TVA

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

JUN 07 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 - RESPONSE TO NRC AUDIT ITEMS - SEISMIC ANALYSIS CORRECTIVE ACTION PROGRAM (CAP) IMPLEMENTATION AUDIT - APRIL 15-19, 1991

During the week of April 15-19, 1991, a team of NRC reviewers visited WBN to conduct an audit of the Seismic Analysis CAP implementation effort. Twenty-eight issues were identified within the design categories of a) platforms, b) steel containment vessel penetrations and pad plates, c) masonry walls, and d) geotechnical. A number of these were verbally reconciled during the visit by commitments for calculation revisions, while the remainder were categorized as open pending additional TVA investigation.

The purpose of this letter is to formally document TVA positions in response to each of these identified issues. Enclosure 1 summarizes each question raised by the staff with an accompanying response. While the majority of these can be considered clarifications and therefore not indicative of programmatic deficiencies with the CAP implementation process, others warranted and have received additional attention in order to effectively prevent recurrence.

Specifically, three items (CAK-7, CAK-9, and CAE-2) were raised which emphasized the need for additional training of engineering personnel in the areas of calculation quality and attention to detail. These issues relate to procedural compliance, formal tracking of calculation open items, and drawing data which deviated from walkdown data. Problem Evaluation Reports (PERs) were issued by TVA to promptly evaluate and reconcile these individual concerns. The extent of condition was addressed for each item, and specific corrective actions developed and implemented. Where required, drawing change notice packages were developed and/or calculation packages revised.

A001 1/1

Accordingly, the concerns identified by the staff have effectively been resolved. To prevent recurrence, formal training was provided to the WBN civil engineering staff on Friday, May 10 and Monday, May 13, 1991, to increase individual awareness in these areas and cumulatively discuss lessons learned from the NRC audit process.

Additionally, TVA will further review the quality-related findings from this audit and other related activities to determine if there are other generic implications and how to address such potential generic problems.

Commitments contained in this letter are summarized in Enclosure 2.

If any questions exist relative to the enclosed TVA response or assessment, please telephone P. L. Pace at (615) 365-1824.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

E. G. Wallace, Manager
Nuclear Licensing and
Regulatory Affairs

Enclosures
cc: See page 3

JUN 07 1991

cc (Enclosures):

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50-390 WATTS BAR TVA

RESPONSE TO NRC-IDENTIFIED QUESTIONS ON SEISMIC ANALYSIS CAP IMPLEMENTATION.

Rec'd W/ Ltr Dtd 6/7/91 9106130220

ENCLOSURE 1

RESPONSE TO NRC-IDENTIFIED QUESTIONS
ON SEISMIC ANALYSIS CAP IMPLEMENTATION

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Steel Containment Vessel

NRC Reviewer(s): Tom Tsai

TVA Responsible Person: Ed Perry

ESI Contact: John Shubert

Issues Discussed/Information Presented:

SCV Parametric Study.

Open Issue(s)/Request(s):

What is the sensitivity of the stress attenuation results (shown on stress contours) based on the model boundary distance from center of attachment to edge of model ($2.5\sqrt{RT}$) to variation in the pad diameter?

TVA Planned Action/Position:

See attached page.

Item Closed.

Prepared By: [signature] 4/30/91

Reviewed By: H. [signature] 4/30/91

Approved By: [signature] 5/2/91

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ASME Code 1971 Winter Addenda suggested distance from a local load source, beyond which the interactive stresses need not be considered is defined as $2.5\sqrt{RT}$. The mathematical model for the parametric studies performed to calculate the stress attenuation under the effects of individually applied loads (forces, moments) for a 6 inch diameter pad, used $2.5\sqrt{RT}$ plus the radius of the pad plate (3 inches) to establish the model outer boundary of 80 inches ($2.5\sqrt{57.5 x 12 x 1.375}+3=80$). These studies showed that the stresses attenuate rapidly and become insignificant within half of the model boundary distance. For the range of pad plate diameters used on this plant, therefore, the results of the attenuation is not very sensitive if the model boundary is from the edge or the center of the pad. Additional analyses using an 18 inch diameter pad with 80 inch and 86 inch model boundary dimensions were performed for the effects of longitudinal moment.

The attached table summarizes the results of these additional study runs. The number of elements representing the model with the 80 inch boundary distance was the same as the model with 86 inch distance. The results, which show element stresses Sx due to longitudinal moment Mx are summarized at various distances from the center of the pad and at the boundary, i.e. at 80 inches for the first model and 86 inches for the second model.

The summaries are provided for stresses along 0° and 45° directions. Sx stresses due to this loading along 90° directions are extremely small and the results are not meaningful for comparison.

The results of both models are essentially identical in the region from the pad center line to the first near zero stress distance. The stresses at the respective boundaries of the models have attenuated approximately by a factor of 100 for 0° and over 200 for 45° to a level of nearly zero stress.

An analysis of the same models with Axial (Py) load was performed to confirm consistency in behavior for Sx stresses along the 90° direction, and the table of results is attached.

The similarity of stress attenuation trends and the resulting stress values in the range of relative significance demonstrates that the results are not significantly impacted by the boundary distance variation, for the range of distances of interest. This additional study has been included in the parametric study calculations WCG-1-606 R1 (RIMS No. B18 910430 271).

Item no.:CAE-1

STRESS DISTRIBUTION FOR A LONGITUDINAL MOMENT LOAD

ELEMENT STRESS-SX

ANGLE - 0.0 DEG.

STRESS LOCATION (ELEMENT NUMBER)	18.0 DIA. 80.0" EDGE (ksi)	DISTANCE FROM CENTER OF PAD (in)	18.0 DIA. 86.0" EDGE (ksi)	DISTANCE FROM CENTER OF PAD (in)
601 (Edge of pad outside)	-0.0357	11.75	-0.0357	11.75
701	-0.0221	16.23	-0.0216	16.62
801	-0.0123	23.56	-0.0116	24.60
901	-0.00558	32.59	-0.00491	34.42
1001	-0.00169	42.93	-0.00127	45.67
1101	0.000349	54.36	0.000458	58.11
1201	0.00103	66.75	0.000923	71.59
1301	0.000510	80.00	0.000429	86.0

ANGLE - 45.0 DEG.

STRESS LOCATION (ELEMENT NUMBER)	18.0 DIA. 80.0" EDGE (ksi)	DISTANCE FROM CENTER OF PAD (in)	18.0 DIA. 86.0" EDGE (ksi)	DISTANCE FROM CENTER OF PAD (in)
654 (Edge of pad outside)	-0.0248	11.75	-0.0248	11.75
754	-0.0154	16.23	-0.0150	16.62
854	-0.00849	23.56	-0.00794	24.60
954	-0.00410	32.59	-0.00359	34.42
1054	-0.00144	42.93	-0.00107	45.67
1154	-0.000014	54.36	0.000152	58.11
1254	0.000495	66.75	0.000416	71.59
1354	0.000177	80.00	-0.000204	86.0

Item no.:CAE-1

RESS DISTRIBUTION FOR AN AXIAL LOAD ELEMENT STRESS-SX

ANGLE - 90.0 DEG.

STRESS LOCATION (ELEMENT NUMBER)	18.0 DIA. 80.0" EDGE (ksi)	DISTANCE FROM CENTER OF PAD (in)	18.0 DIA. 86.0" EDGE (ksi)	DISTANCE FROM CENTER OF PAD (in)
606 (Edge of pad outside)	-0.475	11.75	-0.482	11.75
706	-0.315	16.23	-0.314	16.62
806	-0.177	23.56	-0.169	24.60
906	-0.0685	32.59	-0.0578	34.42
1006	-0.00110	42.93	0.00880	45.67
1106	0.0273	54.36	0.0333	58.11
1206	0.0248	66.75	0.0255	71.59
1306	0.0146	80.00	0.0130	86.0

Date: 04/17/91
Item No: CAE-2

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Steel Containment Vessel

NRC Reviewer(s): Tom Tsai

TVA Responsible Person: Ed Perry

ESI Contact: John Shubert

Issues Discussed/Information Presented:

SCV Walkdown Packages.

Open Issue(s)/Request(s):

DCN/DCA S-15752-A differs from information documented in walkdown packages M-5846-1A thru M-5846-1H.

TVA Planned Action/Position:

Steel containment vessel shell inner and outer composite stretch out drawings and the pad attachment schedule sheets, which are a part of the DCN/DCA S-15752-A, depict the as-built conditions as confirmed by the walkdowns. Minor differences between the drawing and walkdown package information were found in isolated cases which exceed the walkdown measurement tolerances. A Problem Evaluation Report (PER) WBPER910246 has been issued to ensure that the drawing information is correctly reflecting the information contained in the walkdown packages, and the drawings were revised and reissued per DCN/DCA S-16031-A.

Item Closed.

Prepared By: J D Scott / L. E. Perry 4/30/91

Reviewed By: H.T. 5/1/91

Approved By: [signature] 5/2/91

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Date: 04/17/91
Item No: CAE-3

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Steel Containment Vessel

NRC Reviewer(s): Tom Tsai

TVA Responsible Person: Ed Perry, Husein Hasan

ESI Contact: John Shubert

Issues Discussed/Information Presented:

Open Issue(s)/Request(s):

How does the difference between Set A and Set B get factored into the local shell stresses?

TVA Planned Action/Position:

The comparison of Set A to Set B ZPA values shows that the horizontal ZPA for Set A are greater than the Set B ZPA values. However, the vertical ZPA values for Set B exceeded the Set A values which indicates an increase in the axial forces. As shown in the attached calculation sheet, the shell stress due to the increase in the axial forces for Set B is only 67 psi while the stress due to moments has decreased by 319 psi. Thus, the combined effect is a decrease of 252 psi. Therefore, Set A results yield higher stresses in the shell than Set B.

Based on the above results, it is concluded that the increase of the axial forces for Set B has no effect on the local shell stresses. It should be noted that this conclusion is consistent with the conclusion stated in the SCV comparison report.

Item closed.

Prepared By: H. A. Hasan 4/19/91

Reviewed By: [signature] 4/19/91

Approved By: [signature] 5/2/91

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N1

WATTS BAR NUCLEAR PLANT -
STEEL CONTAINMENT VESSELS (SCV)

PREPARED - DRD 4/
CHECKED - [initials] 4/1

COMPARISON OF THE SET A AND SET B LONGITUDINAL STESSES AT THE BASE OF THE SCV FOR SSE E/Q.

1. SCV DATA:

thickness (t) = 1.375 in ✓
Radius = 57.5 FT = 690 in ✓ D = 1380

Area of Base:

$$A = \pi D t = (2)(690)(\pi)1.375$$
$$= 5961\ in^2$$ (Nominal area - Neglect insert plates) ✓

Moment of Inertia:

$$I = \frac{R^2 A}{2}$$

$$= \frac{(5961)(690)^2}{2}$$

$$= 1.419 \times 10^9\ in^4$$ ✓

2. Reference.

Task Report on Steel Containment Vessel Comparison of Set A and Set B Analyses Results. MAY 1990

3. LOAD DATA

From Figure A-14

$F_{SET A}$ = 700 KIPS ; $F_{SET B}$ = 1100 KIPS ✓

WATTS BAR NUCLEAR PLANT
SCV.

PREPARED – DRD 4/..
CHECKED – [illegible] 4/..

From Figure A-15

$M_{SET\,A} = 26 \times 10^4$ K-FT $M_{SET\,B} = 20 \times 10^4$ K-FT ✓

4. LONGITUDINAL STRESSES

A. Due to Axial Loads.

$\sigma_{SET\,A} = F/A = \dfrac{700^K}{5931} = \underline{119\ psi}$ ✓

$\sigma_{SET\,B} = \dfrac{1100^K}{5931} = \underline{184.5\ psi}$ ✓

B. Due to Bending Moments:

$N_{SET\,A} = \dfrac{MR}{I} = \dfrac{(26)(10^7)(12)(690)}{1.419 \times 10^9}$

$= 1517$ lb/in ✓

$N_{SET\,B} = \dfrac{(20)(10^7)(12)(690)}{1.419 \times 10^9}$

$= \underline{1167\ lb/in}$ ✓

$\sigma_{SET\,A} = N/t = 1517/1.375 = 1103$ psi ✓

$\sigma_{SET\,B} = \dfrac{1167}{1.375} = 848$ psi ✓

WATTS BAR NUCLEAR PLANT
SCV.

PREPARED – DRD 4/1
CHECKED – [illegible] 4/1

From Figure A-15

$M_{SET A} = 26 \times 10^4$ K-FT $M_{SET B} = 20 \times 10^4$ K-FT ✓

4. LONGITUDINAL STRESSES

A. Due to Axial Loads.

$\sigma_{SET A} = F/A = \frac{700^K}{5931} = \underline{117 \text{ psi}}$ ✓

$\sigma_{SET B} = \frac{1100^K}{5931} = \underline{184.5 \text{ psi}}$ ✓

B. Due to Bending Moments;

$N_{SET A} = \frac{MR}{I} = \frac{(26)(10^7)(12)(690)}{1.419 \times 10^9}$

$= 1517$ lb/in ✓

$N_{SET B} = \frac{(20)(10^7)(12)(690)}{1.419 \times 10^9}$

$= \underline{1167 \text{ lb/in}}$ ✓

$\sigma_{SET A} = N/t = 1517/1.375 = 1103$ psi ✓

$\sigma_{SET B} = \frac{1167}{1.375} = 848$ psi ✓

Item No.: CAE-3

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TASK REPORT

ON

STEEL CONTAINMENT VESSEL

COMPARISON OF SET A AND SET B ANALYSIS RESULTS

WATTS BAR NUCLEAR PLANT

TENNESSEE VALLEY AUTHORITY

BECHTEL CORPORATION

July 1990

3. IMPLICATION OF SET B (SSRS) RESPONSE ON THE STRUCTURE

Comparison of the Set A and Set B displacements, accelerations, forces, and moments are included in Appendix A. Implication of these comparisons, including additional evaluations needed to address the seismic issues, are discussed in the following paragraphs.

The horizontal ZPA comparison indicates that Set B accelerations of the SCV are lower than the Set A values. On the other hand, comparison of the axial forces indicates that Set B values are greater than Set A values, implying that the vertical accelerations exceed the original values. "Since the horizontal seismic forces are more significant in the design of the shell, and since the total vertical seismic load is low (stress in shell due to axial loads are less than 200 psi for the SSE), it is concluded that there is no impact on the design of the shell."

Although the seismic displacements exceed the original values, the magnitudes are small; maximum displacement for OBE is about 0.12 inch and for SSE is about 0.3 inch. The relative displacements between the SCV and the adjacent structures are taken into consideration in the design of piping and other commodities to accommodate such displacements.

Comparison of the overall seismic shear forces and bending moments indicate that their magnitudes are smaller than those in the original design, thus confirming the adequacy of the existing design.

As noted above, the exceedances in the axial forces do not have any impact on design.

Thus, based on the this review, the original design of the structure is adequate. Therefore, review of the original design is not warranted.

4. IMPLICATION OF SET B ACCELERATION RESPONSE SPECTRA ON SYSTEMS, EQUIPMENT AND COMPONENTS

Comparison of the Set A and Set B ARS are given in Appendix B. A review of this comparison indicates the following general trends:

- The Set A Acceleration Response Spectra (ARS) practically envelop the Set B ARS in the horizontal direction. At the peaks, the differences are significant, indicating the conservatism associated with the original design.

  In the vertical direction, the Set A ARS again exceeds the Set B ARS below about 6 Hz. Between 6 and 20 Hz the Set B ARS exceed the Set A values in some cases. This exceedance is mainly due to an additional peak in the Set B ARS around 8 Hz not present in the Set A ARS. The Set A and Set B peaks of the vertical ARS however, are comparable.

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Steel Containment Vessel

NRC Reviewer(s): Tom Tsai

TVA Responsible Person: Ed Perry

ESI Contact: John Shubert

Issues Discussed/Information Presented:

SCV analysis boundary conditions.

Open Issue(s)/Request(s):

Further explanation is needed for the boundary conditions used in the STARDYNE and ANSYS models.

a) The boundary conditions for the STARDYNE and ANSYS model in the parametric study appear not to be consistent. Are they?

b) Why was rotation about the Y-axis not restrained on the anti-symetric boundary of the STARDYNE model of the parametric study?

c) Why were corner nodes at 0° and 90° of the STARDYNE model not fully restrained in the parametric study?

TVA Planned Action/Position:

See attached page

Item Closed.

Prepared By: [signature] / [signature] 4/30/91

Reviewed By: [signature]

Approved By: [signature] 5/2/91

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a. The STARDYNE program was used to model the cylindrical portion of the SCV while the ANSYS program was used to model the dome of the SCV. The differences between the two programs is that the ANSYS model used an axisymmetric element with a thinner shell thickness (15/16") and had all degrees of freedom restrained except for the direction normal to the shell. All degrees of freedom were restrained in the STARDYNE model.

A comparative study was performed, on the ANSYS model, with all degrees of freedom fixed. The results show very close correlation in stresses at stress levels of relative significance and minor deviations in attenuated stress values near the boundaries. These minor differences will be evaluated and the results will be documented into the parametric study calculation and used as applicable.

b. To properly represent the anti-symmetric boundary conditions which occur along the Z-axis under the effects of applied M_Z moment, the displacement in the X direction cannot be restrained, and in addition since this displacement attenuates with distance the rotation about the Y-axis has to also be allowed to occur. The antisymmetic (STARDYNE) model boundary conditions are consistent with the above requirements.

c. The corner nodes of the outer model boundary at 0° and 90° were restrained in a manner similar to the boundary conditions for the nodes along the 0° and 90° axis, which are either symmetric or anti-symmetric depending on the applied loading, for convenience. Based on previous experience this approach was not expected to impact the validity of the results.

Additional analysis with fully restrained corner nodes was performed with axial (py) loading for comparison purposes. As shown on attached tables the results confirm the initial expectations.

Item No.: CAE-4 (c)

TABLE
6" Diameter Penetration
Axial Load (Py)
Shell Thickness: 1.375"

Along 0 degree Boundary

Distance From Centerline (In.)	Sx Stress (ksi)		Sy Stress (ksi)	
	Calculation	Study	Calculation	Study
3.92	0.45	0.44	1.35	1.34
6.61	0.30	0.29	0.79	0.78
9.75	0.22	0.21	0.59	0.59
14.32	0.12	0.11	0.42	0.42
19.78	0.05	0.04	0.30	0.29
25.96	0.04	0.04	0.21	0.20
32.76	0.06	0.05	0.14	0.13
40.08	0.06	0.06	0.08	0.08
47.89	0.05	0.05	0.05	0.04
56.13	0.04	0.04	0.03	0.02
64.78	0.02	0.04	0.01	0.02
73.82	0.00	0.03	0.006	0.006

Date: 04/17/91
Item No: CAE-5

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Steel Containment Vessel

NRC Reviewer(s): Tom Tsai

TVA Responsible Person: Ed Perry

ESI Contact: John Shubert

Issues Discussed/Information Presented:

SCV thermal movements.

Open Issue(s)/Request(s):

What and where are the guidelines for determining if the change in thermal movements were negligible or need to have further evaluation?

TVA Planned Action/Position:

The guidelines for determining if the change in thermal movements were negligible, acceptable or need to have further evaluation are as follows:

1) If the absolute value of the new movement is 0.005" or less the effect of change in thermal is negligible.
2) If the new movement is in the same direction as the previous movement and of smaller magnitude the change in thermal movement is negligible.
3) If the new movement is in the same direction as the previous movement and with an increase in magnitude less than 0.01" the effect of change in thermal movement is negligible.
4) If the new movement is in the opposite direction as the previous movement or in the same direction with an increase of 0.01" or greater, further evaluation is required.

These guidelines have been incorporated into the Thermal Design Instruction calculation WCG-1-721 R1 (RIMS No. B18 910430 253). The Thermal Comparison Report calculation WCG-1-814 R1 was reviewed and revised for compliance to these guidelines (RIMS No. B18 910430 255).

Item Closed.

Prepared By: [signature] 4/30/91

Reviewed By: [signature] 5/1/91

Approved By: [signature] 5/2/91

2832M

Date: 04/17/91
Item No: CAE-6

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Steel Containment Vessel

NRC Reviewer(s): Tom Tsai

TVA Responsible Person: Ed Perry

ESI Contact: John Shubert

Issues Discussed/Information Presented:

SCV thermal movements interfaces.

Open Issue(s)/Request(s):

How are other programs being informed of the changes in thermal movements due to Main Steam Line Break (MSLB)?

TVA Planned Action/Position:

The programs potentially affected by the SCV shell displacements due to the MSLB thermal effects will be provided with the results of the evaluation via a QIR. Affected programs are Piping and Pipe Support (HAUUP), and suspended systems (i.e., cable tray supports, conduit and conduit supports, and HVAC duct and supports) attached to the SCV shell.

Item Closed.

Prepared By: [signature] / [signature] 4/30/91

Reviewed By: H. [signature] 5/1/91

Approved By: [signature] 5/2/91

2832M

Date: 04/17/91
Item No: CAE-7

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Steel Containment Vessel

NRC Reviewer(s): Tom Tsai

TVA Responsible Person: Ed Perry

ESI Contact: John Shubert

Issues Discussed/Information Presented:

Use of WERCO computer program.

Open Issue(s)/Request(s):

Is description of WERCO computer code available? Is WERCO being used in the SCV calculation program?

TVA Planned Action/Position:

FSAR Appendix 3.8D (page 3.8D-1) references WERCO among the list of other recognized public domain programs used for structural analyses. Attached is the Introduction section of the WERCO manual which is available for review. The program was used in the original design evaluation of pad plates. The corrective action programs will use the program for the pad or penetration evaluation at the point of shell to attachment intersection.

Item closed

Prepared By: [signature] / [signature] 4/30/91

Reviewed By: [signature] 5/1/91

Approved By: [signature] 5/2/91

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1.Ø INTRODUCTION

The WERCO Program has been written to perform the stress calculations as presented in the Welding Research Council (WRC) Bulletin No. 1Ø7, entitled "Local Stresses in Spherical and Cylindrical Shells due to External Loadings." * This WRC Bulletin is a compilation of the work of Professor P. P. Bijlaard of Cornell University. The Bulletin contains a series of non-dimensional curves that are used to obtain the stresses at four locations in the shell around the shell to attachment juncture. The WERCO Program requires the user to only input the geometry of the shell and the attachment, and the loads on the attachment at the juncture. The WERCO Program then selects appropriate factors from the non-dimensional curves presented in the Bulletin and calculates the stresses at four locations around the attachment on the interior and exterior surfaces of the shell at those same locations.

The parameters used to obtain the factors from the curves are first verified to determine if they are within the range of data contained in the WRC #1Ø7. If the user finds that the parameters are not within the established limitation, he may completely bypass this verification step and enter the appropriate factors himself.

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* Welding Research Council Bulletin No. 1Ø7, "Local Stresses in Spherical and Cylindrical Shells due to External Loads" K. R. Wichman, A. G. Hopper, and J. L. Mershon, New York, N. Y., Third Revised Printing - Spring, 1972.

APPENDIX 3.8D COMPUTER PROGRAMS FOR STRUCTURAL ANALYSIS

Computer programs used for structural analysis and design have been validated by one of the following criteria or procedures:

a. The following computer programs are recognized programs in the public domain:

Program	Usage Start Date:Year	Hardware	Source	
AMG032	1965	IBM	R&H	51
AMG033	1965	IBM	R&H	
AMG034	1965	IBM	R&H	
ANSYS	1972	CDC	CDC	
ASHSD	1969	IBM	UCB	
BASEPLATE II	1982	CDC	CDC	51
GENDHK 3	1969	IBM	UCB	
GENSHL 2	1969	IBM	FIRL	
GENSHL 5	1968	IBM	FIRL	
GTSTRUDL	1979	CDC	GT	51
NASTRAN (MSC)	1974	CDC	CDC	
SAP IV	1973	CDC	UCB	
SAP IV	1974	IBM	USC	
SDRC FRAME PACKAGE SAGS/DAGS	1977	CDC	SDRC	
SPSTRESS	1977	CDC	CDC	
STARDYNE	1977	CDC	CDC	
STRESS	1970	EG	CDC	
STRUDL (V2M2)	1972	IBM	ICES	51
STRUDL (Rel. 2.6) (Dynal)	1974	IBM	MCAUTO	
STRUDL (Rel. 4.0)	1975	IBM	MCAUTO	
STRUPAK PACKAGE MAP2DF/SAP2DF	1971	CDC	TRW	
SUPERB	1977	CDC	CDC	
WELDDA	1983	CDC	CDC	
WERCO	1978	CDC	AAA	

All programs on IBM hardware are run under the MVS operating system, on either a 370/165 machine or a 360/50 machine. All programs on CDC hardware are run under the SCOPE 3.3 operating system on a 6600 machine.

The following abbreviations are used for program sources:

CDC - Control Data Corporation, Minneapolis, MI
FIRL - Franklin Institute Research Labs, Philadelphia, PA
GT - Georgia Institute of Technology, Atlanta, GA
ICES - Integrated Civil Engineering System, Worcester, MA
MCATUO - McDonnell-Douglas Automation Company, St. Louis, MO
R&H - Rohm & Haas Company, Huntsville, AL
SDRC - Structural Dynamics Research Corporation, Cincinnati, OH 51
TRW - TRW Systems Group, Redondo, CA
UCB - University of California, Berkely, CA
USC - University of Southern California, Los Angeles, CA
AAA - AAA Technology and Specialties Co., Inc., Houston, TX

b. The following programs have been validated by comparison with a program in the public domain:

RESPONSE FOR EARTHQUAKE AVERAGING SPECTRAL RESPONSE

Summary comparisons of results for these computer programs are provided in Figures 3.8D-1 and 3.8D-2.

c. The following programs have been validated by comparison with hand calculations:

BIAXIAL BENDING - USD
CONCRETE STRESS ANALYSIS
DL42
PLTDL42
THERMCYL
TORSIONAL DYNAMAL 51
PNA100

The following programs have been validated by comparison with analytical results published in the technical literature:

BAP222
DYNANAL 51
ROCKING DYNANAL

Summary comparison of results for these computer programs are provided in Tables 3.8D-1 through 3.8D-10. 51

The following abbreviations are used for program sources:

CDC - Control Data Corporation, Minneapolis, MI
FIRL - Franklin Institute Research Labs, Philadelphia, PA
GT - Georgia Institute of Technology, Atlanta, GA
ICES - Integrated Civil Engineering System, Worcester, MA
MCATUO - McDonnell-Douglas Automation Company, St. Louis, MO
R&H - Rohm & Haas Company, Huntsville, AL
SDRC - Structural Dynamics Research Corporation, Cincinnati, OH 51
TRW - TRW Systems Group, Redondo, CA
UCB - University of California, Berkely, CA
USC - University of Southern California, Los Angeles, CA
AAA - AAA Technology and Specialties Co., Inc., Houston, TX

b. The following programs have been validated by comparison with a program in the public domain:

RESPONSE FOR EARTHQUAKE AVERAGING SPECTRAL RESPONSE

Summary comparisons of results for these computer programs are provided in Figures 3.8D-1 and 3.8D-2.

c. The following programs have been validated by comparison with hand calculations:

BIAXIAL BENDING - USD
CONCRETE STRESS ANALYSIS
DL42
PLTDL42
THERMCYL
TORSIONAL DYNAMAL 51
PNA100

The following programs have been validated by comparison with analytical results published in the technical literature:

BAP222
DYNANAL 51
ROCKING DYNANAL

Summary comparison of results for these computer programs are provided in Tables 3.8D-1 through 3.8D-10. 51

Date: 04/17/91
Item No: CAJ-1

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Geotechnical-Buried Piping

NRC Reviewer(s): C. Costantino

TVA Responsible Person: R. Threlkeld/B. Welch

ESI Contact: J. Ruimerman/Chris Painter

Issues Discussed/Information Presented:

1. Piping running along concrete slab at Intake Pumping Station. It was considered that the earth settlement due to liquefaction began at slab and continued along pipeline. Evaluation of piping used at least a minimum of 100ft math model for the evaluation of pipe stresses.

2. Calculation WCG-1-868 on "Evaluation of Potential Settlement" (CEB 840816 015) indicated "excessive settlement" at two specific locations along ERCW/HPFP piping run. Both occurred at pipe bend locations.

Open Issue(s)/Request(s):

1a. What is the effect of the settlement taking place over a shorter length of pipe (what happens to stress in pipe when the pipe comes off the concrete slab)?

1b. How will the pipe be affected by surcharge load?

1c. Provide an evaluation for stresses of pipe on top of cradle.

2. Address "excessive settlements" effect on the piping and pipe bend stresses.

TVA Planned Action/Position:

TVA has issued the calculation WCG-1-867 (RIMS No. B18 910429 253) to provide additional clarification on the above issues. This calculation showed that the pipe stresses are within allowable limits.

See Attachment A

Prepared By: B. J. Welch *BJ Welch*

Reviewed By: W. Smathers *G. Kh[illegible] 5-1-91* *W. Smathers 5/2/91*

Approved By: *[signature]* *5/2/91*

2832M

Date: 04/17/91
Item No: CAJ-1

ATTACHMENT A

Follow up action on NRC's April 15-19, 1991 audit on TVA calculation, "Evaluation of Potential Settlement".

Calculation WCG-1-867 (RIMS No. B18 910429 253) "Buried ERCW and HPFP Piping/Settlement Evaluation" was issued to address the open issues as follows:

1. Justification of the effective length of piping coming off the Intake Pumping Station cradle which will absorb the differential building and soil settlement. This includes the overburden and self weights with consideration of the missile slab effects on the soil and the piping beneath it.

2. Analysis of piping remaining on the cradle after soil settlement (i.e., the piping in the vicinity of the edge of the cradle).

3. Evaluation of all differential settlements with respect to overburden, self weights and effective pipe lengths assuring that the worst case is considered. This includes consideration of intermediate stress intensification factors. Particular attention was paid to the areas identified on subject calculation, page 101, as having "excessive settlement".

Date: 04/17/91
Item No: CAJ-2

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Buried Piping ERCW/HPFP Yard

NRC Reviewer(s): Carl Costantino

TVA Responsible Person: Ray Threlkeld

ESI Contact: Chris Painter/K. Khurshudyan GK 5-1-91

Issues Discussed/Information Presented:

Buried Piping Calculation WCG-1-682 Rev. 1

Open Issue(s)/Request(s):

Calculation WCG-1-682 Section 7.0

In going from 0.41g to 0.2780 x 10^{-3} in/in strain, a reference to Appendix A is made without further explanation.

TVA Planned Action/Position:

Calculation WCG-1-682 has been revised to expand the discussion in section 7.0 of the calculation to explain how strain has been derived from ground acceleration (e.g. ref., methodologies, etc.)
(RIMS # B18 910426 265).

Item Closed.

Prepared By: J. Ruimerman

Reviewed By: Bill Jewelch G. Khurshudyan 5-1-91

Approved By: [signature] 5/2/91

2832M

Date: 04/17/91
Item No: CAJ-3

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Geotechnical: ERCW/HPFP Pipeline Slope Stability

NRC Reviewer(s): Carl Costantino

TVA Responsible Person: Ray Threlkeld

ESI Contact: Kris Ramachandra

Issues Discussed/Information Presented:

Presented slope stability calculations along ERCW/HPFP Pipeline

Open Issue(s)/Request(s):

Enhance the write-up of the liquefaction considerations along the pipeline to describe the review process to preclude further liquefaction concern.

TVA Planned Action/Position:

Calculation WCG-1-629 has been revised to describe the detail review of liquefaction considerations along the pipeline and write up the details of the review and give references. (RIMS No. B18 910416 253)

Item Closed.

Prepared By: Kris Ramachandra

Reviewed By: J. Ruimerman/J. L. Ehasz H. Totuugely 5/1/91

Approved By: [signature] 5/2/91

2832M

Date: 04/17/91
Item No: CAJ-4

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Geotechnical

NRC Reviewer(s): Carl Costantino

TVA Responsible Person: Ray Threlkeld/B. Welch

ESI Contact: N/A

Issues Discussed/Information Presented:

Calculation WCG-1-547 "Intake Channel-Seismic Stability Analysis of Slopes Near IPS"

NRC questioned the partial soil strength reduction of 30% of ϕ and 50% of c for silty sands during an earthquake event. (Stability analysis of the "during EQ" pseudo-static analysis produced a SF=1.04 [computer] and SF=1.06 [hand check].)

Open Issue(s)/Request(s):

Adequacy of strength reduction variability as it affects the stability of intake channel slope near IPS.

TVA Planned Action/Position:

°Reanalyze, slope utilizing more realistic soil profiles, i.e., reduce conservative 22' thick zone of SM and add 1075 and 1032 crushed stone to trench B to reflect "As Constructed" conditions.

°In reanalysis of slope, perform a sensitivity study by varying SM strength to determine influence of partial strength loss on S.F.

°If reanalysis indicates S.F. $\leq$ 1.0 for a reasonable partial strength loss, then a Newmark analysis would be performed to determine potential displacement of slope. Potential displacement would be evaluated for impact on channel flow.

Refer to Attachment A for results of TVA actions.

Prepared By: H Ray Threlkeld

Reviewed By: Bill J Welch

Approved By: Ruben O Hernandez 5/2/91

2832M

ATTACHMENT A

SH 1 OF 2

Results of TVA actions

- Calculation WCG-1-547, "Intake Channel - Seismic Stability Analysis of Slopes near IPS," has been revised (Rims No. B26910429151).
- The critical section was reassessed to reflect actual field conditions. Information considered in the reassessment include; "as-built" conditions from the underground barrier (ie. depth of the potentially liquefiable layer, consideration of the granular fill (depth and strengths) used, and strengths of the compacted earthfill), inclusion of basal gravel in the profile, use of groundwater table per the design criteria, and reflection of actual slope of the ground surface per the section layout.
- A supplemental parametric study of the critical (modified to relect field conditions) section has been performed and added to the calculation. The following table summarizes the parametric study.

CRITICAL FACTOR OF SAFETY

RUN #	LAYER 2 *		FACTOR OF SAFETY
	COHESION (lb/ft^2)	ϕ	
1	600	20^0	1.398
2	450	20^0	1.330
3	300	20^0	1.260
4	150	20^0	1.186
5	600	15^0	1.322
6	450	15^0	1.251
7	300	15^0	1.176
8	150	15^0	1.098
9	300	14^0	1.160
10	600	10^0	1.245
11	450	10^0	1.170
12	300	10^0	1.092
13	600	5^0	1.165
14	450	5^0	1.061

* Potentially liquefiable silty-sand layer

- The parametric study showed a factor of safety (FS) of 1.16 (versus FS = 1.038 in the original analysis) for the case when the strength parameters for the potentially liquefiable silty-sand layer are reduced to the same level as given in the original analysis.

Date: 04/18/91
Item No: CAJ-5

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Buried Piping Calculation

NRC Reviewer(s): Carl Costantino

TVA Responsible Person: B. J. Welch

ESI Contact: Chris Painter

Issues Discussed/Information Presented:

Calculation on "Evaluation of Potential Settlement" (CEB 840816 015) indicated "excessive settlement" at two specific locations along ERCW/HPFP piping run. Both occurred at pipe bend locations.

This issue was combined with CAJ-1 (part 2)

Open Issue(s)/Request(s):

Address "excessive settlements" effect on the piping and pipe bend stresses.

TVA Planned Action/Position:

TVA issued calculation WCG-1-867 (RIMS No. B18 910429 253) which showed the pipe stresses to be within allowable limits. This response was combined with CAJ-1.

Prepared By: B. J. Welch

Reviewed By: G. Khuseludyan 5-1-91 W. Smathers 5/2/91

Approved By: [signature] 5/2/91

2832M

Date: 4-18-91
Item No: CAJ-6

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Buried Piping Calculation

NRC Reviewer(s): Carl Costantino

TVA Responsible Person: R. Threlked/B. J. Welch

ESI Contact: Chris Painter

Issues Discussed/Information Presented:

Calculation WCG-1-682, "Analysis and Qualification of Buried ERCW Piping", section 4.0, last paragraph on page 8 needs to be expanded or justified.

Open Issue(s)/Request(s):

Delete subject paragraph and show analysis of subject elbows in Z-type configurations in Section 8.0 of calculation.

TVA Planned Action/Position:

Calculation WCG-1-682 has been revised on Z-type configuration of buried piping to specifically address stresses at elbows in Z-type configuration. (RIMS No. B18 910426 265)

Prepared By: CP 5/1/91 [signature] 5/1/91

Reviewed By: Bill J Welch G. Khurshudyan 5-1-91 WLS 5/2/91

Approved By: [signature] 5/2/91

2832M

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Concrete

NRC Reviewer(s): Ahmet Unsal

TVA Responsible Person: Rex Rowell

ESI Contact: Kenneth Lanham

Issues Discussed/Information Presented:

Methodology to determine worst cases for concrete features.

Open Issue(s)/Request(s):

After drawing reviews and walkthroughs, initial screening was done to eliminate concrete features that were considered obviously not worst cases. Were loads considered in this initial screening process?

TVA Planned Action/Position:

See attached page.

Item Closed.

Prepared By: K Lanham 5/2/91 / Rex Rowell 5/2/91

Reviewed By: H. Totmoglu 5/2/91

Approved By: [illegible signature] 5/2/91

2832M

The simpler cases were eliminated based on an attachment/equipment load comparison basis. Other load effects such as:

a. tornado depressurization
b. seismic loads
c. flooding loads (both compartment and site)
d. live loads
e. pipe break pressure loads
f. jet impingement loads

were considered, as applicable, during the selection process and are addressed in the following calculations:

WCG-1-585 Revision 1 Attachment C sheet 1
WCG-1-738 Section 11.2 (columns)
WCG-1-739 Section 11.2 (slabs)
WCG-1-740 Section 11.2 (beams)
WCG-1-741 Section 11.2 (shield walls)
WCG-1-742 Section 11.2 (partition walls)
WCG-1-585 Revision 1 Attachment C sheet 2 - (jet impingement loads are documented in calculation TVA-01-121 (RIMS No. PWP 841204 042) sheet 2 of Attachment C)

In addition, in response to item CAN-2 the above calculations (RIMS Nos. B18 910502 267, B18 910502 263, B18 910502 261, B18 910502 257, B18 910502 269, and B18 910502 265) have been revised to further clarify at what stage in the screening process loads were considered.

Date: 04/17/91
Item No: CAN-2

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Concrete

NRC Reviewer(s): Ahmet Unsal

TVA Responsible Person: Rex Rowell

ESI Contact: Kenneth Lanham

Issues Discussed/Information Presented:

Methodology to determine worst cases for concrete features.

Open Issue(s)/Request(s):

For selection of worst case concrete features in calculation WCG-1-585, what process was used during the intermediate reduction of the population?

TVA Planned Action/Position:

As discussed during the audit, the general steps include the following:

1. The office portion of the walkthrough data sheets was completed during the drawing review.
2. Walkthroughs were conducted and data sheets completed.
3. Obvious worst cases were eliminated based on CAN-1 discussion. (Reference, Conc. Selection Calculation page 11A)
4. Further reductions were based on comparison of key information contained on the walkthrough data sheets (e.g., geometry, quantity and types of attachments, load considerations etc.)
5. For beams, columns, and walls the information was, at this point, transferred to the appropriate spread sheet. (On columns, reserve capacity from previous calculations was utilized to reduce the population).
6. For slabs, an additional population reduction was achieved through a screening calculation (WCG-1-750) utilizing the 2-kip and greater equipment mounted on slab information.
7. For slabs, the resulting information was then transferred.

See Attachment A for a breakdown of the population of concrete features at each screening stage. The following calculations (RIMS Nos. B18 910502 267, B18 910502 263, B18 910502 261, B18 910502 257, B18 910502 269, and B18 910502 265) have been revised to further clarify the process, sequence and stage of comparisons which result in elimination of cases, and loading documentation reviewed:

WCG-1-585	WCG-1-740	WCG-1-742
WCG-1-739	WCG-1-741	WCG-1-738

Item Closed.

Prepared By: K. Lanham 5-2-91 / Rex Rowell 5/2/91

Reviewed By: H. Totmoquel 5/2/91

Approved By: Ruben O Hernandez 5/2/91

2832M

ATTACHMENT A

SUMMARY OF WORST CASE SELECTIONS-CONCRETE FEATURES TASK

Feature Type	Total Population	After Initial Screening	After Further Screening	Listed on Spread Sheet	Final Selection
Beams	77	31	10	10	6
Columns	263	82	50	50	30
Partitions	126	42	23	23	8
Shield Walls	277	58	23	23	17
Slabs	955	338	182	48	22

2832M

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Concrete

NRC Reviewer(s): Ahmet Unsal

TVA Responsible Person: Rex Rowell

ESI Contact: Kenneth Lanham

Issues Discussed/Information Presented:

Scope of concrete program.

Open Issue(s)/Request(s):

Calculation WCG-1-585 excludes the ERCW Pipe Tunnels/Structures, retaining walls at the Intake Pumping Station, and Class 1E Electrical Systems (Manholes, Handholes, and Conduit Banks). Where are these structures and other Category I structures (such as the ERCW Miscellaneous structures) as identified in the FSAR addressed?

TVA Planned Action/Position:

See attached page.

Item Closed.

Prepared By: K. Lanham 5-2-91 / Rex Rowell 5/2/91

Reviewed By: H. Totenquel 5/2/91

Approved By: Ruben O Hernandez 5/2/91

2832M

The following Category I structures other than the primary containment (which is addressed in the SCV task) are covered by the tasks as indicated below:

1. Auxiliary-Control Building and Associated Structures
   a. Control Bay Portion - Concrete Task (CAN)
   b. Auxiliary Building Portion - Concrete Task (CAN)
   c. Waste Packaging Structure - Concrete Task (CAN)
   d. Condensate Demineralizer Waste Evaporator Structure Portion - Concrete Task (CAN)
   e. Additional Equipment Building Portion - Concrete Task (CAN)

2. Diesel-Generator Building - Concrete Task (CAN)

**3. Category I Water Tanks (settlement) and Pipe Tunnels (Seismic analysis and settlement) - Geotechnical Task (CAJ)

4. Class IE Electrical Systems/Structures
   a. Manholes - Settlement under Geotechnical Task (CAJ)
   ** b. Handholes
   c. Conduit Banks - Seismic Anlaysis and Design Concrete Task (CAJ), (CAN)

5. North Steam Valve Room -Concrete Task (CAN)

6. Intake Pumping Station - Concrete Task (CAN)

**7. Miscellaneous ERCW Structures - i.e., standpipe structures (settlement), discharge overflow structure (settlement) - Geotechnical Task (CAJ)

8. Additional Diesel Generator Building - Concrete Task (CAN)

9. Reactor Building Concrete - Concrete Task (CAN)

**10. Retaining Walls at Intake Pumping Station

** There are no identified concrete items requiring resolution.

Date: 04/17/91
Item No: CAN-4

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Concrete

NRC Reviewer(s): Ahmet Unsal

TVA Responsible Person: Rex Rowell

ESI Contact: Kenneth Lanham

Issues Discussed/Information Presented:

Calculation for shear walls in the Intake Pumping Station (IPS).

Open Issue(s)/Request(s):

Calculation WCG-1-585 sheet 15A identified that shear walls in the Intake Pumping Station will be evaluated. Does this represent evaluation of the worst case shear loads in the longitudinal and transverse directions for the Intake Pumping Station as stated on sheet 10 of calculation WCG-1-757? Additionally, does calculation WCG-1-585 address floors due to increase in vertical acceleration as stated on sheet 12 of calculation WCG-1-757?

TVA Planned Action/Position:

Calculation WCG-1-585 (RIMS No. B18 910502 267) has been revised to reference Seismic CAP calculation WCG-1-757 and more clearly identify that the Intake Pumping Station shear walls for worst case shear loads in both longitudinal and transverse directions will be evaluated. In addition, the revised calculation WCG-1-585 identifies that worst case floor slabs in the Intake Pumping Station with increased vertical accelerations will be evaluated.

Prepared By: K. Lanham 5-2-91 / Rex Rowell 5/2/91

Reviewed By: H. Totuncu 5/2/91

Approved By: [signature] 5/2/91

2832M

Date: 4-18-91
Item No: CAK-1

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

Block wall evaluations

Open Issue(s)/Request(s):

On page 713 of ESI block wall calculation WCG-1-767 there are strain values utilized. What is the basis for these values?

TVA Planned Action/Position:

The strain values are included in the revised calculation WCG-1-755, (RIMS No. B18 910502 259) "Design Instruction for Structural Adequacy of Worst Case Concrete Block Walls" and based on the "Recommended Guidelines for the Reassessment of Safety Related Concrete Walls" prepared by Owners and Engineering Firms Informal Group on Concrete Masonry Walls, dated October 6, 1980.

Prepared By: K. Lanham 5-2-91 / Roy Rowell 5/2/91

Reviewed By: H. Totunquely 5/2/91

Approved By: [signature] 5/2/91

2832M

CAK-1

INFORMATION ONLY

RECOMMENDED GUIDELINES FOR

THE REASESSMENT OF

SAFETY RELATED CONCRETE MASONRY WALLS

Prepared by

Owners and Engineering Firms Informal Group

On Concrete Masonry Walls

October 6, 1980

CAK-1

TABLE OF CONTENTS

CAK-1

SECTION 5
IN-PLANE ACCEPTANCE CRITERIA

The objective of this section is to define acceptance criteria for the evaluation of masonry walls covered by the Bulletin. Because of the absence of test data establishing the behavior of masonry walls subjected to simultaneous in-plane and out of plane behavior, no attempt will be made to establish general acceptance criteria for the coupled conditions. Rather, this section establishes sufficiently conservative acceptance criteria for in-plane effects alone that a reasonable margin remains for out of plane loading.

The majority of the walls in question are not intended to be primary structural elements in the buildings in which they are located. For the purposes of this report a non-structural wall is defined as follows:

1. It does not carry a significant part of the buildings story shear or moment.
2. It does not significantly modify the behavior of adjacent structural elements.

In other words, the expected behavior of the building must be substantially the same whether such walls are present or not.

In-plane effects may be imposed on masonry walls by the relative displacement between floors during seismic events. However, the walls do not carry a significant part of the associated story shear, and their stiffness is extremely difficult to define. In addition, since the experimental evidence to date demonstrates that the apparent in-plane strength of masonry walls depends heavily upon the in-plane stress boundary conditions, load or stress on the walls is not a reasonable basis for acceptance criteria.

However, examination of the test data provided by the list of references for this section indicates that the gross shear strain of walls is a reliable indicator for predicting the onset of significant cracking. A significant crack is considered here to be a crack in the central portion of the wall extending at least 10% of a walls width or height. Cracking along the interface between a block wall and steel or concrete members does not limit the integrity of the wall, and is not addressed here. The gross shear strain is defined to be:

$$\gamma = \frac{\Delta}{H}$$

where γ = strain

Δ = relative displacement between top and bottom of wall

H = height of wall

Test results indicate that to predict the initiation of significant cracking, masonry walls must be divided into two categories:

1. Unconfined Walls - not bounded by adjacent steel or concrete primary structure. Significant "confining" stresses cannot be expected.

2. Confined Walls - at a minimum, bounded top and bottom or bounded on three sides.

For unconfined concrete block masonry walls the works of Fishburn (2) and Becica (1) yield an allowable shear strain as defined above of 0.0001. It should be noted that Fishburn's test specimens were 15 days old, on average.

For confined walls, the most reliable data appears to be that of Mayes et al (4). In static and dynamic tests of masonry piers (confined top and bottom) varying block properties mortar properties, reinforcement, vertical load and grout conditions, significant cracking was initiated at strains exceeding about γ = 0.001. It should be noted here that reinforcement can have no significant effect on the behavior prior to cracking. Similarly, the presence of cell grout should have no effect on stress or cracking in the mortar joints at a given strain. Both predictions are confirmed by the data in reference (4). In addition, the data shows that the onset of cracking is not sensitive to the magnitude of initial applied vertical load.

Klingner and Bertero (3) performed a series of cyclic tests to failure and found excellent correspondence with a non-linear analysis in which the behavior of an infilled frame prior to cracking is determined by an equivalent diagonal strut. While the equivalent strut technique has been used by many investigators to study the stiffness and load-carrying mechanisms of infilled frames, Klingner and Bertero found that the quasi-compressive failure of the strut could be used to predict the onset of significant cracking.

After some simplification of the relations in reference (3), the strength of the strut corresponds to a strain at cracking

$$\gamma = \frac{1 + \left(\frac{B}{H}\right)^2}{1000B/H} \qquad (1)$$

in which

B= wall width

H= wall height

assuming E= 1000fm

In summary, the recommended value for permissible in plane strain in unconfined walls is:

$$\gamma_u = 0.0001$$

and in confined walls

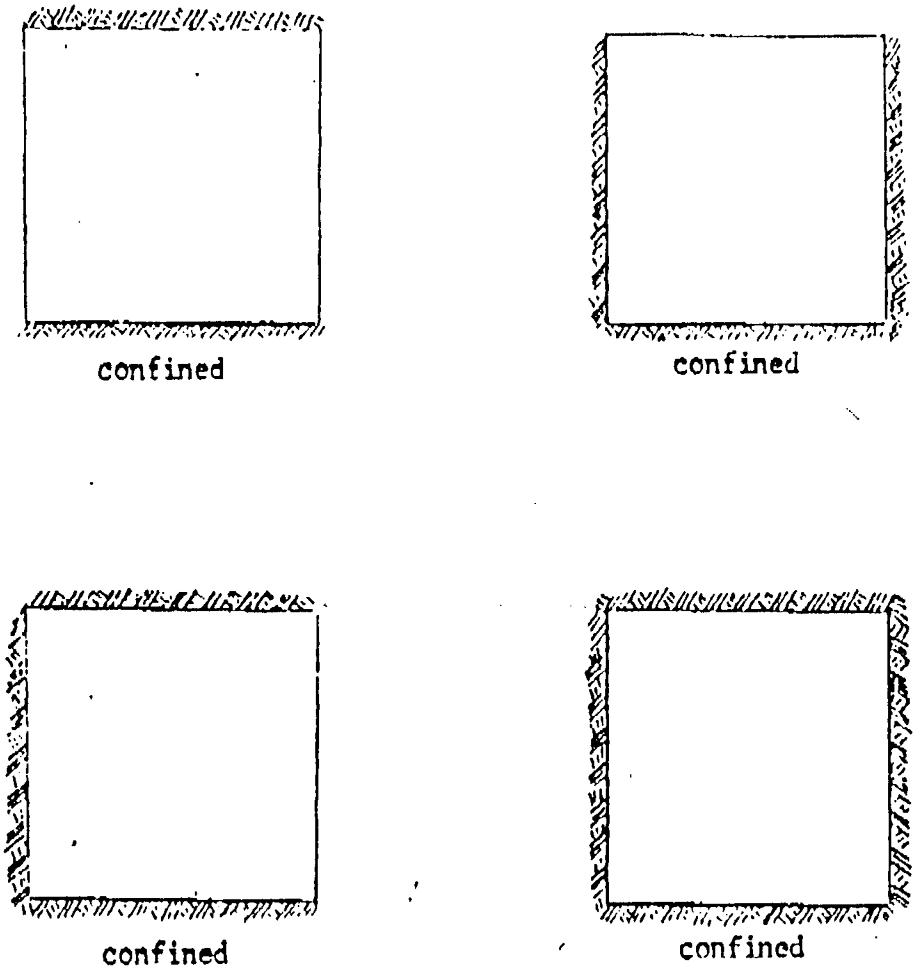
$$\gamma_c = 0.001$$

or

$$\gamma_c = \frac{1 + \left(\frac{B}{H}\right)^2}{2000\frac{B}{H}}$$

Test data has been examined only in the range $0.5 \lesssim \frac{B}{H} \lesssim 2.5$. The single equivalent strut model may not be viable for $\frac{B}{H}$ for outside this range.

CAK-1



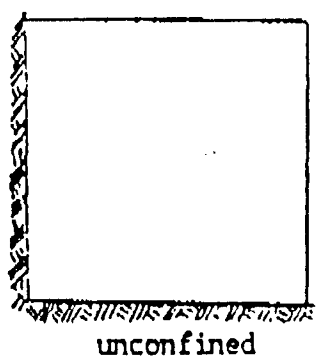


Figure 5.1 Examples Defining "Confined" and "Unconfined" Walls

CAK-1

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NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

Block wall evaluations

Open Issue(s)/Request(s):

For calculation WCG-1-767, under a site flooding condition, will an unbalanced loading condition exist on the block wall compartments due to flood water?

TVA Planned Action/Position:

See attached page.

Prepared By: K. Lanham 5-2-91 / Rex Rowell 5/2/91

Reviewed By: H. Totuncuoglu 5/2/91

Approved By: [signature] 5/2/91

2832M

The governing postulated site flood is based on the hypothetical condition of the worst combination of failure for the five upstream dams. If this unlikely event takes place, the plant shifts to a shutdown mode for the prescribed durations, as described in the FSAR Section 2.4. The rise in the water level at the site and in the buildings, under this hypothetical situation, will occur relatively slowly, ranging from a maximum rate of 1 foot the first 20 minutes to 4 feet after 5 hours and 55 minutes.

Due to numerous discontinuities in the walls, (louvers, openings, etc.) and the number of gaps between the floor and the doors, the water equalizes on both sides of the walls and will not create significant differential pressure across the wall due to water built up. The walls have an inherent capacity to withstand differential lateral water pressure loads of up to a few feet in height.

Date: 4-18-91
Item No: CAK-3

NRC CIVIL/SEISMIC CALCULATION AUDIT

April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

Block wall evaluations

Open Issue(s)/Request(s):

How were cracked sections taken into account for frequency determination of reinforced masonry wall cross sections in calculation WCG-1-767?

TVA Planned Action/Position:

ACI 318-71 provides guidance for calculation of the Effective Moment of Inertia,(Ie)(cracked section) and the Gross Moment of Inertia (Ig). The Code recognizes that Ie may be more than Ig for some sections and limits Ie not to exceed Ig. Both Ie and Ig were calculated for the subject wall, but since Ig controlled for some sections only the Ig was included in the calculation. For other sections both Ie and Ig were included. The revised calculation WCG-1-767 includes the calculation for both Ie and Ig to document that Ig controlled.

Prepared By: K. Lanham 5-2-91 / Ray Rowell 5/2/91

Reviewed By: H. Totuncuoglu 5/2/91

Approved By: Reuben O. Hernandez 5/2/91

2832M

Date: 4-18-91
Item No: CAK-4

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

Block wall evaluations

Open Issue(s)/Request(s):

On page 59 of ESI calculation WCG-1-767, was shear deformation accounted for in the frequency determination of masonry walls in the in-plane direction?

TVA Planned Action/Position:

The subject wall frequency of vibration in the inplane direction was expected to be in the rigid range. The frequency calculated used simplified bending stiffness without shear deformation considerations. The calculation WCG-1-767 has been revised to include frequency calculation considering shear deformation and has confirmed the expected rigid behavior (>33 HZ). Problem Evaluation Report (PER No. WBPER910247) has been developed to identify, evaluate, and disposition this issue for other walls.

Prepared By: K. Lanham 5-2-91 / R. Rowell 5/2/91

Reviewed By: H. Tolunguly 5/2/91

Approved By: Ruben O Hernandez 5/2/91

2832M

Date: 4-18-91
Item No: CAK-5

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

Block wall evaluations

Open Issue(s)/Request(s):

In Design Criteria WB-DC-20-30 Section 3.4.1.1, what TVA documentation supports use of 700 psi compressive strength (f'm) for masonry walls, 1000 psi compressive strength of masonry units (blocks) and type N mortar compressive strength M_O = 750 psi?

TVA Planned Action/Position:

ACI 531-79 Section 4.3, Table 4.3, (attached) provides a compressive strength, f'm, of 700 psi, for masonry unit compressive strength of 1000 psi with corresponding Type N mortar. ASTM C-270-88a, Table 2 (attached) provides average compressive strength of 750 psi for Type N mortar. WBN maintains masonry inspection/test records supporting the use of the f'm = 700 psi. Design Change Notice S-15996-A (RIMS No. B26 910426 847), revised the Design Criteria document WB-DC-20-30 to refer to ACI 531-79 and ASTM C-270-88a, and to delete reference 6.4.2 with renumbering of references as appropriate.

Prepared By: K. Lanham 5/2/91 / R. Rowell 5/2/91

Reviewed By: H. Totten[illegible] 5/2/91

Approved By: [illegible] 5/2/91

2832M

ACI 531-79 CAK-5

CHAPTER 4—MASONRY STRENGTH

4.1—General considerations

The engineer shall consider the influence of strength, stiffness, absorption, and other physical characteristics of masonry ingredients as well as method of construction, thickness, and type of tooling of joints before completing the design of masonry.

4.2—Determination of f_m'

4.2.1—The specified compressive strength of concrete masonry (f_m') shall be based on the unit test method (Section 4.3) or the prism test method (Section 4.4) at an age of 28 days or the age specified.

4.2.2—The specified compressive strength of composite masonry (f_m') shall be based on the provisions of Section 12.2.

4.3—Unit test method

4.3.1—Specified compressive strength f_m' for net area of masonry composed of solid or hollow units shall be taken from Table 4.3 when masonry units are tested in accordance with applicable ASTM standards. Compressive strength of masonry units shall be calculated on net cross-sectional area and the material and workmanship shall conform with applicable requirements of this code.

4.3.2—Values of f_m' in Table 4.3 may be interpolated but not extrapolated.

TABLE 4.3—VALUES OF f_m' FOR MASONRY

Compressive test strength of masonry units, psi, on the net cross-sectional area	Compressive strength of masonry f_m', psi	
	Type M and S mortar	Type N mortar
6000 or more	2400	1350
4000	2000	1250
2500	1550	1100
2000	1350	1000
1500	1150	875
→ 1000	900	700 ←

4.4—Prism test method

4.4.1—Testing shall include test of one set (three specimens) of each "Class of Unit" in advance of beginning operations, and at least one field test (one set) during construction for each 5000 sq ft of wall area.

4.4.2—Prism construction and testing shall conform to requirements of ASTM E 447 and this section.

4.4.3—No reinforcing steel shall be placed in the prism.

4.4.4—The prism test report shall include the level of load (psi) at the appearance of the first detectable crack.

4.4.5—Test prisms which are not uniform and symmetrical in shape shall be positioned with center of thrust of the testing machine aligned with geometric centroid of the area of prism.

4.4.6—The average compressive strength of each set of masonry prisms shall equal or exceed the specified compressive strength of masonry f_m'.

4.4.7—The specified compressive strength f_m' shall not exceed the ultimate strength of the masonry units.

4.4.8—The height-to-thickness ratio of masonry prisms shall be 1.33 minimum and 3.0 maximum.

4.5—Inspection

4.5.1 — When specified, masonry construction shall be inspected during the various work stages by the Engineer/Architect, or by a person acceptable.

4.5.2—Inspection shall include checking for compliance with project drawings and specifications and keeping of records which cover the following:

4.5.2.1 Quality and testing of masonry units and materials for mortar, grout, and making of prisms when required.

4.5.2.2 Proportioning, mixing, and consistency of mortar and grout.

4.5.2.3 Laying, mortaring, and grouting of masonry units and elements.

4.5.2.4 Condition, grade, size, spacing, and placement of reinforcement.

4.5.2.5 Any significant or unusual construction loads on masonry structural elements.

4.5.2.6 General progress of work.

4.5.2.7 When ambient temperature falls below 40 F or rises above 100 F, a complete record of weather conditions and of preconditioning and protection given to masonry materials, and protection and curing of completed work, shall be maintained.

4.5.3—Inspection records shall be available to Building Official, Owner, and Architect/Engineer during progress of work and for two (2) years thereafter.

TABLE 1 Proportion Specification Requirements

NOTE—Two air-entraining materials shall not be combined in mortar.

Mortar	Type	Proportions by Volume (Cementitious Materials): Portland Cement or Blended Cement	Masonry Cement: M	Masonry Cement: S	Masonry Cement: N	Hydrated Lime or Lime Putty	Aggregate Ratio (Measured in Damp, Loose Conditions)
Cement-lime	M	1	...	...	...	¼	
	S	1	...	...	...	over ¼ to ½	
	N	1	...	...	...	over ½ to 1¼	
	O	1	...	...	...	over 1¼ to 2½	
Masonry cement	M	1	...	...	1	...	Not less than 2¼ and not more than 3 times the sum of the separate volumes of cementitious materials.
	M	...	1	...	...	...	
	S	½	...	...	1	...	
	S	...	...	1	...	...	
	N	...	...	...	1	...	
	O	...	...	...	1	...	

4.1.1.1 *Portland Cement*—Types I, IA, II, IIA, III, or IIIA of Specification C 150.

4.1.1.2 *Blended Hydraulic Cements*—Types IS, IS-A, IP, IP-A, I(PM) or I(PM)-A of Specification C 595.

4.1.1.3 *Slag Cement (for Use in Property Specifications Only)*—Types S or SA of Specification C 595.

4.1.1.4 *Masonry Cement*—See Specification C 91.

4.1.1.5 *Quicklime*—See Specification C 5.

4.1.1.6 *Hydrated Lime*—Specification C 207, Types S or SA. Types N or NA limes may be permitted if shown by test or performance record to be not detrimental to the soundness of the mortar.

4.1.2 *Aggregates*—See Specification C 144.

4.1.3 *Water*—Water shall be clean and free of amounts of oils, acids, alkalies, salts, organic materials, or other substances that may be deleterious to mortar or any metal in the wall.

4.1.4 *Admixtures*—Admixtures such as coloring pigments, air-entraining agents, accelerators, retarders, water-repellent agents, antifreeze compounds, and other admixtures shall not be added to mortar unless specified. Calcium chloride, when explicitly provided for in the contract documents, may be used as an accelerator in amounts not exceeding 2 % by weight of the portland cement content or 1 % by weight of the masonry cement content, or both, of the mortar.

NOTE 2—If calcium chloride is allowed, it should be used with caution as it may have a detrimental effect on metals and on some wall finishes.

5. Test Methods

5.1 *Water Retention*—Determine water retention in accordance with Specification C 91, except that the laboratory-mixed mortar shall be of the materials and proportions to be used in the construction.

5.2 *Compressive Strength*—Determine compressive strength in accordance with Specification C 109. The mortar shall be composed of materials and proportions that are to be used in the construction with mixing water to produce a flow of 110 ± 5.

5.2.1 *Specimen Storage*—Keep mortar cubes for compressive strength tests in the molds on plane plates in a moist room or a cabinet meeting the requirements of Specification C 511, from 48 to 52 h in such a manner that the upper surfaces shall be exposed to the moist air. Remove mortar specimens from the molds and place in a moist cabinet or moist room until tested.

5.3 *Air Content*—Determine air entrainment in accordance with Specification C 91 except calculate the air content to the nearest 0.1 % as follows:

$$D = \frac{(W_1 + W_2 + W_3 + W_4 + V_w)}{\frac{W_1}{P_1} + \frac{W_2}{P_2} + \frac{W_3}{P_3} + \frac{W_4}{P_4} + V_w}$$

$$A = 100 - \frac{W_m}{4D}$$

where:

D = density of air-free mortar, g/cm³,
W_1 = weight of portland cement, g,
W_2 = weight of hydrated lime, g,
W_3 = weight of masonry cement, g,
W_4 = weight of sand, g,
V_w = millilitres of water used,
P_1 = density of portland cement, g/cm³,
P_2 = density of hydrated lime, g/cm³,

TABLE 2 Property Specification Requirements[A]

Mortar	Type	Average Compressive Strength at 28 Days, Min. psi (MPa)	Water Retention, min, %	Air Content, max, %	Aggregate Ratio (Measured in Damp, Loose Conditions)
Cement-lime	M	2500 (17.2)	75	12	Not less than 2¼ and not more than 3½ times the sum of the separate volumes of cementitious materials.
	S	1800 (12.4)	75	12	
	N	750 (5.2)	75	14[B]	
	O	350 (2.4)	75	14[B]	
Masonry cement	M	2500 (17.2)	75	...[C]	
	S	1800 (12.4)	75	...[C]	
	N	750 (5.2)	75	...[C]	
	O	350 (2.4)	75	...[C]	

[A] Laboratory prepared mortar only (see Note 1).
[B] When structural reinforcement is incorporated in cement-lime mortar, the maximum air content shall be 12 %.
[C] When structural reinforcement is incorporated in masonry cement mortar, the maximum air content shall be 18 %.

Date: 4-18-91
Item No: CAK-6

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

Selection of worst cases for masonry walls.

Open Issue(s)/Request(s):

For selection of worst case masonry walls, what process was used during the screening phase to eliminate walls from further consideration in Calculation WCG-1-623?

TVA Planned Action/Position:

As discussed during the audit, the worst case selection process for masonry walls was based on the assessment of the total population for the critical attributes. Walkthroughs and drawing reviews were performed for the total population. The masonry walls were separated into reinforced, mortared, and unmortared cases. The total population of all cases were then transferred to the spread sheet and grouped by building with controlling cases selected based on comparison of key attributes.

See Attachment B for a breakdown of the population at each screening stage.

Item Closed.

Prepared By: K. Lanham 5-2-91 / Ray Rowell 5/2/91

Reviewed By: H. Tolunay 5/2/91

Approved By: [signature] 5/2/91

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ATTACHMENT B
SUMMARY OF WORST CASE SELECTIONS FOR MASONRY WALLS

Total Pop. of Masonary Walls	Total Pop. of each Type of Wall	After Initial Screening	After Further Screening	Listed on Spreadsheet	Final Selection
Reinforced	58	*	*	58	10
Mortared	15	*	*	15	4
Unmortared	12	*	*	12	5
Totals	85	*	*	85	19

* Total population was listed on spreadsheet for selection and grouped by building.

2832M

Date: 4-18-91
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NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

Masonry wall allowable stress factor.

Open Issue(s)/Request(s):

Design Criteria WB-DC-20-30 section 3.4.8 requires an allowable stress factor of 1.3 for masonry tension perpendicular to bed joint. Page 268 of calculation WCG-1-767 uses a value of 1.5. Provide justification for the 1.5 factor.

TVA Planned Action/Position:

Calculation WCG-1-767 has been revised to use the factor of 1.3 for tension allowables perpendicular to the bed joint. The use of a 1.5 factor occurred three times in this calculation; however, it did not impact the conclusions of the calculation, which covers all of the mortared walls. A Problem Evaluation Report (PER No. WBPER910247) has been initiated to identify, evaluate, and resolve this item.

Prepared By: K Lanham 5/15/91 / Rex Rowell 5/15/91

Reviewed By: H. Totanoul[illegible] 5/15/91

Approved By: [illegible] 5/15/91

2832M

Date: 4-18-91
Item No: CAK-8

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

HELB flood load effects on masonry walls.

Open Issue(s)/Request(s):

Page 351 of calculation WCG-1-767 states that flood loads from high energy line breaks are unavailable. How is this calculation open item being tracked?

TVA Planned Action/Position:

Local compartment flooding due to the High Energy Line Breaks (HELB) have been identified on 47E235 series drawings, issued since the masonry wall evaluations were completed. The areas where the twelve worst case walls are located were evaluated for the HELB floods. In all cases the HELB floods were minor (in 6" range) and did not control the design. The revised calculation WCG-1-767 reflects this condition.

Prepared By: K. Lanham 5/2/91 / Ray Rowell 5/2/91

Reviewed By: H. Totuncuolly 5/2/91

Approved By: [signature] 5/2/91

2832M

Date: 4-18-91
Item No: CAK-9

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

Masonry block wall with epoxy paint.

Open Issue(s)/Request(s):

An unreinforced, unmortared masonry block wall (shield blocks) with epoxy paint on all sides of individual blocks has been identified as unacceptable in calculation WCG-1-767. How is this calculation open item being tracked?

TVA Planned Action/Position:

Calculation WCG-1-767 is intended to include evaluation of all worst case block walls. Presently twelve out of 19 worst case walls have been evaluated, with two out of five unmortared block walls included in the twelve.

The two restrained unmortared walls evaluated showed that epoxy paint on the contact surfaces of the blocks at higher layers were unacceptable due to the fact that the seismic loading was higher than the resisting friction loading. This fact was documented in the calculation. For the unpainted walls specifically addressed by this calculation, DCN 16018A has been prepared to require the replacement of blocks with unpainted contact surfaces. This item has been included in Problem Evaluation Report (PER No. WBPER910247) for identification, tracking, evaluation, and disposition.

Prepared By: K. Lanham 5/2/91 / R. Rowell 5/2/91

Reviewed By: H. Totaugill 5/2/91

Approved By: Ruben O'Healy 5/2/91

2832M

Date: 4-18-91
Item No: CAK-10

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

Masonry wall evaluations.

Open Issue(s)/Request(s):

How were cracked sections taken into account for evaluation of reinforced masonry wall cross sections in calculation WCG-1-767?

TVA Planned Action/Position:

Moments on reinforced masonry sections were compared to the cracking moment. Five sections did not crack under load and were evaluated based on unreinforced masonry allowables. One section cracked under load and was evaluated considering a cracked section for rebar tension and concrete stress. The calculation WCG-1-767 has been revised to evaluate the other five sections as cracked sections for rebar tension and concrete stress.

Prepared By: K. Lanham 5/2/91 / R. Rowell 5/2/91

Reviewed By: H. Totunogly 5/2/91

Approved By: [signature] 5/2/91

2832M

Date: 4-18-91
Item No: CAK-11

NRC CIVIL/SEISMIC CALCULATION AUDIT
April 15 though April 19, 1991

Program Element: Masonry

NRC Reviewer(s): A. Unsal

TVA Responsible Person: R. Rowell

ESI Contact: K. Lanham

Issues Discussed/Information Presented:

Masonry wall evaluations for shear loads.

Open Issue(s)/Request(s):

In calculation WCG-1-767, provide justification for shear exceeding the friction value given in Design Criteria WB-DC-20-30.

TVA Planned Action/Position:

Design Criteria WB-DC-20-30 specifies that 1.5 times peak g seismic loading be used to verify structural adequacy of the wall without restraints. If the restraints are required, the design criteria specifies the steps to be followed for the design of the restraints and for the checking of the block stability.
The two walls evaluated in calculation WCG-1-767 have external structural steel restraints, and the calculation was revised to use the steps for the restrained walls. The stability of the blocks was confirmed and the shears were calculated to be within the acceptable limits. This item has been included in Problem Evaluation Report (PER No. WBPER910247) for identification, tracking, evaluation, and disposition.

Prepared By: K. Lanham 5/2/91 / R. Rowell 5/2/91

Reviewed By: H. Toleugily 5/2/91

Approved By: [signature] 5/2/91

2832M