1-408, Rev. 2, RIMS B26-90-0323-155, 22 March, 1990

14. "Engineering Analysis of Rock Foundation," TVA-WCG-1-489, Rev. 2, RIMS B26-91-0207-157, 7 Feb. 1991

15. "Intake Channel - Seismic Stability Analysis of Slopes Near IPS," TVA-WCG-1-547, RIMS B18-90-1012-507, 10 October, 1990

16. "DGB/ADGB Slope Stability Analysis," TVA-WCG-1-624, RIMS B26-91-0226-151, 26 February, 1991.

2.6 Steel Platform Structures

2.6.1 Introduction

This section covers the team review of the design calculations for the steel platform structures. There is a total of 138 platforms at Watts Bar nuclear power plant. TVA selected 21 worst case platform structures from the entire population for analysis, and has completed 15 worst case platform structural analyses at the time of the audit. The team reviewed the methodologies used for selection of the worst case platforms and for design calculations.

2.6.2 Audit Review

2.6.2.1 Worst Case Platform Selection

The audit ream reviewed the TVA's documents to determine the adequacy of the methodology used for selection of the worst case platform structures. TVA selected the worst case platform structures based on the overall review of attributes observed during the walkthrough engineering assessment and drawing reviews. The team found that key attributes considered in selection of worst case platforms were adequate. Loads on steel platforms from attachments, torsional effects, connectin details, member size and platform configuratin, elevatin of the platforms, and group representation of the platforms were reasonably well considered. The presence and extent of these key attributes were recorded during the walkdowns, and they were used for structural evaluations.

2.6.2.2 Worst Case Platform Structural Evaluations

TVA used GT-STRUDL computer program for static and dynamic analysis of the platform structures. Also, a computer program was used to calculate the torsional stresses (i.e., St. Vanant shear, warping shear and warping normal stresses) since GT-STRUDL did not include calculation of torsional stresses of the structural members. A mathematical model of the platform structure based on recorded walkdown package and TVA drawings was developed for execution of the programs.

Three loading combinatins were considered during the analysis: (1) DL + LL (100 psf), (2) DL + LL (10 psf-accelerated) + OBE, and (3) DL + LL (10 pse-accelerated) + SSE. The team requested TVA to provide a justification of using the live loads (LL) of 100 psf and 10 psf. TVA responded that a live load used in the analysis was reserve capacity for the structure to account for foot traffic, set down loads, and other short duration transient loads not perfmanently attached to the platform, and the values of 100 psf and 10 psf for static and dynamic analyses, respectively, were consistent with what had been used at other TVA plants previously approved by NRC.

2.6.3 Conclusion

Four design calculations (WCG-1-496, WCG-1-865, WCG-1-907, and WCG-2-50) were chosen randomly from the 15 calculations for detailed review. From the review, the team found that the approach taken by TVA to calculate the seismic responses in the element of the platform structure was reasonable and adequate. The selected platform structure modelled as a three-dimensional lumped-mass system in the GT-STRUDL finite element analysis were properly subjected to horizontal (north-south and east-west directions) and vertical ground motions according to the seismic criteria as defined in the FSAR consistent with current licensing requirements. The structural responses (i.e., displacement, acceleration, shear, and moment) for both the OBE and SSE conditions obtained from the analysis were well compared with the allowable values defined in the 1969 AISC Steel Construction Manual, and have shown adequate seismic factor of safeties. TVA properly determined the necessary modifications to the structural members, steel to steel, and steel to wall if there were any modifications needed on the platform structures. They were well documented in the calculations and in DCN.

Overall, the review of the platform structural analysis showed that detailed calculations have been performed (15 calculations) with the incorporation of walkdown information and Sequoyah experience, and TVA has addressed issues adequately on: (1) attachment loads and the latest revisionsof loads, (2) torsional stresses combined with axial and flexural stresses on members, and (3) details for the design of welded and bolted connections. It is found that the TVA's methodologies used for selection of the worst case platforms and for design evaluations are acceptable.

Design calculations for thermal analysis and embedded plate analysis were not reviewed in this subtask.

2.6.4 List of Open Items

None.

2.6.5 List of Calculations and Time required for Review

The following design calculations (approximately 6,000 pages) were reviewed during the three days of the audit: WCG-1-496, WCG-1-865, WCG-1-907 and WCG-2-50.

2.7 Thermal Analysis

2.7.1 Introduction

TVA activities pertaining to evaluation of thermally restrained steel structures included the development of evaluation criteria, identification of potential thermally restrained cases, selection of worst cases based on field assessment and screening calculations, walkdown of selected worst cases and compilation of non-thermal loads, and evaluation of worst cases for structural adequacy. According to TVA, 204 potential thermally restrained cases have been identified out of which 15 worst cases have been selected. At the time of inspection, the evaluation of 5 worst cases has been completed and one modification has been identified. During the inspection, the staff and consultants reviewed the evaluation criteria, studies previously requested by the staff pertaining to the nonlinear analysis criteria, revision to FSAR Appendix 3.8E. selection of worst cases, and evaluaiton results for five worst cases. Audit review findings are discussed in the following.

2.7.2 Audit Review Findings

2.7.2.1 Evaluation Criteria

TVA Civil Design Guide DG-C1.6.12, R1, provides the analysis methods and evaluation criteria for thermally restrained steel structures. The Project Design

Criteria, WBN-DC-20-21, R6, refers to the Civil Design Guide as far as thermal evaluation is concerned and, therefore, staff review of the evaluation criteria was focused on Civil Design Guide DG-C1.6.12, R1.

(a) Screening - Section 3.2 of DG-C1.6.12 provides general procedures for initial screening of potential thermally restrained structures, and Section 3.3 provides general procedure for final screening for the purpose of selecting worst cases from the potential thermally restrained population. To simplify the screening calculations, the procedure allows the use of generic estimated spring stiffness to represent the steel members, connections, anchors, etc., in the analysis model for the thermally restrained structure. For example, the generic estimated spring stiffness is equal to 10,000 k/in for welds in shear and bolts in shear or tension, 1,000 k/in for concrete anchors, and 100,000 k-in/rad for baseplate rotation. Performance of field assessment and consideration of magnitude of non-thermal loads are also recommended as a part of the final screening for selection of the worst cases. The staff found the general procedure for initial and final screenings to be reasonable. The generic estimated spring stiffnesses were also found reasonable because they tend to be on the stiff side and hence are conservative as far as identifying worst case thermally restrained structures is concerned. For example, the recommended concrete anchor stiffness based on test data as documented in TVA calculation CSG-91-003, R0, is equal to 400 k/in for 1"-diameter wedge bolt anchors, 300 k/in for 3/4"-diameter self-drilling anchors, and 800 k/in and 600 k/in for 3/4" and 5/8" headed concrete anchors, respectively.

(b) Thermal Analysis - Section 5.0 of DG-C1.6.12 provides guidance for both linear and nonlinear analysis of worst case thermally restrained structures. Section 4.0 provides guidance for computing more rigorous spring stiffnesses for thermal analysis. For example, spring stiffness for concrete anchors is specified in TVA Design Standard DS-C1.7.1, and the rotational spring for baseplates is computed either with Roark's formula or, more rigorously, the BASEPLATE II code. According to a comparative study requested by the staff during the audit (Item TT-4), Roark's formula tends to produce a stiffer spring stiffness which is conservative because it restrains the thermally loaded steel member more. The staff accepted the results of the comparative study, and Item TT-4 is closed. Linear analysis is done either manually for simple structures or with computer codes such as STRUDL and ANSYS. Nonlinear analysis is done with ANSYS code using the large displacement option for numerical accuracy. Since the results from a nonlinear analysis could vary depending on the sequence of load application of thermal and non-thermal loads, TVA performed a load sequence study in partial response to a previous staff request for additional information (RAI) in SSER 6, Outstanding Issue 19(j). The load sequence recommended in the Design Guide is to apply all non-thermal loads prior to thermal load in the nonlinear analysis, which is consistent with the result of the load sequence study, although the Design Guide states that other sequences should also be considered. Other than the load sequence, the staff found the general procedures in the Design Guide for both linear and nonlinear analysis are reasonable. As discussed later in 2.8.2.2 of this report, during the inspection, the staff requested additional information regarding the sensitivity of the yield displacement computation to the size of thermal load step used in the load sequence study (Item TT-8) and staff review of the TVA response is incomplete.

(b) Evaluation Criteria - Appendix C of DG-C1.6.12 specifies the acceptance criteria for linear analyses. For both primary and ancillary structural members, they are accepted when the ductility factor computed on the basis of energy balance method is less than 1.5 for a member in shear or tension, or a very short member in compression (for kl/r less than about 13). Alternately, they may be evaluated against 1.7 x AISC allowables in terms of stress. For a compressive member having kl/r exceeding about 13, it is evaluated with an allowable compressive force, Pu, computed in accordance with AISC code. For members subjected to both compression and bending, evaluation considers the interaction between the two. For concrete anchors, they are qualified when the unrestrained thermal growth at the anchor is less than 0.1D (D=anchor diameter) for self-drilling anchors and 0.2D for other than self-drilling anchors.

For nonlinear analysis, evaluation criteria for connections are the same as those for linear analysis. For members, they may be qualified either according to the linear acceptance criteria or based on the following ductility criteria:

- Primary members: ductility factor Ud less than 3;

- Ancillary members: ductility factor Ud or Us less than 0.5 (eu/ey) for members, less than 10 for tension member due to bending, less than 1.3 for compression members having kl/r within 20, and less than 1.0 for compression members having kl/r exceeding 20.

Ud and Us are ductility factor computed on the basis of displacement and strain, respectively. Strains eu and ey correspond to the ultimate and yield strain. The staff did not complete review of the evaluation criteria during the audit. Also, the staff identified a concern with the criteria for a short compression member. For nonlinear analyses, a short ancillary member in compression (kl/r less than 20) is limited to a ductility factor of 1.3 while, for linear analyses, a short compression member (kl/r less than 13) is limited to a energy balance based ductility of 1.5 for both primary and ancillary members. Thus the linear acceptance criteria in this case appears to be less conservative than the nonlinear acceptance criteria for an ancillary member. This item is TT-6, and TVA provided a response during the inspection. Staff review of the TVA response is not yet complete.

2.7.2.2 Studies for Nonlinear Thermal Analysis

TVA performed three studies in response to previous staff RAI to facilitate staff review of the nonlinear analysis and acceptance criteria. In their letter to NRC dated June 6, 1991, TVA submitted an Enclosure 5 documenting the first study (a test correlation study) in response to a previous staff RAI during the April, 1991, inspection. In another letter to NRC dated August 22, 1991, TVA submitted two additional studies (a repeated load study and a load sequence study) in response to a previous staff RAI per SSER 6, Outstanding Issue 19(j). All three studies used ANSYS for the nonlinear analysis. The first study (TVA calculation WCG-1-811) includes four problems. The purpose is to demonstrate the capability of ANSYS for nonlinear thermal analysis and the self-limiting nature of a thermal induced compression in a beam-column as compared to the nature of a non-thermal compression load with the elastic limit is exceeded. Out of the four problems, the first one is intended to correlate the analysis results to test results for a beam-column first subjected to a constant compression at both ends and then subjected to an increasing lateral load at the mid span. There appears close agreement between the analysis and test results at both the elastic and inelastic ranges. The second problem considers the same beam-column specimen (M4x13) used in the first problem. The beam-column was first subjected to a constant lateral load at mid span and they subjected to a temperature rise of from 70 to 460 degrees. The analysis results appear to show the self-limiting nature of the thermal load because the computed axial compression force decreased while the rate of lateral displacement at mid span remained stable after elastic limit of the beam was reached (at about 170 degrees) and also after a displacement-based ductility of 3 was reached (at about 410 degrees). The third problem is an ANSYS nonlinear thermal analysis of a W6x10 beam-column having an eccentric axial restraint at the ends. The beam was subjected to a temperature rise from 70 to 590 degrees in the analysis. The results indicate that the beam reached yield at a temperature about 200 degrees, with the induced axial force at yield in close agreement with the yield load derived from a static load test. The fourth problem is similar to the second one, with the difference that a short, cantilevered ancillary beam replaced the hinge support at one end of the beam-column, thus reducing the thermal restraint to the beam. The results of the test correlation study appear reasonable to the staff as far as the study is concerned. Staff review, however, is incomplete regarding the validity of generalization of the study results to substantiate the nonlinear acceptance criteria proposed by TVA in the Design Guide. The second study, documented in TVA calculation WCG-1-1047, R0, is intended to address the effect of the cyclic nature of seismic loads on a thermally restrained structure loaded beyond the elastic limit. It considered two worst case structures, Case 1-27 and 1-28, at WBN. In both cases, all non-thermal loads were applied prior to the thermal load resulting from a temperature rise of from 70 degrees to the accident temperature of 400 degrees. The SSE seismic load was then subjected to cycling for ten times, in a static manner. Both structures were already loaded into the inelastic range, due to weak-axis bending, prior to cycling the seismic load. The results indicate that the maximum displacement remained essentially constant at the end of each cycle in both cases and a "shakedown" of the structure did not occur. Because cycling of the seismic load was simulated in a static manner in the study, during the audit the staff requested TVA to perform a literature search for available information on tests in which the structure was loaded beyond elastic limit by thermal and cycling non-thermal loads. This is Item TT-10. Such information, if available, would facilitate the staff review of the effect of cyclic load on a thermally restrained strucutre loaded beyond elastic limit.

The third study, documented also in TVA calculation WCG-1-1047, assessed the effect of load sequence between thermal and seismic loads on the same two worst case structures considered in the second study. Dead and sustained live loads were first applied. The SSE seismic load was applied prior to the thermal load in one analysis, and following the thermal load in another analysis. The results indicate that for both structures the maximum displacement appeared to be nearly independent of the load sequence while the yield displacement, defined as the displacement at the onset of the first local yielding of an extreme fiber, appeared to be smaller when thermal load followed the seismic load application. The study thus suggests that the sequence with thermal load following non-thermal loads is more critical because it would give rise to a smaller yield displacement and hence a higher displacement-based ductility factor. During the audit the staff and consultants found that the size of temperature step of 10 degrees used in the study may be too large for accurately pinpointing the first onset of extreme fiber yielding. Thus, in Item TT-8, the staff requested TVA to assess the sensitivity of the computed yield displacement to the size of thermal load step. TVA provided a response to Item TT-8 during the inspection, and staff review of the TVA response is incomplete.

In summary, staff review of the three TVA studies is incomplete. In addition, the inspection resulted in two staff RAI, i.e., Item T-10 for the repeated load study and Item TT-8 for the load sequence study. TVA response to Item TT-8 was provided to the staff during the inspection.

2.7.2.3. Revision to FSAR Appendix 3.8E

The subject FSAR revision was submitted for staff review as Enclosure 2 to the TVA letter to NRC dated June 6, 1991. The staff found that, while intended to remain brief, the proposed FSAR revision includes the linear acceptance criteria for thermal evaluation of only compression members and not members in shear and/or tension. In addition, clarification is required for the definition of the ductility factors because, according to TVA Design Guide C1.6.12, the ductility factor is based on energy balance method for linear acceptance criteria and is based on displacement and/or strain for non-linear acceptance criteria. This concern resulted in Open Item TT-5 during the inspection, and TVA provided their response. Staff review of the TVA response is incomplete, and Item TT-5 remains open.

2.7.2.4 Selection of Worst Case Structures

TVA calculation WCG-1-790, R0, documents the procedure and results of the field assessment and screening calculations that resulted in the selection of 15 worst cases of thermally restrained structures at WBN. This issue is open because staff review for the adequacy of the worst case selection is incomplete.

2.7.2.5 Evaluation of Five Worst Cases

TVA calculation WCG-1-969, R0, documents the results of thermal evaluation of five worst cases: Case 1-27, 2&3-9(C), 1-11, 2&3-8(G), 5-7. ANSYS code was used in the thermal analysis for all five cases. The resulting maximum displacement ductility factor is 4.3 for an axially restrained member in Case 1-27, and is within 1.0 for steel members in all remaining cases. For the axially restrained member in Worst Case 1-27 attaining the ductility factor of 4.3, TVA will provide a slotted hole to one end to help relieve the thermal restraint. A reanalysis of the modified structure indicates that the modification would result in a displacement ductility of less than 1.0 for the steel member in question. Staff review of the thermal evaluation of these five worst cases was based on the assumption that the evaluation criteria specified in Design Guide DG-C1.6.12 are acceptable for the time being. During the audit the staff and consultants found that the concrete anchors were evaluated based on the anchor movement computed from ANSYS analysis of the thermally restrained structure. This contradicts the criteria specified in the Design Guide which uses the unrestrained thermal growth at the anchor as the anchor movement for comparison with the allowable. This gave rise to Item TT-7(a), and TVA provided a response in which they proposed to revise the Design Guide criteria such that the anchor movement for evaluation is not mandated to be the unrestrained thermal movement at the anchor. Staff review of the TVA response is incomplete. During the audit the staff and consultants made two RAI in order to facilitate staff review of the five worst case thermal evaluations. Item TT-7(b) requests TVA to compare the maximum axial compression force from the analysis of Worst Case 2&3-9(C) with the allowable compression force, Pu, specified in Section C2.3.2 of the Design Guide. Item TT-7(c) requests TVA to demonstrate the capability of ANSYS for adequate buckling prediction by providing an example comparing the buckling load predicted by ANSYS with that computed according to the AISC procedure for a given compression member. TVA provided the requested information during the audit and staff review of the response is not yet complete.

2.7.3 Conclusions

Based on the review findings discussed previously and the incomplete status of staff review, the thermal evaluation remains an open issue. The staff found, however, the quality of TVA calculations and qualification of TVA and EBASCO engineers interviewed to be excellent.

2.8.4 List of Open Items

The thermal evaluation as a whole remains an open issue because the staff has not completed their review of all TVA documents and responses to RAI. Areas that remain open and the pertaining open items identified during the inspection are:

(1) Thermal analysis methodology and evaluation criteria. Specific open items include:

TT-6: Contradiction between the nonlinear acceptance criteria for a short ancillary compression member and the linear acceptance criteria for a very short primary or ancillary compression member.

TT-8: Sensitivity of the yield displacement predicted by ANSYS to the size of thermal load step in the load sequence study.

TT-10: Literature search for test data on inelastic beam-columns subjected to thermal and cyclic non-thermal loads.

(2) Revision to FSAR Appendix 3.8E. Specific open item includes:

TT-5: Incompleteness in linear acceptance criteria for members in shear and/or tension. Clarification is also required for the ductility factors in the text.

(3) Selection of Worst Case Thermally Restrained Structures. Staff review of this area is incomplete, and no specific open item was identified during the audit.

(4) Worst Case Structure Evaluation. Staff review is incomplete. Specific open items include:

TT-7(a): Contradiction between Design Guide DG-C1.6.12 and Calculation WCG-1-969 in evaluation of concrete anchor movements.

TT-7(b): Comparison of axial force in Worst Case 2&3-9(C) with allowable compression force specified in C.2.3.2 of Design Guide DG.C1.6.12

TT-7(c): Comparison of buckling load predicted by ANSYS with buckling load computed with AISC procedure.

2.7.5 TVA Documents Reviewed

The staff reviewed about 60% of the total number of pages contained in the following TVA documents:

(1) TVA Letter to NRC dated June 6, 1991, Enclosure 2: Proposed Revision to WBN FSAR Appendix 3.8E.

(2) TVA Civil Design Guide DG-C1.6.12, RI (B41 910506 004)

(3) TVA Design Criteria WB-DC-20-21, R6 (B26 891207 080)

(4) TVA Calculation CSG-91-003, R0 (B41 910809 001)

(5) TVA Calculation WCG-1-811, R0 (B18 910413 253)

(6) TVA Calculation WCG-1-1047, R0 (B18 910907 253)

(7) TVA Calculation WCG-1-790, R1 (B18 910907 251)

(8) TVA Calculation WCG-1-969, R0 (B18 910907 255)

2.8 Above-Ground Vertical Steel Tank

2.8.1 Introduction

The refueling water storage tank (RWST) is the only safety-related above-ground vertical steel tank at WBN. Previous staff SER issued in March, 1991 concluded that the criteria used by TVA for the evaluation of the RWST met the guidance of Standard Review Plan (SRP) 3.7.3. Specifically, the staff concluded that the modeling techniques of the RWST and foundation, the procedures for generating the amplified response spectrum, and the method for evaluating the dynamic stability (overturning and sliding) met the SRP requirements, and the final Set B seismic responses of the tank are acceptable. The only issue remained to be reviewed by the staff is, according to the SER, evaluation of the RWST structural integrity for the Set B seismic loads. During this audit the staff and consultants reviewed the results of structural integrity evaluation performed by TVA, and audit review findings follow.

2.8.2 Audit Review Findings

Results of TVA evaluation of the RWST structural integrity are documented in TVA calculation WCG-1-395, R0. The evaluation address the following areas: primary membrane and primary bending stress in the tank wall and roof; buckling potential of the tank wall and roof; foundation mat and bearing pressure; dynamic overturning and sliding stability; pipe support movements; and tank anchorage. Review finding for each area is separately discussed in the following.

2.8.2.1 Primary Membrane and Bending Stresses in Tank Wall and Roof

For the upset condition, which includes the OBE seismic load, TVA calculation evaluated the primary membrane stress, Pm, in the tank wall and the primary membrane plus bending stress, Pm + Pb, in the tank wall and roof against the respective ASME code allowables, 1.1 Sm and 1.65 Sm. For the faulted condition, which includes the SSE load, Pm + Pb was evaluated against the allowable stress of 2.4 Sm in both the tank wall and roof. The minimum safety factor is equal to about 2.0. The staff found the stress evaluation for tank wall and roof to be adequate.

2.8.2.2 Buckling Evaluation

Bucking evaluation of the tank wall near the base was performed in accordance with the evaluation criteria specified in the design specification WBN-DS-1935-2226-R00. The evaluation considered three different buckling stresses, i.e., axial compression + internal pressure; shear + interal pressure; bending + internal pressure. The resulting minimum factor of safety is about 6.0 and 4.5 for the OBE and SSE condition, respectively. To address the previous staff request in a letter from NRC to TVA dated June 27, 1989, TVA performed additional evaluation fo the potential of the tank wall against elastic buckling (diamond shape) and plastic buckling (elephant foot) near the tank base. The method used by TVA to compute the buckling stress is based on the one proposed by A.D. Veletsos and R. P. Kennedy for the diamond-shape and elephant-foot buckling modes, respectively, and the resulting factors of safety are about 6.0 and 5.5 for the SSE condition. TVA evaluation also found the tank roof to have sufficient margin against buckling. The staff found the buckling evaluation to be acceptable.

2.8.2.3 Tank Foundation

According to TVA calculations, the maximum shear stress in the foundation mat is about 30 psi and 50 psi for the OBE and SSE condition, respectively. The shear stress was computed taking into account the effect of potential separation of the mat from the foundation soil. This concrete mat shear stress is well below the ACI code allowable. The maximum bearing pressure on soil was found to be about 8.0 ksf for the SSE condition, which is well within the allowable bearing pressure of 15 ksf. The staff found the tank foundation evaluation to be adequate.

2.8.2.4 Dynamic Stability

TVA evaluation shows the resulting factor of safety to be 1.7 and 1.9 against overturning and sliding, respectively, for the SSE condition. Both exceeded the minimum safety factor of 1.1 required by the SRP. For the OBE condition, an even larger margin resulted for both overturning and sliding with respect to the minimum required factor of 1.5. The staff found the TVA evaluation for dynamic stability of the tank to be acceptable.

2.8.2.5 Nozzle for Piping Connection

According to TVA, evaluation of the nozzle at piping connection to the tank is the responsibility of the Mechanical Engineering discipline. Therefore, TVA calculation WCG-1-395 only provides the horizontal and vertical seismic displacements of the tank at different elevations, for use by the Mechanical Engineering discipline. The staff will review the structural integrity evaluation of the RWST nozzles when the TVA calculation becomes available. This item remains unreviewed.

2.8.2.6 Tank Anchorage

There are 48 of A307 bolts, 2" in diameter, that anchor the tank to the concrete mat. TVA calculation WCG-1-395 evaluated the anchor bolts for shear and tension separately, without taking into account interaction between the two. This staff concern was identified as Item TT-9 during the audit. TVA resolved the staff concern by evaluating the anchor bolt for shear/tension interaction in accordance with TVA Design Criteria DS-C1.7.1, R0. The resulting factor of safety is about 1.7 for the SSE condition. In addition, TVA checked pullout capacity of the concrete and found the factor of safety to be about 1.2 for the SSE condition. Results of this calculation are documented in TVA response to the staff concern, Item TT-9 (B26 910913 104). Staff review of the response found it sufficient to close Item TT-9. Thus, the staff concludes that the TVA evaluation of tank anchorage is acceptable.

2.8.3 Conclusion

Based on the audit findings discussed previously, the staff concludes that the issue of RWST structural integrity evaluation is closed with the exception that TVA must also demonstrate the structural integrity of nozzles at the piping/tank connections. The staff will review the nozzle evaluation when the results become available. During the audit the staff found that the quality of TVA calculations and the qualification of TVA engineers interviewed to be excellent.

2.8.4 List of Open Items

As stated in 2.8.3, the only item remains open is the structural integrity evaluation of nozzles at the piping to tank connections because calculation was not available for staff review during the audit.

2.8.5 TVA Documents Reviewed

The staff and consultants reviewed about 80% of the total pages contained in the following documents:

(1) TVA Calculation WCG-1-395, R0 (B26 900405 162)

(2) TVA Design Criteria WB-DC-40-31.6 R3 (B26 910510 078)

(3) TVA Design Specification WBNP-DS-1935-7276-R00

(4) TVA response to Item TT-9 (B26 910913 104)

3. CONCLUSIONS

On the basis of the review findings discussed in Section 2, the team concludes that the general approach taken by TVA for resolving issues in the above-mentioned design areas is reasonable and adequate. The team raised a number of open issue in each design area and the staff request TVA to resolve and provide results for future review. These items are listed in Section 2.0.

Enclosure 1

ATTENDANCE LIST

DATE: 9/9/91

Name	Organization
Wayne A. Massie	TVA
Sang Bo Kim	NRC
Tom N.C. Tsai	NCT Engineering
Ahmet Unsar	HEA, IN
Yong S. Kim	NRC
Jerry L. Bitner	RLCA
Don Rutherford	RLCA
Clyde L. Hawn	EBASCO
Clifford Kent	EBASCO
Jim Ruimerman	EBASCO
R. K. Alexander	TVA-NE
R. O. Hernandez	TVA Egr/Madds
S. W. Crowe	NQA
W. L. Elliott	TVA-NE
F. E. Laurent	TVA-NQA
Raj D. Reheja	TVA
Rick Purcell	TVA Site Lic.
John Garrity	TVA
R. J. Mithisen	EBASCO
A. W. Layfield	EBASCO
P. L. Pace	TVA Site Lic.
Jim Cruise	TVA Site Lic.
Nick Kazanas	TVA
Toturgul, Husey	EBASCO
Odar, Enver	EBASCO
Pannell, George L.	TVA
Ron Gibbs	USNRC
Glenn Walton	NRC
H. Livermore	NRC RIT

Enclosure 2

ATTENDANCE LIST

DATE: 9/13/91

Name	Organization
Wayne A. Massie	LBN TVA
Ahmet Unsar	HEA
Ruben O. Hernandez	TVA Egr/Madds
Tom N.C. Tsai	NCT Engineering
Sang Bo Kim	NRR/ESGB
Yong S. Kim	NRC/NRR/ESGB
Pannell, George L.	TVA
Glenn Walton	NRC
H. Livermore	NRC RIT
K. Barr	NRC
H. Weber	TVA
R. Purcell	TVA Site Licensing
S. W. Crowe	NQA-TVA
W. L. Elliott	TVA-NE
R. K. Alexander	TVA-NE
Envar Odar	ESI
A. W. Layfield	ESI
R. J. Mithisen	EBASCO
J. L. Ehasz	ESI
Jim Ruimerman	ESI
John Garrity	TVA
P. L. Pace	TVA Site Lic.
N. C. Kazanas	TVA