TVA

Tennessee Valley Authority, 1101 Market Street, Chattanooga, Tennessee 37402

JUN 06 1991

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 - EVALUATION CRITERIA FOR STEEL STRUCTURES WITH THERMAL RESTRAINT

In accordance with the NRC request made during the Seismic Analysis Corrective Action Program audit exit, April 19, 1991, enclosed is the following information relative to the WBN evaluation criteria for steel structures with thermal restraint.

Enclosure 1 - Responses to supplemental NRC questions on WBN Final Safety Analysis Report (FSAR), Section 3.8, "Category I Structures"

Enclosure 2 - Proposed revision to WBN FSAR Appendix 3.8E

Enclosure 3 - Design Guide C1.6.12, "Evaluation of Steel Structures with Thermal Restraint," Revision 1

Enclosure 4 - Design Criteria WB-DC-20-21, "Miscellaneous Steel Components for Category I Structures," Revision 6

Enclosure 5 - Test correlation study for thermal use of ductility ratio WCG-1-811, Revision 0

This information was requested by NRC audit team leader, T. Cheng, in order to facilitate review of this issue at NRC headquarters, while focusing the team's site attention on items that could not be effectively evaluated away from WBN.

TVA concurred with this request and agreed to formally submit this information to the staff.

No new commitments are contained in this submittal.

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If there are any questions, please telephone P. L. Pace at (615) 365-1824.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

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50-390 WATTS BAR TVA

RESPONSE TO SUPPLEMENTAL NRC QUESTIONS ON FSAR SECTION 3.8

w/ltr dtd 6/6/91 #9106100406

-NOTICE-

ENCLOSURE 1

RESPONSES TO SUPPLEMENTAL NRC QUESTIONS
ON WATTS BAR NUCLEAR PLANT
FINAL SAFETY ANALYSIS REPORT, SECTION 3.8,
"CATEGORY I STRUCTURES"

NRC Questions and TVA Responses

Additional questions relating to the TVA response to NRC Question 1.

NRC Question

Q1.1 Address differences between the information in the FSAR relating to thermal evaluations and the response to the NRC question.

TVA Response

A1.1 A revision to the FSAR is currently being prepared to clarify TVA's methodology for evaluating thermal loads. The TVA methodology for evaluating thermal loads is captured in Civil Design Guide (DG) C1.6.12, Revision 1, "Evaluation of Steel Structures With Thermal Restraint," and WBN Design Criteria WB-DC-20-21, "Miscellaneous Steel Components for Category I Structures," as modified through Design Change Notice S-16078-A. Copies of these documents and the FSAR change are included with this submittal.

NRC Question

Q1.2 Clarify applicability of energy balance if it exceeds elastic.

TVA Response

A1.2 The load-displacement relationship for steel can be conservatively idealized in an elasto-plastic manner. The resulting displacements in the region beyond yield will stabilize at a constant load. Therefore, the energy represented by the area under the idealized extension of a linear load-displacement curve can be balanced against the energy represented by the area under the idealized elasto-plastic load-displacement curve. This relationship in terms of energy balance is shown graphically and in the form of an equation in section B2.0 of DG C1.6.12. The energy balance method is used to compute ductility ratios for members loaded in shear or tension and for very short compression members (see DG C1.6.12, section C2.3). A limiting ductility ratio of 1.5 is used for linear acceptance. This value is considered reasonable because Standard Review Plan allowable stresses (section 3.8.4) based on a linear approach similarly go beyond yield.

ENCLOSURE 1

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NRC Question

Q1.3 Prepare example calculations on actual application, one with modifications and one without modifications.

TVA Response

A1.3 Calculations are currently being developed which will demonstrate the use of the TVA evaluation methodology. One actual application calculation, "Worst-Case Selection of Thermally Restrained Structures," (calculation WCG-1-790) which demonstrates the TVA methodology has been completed and is available for review. Detailed evaluations of the worst-case structures will be performed in accordance with the TVA methodology. Modification will be required if the acceptance criteria cannot be met.

NRC Question

Q1.4 How do you use μ=3 and when is μ remote utilized. Address primary load. Discuss assumptions in some detail.

TVA Response

A1.4 Ductility ratios (μ) are used as acceptance criteria in non-linear analysis to limit the amount of deformation in a steel member. Non-linear analysis is performed to demonstrate self limiting and secondary behavior under combined thermal and non-thermal loads. To further ensure that displacements are limited, the maximum ductility ratio for primary members is taken as 3. For ancillary members, ductility ratios taken from section 3.5.3 of NUREG 0800 may be used on a case-by-case basis. Ancillary members inelastically deform in a predictable, self-limiting manner and can sustain larger deformations than a primary member without loss of function. No ancillary members have been identified to-date in the thermally restrained structure population.

NRC Question

Q1.5 Discuss displacement/strain ratios and when each is used.

Allowable Stress	Load Combinations
(8) 1.7 x AISC Allowable*	$D + L + T_a + R_a + P_a + 1.0\ (Y_j + Y_r + Y_m) + E'$
(9) 1.6 x AISC Allowable*	$D + F_a$
(10) Table 3.8E-1 Limiting Stress	$D + L + E'$
(11) Table 3.8E-1 Limiting Stress	$D + L + W_t$

* See Table 3.8E-1 for limiting values

Evaluations of miscellaneous and structural steel designed prior to July 1979, may be performed using load combinations (2), (10), and (11) unless other specific loads of a significant nature exist, in which case, the appropriate load combinations of Section 3.8E4 must be considered. The design of modifications must meet all load combinations in Section 3.8E4.

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In factored load combinations (4) through (8), thermal loads are neglected when it was shown that they are secondary and self-limiting in nature and where the material is ductile. The justifications for neglecting thermal loads was documented in the calculations, if applicable. DELETE

Thermal analyses are performed using either linear or non-linear analysis techniques. The Energy Balance method is used as long as ductility ratios are shown to be less than 1.5.

Acceptance of overall structure is based on demonstrating that the Displacement Ratios (ductility ratio based on displacements), associated with postulated collapse mechanism, are less than 3. Acceptance of members and connections remote from postulated collapse mechanisms shall be based on demonstrating that the Displacement Ratios are less than those acceptance values tabulated in Table 3.8E-2. Strain Ratios (ductility ratios based on strain) may be conservatively used in lieu of Displacement Ratios.

REPLACE WITH ATTACHMENT A

In combinations (6), (7), and (8), the maximum values of P_a, R_a, Y_j, Y_r, and Y_m, including an appropriate dynamic load factor, was used unless a time-history analysis was performed to justify otherwise. Combinations (5), (7), and (8) were first satisfied without the tornado missile load in (5) and without Y_r, Y_j, and Y_m in (7) and (8).

ENCLOSURE 1

RESPONSES TO SUPPLEMENTAL NRC QUESTIONS
ON WATTS BAR NUCLEAR PLANT
FINAL SAFETY ANALYSIS REPORT, SECTION 3.8,
"CATEGORY I STRUCTURES"

TVA Response

A1.5 Displacement based ductility ratios (μd) are established as the ratio of the actual displacement to the displacement at yield. Alternately, the ductility ratio may be established as the actual strain to the yield strain (μs). For primary members, displacement-based ductility ratios are used. The acceptance of ancillary members is based on either displacement or strain-based ratios (μd or μs).

NRC Question

Q1.6 Provide test data to justify ratios to support thermal use of ductility ratios.

TVA Response

A1.6 Analysis utilizing the non-linear provisions of the ANSYS computer program has been performed to establish correlation with published test data (calculation WCG-1-811) and is included with this submittal. The test considers a beam column subjected to static loads, and an excellent agreement is found between ANSYS analysis results and the test results. The same beam column subjected to temperature load exhibits reserve capacity after the ductility ratio allowable (3) is exceeded. The analysis results also demonstrate the self-limiting nature of the thermally-induced force in the member.

ENCLOSURE 2

PROPOSED REVISION TO WATTS BAR NUCLEAR PLANT
FINAL SAFETY ANALYSIS REPORT,
APPENDIX 3.8E

ATTACHMENT A

REVISION TO FSAR APPENDIX 3.8E
FOR THERMAL ANALYSIS

Replace the third and fourth paragraph on page 3.8E-6 with the following:

Thermal analyses are performed for restrained structures located in high temperature environments. A screening process is used to classify structures and select worst-case structures for analysis. Analyses are performed using either linear or non-linear analysis techniques. Analyses include consideration of the thermally-induced load and applied non-thermal loads. For linear analysis, acceptance of compression members is based on a ductility ratio of 1.5 for low values of Kl/r and transitions to the AISC column allowables with a factor of safety of 1. For combined bending and compression, acceptance is based on a parabolic interaction curve. For non-linear analysis, the ANSYS computer program is used. Acceptance is based on a ductility ratio (determined from displacements) of 3 for primary members. For ancillary (secondary) members, acceptance is based on ductility ratios determined from displacements or strains. The allowable ductility ratio is 10 for tension due to flexure and one-half the ultimate strain divided by the yield strain for members subjected to tension. These ductility values are the values normally used for seismic and impact barrier design.

TABLE 3.8E-2

ACCEPTABLE DISPLACEMENT RATIOS, μ

1. STRUCTURAL STEEL TENSION MEMBERS

$$\mu = 0.25\ \varepsilon_\mu/\varepsilon_y \leq 0.1/\varepsilon_y$$

Where
ϵ_μ - Percentage elongation at failure (rupture)
ϵ_y - Strain corresponding to yield stress

2. STRUCTURAL STEEL FLEXURAL MEMBERS

A. Open Sections

$$\mu \leq 12.5$$

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B. Closed Sections

$$\mu \leq 20.0$$

C. Members Where Shear Governs Design

$$\mu \leq 5.0$$

D. Elements In Uniform Compression Due To Bending

$$\frac{b}{t} \leq \frac{76}{F_y} \text{ for unstiffened plate elements}$$

$$\frac{b}{t} \leq \frac{238}{F_y} \text{ for stiffened plate elements}$$

Where

b is the actual width of stiffened and unstiffened compression elements, inches

3. STRUCTURAL STEEL COLUMNS

$$\mu = 0.225/\lambda^2 \leq 10 \leq \varepsilon_{st}/\varepsilon_y$$

$$\lambda = (K\ell/\pi r)\sqrt{\frac{F_y}{E}}$$

ϵ_{st} - Strain corresponding to the onset of strain hardening

$K\ell$ - Effective length of column in the plane producing the largest $K\ell/r$ ratio

r - Radius of gyration corresponding to plane of bending used to define $K\ell$

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