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DEC 30 1993

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

Gentlemen:

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

WATTS BAR NUCLEAR PLANT (WBN) - UNITS 1 AND 2 - RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION (RAI) CONCERNING STRUCTURAL ASPECTS OF DESIGN BASIS ACCIDENT SPECTRA AND LEAK BEFORE BREAK ANALYSIS (TAC M79692 AND M79693)

Reference: NRC letter to TVA dated October 15, 1993, "Request For Additional Information Concerning Structural Aspects of Design Basis Accident Spectra and Leak-Before-Break Analysis (TAC M79692 and M79693)"

The referenced correspondence noted that additional information is required in order for the NRC staff to complete its review of the structural aspects of the Design Basis Accident (DBA) Spectra and Leak-before-break (LBB) Analysis.

The enclosure to this letter addresses to the extent possible the identified NRC requests. As some of the responses involve proprietary data or bulk calculations, it is requested that an onsite review be scheduled to supplement the information in this submittal.

If additional information is required, contact P. L. Pace at (615)-365-1824.

Very truly yours,

W. J. Museler

William J. Museler

Enclosure
cc: See page 2

D030

cc (Enclosure):

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ENCLOSURE

RESPONSE TO NRC REQUEST DATED OCTOBER 25, 1993
FOR ADDITIONAL INFORMATION
DESIGN BASIS ACCIDENT(DBA) SPECTRA
FOR THE STEEL CONTAINMENT VESSEL (SCV)
(TAC M79692 AND M79693)

References:

1) NRC Request for Additional Information (RAI), dated 3/25/93 (TAC M79692 AND M79693)

2) TVA letter dated 5/22/93, Response to NRC RAI - Design Basis Accident Spectra for the Steel Containment Vessel.

3) NRC Request for Additional Information, dated 10/25/93 (TAC M79692 AND 79693)

4) NRC Audit Report for the Special Calculation Audit Relating to the Civil Calculation Program and Implementation, Section 2.4.2, dated January 23, 1992.

5) Watts Bar Safety Evaluation Report (SER), NUREG-0847

6) Watts Bar Safety Evaluation Report, Supplement 3, January, 1985.

Responses to each of the questions presented in Reference 3 are provided below to the extent achievable without the transmittal of proprietary data or bulk calculations. As discussed in the telecon with NRC (Chris Green and reviewer Yong Kim) on November 10, 1993, the NRC acceptance of the Steel Containment Vessel design is documented in Section 3.8.1 of the original SER (NUREG-0847) and Supplement 3 of the SER (References 5 and 6). The ANSYS model was previously reviewed and accepted during the Special Calculation Audit of the Civil Calculation Program (Reference 4).

The text of the NRC questions is repeated below for reference. A considerable amount of the information included in the following response to each question was provided in the TVA's previous response (Reference 2).

Question 1:

Provide details of the ANSYS finite element model, including dimensions and material properties of the steel containment vessel used in the analyses.

Response:

The Steel Containment Vessel (SCV) ANSYS model is included in the DBA Spectra Calculation, which is extremely large (over 2000 pages). Rather than transmit that calculation in response to a similar question in Reference 1, TVA provided a detailed written description of the SCV in Reference 2 and noted that the detailed ANSYS model had already been reviewed in depth by the NRC staff during the Civil Calculation Audit (Reference 4). That audit reviewed both the ANSYS model and the methodology for performing the thermal analysis of the SCV for the temperature transient due to a main steam line break (MSLB). The staff concluded in Section 2.4.2 of the audit report that the model and the analysis methodology were acceptable. The identical ANSYS model was used for analysis of the subcompartment pressurizations and subsequent generation of the DBA spectra.

Question 2:

Provide detailed information related to the dynamic analysis, such as the basis for selecting parameters for the dynamic model, boundary conditions adopted, method used for solving the equations of motion, type and number of time histories used, time steps and damping values adopted, locations and directions of loading applications, foundation representation in the dynamic model, consideration of torsional and rocking effects, floor response spectra generation, and thermal loading consideration.

Response:

a. Basis for selecting parameters for the dynamic model

The mathematical representation of the SCV is an assembly of axisymmetric shell elements. Circumferential stiffeners are provided at approximately 10 foot centers and are represented explicitly in the ANSYS model. Vertical stiffeners are spaced at approximately 5 degree intervals around the containment shell between the first and second circumferential ring stiffeners. The vertical stiffeners are accounted for by adjusting the properties of the corresponding axisymmetric elements, as ANSYS cannot model the vertical stiffeners explicitly. Element elastic properties were represented as orthotropic to account for the effect of vertical stiffeners. Element densities were increased to account for the mass of the attached personnel lock, equipment hatch, equipment, piping, cable trays, and etc.

The finite element model uses the STIF61 axisymmetric conical shell element, which is the appropriate ANSYS element for the analysis of a thin shell subjected to non-axisymmetric loadings. The element formulation is for a linear elastic material. Acceptable loading on the element includes the specification of uniform dynamic loads over defined zones of the element circumference. The STIF61 element formulation accounts for nonlinear effects due to stress stiffening. However, the stress stiffening options are not utilized in the SCV analysis. Therefore, the ANSYS analysis of the SCV is a linear analysis. The STIF61 element is a biaxial shell with both membrane and bending capabilities. The element has four degrees of freedom at each node: translation in the radial, vertical, and tangential directions and rotation about the tangential axis.

b. Boundary conditions adopted

The SCV is secured by anchors to a reinforced concrete base mat. To simulate this boundary condition, the ANSYS model is terminated at the elevation of the base mat and is considered fixed at the base.

c. Method used for solving the equations of motion

A Houbolt numerical integration method is used by ANSYS (Version 4.3A) for all transient dynamic analyses. The Houbolt method is described in detail in the textbook by K. J. Bathe, "Finite Element Procedures in Engineering Applications" (Prentice-Hall).

d. Type and number of time histories used

Westinghouse WCAP-12057 contains 15 pressure time history load cases, which represent the governing breaks for subcompartment dynamic pressurization. Each load case contains pressure transient time histories for each subcompartment adjacent to the inner shell surface. For a given load case, each pressure time history was applied to that portion of the SCV model exposed to conditions in the affected subcompartment. Hence, different loads were applied over adjoining portions of each ring element by the locations of subcompartments. This methodology produced an overall loading application pattern which was non-axisymmetric in nature.

Load cases for the ANSYS analysis are generated by decomposing the pressure transient time histories for each of the 15 load cases into an equivalent time dependent Fourier loading of 17 terms. The accuracy of a Fourier representation was previously demonstrated in Reference 2. The ANSYS analysis for each load case generates a set of 17 displacement time history results (one for each corresponding term of the Fourier loading for that load case). The total response for each load case is developed by algebraically summing the 17 displacement time histories. This analysis sequence is repeated for each of the 15 load cases.

These Fourier terms were generated by the ANSYS/PREP6 preprocessor, which was also used to generate equivalent Fourier loadings for the thermal transient analysis, which was accepted by the NRC staff in the special audit of Reference 4.

e. Time steps

The time interval between adjacent loading time steps is used as the time step for numerical integration. The WCAP pressure time histories are digitized at a variable time step, which averages approximately 0.002 second. An acceptable time step for capturing contributions to the total response from the highest structural modes of interest is given in Biggs (Introduction to Structural Dynamics) as 1/10th the highest natural frequency. The highest modes of interest for the SCV are in the order of 25 Hz, which indicates that a time step of approximately 0.004 second (i.e., 1/10th of 1/25 Hz) captures appropriate model responses. Therefore, the loading time steps in the order of 0.002 second is an acceptable time step for numerical integration.

f. Damping values

A structural damping of 1 percent of critical damping was consistent with the summary damping information presented in WBN FSAR Table 3.7-2 and with the values used in the seismic and thermal transient analyses of the SCV.

g. Locations and directions of loading applications

The STIF61 axisymmetric element allows loads to be defined continuously over all or part of the element circumference. This capability was essential to accurate application of pressure time history loads for each subcompartment around the circumference. The pressure loadings were converted to equivalent Fourier loadings as described in Section 2d above. The equivalent Fourier loading corresponding to each of the 15 load cases was applied as a radial load on the inner surface of each circumferential ring element.

h. Foundation representation in the dynamic model

The SCV is anchored into a reinforced concrete base mat which is supported and keyed into competent bedrock. The appropriate simulation is to model the foundation as a point of fixity in the ANSYS model. The use of a fixed base model is consistent with the seismic analysis and the thermal transient analysis of the SCV.

i. Consideration of torsional and rocking effects

As noted in Section 2b, the SCV is continuous over and attached to the reinforced concrete base mat, which is keyed into competent rock. Therefore, rocking behavior as a result of foundation flexibility is not a model characteristic. The model uses the STIF61 axisymmetric element, which is a biaxial shell with both membrane and bending capabilities and with four degrees of freedom at each node: translation in the radial, vertical, and tangential directions and rotation about the tangential axis. These degrees of freedom are sufficient to capture the behavior of the SCV. The non-axisymmetric loads act radially through the centerline of the SCV and, as such, have no potential to excite structural torsion modes.

j. Floor response spectra generation

The methodology and computer programs used to generate acceleration response spectra (ARS) are the same as used for seismic analysis of Category I structures and have been previously accepted by the NRC. Required input to the programs includes acceleration time histories corresponding to the points at which spectra are desired. As noted in TVA's previous response (Reference 2), the APTH/COMPOST postprocessing program develops a total displacement time history for each load case by algebraically summing the 17 displacement time histories from the Fourier loading function. The postprocessor then performs double differentiation of the total displacement time history for each load case to compute a corresponding acceleration time history. The postprocessor computes acceleration time histories for any desired azimuth around each axisymmetric element and at designated elevations within the model. The output time histories from the APTH/COMPOST program are then input into the spectra generation programs.

ARS were generated for 10 selected elevations and at 16 selected azimuths around the circumference of the SCV in the radial, tangential, north-south, east-west, and vertical directions. These ARS were calculated for each of the load cases separately for fixed damping values of 1, 2, 3, 4, 5, and 7 percent of critical and for ASME N411 variable equipment damping. Results from each load case were then enveloped for each azimuth and elevation. The envelope ARS are then used in the evaluation of commodities attached to the SCV.

k. Thermal loading consideration

The thermal effects associated with pipe breaks in the containment lower compartment do not coincide with the effects of dynamic local pressurizations. Local pressurization effects were shown in WCAP-12057 to generally peak within 0.05-0.4 second and reach relative equilibrium within 1 second. The pressure transient time histories generated by Westinghouse are terminated at one second. As discussed in WBN FSAR Section 3.8A, significant thermal effects on the SCV are negligible within that time frame, with thermal peaks occurring approximately 5 seconds or more after the pipe break. Therefore, the thermal transients are not considered to occur simultaneously with DBA pressure transients.

Question 3:

Provide the input (the local pressure time histories) used for analysis, and the output (SCV response spectra at the bottom of the SCV connected to the concrete foundation). Also, discuss how these outputs were used in confirming that the SCV stresses and strains induced by the local pressure meet the licensing basis acceptance criteria.

Response:

a. Local pressure time histories used for analysis

The applicable portions of WCAP-12057, which contains pressure transient listings and plots, is over 1000 pages in length. The WCAP is a proprietary Westinghouse document and is available for review on site.

b. SCV response spectra at the bottom of the SCV

No spectra were generated at the point where the SCV is connected to the base mat. As noted earlier, the bottom of the SCV is modelled as a fixed connection to a rigid concrete structure.

c. SCV stress evaluation

This analysis did not result in calculation of design stresses or strains in the SCV. In accordance with published NRC guidance on General Design Criterion (GDC) 4, the design basis pressurization loading for the SCV results from the non-mechanistic double-ended guillotine rupture of the primary loop. These and other design loads for the SCV are discussed in FSAR Section 3.8.1. NRC staff review and concurrence is documented in Section 3.8.1 of the SER and in Supplement 3 (References 5 and 6).

Question 4:

Discuss the adequacy and validity of using ANSYS code for pressure time history analyses for large structure such as Watts Bar SCV from the stand point of code verification.

Response:

The SCV is modelled as a thin shell axisymmetric structure using the finite element type and analysis capabilities of ANSYS described above. Shell structures are classified as thin or thick shells based on the thickness being small relative to the radius. The ratio of shell radius to thickness for the SCV is a minimum of 460, which far exceeds the minimum value for thin shell behavior of 25 given on page 24-2 of Gaylord and Gaylord, "Structural Engineering Handbook," (Third Edition).

The ANSYS computer code includes verification for analysis of thin shell structures. The SCV analysis methodology has relied only on documented features of the ANSYS computer code. The ANSYS code was verified and maintained in accordance with approved QA procedures for software development and verification. The verification package is available for inspection in the offices of Control Data Corporation (CDC).