TELEDYNE ENGINEERING SERVICES

TELEDYNE ENGINEERING SERVICES

TELEDYNE ENGINEERING SERVICES

TELEDYNE ENGINEERING SERVICES

TELEDYNE ENGINEERING SERVICES

TELEDYNE ENGINEERING SERVICES

TELEDYNE ENGINEERING SERVICES

TELEDYNE ENGINEERING SERVICES

TECHNICAL REPORT

TECHNICAL REPORT TR-5319-1

MARK 1 CONTAINMENT PROGRAM

PLANT-UNIQUE ANALYSIS REPORT OF THE TORUS SUPPRESSION CHAMBER

FOR

VERMONT YANKEE
NUCLEAR POWER STATION

APRIL 8, 1983
REVISION 1

YANKEE ATOMIC ELECTRIC COMPANY
1671 WORCESTER ROAD
FRAMINGHAM, MA 01701

TECHNICAL REPORT TR-5319-1

MARK 1 CONTAINMENT PROGRAM

PLANT-UNIQUE ANALYSIS REPORT OF THE TORUS SUPPRESSION CHAMBER FOR VERMONT YANKEE NUCLEAR POWER STATION

APRIL 8, 1983
REVISION 1

TELEDYNE ENGINEERING SERVICES
130 SECOND AVENUE
WALTHAM, MASSACHUSETTS 02254
617-890-3350

RECORD OF REVISIONS

REVISION	PAGE	DESCRIPTION
1	Cover	Changed Revision 0 to Revision 1 and date from 11/20/82 to 4/8/83
	Title	Changed Revision 0 to Revision 1 and date from 11/20/82 to 4/8/83
	x	Added Table 4
	1	Changed Reference 9 to Reference 1
	2	Reformatted because of change on Page 1
	31	Deleted Reference 9
	32	Deleted Reference 9
	58	Changed Reference 9 to Reference 1
	108	Deleted Reference 9
	113	Added Table 4

FIGURES AND TABLES (CONTINUED)

1.0 GENERAL INFORMATION

The purpose of the Mark 1 Torus Program is to evaluate the effects of hydrodynamic loads resulting from a loss of coolant accident and/or an SRV discharge on the torus structure. This report summarizes the results of extensive analysis on the Vermont Yankee torus structure and reports safety margins against established criteria. The content of this report deals with the torus shell, external support system, vent header system and internal structures. Analysis and results for piping attached to the torus (including shell penetrations and internal piping), for the SRV line (except for the submerged portion and tee-quencher) and for the SRV line vent pipe penetration will be presented in a separate piping report, TR-5319-2.

The criteria used to evaluate the torus structure is the ASME Boiler & Pressure Vessel Code, Section III, Division 1, with addenda through Summer 1977 (Reference 11) and Code Case N-197. Modifications were done under Section XI of the ASME Code and meet the Summer 1978 Edition of Section III for design, materials and fabrication.

A great many technical reports have been written and issued as a part of this program. These reports provide detailed descriptions of the phenomena, the physics controlling the phenomena, calculational methods and detailed procedures for plant-unique load calculations. Several of these documents are listed as references in this report. The approach of this report will be to reference these documents, wherever possible, and to avoid a re-statement of the same information.

A major part of this program has dealt with providing plant-unique load calculation procedures (Reference 1 is an example of this). In most cases, the loads used to support the analysis were calculated in strict accordance with those procedures, as amended by NUREG 0661 (Reference 2). In some cases, optional methods have been used; these methods are specifically referenced in

Program documentation. Examples of these are the use of plant-unique SRV test data to calibrate SRV analysis, and use of plant unique quarter scale pool swell movies to refine certain water impact and froth loads. In a few cases, analysis assumptions have been made that do not appear in Program documentation; these are identified in the text.

Extensive structural analysis was performed as a part of this evaluation. The major analysis was for dynamic response to time-varying loads. Analysis for static and thermal conditions also form a part of this work. The computer code used to perform almost all of this analysis was the STARDYNE code, as marketed by Control Data Corporation. STARDYNE is a fully verified and accepted code in this industry; details of the code are available through CDC. Cases where a computer code other than STARDYNE is used will be identified in the text. All dynamic analysis used damping equal to 2% of critical, unless stated otherwise.

As an aid in processing the large amounts of calculated data, post-processors for the STARDYNE program were written and used. These programs were limited in function to data format manipulations and simple combinations of load or stress data; no difficult computational methods were included.

The loads and load combinations considered in this program required special consideration to determine the appropriate levels of ASME Code application. Reference 3 was developed to provide this standard. Table 5-1 of Reference 3 is the basis for all the evaluation work in this report; it is reproduced in this report as Table 1. This table shows 27 load combinations that must be considered for each structure. The number actually becomes several times that when we consider the many different values associated with various SRV discharge conditions. The approach used in the final evaluation of structures is to reduce this large number to a relatively small number of cases by conservative bounding. For example, load combinations including SSE seismic, have a higher allowable than the same combination

This model includes 587 structural nodes, 664 plate elements, 2261 static degrees of freedom and 362 dynamic degrees of freedom. Symmetric boundary conditions were used at both ends of the model.

The model was modified for various load calculations to account for differences in the percent of the water mass that is effective for that load event. In all cases, modeling of the water mass was accomplished using a 3-D virtual mass simulation as an integral part of the structural analysis. The percent of water mass used is identified in the discussion of each load calculation that follows.

The 360^{0} beam model of the torus is shown in Figure 3-4. This model was used to evaluate the effects of lateral loads on the support system and earthquake restraint system. The beam element properties were selected to simulate combined bending and shear stiffness of the sections. Water mass was lumped with the structure weight on the wetted nodes.

3.2 Loads Analysis

3.2.1 Pool Swell Loads (4.3.1 & 4.3.2)

Analysis for pool swell loads was done using the finite element model shown in Figure 3-1. This was a dynamic analysis performed in the time domain by applying a force-time history, to simulate the pressure-time histories of the pool swell event to each node on the computer model. Input pressure-time histories were varied in both the longitudinal and radial directions in accordance with the information in References 1, 2 and 10. Typical pressure-time history curves are shown in Figures 3-5 through 3-7. (These pressure-time histories are taken directly from Reference 10, before adjustment, as required by Reference 2. Therefore, the amplitudes shown are slightly different than the loads used in the analysis).

The computer analysis was run for two different pool swell conditions, full ΔP and zero ΔP. Figures 3-5 through 3-7 show comparative values and time histories for the two cases. The only difference between the analyses was the input loads; the models were identical. Details of the full load distribution can be found in References 1 and 10.

Plant-unique quarter scale pool swell tests showed that the effective water mass was less than 100% after bubble breakthrough and was slightly different for both zero and full ΔP conditions (Reference 4). The water mass used in the computer simulation was constant throughout the analysis and was set at the average of the two reduced masses identified in the quarter scale tests. The reduced and average mass values are given in Table 3. This simplification in water mass analysis is consistent with the relatively slow (pseudo-static) nature of the pool swell load. This simplification only affects the inertial (frequency) calculation; the effects of weight are accurately calculated for each load and time in the deadweight analysis.

3.2.2 Condensation Oscillation - DBA (4.4.1)

Analysis for condensation oscillation (CO) was also done with the structural model shown in Figure 3-1.

The condensation oscillation shell load is specified as a spectrum of pressures in 1 Hz bands (Reference 1). The analysis for this load was performed by considering the effects of unit loads at each load frequency (harmonic analysis) and then scaling and combining the individual frequency effects to determine total stress at selected elements. The three variations in the CO spectrum (Reference 1) were evaluated by re-scaling the results of the unit load analysis. 100% of the water mass was used for all CO analysis. A plant-unique factor was applied to the nominal condensation oscillation pressures as discussed in Reference 1; the factor is listed in Table 3.

The combination of individual harmonic stresses into total element stress was done by considering frequency contributions at 31 Hz and

4.3.2 Chugging Loads

4.3.2.1 Downcomer Lateral Loads (4.5.3)

Reference 1 identifies downcomer lateral loads as static equivalents with random orientation in the horizontal plane. The major consequence of this loading is to produce high local stress in the VH/downcomer intersection. The detailed shell model (Figure 4-1) was used to identify stresses in the downcomer intersection due to static loads applied at the base of the downcomer. Frequencies of the first downcomer response mode were taken from a dynamic analysis on the same model (Figure 4-1) with the downcomers full of water to the operating level. This frequency was necessary to determine the proper dynamic scale factor to apply to the static load.

The stress results from the statically applied load were used as a basis for a fatigue evaluation of the intersection in accordance with Reference 1.

4.3.2.2 Chugging - Synchronized Lateral Loads

The random nature of the downcomer lateral chugging load provides for all combinations of alternate force orientations on adjacent pairs of downcomers. Various load combinations were examined to determine stress levels in the vent header and mitre joint as a result of these loads. The cases considered are shown in Figure 4-6.

These cases were considered by applying static loads to the beam model (Figure 4-4) and determining final stresses as described in Section 4.2.

4.3.2.3 Internal Pressure (4.5.4)

Three vent system internal pressures exist during chugging. They are:

REFERENCES

1. G.E. Report NEDO-21888, Rev. 2, "Mark 1 Containment Program Load Definition Report", dated November 1981.

2. NRC "Safety Evaluation Report, Mark 1 Containment Long-Term Program", NUREG 0661, dated July 1980.

3. G.E. Report NEDO-24583-1 "Mark 1 Containment Program Structural Acceptance Criteria Plant Unique Analysis Application Guide" dated October 1979.

4. G.E Report NEDO-21944 "...¼ Scale 2-D Plant Unique Pool Swell Test Report" dated August 1979.

5. G.E. Report NEDO-24615 "....¼ Scale Suppression Pool Swell Test Program: Supplemental Plant Unique Test", dated June 1980.

6. G.E. Report NEDE-24840 "Mark 1 Containment Program - Evaluation of Harmonic Phasing for Mark 1 Torus Shell Condensation Oscillation Loads" October 1980.

7. G.E. Report NEDE-24519-P "Mark 1 Torus Program Seismic Slosh Evaluation" dated March 1978.

8. G.E. Report NEDE-21968 "Analysis of Vent Pipe - Ring Header Intersection" dated April 1979.

9. Deleted.

10. G.E. Report NEDO-24581, Rev. 1, "Mark 1 Containment Program - Plant Unique Load Definition - Vermont Yankee Generating Station" dated October 1981.

TABLE 4

SRV LOAD CASE/INITIAL CONDITIONS

	Design Initial Condition	Any One Valve	ADS* Valves	Multiple Valves
		1	2	3
	1 NOC*., First Act.	A1.1		A3.1
A	2 SBA/IBA,* First Act.	A1.2	A2.2	A3.2
	3 DBA,* First Act.[1]	A1.3		
	1 NOC, Subsequent Act.			C3.1
C	2 SBA/IBA, Sub. Act. Air in SRV/DL			C3.2
	3 SBA/IBA, Sub. Act. Steam in SRV/DL			C3.3

(1) This actuation is assumed to occur coincidently with the pool swell event. Although SRV actuations can occur later in the DBA accident, the resulting air loading on the torus shell is negligible since the air and water initially in the line will be cleared as the drywell to wetwell P increases during the DBA transient.

* ADS = Automatic Depressurization System

NOC = Normal Operating Condition

SBA = Small Break Accident

IBA = Intermediate Break Accident

DBA = Design Basis Accident