GENERAL ELECTRIC

NUCLEAR POWER

SYSTEMS DIVISION

GENERAL ELECTRIC COMPANY, 175 CURTNER AVE., SAN JOSE, CALIFORNIA 95125

RHB 041-80 MFN 104-80

MC 682, (408) 925-5722

May 29, 1980

U. S. Nuclear Regulatory Commission
Division of Safety Technology
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

Attention: Karl Kniel, Chief
Generic Issues Branch

Gentlemen:

SUBJECT: NRC REQUEST FOR ADDITIONAL INFORMATION, DFFR ROUND 2 QUESTIONS

References:

1) Letter, L. J. Sobon to O. D. Parr, dated July 7, 1977, "Amendment 2 (June 1977) to Mark II Containment Dynamic Forcing Functions Information Report" (DFFR), NEDE/NEDO-21061, Revision 2
2) Letter, L. J. Sobon to O. D. Parr, dated September 15, 1977, "Amendment 2, Supplement 1 (August 1977) to Mark II Containment Dynamic Forcing Functions Information Report" (DFFR) NEDO-21061, Revision 2
3) Letter, L. J. Sobon to J. F. Stolz, dated November 3, 1977, "Amendment 2, Supplement 2 (September 1977) to Mark II Containment Dynamic Forcing Functions Information Report" (DFFR), NEDO-21061, Revision 2
4) Letter, L. J. Sobon to J. F. Stolz, dated June 30, 1978, "Mark II Containment Dynamic Forcing Functions Information Report" (DFFR) NEDE/NEDO-21061, Revision 3

To date there have been three sets of questions or requests for additional information regarding the Mark II Containment Dynamic Forcing Functions Information Report (DFFR) NEDE/NEDO-21061. When Revision 2 of the DFFR was issued, Appendix A was established as a repository for responses to these questions. Responses to most of the Round 2 questions were transmitted via References 1, 2 and 3 for incorporation into Appendix A of DFFR, Revision 2. The portions of question responses not addressed were to have been documented in a future supplement.

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The purpose of this letter is to transmit seventy (70) copies of the complete set of Round 2 question responses. The pages have been prepared in a format for direct insertion into Appendix A of DFFR, Revision 3. You will recall that DFFR, Revision 3 did not include an update of Appendix A (Reference 4). This transmittal provides the updating of Round 2 question responses for placement into Appendix A. The General Electric Company Proprietary information identified in the responses to Questions M020.28, and M020.45 is being forwarded by separate letter.

This submittal is made by General Electric on behalf of the Mark II Owners Group as part of the Mark II Containment Program under Task C.6.

Very truly yours,

S.J. Stark for R.H. Buchholz

R. H. Buchholz, Manager
BWR Systems Licensing
Safety and Licensing Operation

RHB:pes/545-546

cc: C. Anderson, NRC
J. Kudrick, NRC
H. Chau, Mark II Owners Group
L. Gifford, GE - Bethesda
File: 3.4.4.6

APPENDIX A-2
RESPONSES TO NRC QUESTIONS

NRC QUESTIONS DATED JANUARY 14, 1977, WITH RESPONSES

Series 020: Containment Systems Branch

Series 030: Structural Engineering Branch

Question	Keyword Index to Questions	Response Date	
			R2
M020.27	Inventory Effects on Blowdown	6/77	A2
M020.28	Wetwell Backpressure	6/77	
M020.29	Vent Thrust Loads	9/77	S2
M020.30	Vent Lateral Drag Forces	9/77	
M020.31	3D Tests	6/77	
	1. Scaling Analysis	6/77	
	2. Vent Flow Asymmetry	6/77	
	3. Ap/Av Spatial Variation	2Q78	R3
M020.31	Incorrect Reference	6/77	
M020.33	Diaphragm Floor Upward Load	8/77	S1
M020.34	High Vent Flow Loads	6/77	A2
M020.35	Pool Swell Model		
	1. Isentropic Bubble	8/77	
	2. Breakthrough	8/77	
	3. Test/Model Comparison	8/77	S1
	4. Drywell Pressure	8/77	
	5. Compressibility Effects	8/77	
	6. Pool Swell Parameter Sensitivity	8/77	
M020.36	Breakthrough Model	6/77	
M020.37	Downcomer Lateral Load	6/77	
M020.38	Multiple Vent Chugging - Statistical	2Q78	R3
M020.39	Boundary Load Parameter Sensitivity	6/77	A2
M020.40	Multiple Vent Chugging - Tests	2Q78	R3
M020.41	50% Design Margin	9/77	A2 S2
M020.42	Loads on Submerged Structures	8/77	S1
M020.43	Downcomer Support Loads	2Q78	R3
M020.44	Pool Swell Waves and Seismic Slosh	6/77	A2

NRC QUESTIONS DATED JANUARY 14, 1977, WITH RESPONSES

Question	Keyword Index to Questions	Response Date	
M020.45	NEDE 13442P-01 Deficiencies		R2
	1. All Test Data	2Q78	R3
	2. Instrumentation	2Q78	R3
M020.46	Run 5101-29 Raw Data	6/77	A2
M020.47	Ramshead Radial Orientation	8/77	S1
M020.48	S/RV Load Models and Calculations	9/77	S2
M020.49	Multiple SRV Actuation		
	1. Model	2Q78	R3
	2. Pressure-Time Histories	2Q78	R3
	3. Wall Load Plots	2Q78	R3
	4. Test/Model Verification	2Q78	R3
M020.50	SRV Bubble Dynamic Model		
	1. Bubble Formation Efficiency	2Q78	R3
	2. Drag Coefficient	8/77	S1
	3. Multiple Bubble Effects	8/77	S1
	4. Pool Boundary Effects	9/77	A2 S2
M020.51	Bubble Formation Location	9/77	A2 S2
M020.52	Ramshead Influence Coefficient		
	1. Parameters	9/77	A2 S2
	2. Linear Superposition	9/77	A2 S2
	3. Nomenclature	9/77	A2 S2
M020.53	Bubble Frequency		
	1. Equations and Assumptions	9/77	A2 S2
	2. Initiating Transient	2Q78	R3
M020.54	Quencher Loads	6/77	A2
M020.55	SRV Loads on Submerged Structures	8/77	S1
M020.56	Primary and Secondary Loads	8/77	S1
M020.57	Additional Pressure Suppression Tests	2Q78	R3
M020.58	Plant Unique Pool Swell Calculation		
	1. Deviations from Model	6/77	A2
	2. Model Inputs	6/77	A2
	3. Parameter Time-Histories	6/77	A2
	4. Comparison with 4T	9/77	S2

NRC QUESTIONS DATED JANUARY 14, 1977, WITH RESPONSES

Question	Keyword Index to Questions	Response Date	
M020.59	Downcomer Lateral Braces		R2
	1. Description	6/77	A2
	2. Effects on Pool Swell	2Q78	R3
	3. Impact and Drag Loads	6/77	A2
	4. Downcomer Flanges	6/77	A2
M020.60	Wetwell Pressure History	6/77	A2
M020.61	Pool Swell Inside Pedestal	6/77	A2
M020.62	Pool Temperature Monitor	2Q78	R3
M020.63	Suppression Pool Temperature Limit		R3
	1. Temperature Time-History	2Q78	R3
	2. Instrumentation/Alarm	2Q78	R3
	3. Operator Action	2Q78	R3
M130.8	Load Combination	8/77	S1
M130.9	Structural Design	8/77	S1
M130.10	Basemat Model	8/77	S1
M130.11	Acceptance Criteria	8/77	S1
M130.12	SRV Structural Response	8/77	S1
M130.13	Static Equivalent Lateral Load; Fluid Structural Response	8/77	S1
M130.14	Chugging; Fluid Structure Interaction	6/77	A2
M130.15	Wall Stiffness Effects	8/77	S1

Reference Source: Letter with enclosure, "Mark II Containment - Request for Additional Information," to N. W. Curtis, Pennsylvania Power & Light Company, from Olan D. Parr, NRC dated January 14, 1977.

R2 - DFFR Rev. 2, 9/76

A2 - DFFR Rev. 2 Amend. 2, 6/77

S1 - DFFR Rev. 2 Amend. 2 Supp. 1, 8/77

S2 - DFFR Rev. 2 Amend. 2 Supp. 2, 9/77

Revision 3 6/78

QUESTION M020.27

The calculated drywell pressure transient typically assumes that the mass flow rate from the recirculation system or steamline is equal to the steady-state critical flow rate based on the critical flow area of the jet pump nozzle or steamline orifice. However, for approximately the first second after the break opening, the rate of mass flow from the break will be greater than the steady-state value. It has been estimated that for a Mark I containment this effect results in a temporary increase in the drywell pressurization rate of about 20% above the value based solely on the steady-state critical flow rate. The drywell pressure transient used for the LOCA pool dynamic load evaluation, for each Mark II plant, should include this initially higher blowdown rate due to the additional fluid inventory in the recirculation line. 2

RESPONSE

The drywell pressure transients have been recalculated with the additional blowdown flow rate produced by the inventory effects included in the analysis. The impact of the revised drywell pressure history will be assessed on a project unique basis and the results of these studies will be reported in the individual plant Design Assessment Reports.

QUESTION M020.28

The importance of the effect of wetwell backpressure on Mark II pool dynamic loads (i.e., pool swell and steam loads) was discussed in the 4T test report NEDE-13442P-01 and in the June 14, 1976 4T test application memorandum. The 4T test matrix, including Phases I through III, does not include tests that allow separation of pool dynamic effects attributable to vent submergence and wetwell backpressure. We require that additional 4T tests, with these parameters uncoupled, be performed for the purpose of developing plant specific pool swell and steam loads.

RESPONSE

In general, the Mark II suppression pool dynamic loads during a loss-of-coolant accident can be divided into two categories: those loads that depend on the gross dynamics of the suppression pool during drywell to wetwell air venting and those that depend on the thermodynamic considerations of steam condensation. Included in the first category are loads produced by the pool swell air bubble, formation, bulk pool swell, froth formation (if any) and fallback. The second category includes loads produced by the chugging and steam condensation pressure oscillation phenomena. The following is a discussion of the influence of wetwell backpressure and vent submergence on each of these phases of the blowdown transient. R2

The Mark II 4T test program showed that the initial clearance between the pool surface and the suppression pool ceiling (ceiling clearance) and the initial vent submergence had an effect on the dynamics of the suppression pool during pool swell. The compression of the wetwell air space is the primary parameter acting to retard and limit the bulk pool swell and the initial volume of the wetwell air space is defined by the ceiling clearance. The mass of water accelerated is a direct function of the vent submergence. In the 4T facility, only three discrete combinations of ceiling clearance and submergence were actually tested (e.g., a 9-ft submergence test always has a 1.5-ft ceiling clearance).

Three parameters which describe pool swell are the air bubble pressure rise above ambient, the maximum pool surface velocity and the maximum pool swell height. Previously, these parameters have been plotted against submergence or some other test variable, but now a new variable has been defined: the ratio of ceiling clearance to submergence. This variable combines the parameter which defines the air space backpressure with the submergence. When the pool swell parameters are plotted as a function of the ratio of ceiling clearance to submergence, trends are indicated which suggest that the present data can be used to define values of these parameters for other values of ceiling clearance and submergence. The air bubble pressure rise, the maximum pool surface velocity and the maximum pool swell height are plotted as a function of this new variable in Figures 28-1,* 28-2* and 28-3*, respectively.

To investigate the validity of this extrapolation, an analytical parametric study of the effects of variations in ceiling clearance was performed. The Mark II pool swell model was used for this study and the best estimate of the test boundary conditions were employed in the model. Figure 28-4* shows a comparison of the measured air bubble pressure rise during pool swell to the value predicted by the analytical pool swell model. Figure 28-5* shows the

*This figure is contained in the proprietary supplement.

same type comparison for the maximum pool surface velocity. Figure 28-6* is a comparison of the measured maximum pool swell height from the 4T tests and the pool swell model predictions for these same tests. Because of the generally good agreement between the data and the model predictions, the model can be used to perform the parametric study. To establish a base with which to compare the effects of parameter variations, the model predictions are plotted in Figures 28-7,* 28-8* and 28-9* as a function of the ceiling clearance-to-submergence ratio. These are essentially the same plots as Figures 28-1,* 28-2* and 28-3,* respectively, except that Figures 28-1,* 28-2* and 28-3* are the actual test data. R2

Seven tests were chosen for the parametric study and the test conditions are summarized in Table 28-1.** The ceiling clearance was the parameter which was varied and for each of these tests the air bubble pressure rise, the maximum pool surface velocity and the maximum swell height were predicted for three values of the ceiling clearance (i.e., 27.0, 29.5, and 31.5 ft). Fourteen additional data points were thus obtained for each parameter, and these are plotted in Figures 28-7,* 28-8* and 28-9* along with the base data. As is evident, plotting these parameters as a function of the ratio of ceiling clearance to submergence collapses the data. That is, the maximum swell height divided by submergence for all values of the ratio of ceiling clearance and submergence fall on the same line; likewise for the air bubble pressure rise and the maximum pool swell velocity. Thus, this study confirms that the trends indicated by the actual test data (Figures 28-1,* 28-2* and 28-3),* which is based on three values of ceiling clearance and submergence, are correct and that the air bubble pressure rise, the maximum pool surface velocity and the maximum swell height for other values of ceiling clearance and submergence can be determined within the range of the test data from the data presently available.

The conclusion of the parametric study is that, while the ceiling clearance and submergence were not varied independently in the actual tests, the data can be plotted in a way which allows the effects to be considered separately.

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*This figure is contained in the proprietary supplement.

**This table is contained in the proprietary supplement.

Also, because the range of the ratio of ceiling clearance to submergence for the Mark II containments (2.1 to 3.6) has been nearly bounded by the test series, the present data are sufficient to define the air space backpressure and submergence effects for the Mark II containments. R2

The other two phenomena which are dependent on the gross dynamics of the suppression pool are the pool swell froth formation and the pool fallback. The 4T tests showed that there was no froth formation following pool swell because of the air space backpressure. The magnitude of the backpressure and the maximum pool swell height are intimately related and dependent on the initial ceiling clearance and the submergence. Since the ceiling clearance-to-submergence ratio of the tests is nearly bounding for the Mark II containments, the observations from the tests (i.e., no froth formation) would correctly apply directly to the Mark II containments. The elevation from which the pool falls back is equal to the maximum pool swell height. Hence, the observations and conclusions mentioned above for the maximum swell height would apply. That is, since the test parameters affecting the maximum swell height are nearly bounding and the maximum swell height is correctly modeled, so is the pool fallback phenomena.

The second category of suppression pool dynamic loads includes those that depend on the thermodynamic considerations of steam condensation. This includes the chugging and steam condensation oscillation phenomena. During the 4T tests, the wetwell air space backpressure varied simultaneously with the submergence. The different submergences resulted in different air space volumes and correspondingly different air space backpressures, with the deeper submergence also having the high backpressure. Figure 5-21 of 4T test report NEDE-13468P shows this air space pressure variation with submergence. The local pressure (i.e., the pressure at the vent exit) is composed of the hydrostatic head (due to vent submergence) plus the air space pressure. Thus, it would appear that the two parameters of submergence and air space pressure might be combined for steam condensation phenomena to form a single parameter, the local vent exit pressure. The pool boundary pressure resulting from high mass flux steam condensation pressure oscillations is shown in Figures 5-41 and 5-43 of the 4T test report (NEDE-13468P); from medium mass flux steam condensation pressure oscillations is shown in Figures 5-47 and 5-49; and from chugging is shown in Figures 5-91 and 5-92. All of this data is plotted as a function of vent submergence, which includes the effects of air space pressure, and there is not a significant dependence evident. The abscissa could be changed from submergence to the vent exit pressure by multiplying by the density of water and adding the air space pressure and conclusion would be the same. That is, within the range of test data, the air space backpressure and submergence collectively do not have a significant effect on the steam condensation phenomena. R2

QUESTION M020.29

Thrust loads on the vent system of a Mark II containment are reaction forces due to vent flow caused by the LOCA pressure transient. These loads would be transmitted to the diaphragm separating the drywell and wetwell volumes through the vent deflectors and the vent deflector supports. Analyses of these thrust loads have not been provided in the DFFR. We require that these thrust loads be investigated. Provide a description of the method of analyses, the magnitude, and duration of this load for each Mark II plant.

RESPONSE

The thrust loads on the vent system are the reaction forces due to vent flow caused by the LOCA pressure transient. This reaction force can be estimated by applying the steady-state momentum balance equation between the inlet and exit sections of the vent (e.g., Bisd et al., "Transport Phenomena," John Wiley & Sons, pg. 211, 1960). The thrust load is then given by: S2

$$F_T = \frac{AG_e^2}{\rho_e} - A\,(P_D - P_e) - mg$$

where F_T is the upward thrust load on the vent; A is the cross-sectional area of the vent; G_e is the mass flux at the vent exit; ρ_e is the density of the fluid at the vent exit; P_D is the drywell pressure; P_e is the vent exit pressure; m is the mass of fluid contained in the vent between the entrance and exit sections; and g is the standard acceleration due to gravity.

Data from a typical BWR Mark-II plant is used to determine the magnitude of this thrust load. These data are summarized here on a per downcomer basis.

S2

$A = 452 \text{ in.}^2$

$G_c = 80 \text{ lbm/sec-ft}^2$

$\rho_e = 0.214 \text{ lbm/ft}^3$ (steam at 55 psia, 60% quality)

$P_D = P_e - 5$ psi (average value)

$m = 30.23$ lbm (based on 45-ft-long downcomer and a fluid density of 0.214 lbm/ft^3)

Substituting these data into the equation for F_T, the thrust load on a single downcomer vent is calculated as:

$$F_T = \frac{(452)\,(80^2)}{(144)\,(0.214)\,(32.2)} - (452)\,(5) - \frac{(30.23)\,(32.2)}{(32.2)}$$

$$= 2915 - 2260 - 30.23$$

$$= 624.8 \text{ lb}_f$$

A typical plant may have 100 downcomers with a drywell floor area of 5000 ft^2. This will correspond to a thrust load of 0.087 psi. Therefore, this load is negligible for design purposes. Since the entire LOCA transient last about 350 sec, the duration of the thrust load would also last for about 350 sec.

For each of the Mark II plants under construction, the magnitude and duration of this load will be provided in the respective Design Assessment Report.

R2

QUESTION M020.30

Significant differences in the pool area/vent area ratio exist from location to location within a given Mark II plant. These differences may lead to cross flow and lateral drag forces on the vents during pool swell. Based on the DFFR Section 4.4.7, it would appear that this lateral drag load on the vents would be computed based on the maximum pool surface velocity and the density of water. Confirm this interpretation of the DFFR. In addition, provide the magnitude and duration of this load for each Mark II plant. Alternatively, provide justification for not including this load.

RESPONSE

The interpretation of the DFFR for the computation of the drag loads in general is currently under examination by a task force of the Mark II Owners Group. As soon as the methodology for properly determining the drag loads has been established by this task force, an analytical model report and an application memorandum will be prepared and issued. The report and the memorandum will provide the guidelines and the basis for computing the plant specific drag loads for all piping, including the downcomer vent, in the suppression pool. R2 S2

QUESTION M020.31

We require that 3D tests be performed to substantiate the pool swell loads. These loads are currently based on a one-dimensional pool swell model and single vent 4T tests. The following items should be considered as a part of the 3D test program.

RESPONSE

The EPRI Report (EPRI NP-441, Project 693-1, April 1977) on the scaled Mark II Air Tests describes the comprehensive 3D model tests performed by EPRI. As discussed in the report, these tests show that the hydrodynamics described in the DFFR and supporting reports are correct characterizations of the actual phenomena that would occur during the vent clearing and pool swell portions of hypothesized Design Basis Loss-of-Coolant Accident (DBA-LOCA).

Responses to specific portions of this question are provided below:

QUESTION M020.31 (Continued)

1. A comprehensive scaling analysis of the test facility and error analysis of the test data.

RESPONSE

A scaling analysis of the EPRI test facility and an error analysis of the test data is provided in the EPRI report.

QUESTION M020.31 (Continued)

2. A determination of the sensitivity of pool swell loads to asymmetries in vent flow loads and the drywell/wetwell pressure transient.

RESPONSE

No vent load asymmetries were noted in the EPRI tests. The relationship of the drywell/wetwell pressure transient to the pool swell loads is described in the 4T Test Reports NEDE-13442P-01 and NEDE-13468P. R2

QUESTION MD20.31 (Continued)

3. A determination of the effect of spatial variations of the pool area to vent area ratio within a given plant on the pool swell phenomena.

RESPONSE

R3

As listed in Table 4-3 of the DFFR, the average ratio vent area to pool area varies between 0.049 and 0.082 for the Mark II plants. In the 4T tests the vent area to pool area ratio was varied from 0.057 to 0.086. The 4T tests showed that the pool swell phenomena was always one dimensional in nature throughout this range. Because of this and the fact that the tests nearly covered the range of vent area to pool area ratios existing for the Mark II designs provides confidence that the bulk effects of pool swell are well understood and are well represented by the 4T tests.

Mark II 1/13 scale multivent air tests have also been performed (EPRI Report NP-441, "Dynamic Modeling of a Mark II Pressure Suppression System," April 1977). The test facility had a representative Mark II vent arrangement in which the local ratio of vent area to pool area varied from a maximum of 0.087 to a minimum of 0.024. The represents a factor of 3.63 difference in the local ratio of vent area to pool area across the suppression pool. Even with this significant variation in vent spacing, the pool surface remained essentially flat during the pool swell transient. As was the case in the 4T tests, the pool swell was demonstrated to be one dimensional in nature.

Table 1 lists the maximum and minimum values of local ratio of the vent area to pool area for the Mark II plants. The multivent air tests were performed with a difference in the vent area to pool area ratio (3.63) which is bounding for all but two of the Mark II designs and these plants are not far outside the range that was tested.

In summary, the 4T tests provide confidence that the bulk effects of the variation in the average ratio of vent area to pool area are well understood and well defined. In addition, the 3 dimensional multivent air tests nearly cover the range of variation of the vent area to pool area within a single suppression pool and these tests demonstrated that, even with significant variations in the vent area to pool area ratio, the pool swell phenomena can still be accurately characterized as one dimensional. Therefore, spatial variations of pool area to vent area do not significantly influence the pool swell phenomenon and would not invalidate any of the pool swell dynamic loads presented in the Mark II Dynamic Forcing Functions Information Report. R3

Table 1

RANGE OF VENT AREA TO POOL AREA RATIOS FOR THE MARK II CONTAINMENT DESIGNS

$\frac{A_{VENT}}{A_{POOL}}$

PLANT	MIN	MAX	RATIO
Limerick	0.024	0.099	4.13
*Susquehanna	0.024	0.087	3.63
Shoreham	0.037	0.125	3.38
LaSalle	0.047	0.095	2.02
Zimmer	0.064	0.077	1.20
Nine Mile Point	0.029	0.123	4.24
WNP-2	0.125	0.190	1.52
Bailly	0.050	0.062	1.24
4T	0.05	0.086	1.72

*Same as 1/13 scale multivent tests.

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QUESTION M020.32

The DFFR includes the statement on page 4-43 that a typical jet impingement load on the basemat can be computed utilizing the velocity attenuation given in Figure 12.3 of Reference 13. Clarify this reference, since Reference 13 does not contain a Figure 12.3. R2

RESPONSE

The velocity attenuation data are provided in Figure 12.3 of Reference 14, not Reference 13. This typographical error in the DFFR will be corrected as part of the next revision of this document.

QUESTION M020.33

The diaphragm pool swell upward load was based on the unheated drywell test Run 33. This test was conducted with a vent submergence of 11 ft. Figure 5-23 in Reference NEDE-13442P-01 shows that the diaphragm upward load increases with increasing vent submergence. The current peak upward design load for the diaphragm does not appear to include sufficient margin for both this effect and uncertainty in the measured load. Address this concern and provide an error analyses to substantiate the peak upward design load for the diaphragm. S1

RESPONSE

The value of 2.5 psi recommended as a design value for the upward load on the diaphragm floor in Mark II containments was based on consideration of all 4T test data, Phases 1, 2, and 3 (Ref NEDE-13442P, NEDE-13468P, Phases I, II, and III Applications Memorandum). This value was selected to conservatively bound the maximum pressure difference observed ($P_{wetwell}$ - $P_{drywell}$). Phase 2, 3 tests (NEDE-13468P) indicated no upward load would exist, i.e., $P_{drywell}$ was always greater than $P_{wetwell}$ in these tests. (See Figures 5-29, 5-30 of NEDE-13468P) Phase 1 tests (See Figure 5-28 of NEDE-13442P) revealed $P_{drywell}$ > $P_{wetwell}$ in over half the test runs. The remaining Phase 1 runs indicated a very small upward ΔP, less than 1.2 psi, with exception of test run 33, which had an initially cold drywell which is not representative of a Mark II containment initial condition. This test indicated a maximum upward ΔP on only 2.2 psi (NEDE-13442P). The absolute drywell pressure peak during the pool swell transient in test run 33 was less than all other test runs, due to considerable steam condensation in the drywell, while wetwell freespace pressure was similar to other runs. Since these conditions were believed to bound the range of possible blowdowns which result in pool swell, the 2.2 psi measured was viewed as a maximum and a bounding design load of 2.5 psi was, therefore, recommended. S1

A trend of increasing upward ΔP with increasing submergence is indicated by the 2-1/2-in. venturi data shown on Figure 5-28 of NEDE-13442P (Phase I tests). However, the 3-in. venturi data on this same figure does not support this trend.

The Phase 2, 3 tests also do not support this trend, indicating essentially no submergence effect over the tested range (See Figure 5-29 of NEDE-13468P).

Uncertainties in the measured 4T test pressures (drywell and wetwell) used to indicate the diaphragm floor differential pressure are discussed in Appendix G of NEDE-13468P. The uncertainty in the diaphragm floor differential pressure has been determined to be about ± 0.25 psi.

Based upon the above considerations, it is concluded that the recommended 2.5 psi upward load for design of the diaphragm floor adequately accounts for the small uncertainty in measured pressures, and weak, if any, effect of increased vent submergence on the diaphragm floor upward differential pressure.

R2

QUESTION M020.34

The DFFR in Section 4.2.2 states that downcomer and pool boundary loads will not be considered during periods of high steam flow since the load derived from the 4T tests are lower then corresponding low steam vent flow lateral loads. It is our position that high steam flow loads should be considered since these loads, in combination with other loads, may be significant. It was stated in the 4T at high steam vent flow. However, in NEDO-21078 (Figure 3-19), foreign licensee data indicate significant lateral loads at a vent flow of 20.7 lb/ft^2 in tests conducted with an air mixture of 1%. Specification of a high vent flow downcomer load should reflect this data as well as the 4T data. For structures in the pool it is our position that the ±4 psi, 4 Hz load derived from PSTF tests should be used. This load should be confirmed by data from the 4T tests.

RESPONSE

With regard to pool boundary loads during high steam flow, Section 4.2.2 of the DFFR has been superseded by the information presented in Section 6.1 and 6.2 of the Mark II Applications Memorandum published in January 1977.* R2

These section of the Applications Memorandum provide information on the suppression pool boundary loads that could occur during periods of high and medium steam mass flow in the drywell to wetwell vent system. The memorandum provided numerical information on these loads, known as condensation oscillations, and recommends use on an interim basis to evaluate the structural significance of this loading phenomenon. This is believed to be a conservative procedure.

The concern expressed in the question with regard to lateral loads on the downcomers during periods of high mass flow may be based on a misunderstanding of the loads specified in the DFFR. The current DFFR specification of 8800 lb_f equivalent static load is currently applied over the entire period when lateral loads could occur (Figure 5-2 in the DFFR); i.e., from 4 to 60 sec after the DBA, which is a period that encompasses high, medium and low steam flow conditions.

This combination of large vent lateral loads with other loads occurring during high steam flow is believed to be a very conservative approach. Note that the data point from Figure 3-19 referenced in this question indicates loads vary much less than the DFFR specification (i.e., 4333 lb_f from Figure 3-19 versus 8800 lb_f from the DFFR). Additionally, Section 4 of the Mark II Applications Memorandum published in 1977 shows that the Phase I, II and III 4T tests confirm the conservatism of the current DFFR lateral load specification for downcomers.

QUESTION M020.35

With regard to the pool swell dynamic analytic model described in Section 4.4 of the DFFR, we have a number of concerns. We request modifications and/or clarification of the methodology in response to the concerns listed below:

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*"Mark II Pressure Suppression Test Program, Phases I, II and III of the 4T Tests, Applications Memorandum, January 1977;" Letter and Report to Olan Parr (NRC) from L. J. Sobon, dated 2/24/77.

QUESTION M020.35 Continued)

R2

1. Assumption 5 on page 4-16 of the DFFR sets the bubble air temperature equal to the (isentropic) drywell air temperature. This assumption is unrealistic from a physical standpoint, and whether or not it is conservative is not obvious a priori. It is our position that this assumption should either be replaced by an application of the first law of thermodynamics to the bubble or show that the use of the drywell air temperature results in conservative pool swell calculations.

RESPONSE

S1

In the pool swell analytical model the air bubble temperature is defined as being equal to the isentropic drywell air temperatures. The pool swell has been verified by comparison with the 4T test data in NEDE-21544P "An Analytical Model of the Pool Swell Phenomenon" and by comparison with the EPRI 1/13 scale multivent test data. These comparisons with the test data show that setting the air bubble temperature equal to the isentropic drywell air temperature is appropriate.

QUESTION M020.35 (Continued)

2. The point at which breakthrough occurs is crucial in determining the loading conditions experienced by the containment structure. It is our position that the evidence presented to date does not provide a rational basis for estimating when this event occurs. We cannot conclude on the current breakthrough model without adequate test confirmation. Thus, we require confirmation of the breakthrough model with test data.

RESPONSE

S1

The maximum pool swell height for Mark II containments was specified in the DFFR (NEDO-21061) to be equal to or less than 1.5 times the initial vent submergence. The 4T Mark II tests pointed out the importance of the wetwell air space backpressure to the maximum swell height and verified the 1.5 value for the Mark II containment design. A discussion of the maximum pool swell heights measured in the 4T tests is presented in NEDE-21544-P (The Mark II Pool Swell Model) and in the response to Question 020.28.

R2

QUESTION M020.35 (Continued)

3. In general, confidence in the pool swell model can only develop when comparison of theory and experiment shows favorable results. It is our position that, at this time, such demonstration has not been made. We require confirmation of the pool swell model with test data.

RESPONSE

S1

Confirmation of the pool swell model by comparison with test data has been completed. See the response to Question 020.36.

QUESTION M020.35 (Continued)

4. Equation (4.12) of the revised version of DFFR differs from its counterpart in the earlier version, Equation (4.4.10). The latter is correct if P_D is interpreted as the instantaneous total pressure in the drywell. The version presented in Equation (4.12) is correct if P_D is the static pressure evaluated at inlet conditions. Clarification is requested.

RESPONSE

S1

Equation 4.12 of revision 2 of the DFFR and its counterpart in revision 1, equation 4.4.10, are identical and P_D is incorrectly referred to as the drywell pressure. The subscript D actually refers to the vent inlet conditions in equations 4.6 through 4.12 of revision 2. However, in equation 4.13, the pressure ratio P_B/P_D is the pressure ratio from the drywell stagnation conditions to the vent exit. There is included in the definition of P_B/P_D in equation 4.13 an assumed isentropic contraction of the vent flow from the drywell stagnation conditions to the vent entrance. That is, $P_B/P_D = P_B/P_I * P_I/P_D$, where subscript I refers to vent inlet conditions. P_B/P_I is the pressure ratio across the vent, and P_I/P_D is the pressure ratio for the isentropic contraction from the drywell stagnation conditions to the vent inlet.

The pool swell model topical report (NEDE-21544) has a slightly different derivation of the vent flow equations and contains a graphical representation of equation 4.13 (which is equation 4.12 of NEDE-21544) in Figure 4-1. The sketch in the figure illustrates how the air bubble-drywell pressure ratio is defined, showing the isentropic contraction from Section 0 to 1 and adiabatic frictional flow from Section 1 to 2. R2

QUESTION M020.35 (Continued)

5. Equation (4.10) does not consistently account for compressibility effects between the drywell total conditions and the inlet static conditions. These effects should either be accounted for or show that these effects result in conservative pool swell calculations.

RESPONSE

The vent flow in the pool swell model is analytically described in two parts; an isentropic contraction from the drywell stagnation conditions to the vent inlet followed by constant area, adiabatic, frictional flow from the vent inlet to the vent exit. Equation 4.6 through 4.12 in the DFFR are based on the ratio between the vent inlet pressure and the vent exit static pressure (which is equal to the air bubble stagnation pressure). With P_D in the above equations defined as the vent inlet conditions, it can be seen that equation (4.10) does account for compressibility effects between the drywell stagnation conditions and the vent inlet static conditions. Thus, while it was not clearly described in the DFFR, compressibility effects from the drywell stagnation conditions to the vent inlet static conditions have been accounted for by an isentropic contraction in the vent flow equations of the pool swell model. S1

QUESTION M020.35 (Continued)

6. The sensitivity of the pool swell model predictions to the choice of initial condition (e.g., initial pool velocity and bubble pressure) and vent friction factor has not been examined. It is our position that a parametric numerical study be undertaken to examine the sensitivity of pool swell calculations of these parameters.

RESPONSE

A topical report has been issued exclusively on the pool swell model (NEDE-21544). This report includes a comprehensive model description and extensive comparisons with the 4T test data. In order to perform the data comparisons presented in the report, the correct boundary conditions for the model had to be defined. S1

During this time, the sensitivity of the model to variations in the boundary conditions was investigated. The parameters which were evaluated are: 1. The initial velocity of the pool mass, 2. the thickness of the pool to be accelerated (which is equal to the vent submergence at the time of vent clearing), 3. the air bubble temperature, 4. the vent system loss coefficient, and 5. the polytropic compression coefficient for the wetwell airspace. Variation of the maximum pool swell velocity was used as a measure to evaluate the sensitivity of the model to these parameters. The sensitivity analyses are based on the nominal 4T conditions of a steam blowdown through a 2-1/2-in.-diameter venturi into a 70°F pool and with 11 ft of submergence for a 20-in.-diameter vent. R2 S1

These five parameters were studied because it is believed they represent the pool swell conditions about which the greatest uncertainty could be considered to exist. As will be shown below, the pool swell velocity predictions are not particularly sensitive to reasonable variations in any of these parameters. This provides confidence that none of the pool swell loading conditions being used for Mark II design assessment studies contains significant errors due to inexact phenomena assumptions or model input information.

1. Initial pool velocity

The pool swell starts at the time of vent clearing, hence, the pool has some initial velocity due to the water being expelled from the vents. If it is assumed that the vent velocity varies linearly with time, then the initial velocity of the pool can be calculated from the measured vent clearing time. For the 4T tests, a representative value for the pool surface velocity at the time of vent clearing was determined to be between 1.5 and 2.5 ft/sec.

A value of 2.5 ft/sec is generally used in the model. For this sensitivity study, the initial velocity was varied from 0 to 5 ft/sec. As can be seen in Figure 1, this variation in the initial velocity has an insignificant effect on the maximum pool surface velocity.

2. Vent Submergence

The pool swell model assumes that the thickness of the pool mass which is accelerated upwards is equal to the vent submergence at the time of

R2 S1

vent clearing. For a nominal 11-ft submergence with a 20-inch-diameter vent, this would be 11.63 feet. Figure 2 shows the affect on the maximum pool swell velocity if the thickness of the swell mass were reduced. As would be expected as less mass is accelerated, the maximum velocity increases.

3. Air bubble temperature

One of the options available in the pool swell model is to set the air bubble temperature equal to a constant. For the best estimate model/data comparisons presented in the pool swell model topical report, it was decided to assume a constant bubble temperature with the magnitude defined by a adiabatic compression of the air initially in the vent line (Subsection 6.4.2 of NEDE-21544). This generally resulted in a bubble temperature of about 250°F. Figure 3 shows the expected effect of changes in the air bubble temperature on the maximum swell velocity. The higher temperature resulting in a higher bubble pressure and consequently a higher maximum swell velocity. When the model is used for design purposes, the bubble temperature is set equal to the current drywell temperature, which results in the bubble temperature increasing as the drywell pressure increases.

4. Vent system loss coefficient

The calculation of the flowrate of air from the drywell to the suppression pool is based on the flow characteristics of the vent system. The vent system loss coefficient (i.e., fL/D), based on the vent exit velocity, for the 4T facility was determined to be 2.5 for the 20-in. vent and 3.5 for the 24-in. vent. For design calculations, however, the loss coefficient for the particular plant being analyzed would, of course, be used. The variation in the maximum swell velocity with changes in the loss coefficient is shown in Figure 4, where only a small dependence is evident.

5. Polytropic compression coefficient

During the pool swell transient, the wetwell air space undergoes a polytropic compression as a result of the upward motion of the pool surface. The polytropic coefficients used in the pool swell model for model/data comparisons were determined from the test data for the different test conditions of the 4T facility. The values ranged from approximately 1.2 to 1.3; if the compression was isentropic, the coefficient would, of course

R2

be 1.4. Figure 5 shows that the maximum swell velocity is not very sensitive to variations in the polytropic coefficient. S1

In summary, these sensitivity studies show that the maximum velocity predictions of the pool swell model are not particularly sensitive to the various input parameters. The model is analytically well behaved with variations in the boundary conditions causing reasonable and expected trends in the model predictions.

Figure 1. Effect of Variations in the Initial Pool Velocity on the Maximum Pool Swell Velocity

R2

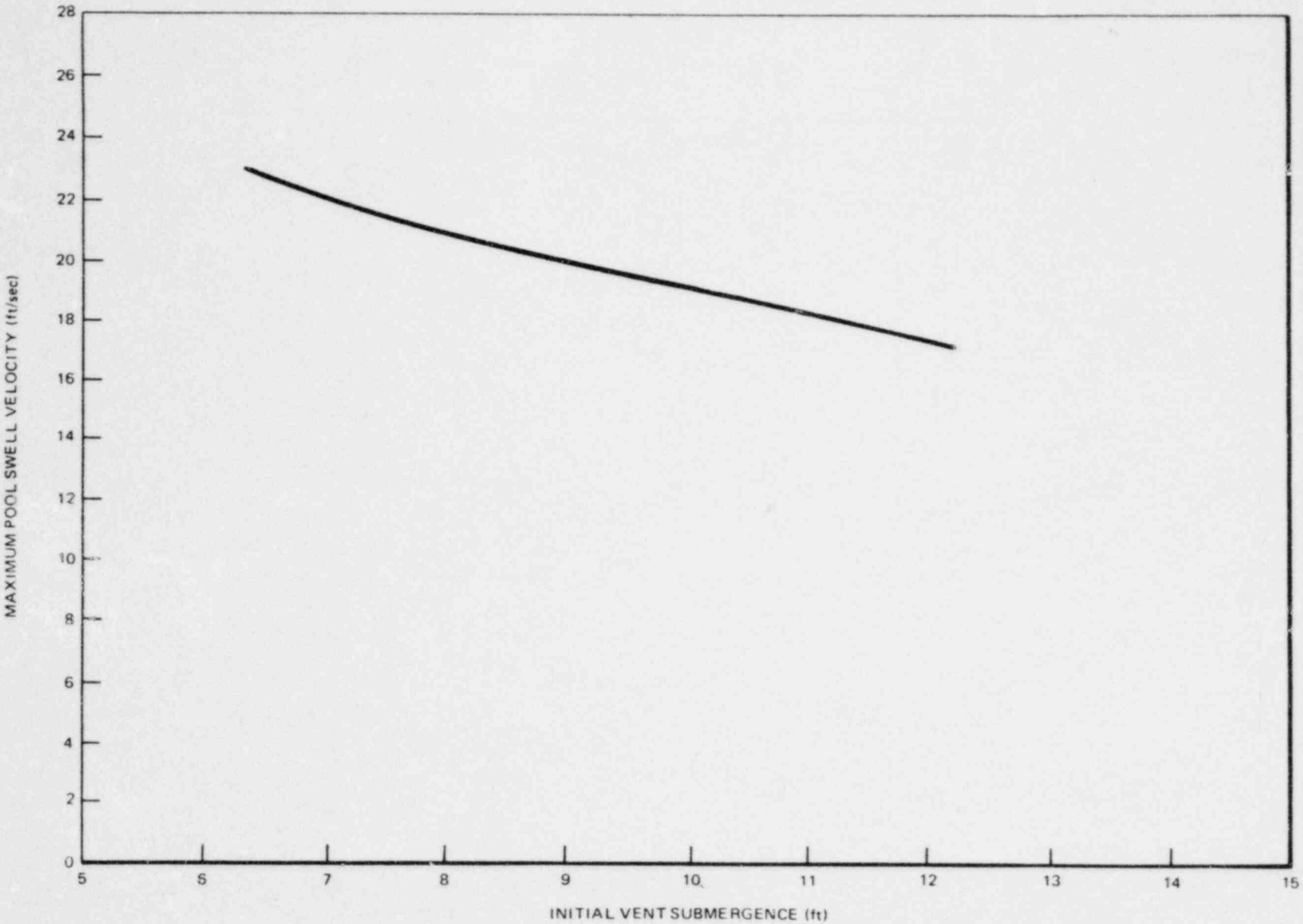

Figure 2. Effect of Variations in the Initial Vent Submergence on the Maximum Pool Swell Velocity

R2

R2

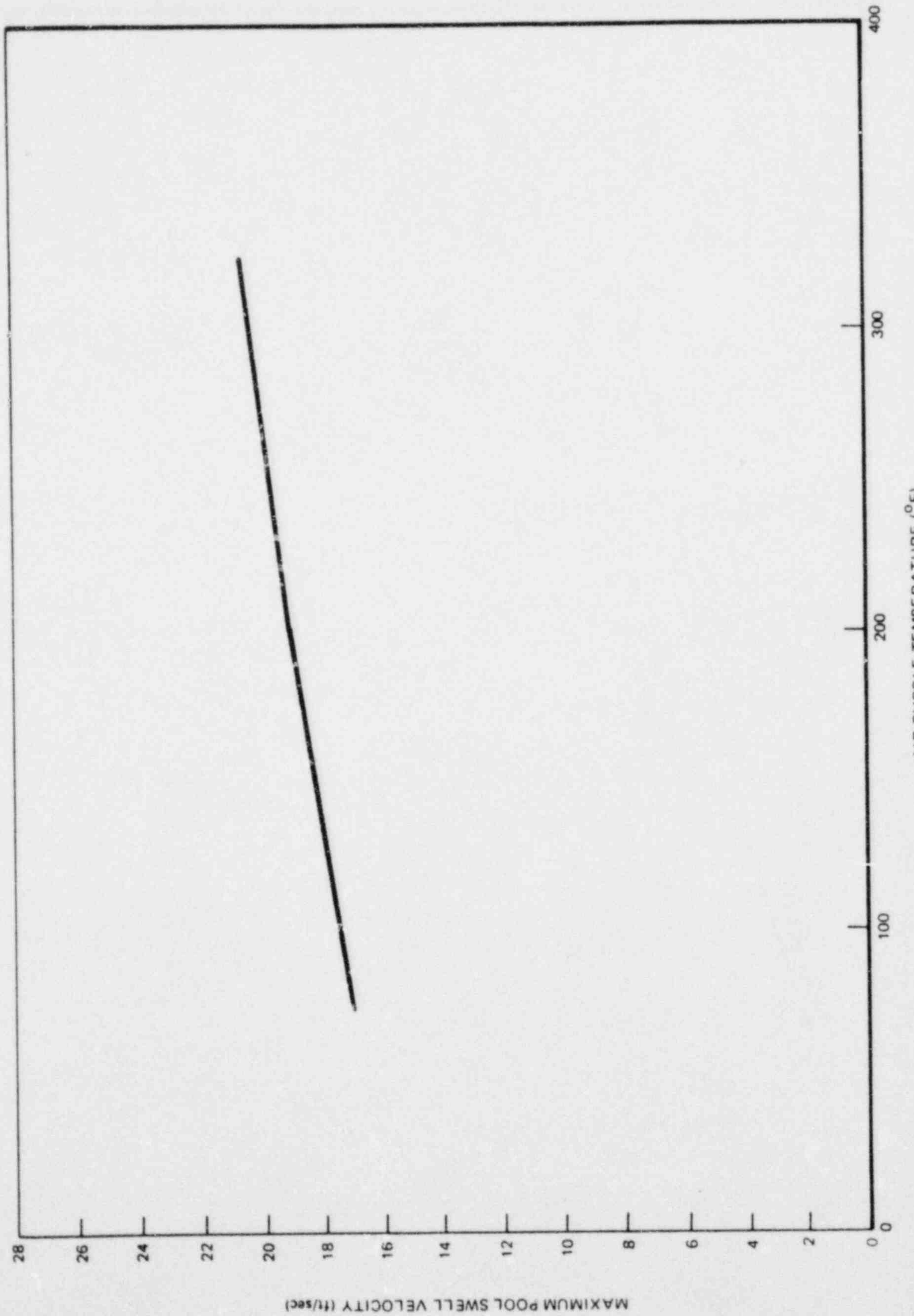

Figure 3. Effect of Variations in the Air Bubble Temperature on the Maximum Pool Swell Velocity

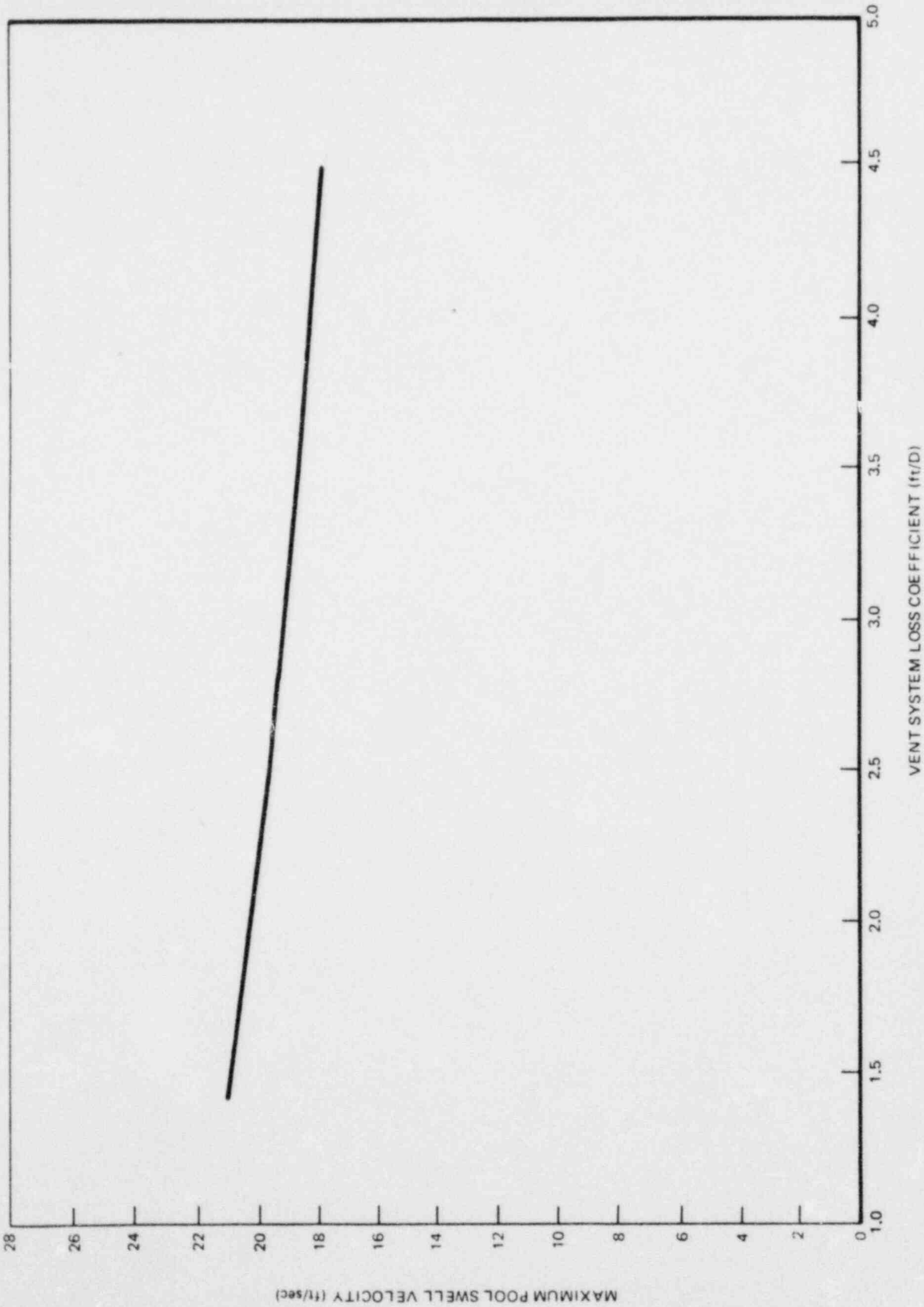

Figure 4. Effect of Variations in the vent System Loss Coefficient on the Maximum Pool Swell Velocity

R2

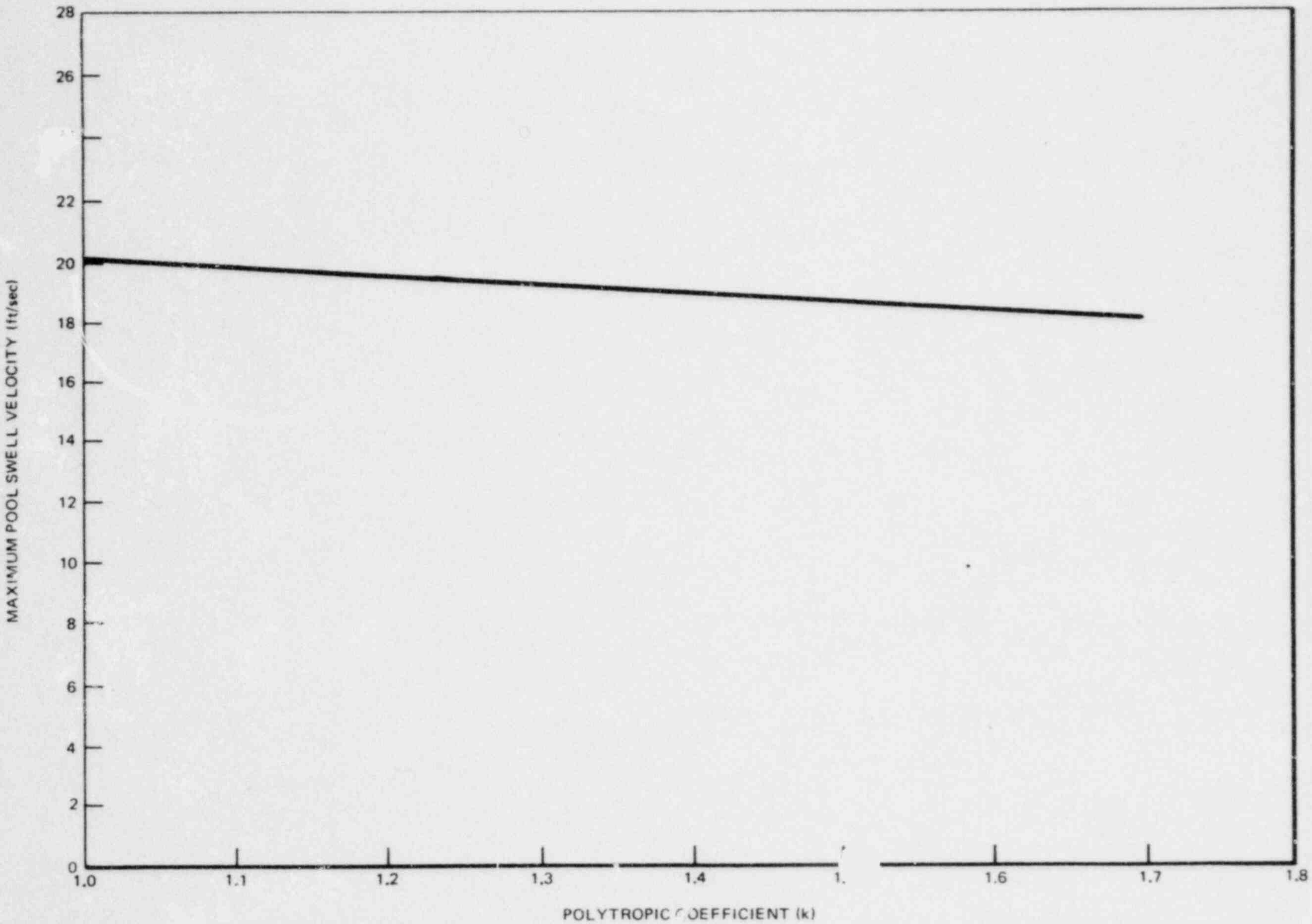

Figure 5. Effect of Variations in the Polytropic Coefficient on the Maximum Pool Swell Velocity

R2

R2

QUESTION M020.36

The Mark II containment supporting program as described in NEDO-21297 identifies in Section II.2.A.1 development of a pool swell velocity breakthrough model. Provide a detailed description of this model and an evaluation of this model using the 4T test data. The model should be verified over a range of conditions to reflect the variations in design between Mark II plants.

RESPONSE

An analytical pool swell model has been developed and a detailed description was originally provided in the Mark II Containment Dynamic Forcing Functions Information Report (DFFR: NEDO-21061). The model, derivation of equations and description of the model assumptions have been documented in the report "Mark II Pressure Suppression Containment Systems: An Analytical Model of the Pool Swell Phenomena;" NEDE-21544P, which supersedes and is more detailed than the DFFR model description. This document also includes a comprehensive comparison of the model with the 4T test data and shows that the model provides a correct interpretation of the pool swell phenomena.

QUESTION M020.37

The DFFR in Section 4.3 states that the downcomer lateral load specification during low steam flow is 8800 lbs. The basis for this specification is the foreign licensee data reported in NEDO-21078. It is our position that these data are not directly applicable for Mark II plants. Accordingly, we require a clear demonstration that this design load represents an upper bound when all the loads are derived from the 4T test program.

RESPONSE

The lateral loads on the downcomer were continuously monitored during all phases of the 4T test program; the results are presented in NEDE-13442P-01 and 13468P. The 4T pressure suppression tests were conducted over a range of conditions representative of those that would occur in a Mark II containment system during a loss-of-coolant accident. An evaluation of all chugs observed during Phases I, II and III of the 4T tests showed that for a range of bracing configurations, the maximum observed static equivalent lateral load was approximately 3000 lb_f. This is significantly less than the DFFR design specification of 8800 lb_f static load on the vent.

Additional information related to the determination that the 8800 lb_f static equivalent load is bounding is presented in the report, "Mark II Lead Plant Topical Report - Pool Boundary and Main Vent Chugging Loads Justification " (NEDE-23617-P), which was submitted in July 1977. R2

QUESTION M020.38

Provide a description of the analytical efforts described in the 4T test applications memorandum Section 6.0 to investigate the statistical nature of multiple vent chugging.

RESPONSE R3

A description of the analytical effort investigating the statistical nature of multiple vent chugging is provided in Section 2.1.3 synchronization of NEDO/NEDC-21669-P, "The Multivent Hydrodynamic Model for Calculating Pool Boundary Loads due to Chugging - Mark II Containments," dated February 1978.

QUESTION M020.39

The 4T test report NEDE-13442P-01 does not provide sufficient information on pool boundary loads. In the final 4T test report, provide a quantitative evaluation of the effect of the following parameters on pool boundary loads:

1. pool temperature;
2. vent air admixture;
3. vent mass flux;
4. wetwell air space backpressure;
5. downcomer submergence; and
7. vent proximity to pool boundary.

The pool boundary design load should consider load sensitivity to the above parameters and differences between the 4T test facility and specific Mark II plant designs.

RESPONSE

The information requested in Questions M020.38 and M020.39 is discussed in depth in the report, "Mark II Lead Plant Topical Report - Pool Boundary and Main Vent Chugging and Lateral Loads" (NEDE-23617-P), which was issued in July 1977.

QUESTION M020.40 R2

A preliminary uniform and asymmetric chugging wall load distribution for the Mark II systems was provided in Section 6.0 of the 4T test applications memorandom. This load was developed from 4T test data. The 4T test represents a unit cell with a single downcomer. We require that the boundary loads be based on steam tests which include both single and multiple downcomer.

RESPONSE

Load magnitudes are based on full scale single cell 4T data. Multivent information being obtained from a subscale multivent is presently in progress. This program is described in detail in NEDO-23697A, Rev. 1 and its appendices. The tests will establish the required multivent data base for confirmation of the methodology for specifying boundary loads.

QUESTION M020.41

In NEDO-21297, the Mark II containment supporting program report, Section III.2.A.4.a, it is stated that the applicability of PSTF data to Mark II geometry and structures is provided in NEDE-13426P and NEDC-20989-2P. This information does not appear to have been provided in these reports. We require that you provide this information. In addition, provide the basis for the 50% design margin applied to impact loads as described in Section 4.4.6.1 of the DFFR.

RESPONSE

The basis for the 50% design margin for the impact loads described in Section 4.4.6.1 of DFFR is as follows. S2

The impact test data are given in Figures 4-34, 4-35 and 4-36 of DFFR. As can be seen in these figures there is scatter in the data and the solid lines drawn in these figures do not bound all of the data points. Therefore, a design margin was needed to bound the scatter in the data.

In Figure 4-34, the largest difference between the test data and the solid line is 3.7 psi; i.e., the test data is higher than the value given by the solid line. Thus a margin of 13.8% applied to the solid line will bound all of the scatter in the data shown in Figure 4-34.

S2

In Figure 4-35, the largest difference between the test data and the solid line is 7.0 psi. To bound this scatter a margin of 21% should be applied to the correlation given in Figure 4-35.

Finally, in Figure 4-36, the largest difference between the test data and the solid line is 7.5 psi. This results in a margin of 16% to be applied to the solid line to bound all of the scatter in the data.

Thus a design margin of 21% applied to the solid line correlations in Figures 4-34, 4-35 and 4-36 would just bound all of the scatter in the test data. However, this margin of 21% was doubled and then rounded off to 50%.

R2

QUESTION M020.42

For water impact loading of structures, one should consider whether it is necessary to specify the actual loading history or simply the total impulse. If the loading history is needed, the DFFR (NEDO-21061 Rev. 2) proposes the use of impact pressure correlations (Figures 4-34, 4-35 and 4-36) and pulse duration (Figure 4-37) corresponding to PSTF conditions (NEDE-13426P). Both parameters depend on the length of target and the shape of the approaching pool. Provide the basis that allows one to assume that these conditions are the same in an actual Mark II pool and the PSTF.

For flat targets in the range of 13 to 20 inches, the total impulse due to water impact, as calculated from the pressure correlations (Figure 4-36) and pulse duration (Figure 4-37) in the DFFR, is not conservative compared to PSTF data. For example, for 20-inch I beams, the Mark II impulse is only 60% of the PSTF data (as determined from Figure 6-8, NEDE-13426P). This nonconservatism eliminates the 50% design margin used by GE to specify the design loads.

RESPONSE

S1

The impact pressures presented in Figures 4-34, 4-35 and 4-36 of DFFR are actual test data. These pressures do indeed depend on the width of the target and the shape of the approaching pool. For the majority of the PSTF tests the approaching pool surface was relatively flat (NEDE-13426P, Section 6.4). In the Mark II suppression pool, the pool surface is also relatively flat during the pool swell phenomenon. Further, the widths of the targets in a Mark II suppression pool are also of similar magnitude as the PSTF tests. Therefore, it was prudent to use the actual loading history in DFFR, rather than the total impulse. After all, the hydrodynamic mass correlation (NEDE-13426P, Figure 6-8) is derived from the same set of test data which appears in Figures 4-34, 4-35 and 4-36 of DFFR. S1

The correlation presented in Figure 6-8 of NEDE-13426P is a fit of the same data used in DFFR. However, hydrodynamic mass is a derived concept and it is not a correlation of the raw data itself. The impact data presented in DFFR is almost the same as the raw data, and hence it is directly applicable to impact load calculations.

The example cited in this question is reexamined here to clarify the use of DFFR results. For the flat target of width 20 inches and impact velocity of 29 ft/sec, the peak pressure is 60 $lb_f/in.^2$ (DFFR, Figure 4-36). The area under the curve in Figure 4-37 of DFFR is 4.13 msec. Therefore, the impulse based on DFFR is 35.7 lb_f-sec/ft^2. For the same target, by extrapolation of results in Figure 6-8 of NEDE-13426P, the impulse is 45 lb_f-sec/ft^2. Thus, without adding any design margin the DFFR result is about 80% of the correlation given in NEDE-13426P. However, if the recommended 50% margin is added to 35.7 lb_f-sec/ft^2, the design value of the impulse becomes about 54 lb_f-sec/ft^2, which is 20% larger than the correlation given in NEDE-13426P.

R2

QUESTION M020.43

Justify the use of the PSTF impact data for cylinders and I-beams associated with the downcomer lateral support system. Show that this data which was obtained from tests on simple geometries applies to the structures comprising a typical downcomer support system.

RESPONSE

R3

This information is provided in the general response to Question M020.72 of the NRC questions dated June 30, 1978. A more specific response will be included in the individual plant Design Assessment Reports (DAR's).

QUESTION M020.44

Table 5-1 and Figures 5-1 through 5-16 in the DFFR provide a listing of the loads and the load combinations to be included in the assessment of specific Mark II plants. This table and these figures do not include loads resulting from pool swell waves following the pool swell process or seismic slosh. We require that an evaluation of these loads be provided for the Mark II containment design. R2

RESPONSE

This information will be provided in the individual plant Design Assessment Reports (DAR's).

QUESTION M020.45

The 4T test report (NEDE-13442P-01) exhibits certain deficiencies which should be corrected in the final version; for example:

1. More extensive presentation of measured results should be included in the final report. As an example, the data given in Figure 5-15 should be provided for all test runs.

RESPONSE

The additional data requested can be found in NEDE-21544-P, "Mark II Pressure Suppression Containment System: An Analytical Model of the Pool Swell Phenomenon," dated December 1976. R3

QUESTION M020.45 (Continued)

2. More detailed description in terms on configuration, principle of operation, calibration, orientation and location of instrumentation should be included in the final report.

RESPONSE

The information requested is contained in NEDE-13468-P, "Mark II Pressure Suppression Test Program, Phase II and III Tests," dated December 1976. R3

QUESTION M020.46 R2

Provide raw data generated during a selected 4T test run. Signal traces of the conductivity probes are of particular interest, but wetwell and drywell pressure histories and pitot-static probe traces should also be provided. Both short-term and long-term histories should be included. The specific run selected for this purpose is Run M101-29.

RESPONSE

The requested data plots from this run are attached.* The data are plotted on two different time scales: 0 to 10 seconds for short term and 0 to 169 seconds for long term. Pool level probes were not plotted over the long term because the pool swell transient is complete within the 0 to 10 second short-term plot. Vent level probes are plotted on the long term in order to track the chugging and vent recovering transients. An upward step in the plotted probe output indicates a transition from liquid to vapor present at the sensor. A downward step similarly indicates a transition from vapor to liquid.

The pitot-static probe data is given in reduced form as vent flow rate. Two curves for vent flow are given, one assuming the flow to be all air and the second all steam. Note: the pitot-static probe data from this run is not valid. The indicated vent flow is oscillatory, and the pitot tube differential pressure shows an offset, probably due to an air bubble in the tubing line from the probe to the pressure transducer.

The drywell and wetwell pressures (and the difference between them) are given in both long and short-term plots. The curve labeled "Z51 0.0 Wall Press" is the pressure at the 51-ft elevation on the North side of the 4T tank (i.e., the top of the wetwell air space).

*These figures are contained in the proprietary supplement.

QUESTION M020.47 R2

Figure 3.3 Type 2 shows the ramsheads oriented radially toward the containment wall. The bubble discharged from the ramshead directed toward the boundary may behave differently from the bubble discharged from the ramshead oriented tangentially or in parallel with the boundary. Since the experiments for the SRV tests such as Quad Cities and the Monticello tests have been performed for the ramshead oriented in parallel with the boundary, discuss and justify the applicability of the test data for ramshead directed toward the boundary.

RESPONSE

The method of images, to which Figure 3.3 applies, accounts explicitly for the positions of the bubbles relative to the pool boundaries for the determination of the spatial distribution of pressure. An improved correlation of Quad Cities test data (see response to question M020.48) uses boundary conditions specifically for a torus, while the boundary conditions for Mark II suppression pool are represented correctly for cylindrical geometry. Thus, the differences in boundary geometry and the ramshead orientation are accounted for analytically.

The question of boundary and orientation effects on bubble penetrations and dynamics are treated in the responses to question M020.50 and .51.

QUESTION M020.48

Provide a brief description and the name of the computer code used for the S/R valve load calculations. Include an analysis based upon the following input data:

1. parameters given in Table 2-4 of the Topical report NEDE-21062-P;

2. bubble formation efficiency = 0.1;

3. location of the pressure transducers No. 1 and No. 5 as shown on Figure 2-7 of NEDE-21062-P; and

4. compare the calculated results to those in NEDE-21062-P and justify any differences.

RESPONSE R2 S2

SRV load calculations use a system of computer codes. Each code represents one aspect of the SRV discharge phenomena. The code used for calculation of vent clearing results presented in the DFFR is RVFORCE, provided by GE. Bubble dynamics were calculated with the S&L code SRV/DYNAM, which is an implementation of the equations given in Table 3-2 of the DFFR. The geometric relationship between bubble pressure and pressure loads on pool boundaries was calculated using the S&L code SRV/IMAGES, which is based on the method of images as described in Section 3.2.2.2. of the DFFR. An additional code, SRV/WALL-SS by S&L, combines the time dependent results of bubble dynamics calculations and the geometry dependent results from the method-of-images to generate load-time histories on pool boundary walls (and submerged structures) such as presented in Figures 3-4 through 3-9 in the DFFR.

The codes described above have been used with the parameters reported in NEDE-21962-P, Table 2-4. The vent clearing results given in the same report (top of p. 2-9) were used as input to the bubble dynamics code (SRV/DYNAM) with the following results compared to those in Table 2-5 of the report for $\eta = 0.1$.

	SRV/DYNAM	NEDE-21062-P	
$(\Delta P_b R_b)_{max}$ =	47.7	55.1	psid-ft
$(\Delta P_b R_b)_{min}$ =	-18.4	-18.5	psid-ft
f =	11.3	12.5	Hz

A measured frequency of 8 Hz was reported.

The method of images for th toroidal geometry of the Quad Cities suppression pool was used to calculate the relationship ($p^* = \Delta P_w/\Delta P_b R_b$) between bubble pressure (ΔP_b) and the pressure (ΔP_w) at the locations of five transducers as reported in NEDE-21062-P (the location of transducer No. 5 was corrected to "z" = 10.15' in Table 2-1 of the report). The bubbles were assumed to be located vertically at the submergence depth of the ramshead and 4 feet horizontally from each ramshead exit. Combining this relationship with the above

R2 S2

bubble dynamic results from SRV/DYNAM gave the results tabulated below and compared with the test data in Table 2-3 of the report for actuation of valve "B".

Transducer Number	$P^* = \frac{\Delta P_w}{\Delta P_b R_b}$	$\Delta P_w = P^* (\Delta P_b R_b)$ max. (47.7)	min. (-18.4)	ΔP_w, Test Data max.	min.
P1	0.4320	20.6	-7.9	25.0	-15.5
P3	0.3957	18.9	-7.3	12.5	-10.5
P4	0.4621	22.0	-8.5	17.5	-12.5
P5	0.2865	13.7	-5.3	11.8	-5.0
P6	0.0769	3.7	-1.4	6.2	-5.0

Transducer number P1 was located very near the ramshead exit. Transducers P3 through P6 were located along a line on the bottom of the pool. Calculated pressure for P1 is not expected to agree with the test data because of the assumed bubble position for the calculation. The above results for P3 through P6 indicate that the calculated maximum pressure is generally high and the magnitude of the minimum pressure is generally low compared to test data. Furthermore, the rate at which the measured wall pressure amplitude decays in time is not adequately predicted by the model.

An attempt has been made to improve the correlation of calculations with measurements by introducing further improvements into the analytical model.

First, it is recognized that the frequency of bubble pulsation is theoretically determined by the mass and internal energy of the bubble and is independent of the amplitude of the pressure pulses. Therefore, the bubble formation efficiency (η) can be determined which will give the measured frequency. A parametric study of bubble dynamics for the Quad Cities test case indicates that for the measured frequency of 8 Hz, the corresponding bubble formation efficiency is 0.8. This result is plausible with regard to discharge temperature indicated by the calculated air discharge pressure and density from vent clearing (see below). If the efficiency is taken to be the ratio of bubble to discharge temperature, then an efficiency of 0.8 with a discharge temperature of 700°R would indicate a bubble temperature of 560°R or 100°F, which is typical of pool temperature during SRV discharge.

R2 S2

The amplitude of pressure pulsations has been found analytically to be very sensitive to the duration of bubble formation. This effect has been introduced into the bubble dynamics analytical model as the fraction of air (fa) in the discharge flow. Smaller air fraction gives proportionately longer duration. For given values of total air mass and efficiency, a value of air fraction can be determined which results in bubble pressure consistent with measured pressures.

In the model, the calculated wall pressure decay is the result of two considerations: (1) attenuation due to the bubble rising and moving away from the wall, and (2) decreasing hydrostatic pressure as the bubble rises and the concomitant decrease in bubble pressure amplitude. These effects are not sufficient by comparison with test data. Therefore, a damping term has been introduced into the equation of motion for calculating bubble dynamics. A damping factor has been determined based on the theoretical natural frequency of the bubble and the phenomena of acoustic, thermal, and viscous damping. Acoustic damping is effective for large bubbles, while thermal and viscous damping are significant only for very small bubbles with frequencies in the kilohertz range. It is noted that the theoretical and measured frequencies are in good agreement.

The relative magnitudes of calculated maximum and minimum bubble pressures have been brought into agreement with the test data by an improved definition of the environmental pressure (P_∞) in the equation of motion for a bubble. In an infinite pool, the environmental pressure is undisturbed pressure infinitely far from the bubble. In a pool with hydrostatic pressure varying with depth, the environmental pressure was previously arbitrarily taken to be the quiescent or equilibrium pressure at the depth of the bubble. By the improved definition, environmental pressure in a bounded pool varies from the equilibrium pressure at zero bubble pressure amplitude, approaching the pool surface pressure as bubble pressure amplitude increases. This is a conceptual approximation of the "undisturbed" pressure away from the bubble. Note that bubble pressure amplitude (ΔP_b) is defined as the difference between absolute bubble pressure and equilibrium pressure (P_b - P_{eq}).

For the Quad Cities test case, with an efficiency of 0.8, an air fraction of 0.21 was found to give a maximum bubble pressure which best fits the test data for transducers located on the bottom of the pool. It was also found that the spatial distribution of these measured pressures is best represented in the analytical model using the method of images if the distance penetrated by the bubble is 5 feet from the ramshead exit, rather than the 4 feet previously assumed. This was found by varying the penetration and using the method of least squares to correlate the image results with the test data and also determine the appropriate product of maximum bubble pressure and radius. The results for 5-ft penetration are as follows. R2 S2

Transducer Number	$P^* = \frac{\Delta P_w}{\Delta P_b R_b}$	$\Delta P_w = P^* (\Delta P_b R_b)$ max. (38.7)	min. (-23.0)	ΔP_w, Test Data max.	min.
P1	0.3417	13.2	-7.9	25.0	-15.5
P3	0.3388	13.1	-7.8	12.5	-10.5
P4	0.4420	17.1	-10.2	17.5	-12.5
P5	0.3320	12.8	-7.6	11.5	-5.0
P6	0.0869	3.4	-2.0	6.2	-5.0

The standard errors of the differences between calculations and test data are 1.0 psi for maximum pressure and 1.5 psi for minimum pressure.

The air fraction which produces the best fit maximum bubble pressure-radius product was determined by varying the air fraction for constant efficiency in the bubble dynamics model. For an efficiency of 0.8 determined previously by measured frequency, an air fraction of 0.21 corresponds to the maximum pressure-radius product of 38.7 psid-ft. The corresponding minimum pressure-radius product is -23.0 psid-ft, for which the calculated pressure magnitudes are generally somewhat lower than the test data, as shown above.

It is noted that Monticello test data does not indicate the same high ratio of minimum to maximum pressure as is reported for the Quad Cities test.

The bubble dynamics calculations for the above results were made using discharge conditions from a vent clearing model (S&L program BUBBLEPIPE) which inlcudes the effects of friction and exit pressure loss for the water leg and in which the boundary of the finite difference grid moves with the gas/water interface. The discharge condition from BUBBLEPIPE differ significantly from those from RVFORCE reported in NEDE-21062-P for rhe same input specifications as follows: S2

	BUBBLEPIPE	NEDE-21062-P	
Water velocity	208	252	ft/sec
Discharge pressure	95	129	psia
Discharge density	0.379	0.21	lbm/ft^3

System specifications were then corrected according to Table 4.3-8 of NEDC-21581-P as follows:

	Corrected	NEDE-21062-P	
Pipe (air) length	74	111	ft
Friction factor (equivalent)	0.023	0.015	
Steam flow rate	152	144	lbm/sec
Valve opening time	0.05	0.188	sec

The discharge conditions calculated for the corrected input and used for the bubble dynamics calculations described previously were as follows:

Water velocity	254.5	ft/sec
Discharge pressure	149.5	psia
Discharge density	0.576	lbm/ft^3

R2

QUESTION M020.49

Provide a transient analysis of the vent clearing, pool dynamic, and bubble pressure phenomena as a result of SRV multiple actuation. Include the following:

1. Descriptions of the analytical model, including all assumptions and equations.

2. Graphs showing the vent-clearing time and pool dynamic bubble pressure as a function of sequential actuation. The number of sequential actuations should be large enough to clearly indicate that the bubble pressure due to multiple actuation has reached the maximum value.

3. Graphs showing the peak wall pressure, positive as well as negative as a function of the sequential actuation of the relief valves. R2

4. Verification of the analytical results by comparison with experimental data. If the experiments were conducted in a different configuration and/or in a different geometry of suppression pool, justification of applicability of the experimental data to the SRV system for each plant should be provided.

RESPONSE R3

In cases where the SRV discharge line air clearing loads are evaluated with ramshead method for plants equipped with quenchers, the ramshead methods are justified by the margin by which they overpredict the magnitude of the loads that will actually occur. During T-Quencher tests at Monticello (1), the peak measured torus shell loads were approximately one fourth positive and one half negative of the peak torus shell loads calculated for comparable conditions with the Mark II ramshead methods (2) for single valve actuations. The tests were performed at 1000 psia reactor dome pressure for single and multiple actuations, cold pipe and hot pipe, normal water level, elevated water level, and depressed water level. This demonstrates the conservatism of the ramshead methods when applied to plants equipped with quenchers and justifies their use in these cases. For plants analyzing the SRV loads from the Mark II T-Quencher or X-Quencher, this information will be provided in the individual plant Design Assessment Reports (DAR). Calculated multiple valve actuations will be higher.

REFERENCES:

(1) "Mark I Containment Program Final Report Monticello T-Quencher Test" NEDE-21864-P, July 1978; pp. 3-6, 3-7, 8-14 and 8-21.

(2) "SRV Ramshead Bubble Dynamics Analytical Model Comparisons with Test Data," Gen 0394, June 30, 1977; pp.8, 11.

QUESTION M020.50

Provide justification for the assumptions used in the SRV bubble dynamic model. Include the following: R2

1. A detailed discussion of the development of bubble formation efficiency. It should be noted that the bubble formation efficiency could be a function of air and water temperatures, air pressure, pipe size, pool geometry, submergence, and the degree of air and steam mixing. Therefore, this empirical correlation developed from some particular test data may not be universally applicable.

2. Justification for using a drag coefficient of 2.5 for computing bubble depth.

3. Justification for assuming that the dynamics of a bubble are not affected by the presence of other bubbles.

4. Justification for assuming that the pool boundaries do not affect the motion of the bubble and the discharge rate of air during the process of bubble formation.

RESPONSE

Reference response to M020.49 R3

QUESTION M020.51

The analytical model assumes that the bubble will be formed at a point 4 feet from the exit of the ramshead. It is noted that this assumed bubble initial position was derived from Quad City test data. Therefore, it should be treated as an empirical correlation rather than a constant. Discuss and justify the applicability of this empirical correlation for the Mark II containment.

RESPONSE

The analytical SRV discharge model assumes an initial bubble position. The bubble position or penetration can be an important parameter in determining containment boundary loads and loads on submerged structures. Bubble penetration is primarily dependent on the discharge line clearing transient and S2 the proximity of pool boundaries to the discharge device exit plane. For the case of a ramshead orientated tangentially in either a Mark I or Mark II suppression pool, the proximity of the pool boundaries to the exit will have an insignificant effect. Hence, the bubble penetration determined for a given set of vent clearing results would apply to a tangential orientation in either containment type. For a canted or radial orientation the penetration may be restricted by a boundary and would therefore not exceed that determined for the tangential orientation. Hence, for a radial or canted orientation the bubble would conservatively be assumed to be closer to the wall than would be expected. Thus, the bubble penetrations determined in the Quad Cities or Monticello tests are appropriate for use in Mark II containments when geometric effects are considered. The bubble penetration sensitivity to the vent clearing transient must still be addressed. If the Quad Cities or Monticello bubble penetrations were applied to Mark II plants which had similar vent clearing transients, the bubble positions would be adequate and appropriate. S2

R2

QUESTION M020.52

Provide the following additional information on using the influence coefficient method for ramshead loads computation:

1. Discuss and justify analytically and experimentally the selection of the influence parameters.

RESPONSE

The independent parameters used to represent the vent clearing phenomenon are derived and discussed in NEDO-10859, Appendix B. These parameters represent all of the variables in the analytical model as formulated in the dimensionless differential equations for vent line pressure and density. The independent parameters for bubble dynamics are simply the independent variables normalized by their respective base values. The independent variables are represented in the differential equations and initial conditions of Table 3-2.

Influence coefficiencies were determined by varying each parameter independently for constant (base case) values of the other parameters. This parameterization yielded an essentially linear relationship between each dependent and independent parameter. The influence coefficients were calculated by the method of least squares. It was found necessary to use a nonlinear transformation of two of the bubble dynamics variables to obtain a reasonably linear fit. The two variables transformed were line length with respect to maximum bubble pressure and discharge pressure with respect to minimum bubble pressure, as indicated in Table 3-5. R2

The ranges of the individual variables used to calculate the influence coefficients are tabulated below.

RANGES OF INDEPENDENT VARIABLES FOR INFLUENCE COEFFICIENTS IN SECTION 3.2

	Minimum	Base	Maximum	
D	0.666	0.834	0.994	ft
L	50	150	250	ft
L_s	10	20	30	ft
Vent Clearing:				
f_e	0.01	0.05	0.09	
P_s	1050	1150	1250	psia
$\dot{m}s$	150	250	350	lbm/sec
Bubble dynamics:				
V_{dl}	300	450	600	ft/sec
P_d	50	150	250	psia
ρ_d	0.10	0.30	0.50	lbm/ft^3

QUESTION M020.52 (Continued)

2. Discuss and justify analytically and experimentally the use of the linear superposition principle for computing the ramshead.

RESPONSE S2

The principle of linear superposition was first applied to the analysis of SRV discharge phenomena in NEDO-10859, where the charge $\Delta\Phi$ in a function Φ of parameters Π_i is represented as

$$\Delta\phi = \Sigma\ (\partial\phi/\partial\Pi_i) \times \Delta\Pi_i$$

R2

S2

This approximation is the first term of a Taylor series and neglects the higher order partial derivative and the crossed partial derivative of the function with respect to the parameters. That is, two conditions are necessary. First, the function must be linearly dependent on each parameter, and second, each partial derivative (influence coefficient) with respect to a given parameter must not vary as the other parameters are varied. The first condition of linearity has been reasonably satisfied as indicated by the least squares linear fit for the influence coefficient for each selected parameter and function. The second condition, that each influence coefficient is constant over the range of all other parameters, remains to be evaluated. This evaluation will require a multidimensional parameterization. It is anticipated that a number of model improvements will be made as a result of test data analysis, and the present base cases and influence coefficients will change accordingly. Therefore, the evaluation of the conditions for linear superposition is being deferred, pending the completion of model changes.

QUESTION M020.52 (Continued)

3. The nomenclature for those variables shown on Table 3-4.

RESPONSE

Nomenclature for Section 3.2

A inside area of vent line cross section

A_w azimuth at a point on a pool boundary

C_i speed of sound at initial, quiescent conditions

D inside diameter of vent line

F_b force on bubble

f_e equivalent friction factor

k ratio of specific heats

L total length of vent line, including submerged portion

L_s length of initial water column in vent line

m initial mass of air in line

m_b mass of air in bubble

$\dot{m}s$ flow rate of steam into vent line

m_v virtual mass of accelerating bubble

P_b absolute pressure in bubble

R2 S2

P_d absolute pressure in vent line at discharge end (inlet to discharge device) immediately after water clears

P_{dL} absolute pressure in vent line at air/vent interface

P_i initial, quiescent absolute pressure in vent line

P_s absolute pressure of steam upstream of SRV

P_v absolute pressure in vent line downstream of SRV

P_w pressure at point on a pool boundary (wall)

P_∞ absolute, quiescent pressure at given depth in pool

R_b radius of bubble

R_d radial position of bubble center

R_w radius at point on a pool boundary

R_1 inner radius of pool

R_2 outer radius of pool

rv vector distance

t time

t_c vent clearing time interval, from when SRV starts opening to when water clears line

t_p period of bubble pulsation

t_v SRV opening time interval

V_{dL} velocity of water at discharge end of vent line

Y dependent variable

Z_b depth of bubble center from free surface

Z_d depth of discharge centerline from free surface

Z_p depth of pool (free surface to basemat)

Z_w depth at a point on a pool boundary (wall)

ΔP pressure difference from quiescent pool pressure

η bubble formation efficiency

Π independent parameter

ρ_d density in vent line at discharge end immediately after water clears

ρ_i density of initial, quiescent air in vent line

ρ_L density of water

ρ_s density of steam upstream of SRV

ϕ dependent parameter

R2 S2

Nomenclature Corrections

Table 3-2, page 3-12:

Change	P	to	P_b
	R	to	R_b
	F	to	F_b
	Z	to	Z_b
	L_s	to	Z_d

Table 3-4, page 3-20:

Change	M_∞	to	$\dot{m}_s$
	K	to	k
	P_o	to	P_s
	P_{max}	to	P_v
	P_{coL}	to	P_{dL}
	f	to	f_e

QUESTION MD20.53 R2

Provide a detailed description of the computational method of bubble frequencies due to multiple valve actuation. Include the following information: S2

1. All equations and assumptions used.

RESPONSE

The following computations are made to evaluate pressure loads on pool walls due to the sequential discharge of multiple SRV's.

1. For each individual line, determine the vent clearing discharge characteristics using influence coefficients or the corresponding analytical model for vent clearing:

   water, velocity, V_{dL}

   sonic discharge pressure, P_d

   sonic discharge density, ρ_d

   clearing time, t_c

2. Determine the bubble dynamic variables as function of time for each bubble pair using the vent clearing results and influence coefficients or the corresponding analytical model for bubble dynamics:

   dynamic bubble pressure, ΔP_b

   bubble radius, R_b

   bubble depth, Z_b

   All bubble histories must be on one time scale determined by the pressure setpoints and clearing times for the different valves.

3. Determine the radial and azimuthal position (R_d, A_d) of each bubble involved in the postulated SRV discharge sequence. Assume that each bubble rises vertically from an initial position determined by the location and orientation of the discharge device (ramshead) and the distance penetrated by the bubble into the pool.

4. Determine the coordinates of load points (R_w, A_w, Z_w) on the pool wall (pedestal, basemat, or containment) for which pressure histories are to be computed. An array of load points should be chosen sufficient to characterize the distribution of pressure for analysis of structural response.

5. For each load point, determine the geometry dependent relationship $(P^*_{wb} = \Delta P_w/\Delta P_b R_b)$ between pressure at the load point and pressure at each bubble position as a function of bubbles radius (R_b) and depth (Z_b).

Use the tabulated results from the method of images model for specific pool dimensions (R_1, R_2, Z_p). R2

6. Generate the pressure time history at each load point by combining the time dependent bubble variables and geometry dependent pressure relationship. The products of the geometric function, bubble pressure and bubble radius are summed for all vent lines at each point in time (t): S2

$$\Delta P_{wt} = \Sigma \, P\overset{*}{w}_b \, \Delta P_{bt} R_{bt}$$

QUESTION M020.53 (Continued)

2. The transient of the primary system from which the sequence of SRV's initiation is assumed. R3

RESPONSE

This information will be provided in the individual plant Design Assessment Report (DAR).

QUESTION M020.54

DFFR Section 3.3 presents the quencher loads based on the statistical method described in GESSAR-238 NI Appendix 3B, Amendment 43. As a result of our review, however, we find this statistical method is not applicable for the Mark II containment because some of the key parameters, such as the air volume, exceeds the test envelope. Extensive extrapolation of the test data is thus required. We believe that the current data base is not sufficient to justify the applicability of the statistical method of predicting quencher loads for the Mark II containment. Therefore, we require additional test data, such as could be provided by the Caorso test.

RESPONSE M020.54

The Caorso quencher tests described in NEDO-21297 are scheduled to be conducted in June and September of 1977. This test program will involve a matrix of 38 tests that will provide a significant body of full scale confirmatory data on the performance of the quencher device in a Mark II containment system. The test matrix proposed in NEDO-21297 (LRP description) has been modified somewhat and is described in NEDM-20988. A test report describing the test results and providing comparisons of the observed loads with those predicted by the methods presented in Section 3.3 of the Dynamic Forcing Functions Report will be published in the third quarter of 1978. Prior to the publication of this test report, two preliminary data reports will be published in August and November 1977 to appraise the progress of this program. The Caorso tests are expected to confirm that the loading methodology presented in the DFFR is based on a conservative application of existing quencher data and that no significant modifications of these methods will be required. R2

QUESTION M020.55

The computational method described in DFFR Section 3.4 for calculating SRV loads on submerged structures is not acceptable. It is our position that the Mark II containment applications should commit to one of the following two approaches:

1. Design the submerged structures for the full SRV pressure loads acting on one side of the structures; the pressure attenuation law described in Section 3.4.1 of NEDO-21061 the ramshead and Section A10.3.1 of NEDO-11314-08 for the quencher can be applied for calculating the pressure loads.
2. Follow the resolution of GESSAR-238 NI on this issue. The applicant for GESSAR-238 NI has proposed a method presented in the GE report, "Unsteady Drag on Submerged Structures," which is attached to the letter dated March 24, 1976 from G. L. Gyorey to R. L. Tedesco. This report is actively under review.

RESPONSE

The generic method presented in the report "Unsteady Drag on Submerged Structures" is used for submerged structure loads calculation. This method provides a realistic description of pressure drag for submerged structures and the DFFR Section 3.4 will be updated to reflect the new methods.

QUESTION M020.56

The response to question 020.26 wherein we requested a differentiation between primary and secondary loads is unacceptable. The original design assessment reports for individual plants with Mark II containments specified substantial changes in Mark II containment structures to accommodate pool dynamic loads.

R2

We recognize that a specified pool dynamic load may not be a primary load on all Mark II plants because of differences in the design of Mark II plants. However, if it is a primary load on any Mark II plant, it should be treated as such in the generic Mark II pool dynamic load program. Based on our preliminary review of the original design assessment reports, the DFFR and the reports submitted to us dealing with the definition of the Mark II pool dynamic loads, we have concluded that the following loads should be viewed as primary loads for the Mark II containment design.

1. SRV loads for both the ramshead and quencher designs.
2. Steam chugging loads including loads on the downcomers and the pool boundary.
3. Pool swell loads including impact and drag loads.

Our generic review of these Mark II pool dynamic loads will consider them to be primary loads unless it can be shown that a given load is secondary in terms of structural capability of load magnitude.

RESPONSE

Of the three types of dynamic loads mentioned in this question, the load due to SRV is the controlling load for certain Mark II containments. In such cases design modifications were recommended in order to accommodate these loads. The stresses in the containment structure due to the SRV load are within the allowable limits and hence the containment can withstand this load. Similarly the steam chugging load is not necessarily the controlling load for in-plant.

The pool swell load has been accommodated either by designing the structures to withstand these loads or by raising the structures and equipment above the range of pool swell.

QUESTION M020.57

A number of pressure suppression tests will be conducted within the next few years. Results of many of these tests should be applicable to the Mark II containment design. For each of the tests listed below discuss the participation or monitoring activities of the Mark II owners group.

1. Japan Atomic Energy Research Institute multivent small scale and full scale 1/18 sector tests.

2. Mark I 1/4 scale air, 2 vent full scale steam, and multivent steam tests. R2
3. German tests
4. Livermore air and steam tests
5. EPRI 1 vent 1/13 scale Mark II tests and Mark I-scale tests
6. LOFT suppression tests
7. Mark III multivent steam tests.

RESPONSE

The Mark II Owners Group is currently monitoring all available test activities under Task C.9, World Test Monitoring Program.

The scope of this program includes surveying known pressure suppression containment test programs and facilities to gather information which will be reviewed for applicability to Mark II, catalogued, and filed. The available information will be reviewed to a level of basic understanding (not detailed technical knowledge) of the test objectives, the test performance and measurement methods, and the significant test results. Specific analyses of the data will not be undertaken, but the test results will be referred to individuals or groups working in similar areas. Where results appear significant and warrant further analysis which is not within the scope of current activities, the need for such additional activity will be identified so the appropriate proposals can be prepared. R3

QUESTION MD20.58

Relating to the pool swell calculations, we require the following information for each Mark II plant: R2

1. Provide a description of and justify all deviations from the DFFR pool swell model. Identify the party responsible for conducting the pool swell calculations (i.e., GE or the A&E). Provide the program input and results of bench mark calculations to qualify the pool swell computer program.
2. Provide the pool swell model input including all initial and boundary conditions. Show that the model input represents conservative values with respect to obtaining maximum pool swell loads. In the case of calculated input, (drywell pressure response, vent clearing

time) the calculational methods should be described and justified. In addition, the party responsible for the calculation, (GE or the A&E) should be identified. R2

3. Pool swell calculations should be conducted for each Mark II plant. The following pool swell results should be provided in graphical form for each plant:
   a. Pool surface position versus time;
   b. Pool surface velocity versus time;
   c. Pool surface velocity versus position; and
   d. Pressure of the suppression pool air slug and the wetwell air versus time.

RESPONSE

The requested information in items 1, 2 and 3 of MD20.58 will be discussed in the individual plant Design Assessment Reports (DAR's)

QUESTION MD20.58 (Continued)

4. The calculated drywell pressure response and the enthalpy flux in the downcomer vent should be compared to the 4T 2-1/2 in. and 3 in venturi data.

RESPONSE

The following figures 1 through 9 show comparisons between the drywell pressure transients calculated for each Mark II containment project and the bounding pressure traces from the applicable Phase 1 4T tests (NEDE-13442-P) (24-in. downcomer vents, closed tank, preheated drywell) over the period of interest for pool swell (t < 2 sec). S2

These figures show that the test pressure transients are representative of the calculated pressure transients in all cases and in fact bound the calculated pressure transients in all but three cases. In these three cases, the calculated Mark II pressure transients reach pressures somewhat higher than the maximum 4T tests pressure. However, the pool swell response (velocity, height) for calculating loads in Mark II containments is not based directly upon the 4T tests, but rather upon an analytical model (NEDE-21544P) which has been verified by the 4T data. Calculations of pool swell for Mark II

R2 S2

containments using the analytical model utilize the appropriate calculated drywell pressure response (NEDM-10320) as an input.

The 4T tests, which were conducted over a substantial range of drywell pressure transient conditions representative of Mark II conditions, did not indicate any basic phenomenological changes in the pool swell response as a function of increasing drywell pressure. The pool swell analytical model (NEDE-21544P) is therefore considered to be applicable to all Mark II containments and reflects the influence of calculated drywell pressures on pool swell response.

Figure 10 shows the bounding maximum drywell pressure transient from the Phase II, III 4T tests (NEDE-13468P) (20 in vents). It is slightly higher than the maximum for the Phase I tests and is from a liquid blowdown. Pool swell response for the Phase II, III tests was basically the same as for the Phase I tests.

With regard to the request for comparison of the enthalpy flux calculated for Mark II containments and that present in the 4T tests, it is difficult to comply since the steam air mixture in the 4T vent flow was not measured. In pool swell calculations for Mark II projects, however, all air flow is conservatively assumed. Comparison of this model against the 4T test data has been addressed in Reference NEDE-21544P and the influence of vent flow and the amount of steam in the vent flow on pool swell has been addressed in this report and a previous NRC question response. (See response to NRC question 020.25.)

R2

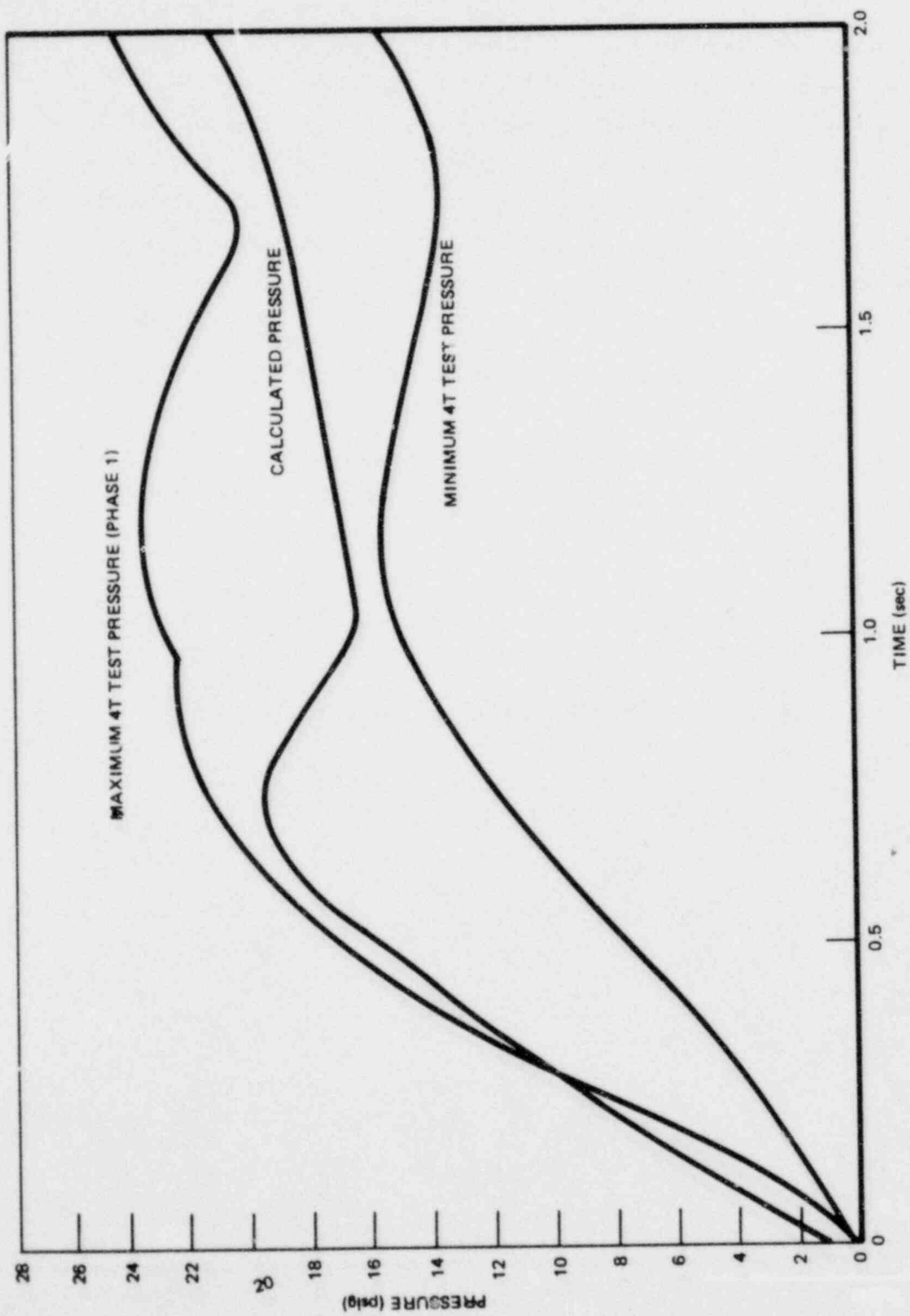

Figure 1. Drywell Pressure Short Term Response Recirculation Line Break - La Salle

R2

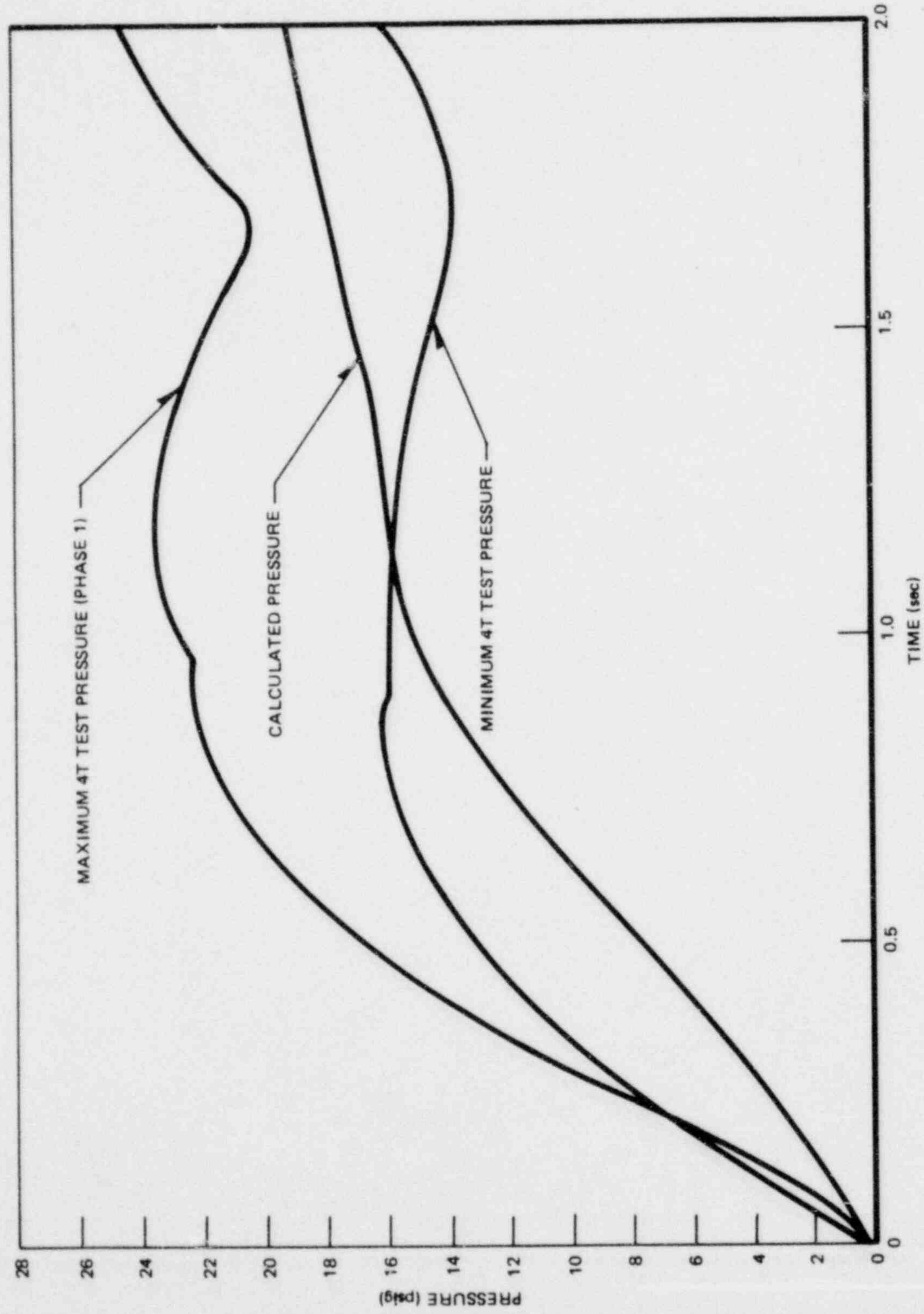

Figure 2. Drywell Pressure Short Term Response Recirculation Line Break - Zimmer

R2

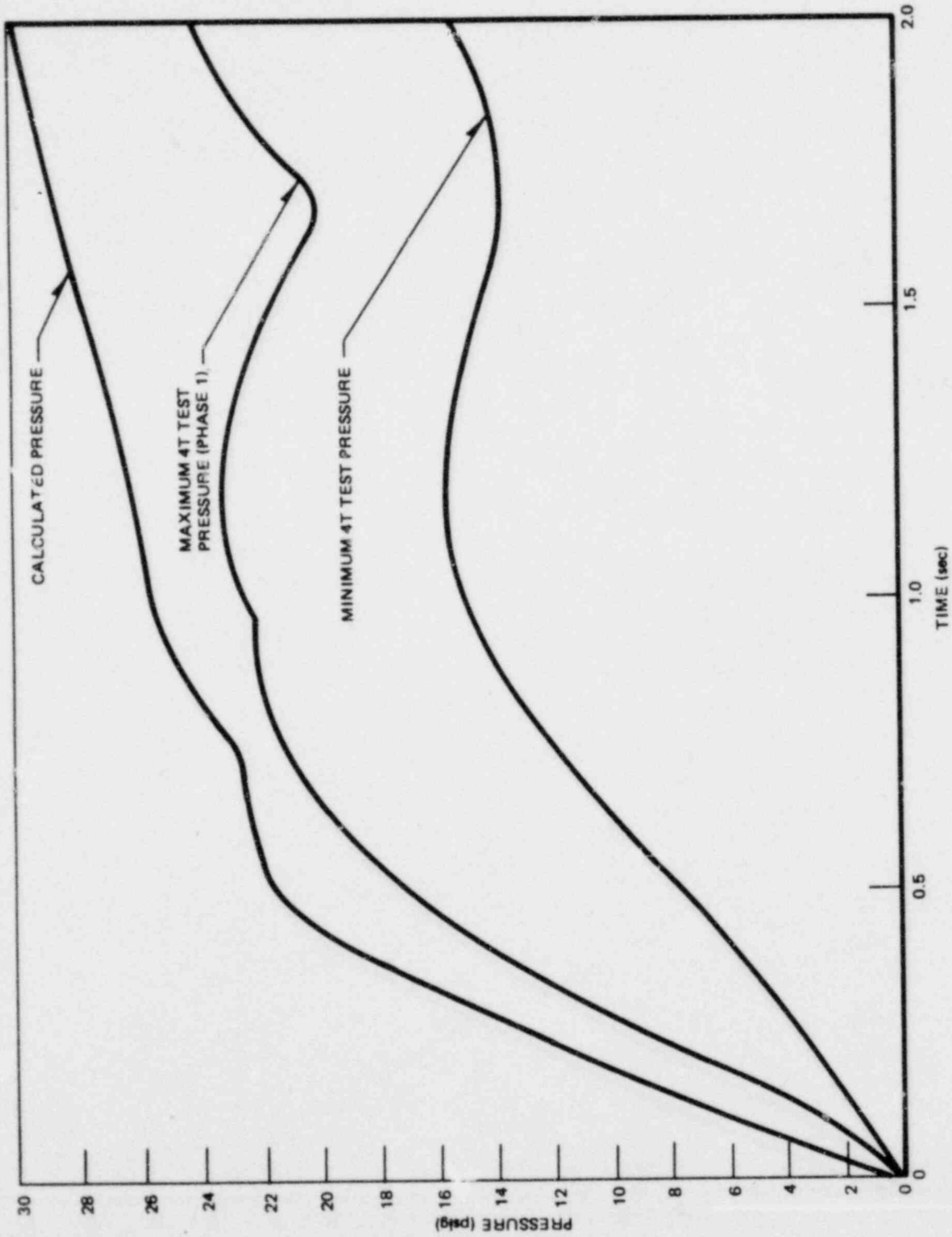

Figure 3. Drywell Pressure Short Term Response Recirculation Line Break - Shoreham

R2

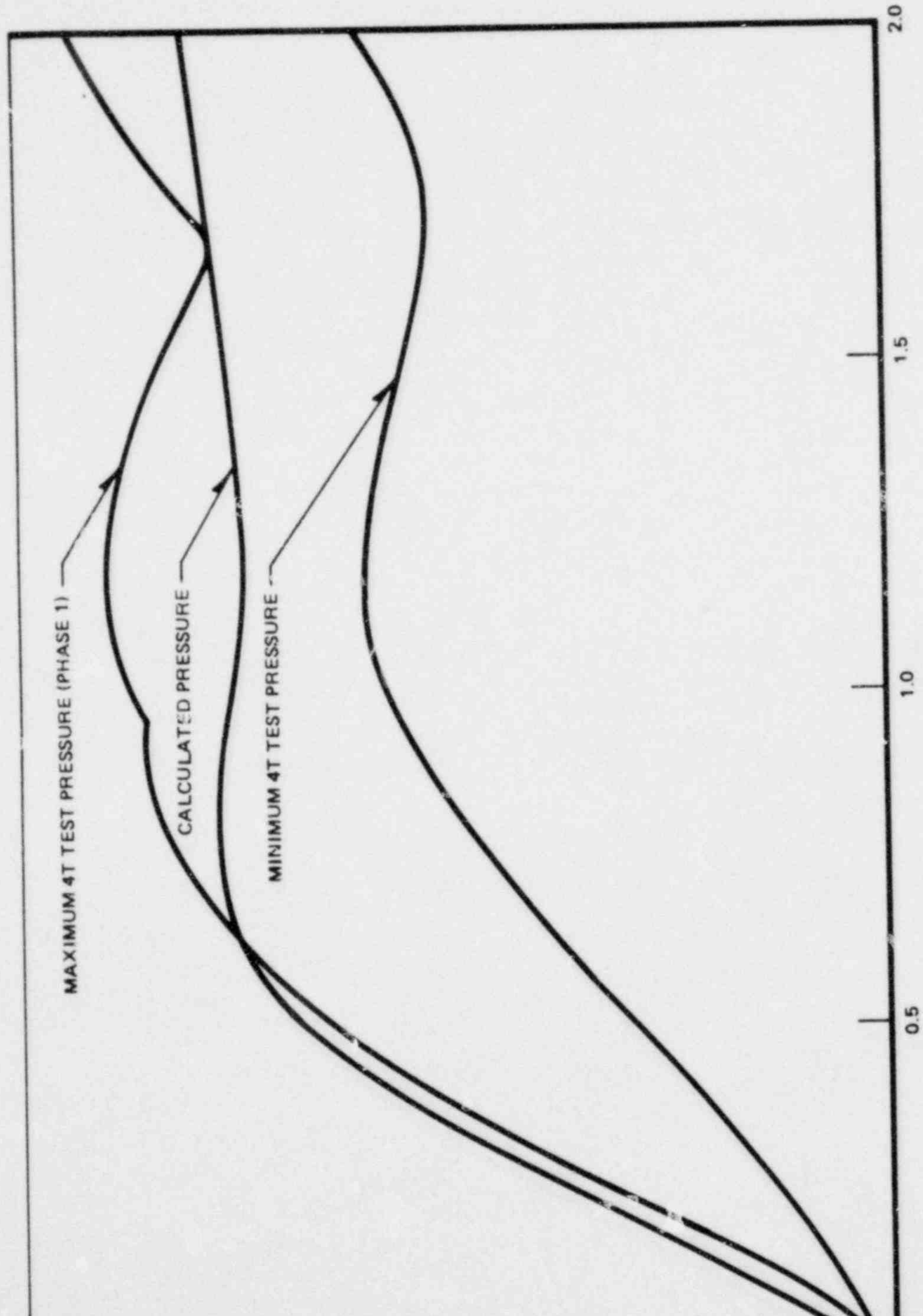

Figure 4. Drywell Pressure Short Term Response Recirculation Line Break - Hanford

R2

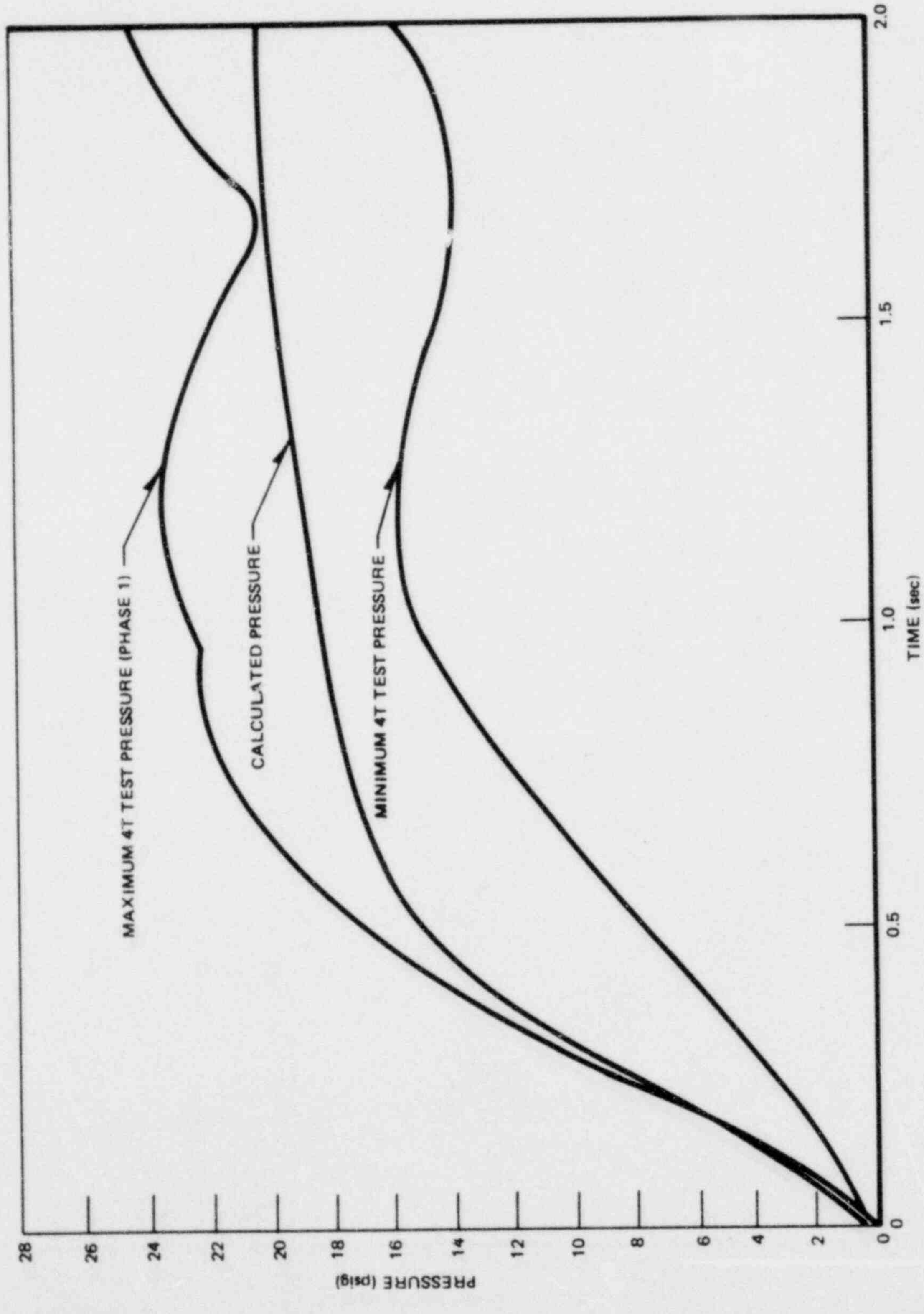

Figure 5. Drywell Pressure Short Term Response Recirculation Line Break - Laguna Verde

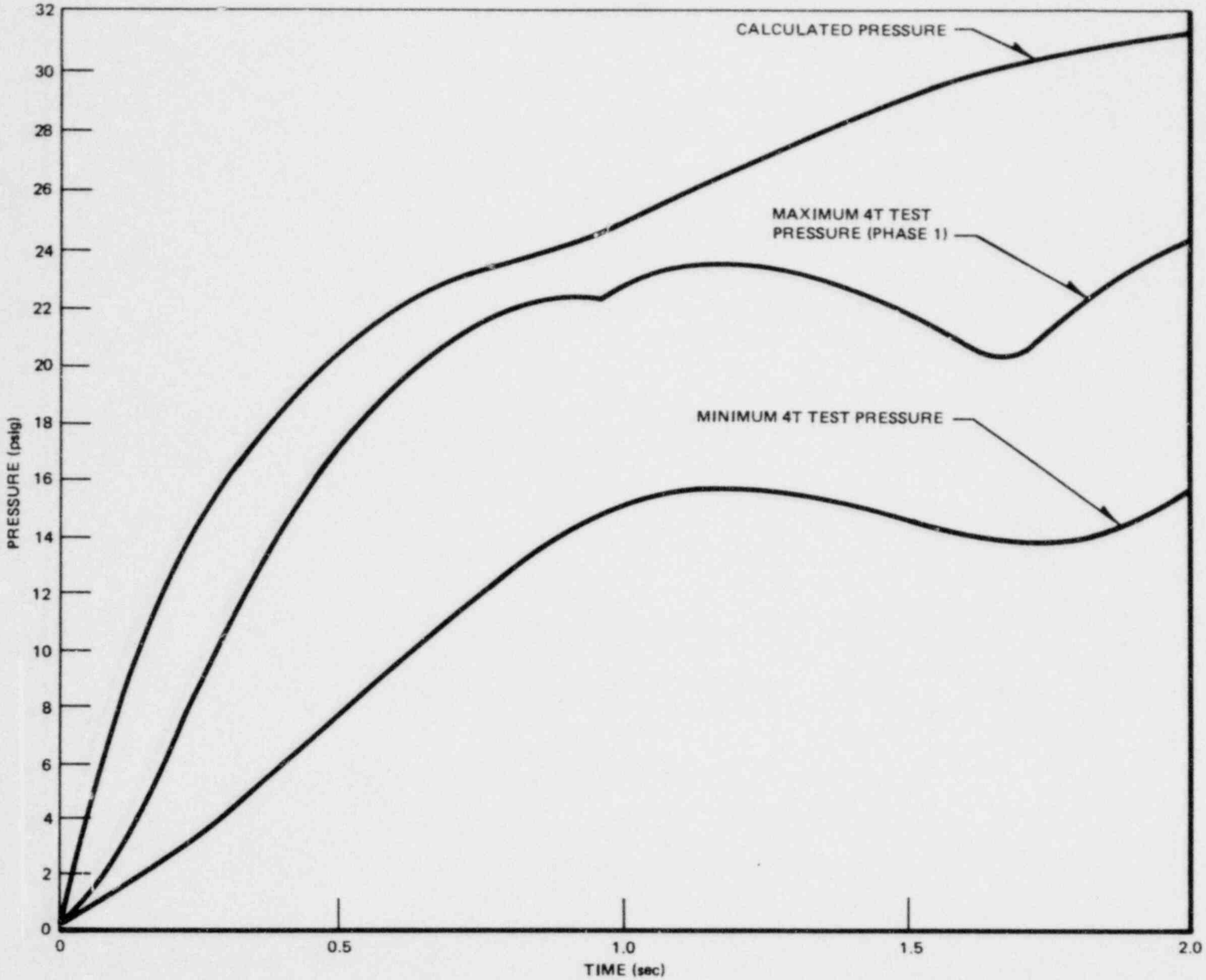

Figure 6. Drywell Pressure Short Term Response Recirculation Line Break - Susquehanna

R2

R2

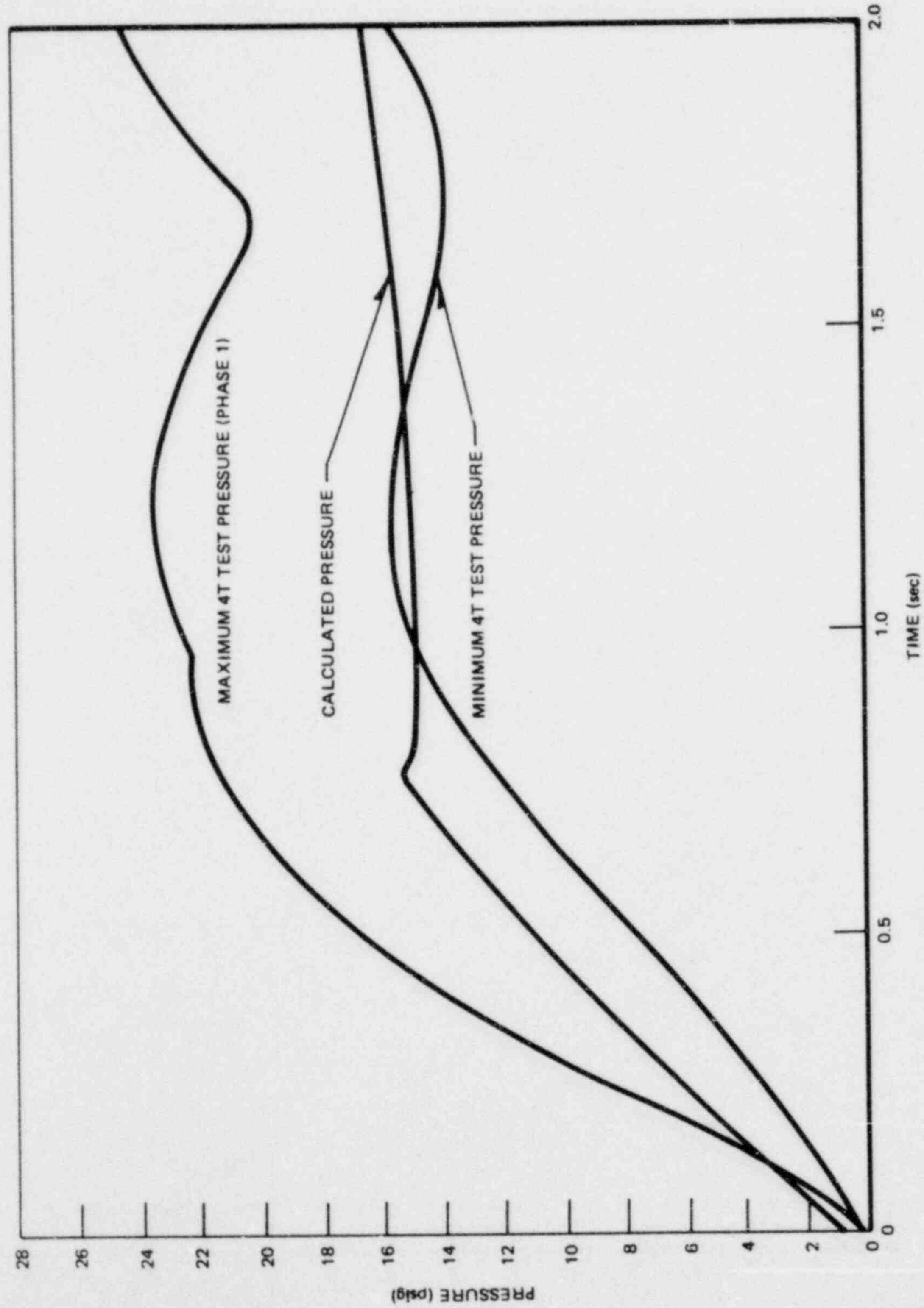

Figure 7. Drywell Pressure Short Term Response Recirculation Line Break - Nine Mile Point

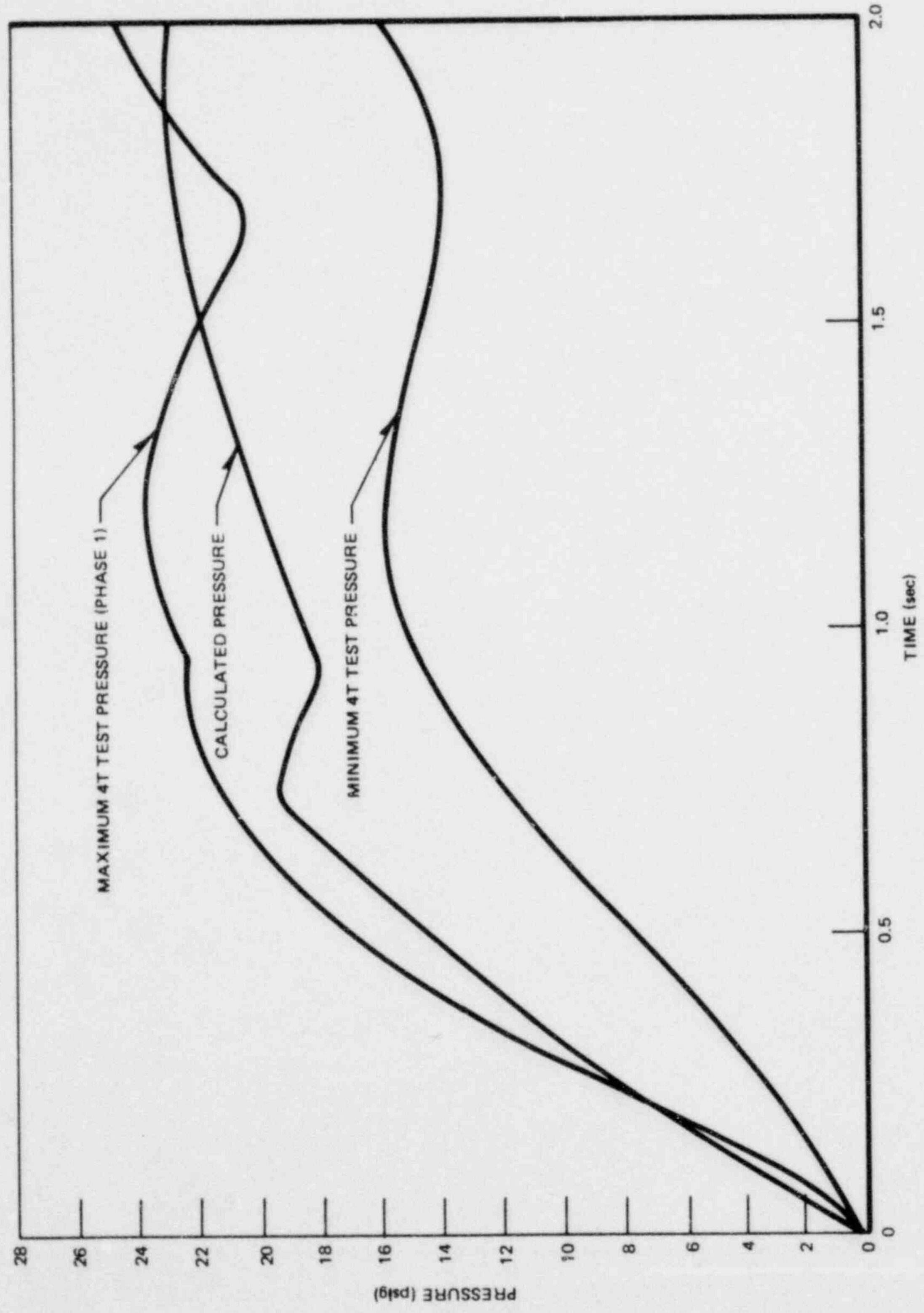

Figure 8. Drywell Pressure Short Term Response Recirculation Line Break - Bailly

R2

R2

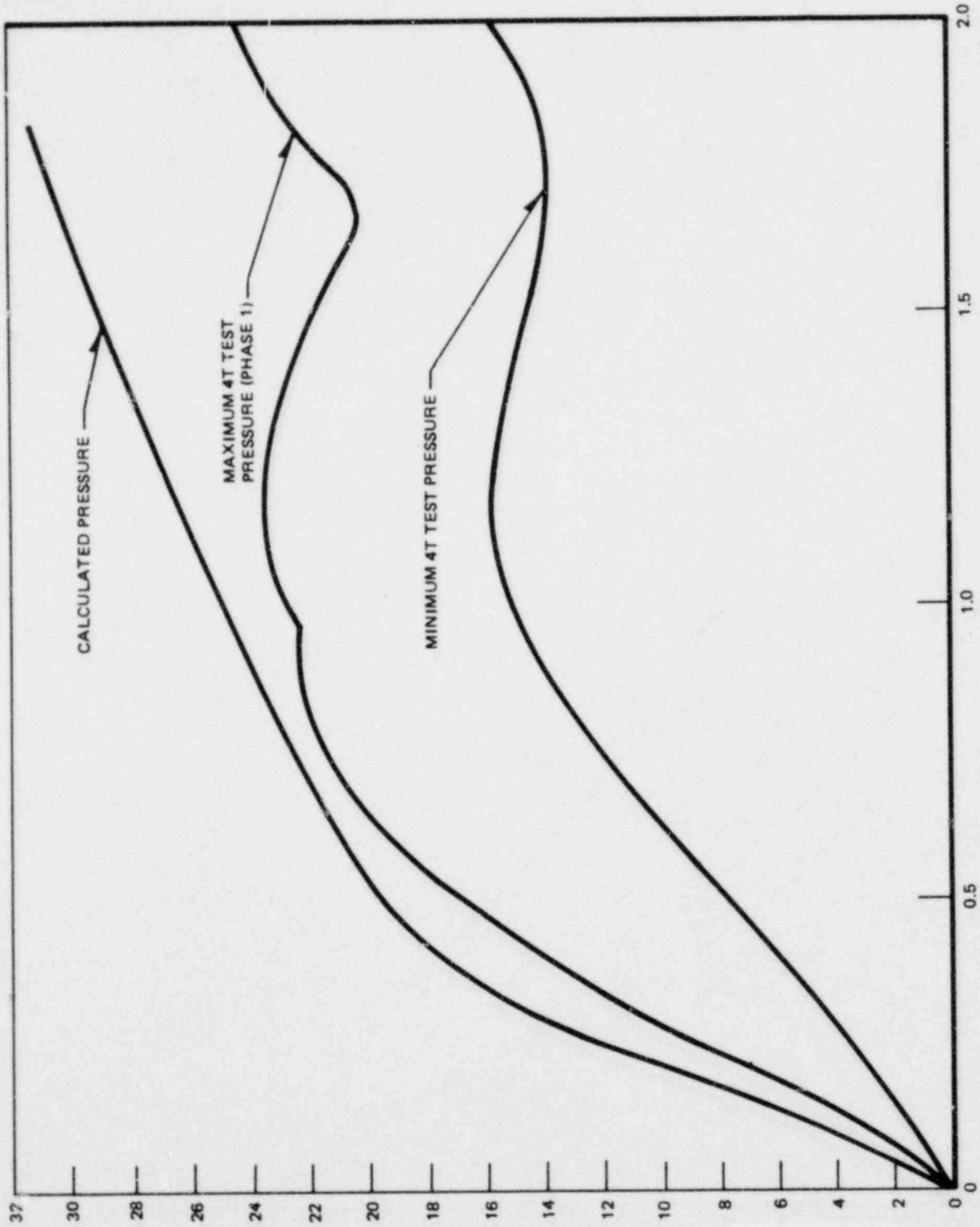

Figure 9. Drywell Pressure Short Term Response Recirculation Line Break - Limerick

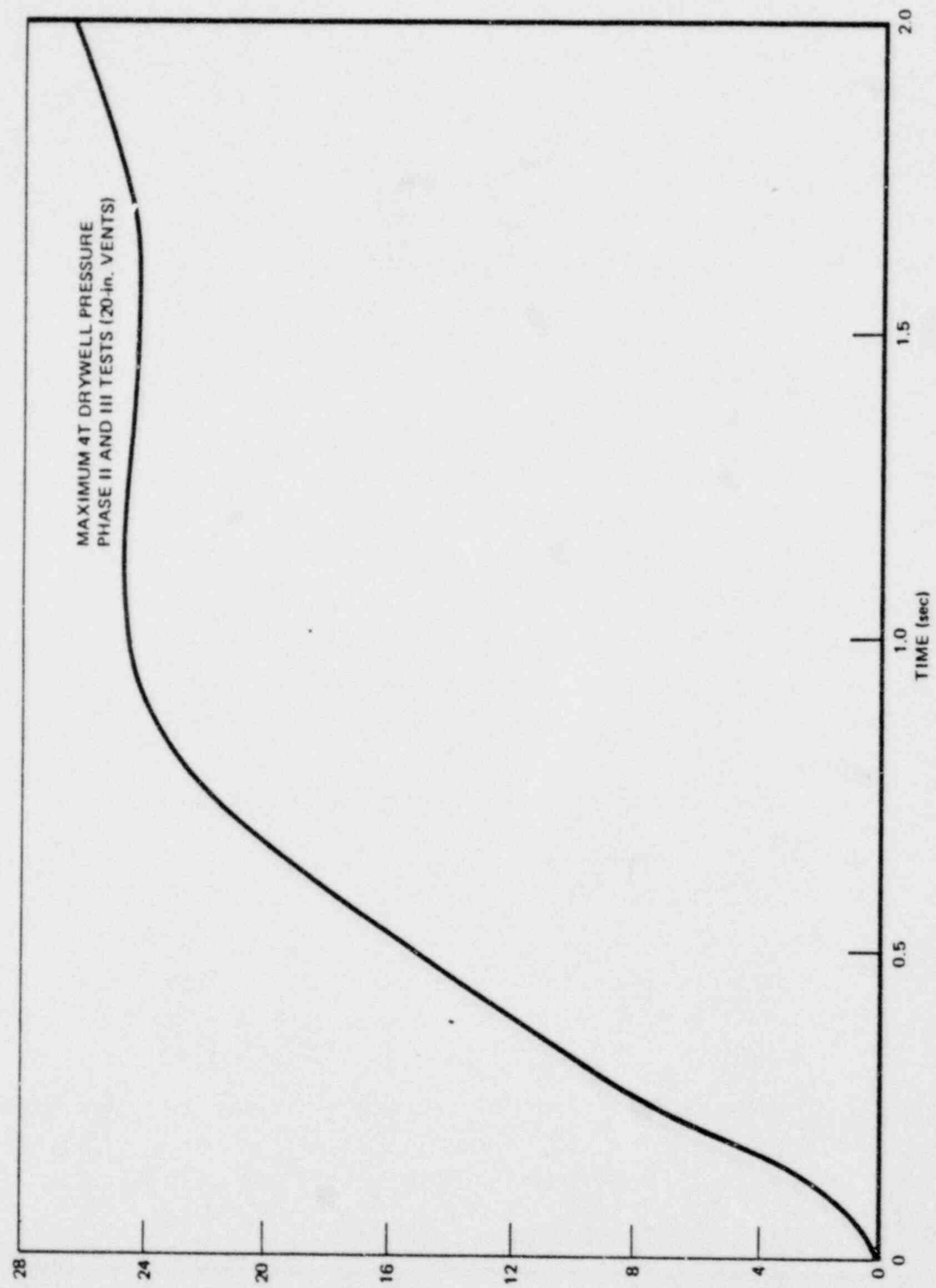

Figure 10. Drywell Pressure

R2

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QUESTION M020.59

In the 4T test report NEDE-13442P-01 Section 3.3 the statement is made that for the various Mark II plants a wide diversity exists in the type and location of lateral bracing between downcomers and that the bracing in the 4T tests was designed to minimize the interference with upward flow. Provide the following information for each Mark II plant:

1. A description of the downcomer lateral bracing system. This description should include the bracing dimensions, method of attachment to the downcomers and walls, elevation and location relative to the pool surface. A sketch of the bracing system should be provided.

RESPONSE

The requested information will be provided in the individual plant Design Assessment Reports.

QUESTION M020.59 (Continued)

2. An assessment of the effect of the bracing system on the pool swell phenomena and drywell pressure response.

RESPONSE

An analysis of the effects of bracing on pool swell has been conducted using a modified version of the Pool Swell Analytical Model (PSAM) described in NEDE-21544-P. The modification consisted of additional terms in the slug momentum equation to account for standard and acceleration drag forces applied by the bracing. The drywell pressure response was determined with a wetwell feedback effect. The analysis found that bracing at all elevations decreased the maximum pool swell velocity and maximum swell height when compared to the case without bracing. Therefore, not accounting for bracing in design evaluations increases the conservatism in the calculated maximum pool velocity and swell height. The effect is more noticeable for bracing above the initial pool surface than for bracing below the initial pool surface. R3

Bracing caused an increase in the maximum drywell and air bubble pressures during pool swell when compared to those maximum pressures found without bracing. Here again, the effect is more noticeable for bracing initially above the pool.

In the limiting plant studied with bracing located six feet above the pool surface, (the maximum bracing height studied) and a blockage of 30 percent, the underprediction of bubble pressure realized by neglecting the bracing was approximately 20 percent. However, the maximum bubble pressure with bracing considered was still well within containment design values. The increase in drywell pressure during pool swell due to bracing was approximately 8 percent, but the increase in maximum drywell pressure (occurring well after pool swell) was less than 3/10 of 1 percent. This small increase in drywell pressure would be more than compensated by conservatism in the drywell pressure calculation. R3

For bracing located at the initial pool surface, the change in bubble pressure and drywell pressure is approximately one-half that for bracing located six feet above the pool surface.

In conclustion, it was found that bracing may have an effect on pool swell - the calculated pool swell velocity and swell height decrease and the maximum air bubble pressure and the maximum drywell pressure during pool swell increase. In design evaluations, neglecting bracing increases the conservatism in the calculation of maximum pool velocity and swell height and conservatism in the drywell pressure calculation more than compensates for the increase in drywell pressure found when bracing is included. The increase in bubble pressure, while noticeable, is insignificant because of the large margin existing between it and the containment design pressure.

QUESTION M020.59 (Continued) R2

3. The basis for calculating the impact or drag load on the bracing system or downcomer flanges. The magnitude and duration of impact or drag forces on the bracing system or downcomer flanges should also be provided.
4. An assessment of the effect of downcomer flanges on vent lateral loads.

RESPONSE

The requested information in items 3 and 4 of M020.59 will be discussed in the individual plant Design Assessment Reports (DAR's).

QUESTION M020.60 R2

In the 4T test report NEDE-13442P-01 Section 5.4.3.2 the statement is made that an underpressure does occur with respect to the hydrostatic pressure prior to the chug. However, the pressurization of the air space above the pool is such that the overall pressure is still positive at all times during the chug.

We require that each Mark II Plant provide sufficient information regarding the boundary underpressure, the hydrostatic pressure, the air space and the SRV load pressure to confirm this statement or alternatively provide a bounding calculation applicable to all Mark II plants.

RESPONSE

The requested information will be discussed in the individual plant Design Assessment Reports (DAR's).

QUESTION M020.61

Significant variations exist in the Mark II Plants with regard to the design of the wetwell structures in the region enclosed by the reactor pedestal. These variations occur in the areas of (1) concrete backfill of the pedestal, (2) placement of downcomers, (3) wetwell ai space volumes; and (4) location of the diaphragm relative to the pool surface. In addition to variation between plants, for a given plant, variations exist in some of these areas within a given plant. As a result, for a given plant, significant differences in the pool swell phenomena can occur in these two regions. We will require that each plant provide a separate evaluation of pool swell phenomena and loads inside of the reactor pedestal.

RESPONSE

The requested information will be discussed in the individual plant Design Assessment Reports (DAR's).

QUESTION M020.62 R2

For the suppression pool temperature monitoring system, provide the following additional information:

1. Type, number and location of the temperature instrumentation that will be installed in the pool.

2. Discuss and justify the sampling or averaging technique that will be applied to arrive at a definitive pool temperature.

RESPONSE R3

This information will be provided in the individual plant Design Assessment Report (DAR).

QUESTION M020.63 R2

For limiting the suppression pool temperature, provide the following additional information:

1. Present the temperature transient of the suppression pool starting from the specified temperature limits for the following transients:

    a. Struck open relief valve

    b. Primary system isolation

    c. Initiation of auto depressurization system

2. Describe the instrumentation which will alert the operator to take action to prevent the pool temperature limit to be exceeded.

3. Describe the operator actions and operational sequence for those transients stated in Item 1 above. Provide and justify the assumption of time for initiating each action and the corresponding pool temperature.

R3

RESPONSE

This information will be provided in the individual plant Design Assessment Report (DAR)

R2

QUESTION M130.8

Responses to previous SEB questions, 130.1 and 130.2 are insufficient. DFFR Tables 2-1 and 5-1 have not provided any load profiles and time histories. DFFR Figures 5-1 through 5-16 have no indications of how the load time histories are combined. Provide the information requested.

RESPONSE

DFFR sections referred to in Tables 2-1 and 5-1 provide the corresponding load profiles and time-histories. Rather than combining the time-histories of the loads shown in Figures 5-1 through 5-16, the dynamic responses due to each of the current loads will be combined.

QUESTION M130.9

Clarify the last sentence on Page 5-20 of the DFFR. Will structures be designed using load combinations 4a, 5a and 7a of Table 5-2?

RESPONSE

Load combinations 4a, 5a, and 7a of the DFFR Table 5-2 will be used in the assessment of the structures.

QUESTION M130.10

It is questionable that the base mat or drywell floor may be modeled as a thin shell as described in DFFR Section 5.4.2. Support this assertion or modify the section to eliminate the thin shell modeling option.

R2

RESPONSE

DFFR Section 5.4.2 was modified in Revision 3 of the DFFR as follows:

5.4.2 STRUCTURAL MODEL

The structural model should adequately represent those components that can be expected to be significantly affected by the SRV loads as well as those that may appreciably influence the response. Thus, the model should include the basemat, primary containment, reactor support pedestal, and drywell floor. These elements may be modeled as thin shells wherever applicable on the basis of the radius-thickness ratio. The RPV may also be modeled as a thin shell or as a rigid mass in a simpler model. At least the mass of large neighboring structures, such as the reactor building, should be included. It is desirable to include large rigidly connected adjoining structures in the model to at least approximate their stiffening influence. The mass of suppression pool water may be lumped with the basemat elements.

QUESTION M130.11

The reference in DFFR Section 5.5 to use of the strength allowable of ACI-218-71 is not considered appropriate. The specific strength acceptable criteria should be specified. An acceptable set of such allowable are those incorporated into US NRC SRP 3.8.

RESPONSE

The specific acceptable strength criteria are as specified in the plant Safety Analysis Report.

DFFR Section 5.5 was modified in Revision 3 of the DFFR deleting reference to ACI-318-71 as follows:

5.5 ACCEPTANCE CRITERIA

The same criteria detailed in the corresponding Safety Analysis Report should apply for each individual plant when including the effects of the SRV discharge load.

R2

QUESTION M130.12

Reference is made in DFFR Section 5.4.3 to studies of structural response to SRV load. Provide citations for this reference and where such studies are not readily available, copies are requested.

RESPONSE

Studies mentioned in Section 5.4.3 are the results of analysis completed for a specific plant at the time of writing of the DFFR. Reference to the studies was intended to indicate the need for considering strain dependent soil properties. Discussions of the dynamic strain-dependent soil properties used can be found in the individual plant Design Assessment Reports (DARs).

QUESTION M130.13

The 4T test applications memorandum states that high magnitude short duration dynamic lateral loads were observed. Provide a description of the method used to convert from a dynamic lateral load to an equivalent static lateral load. In addition, provide a description of the methods used to access the affect of load structure interaction in the 4T tests and in the various Mark II vent designs.

RESPONSE

The dynamic and equivalent static lateral loads were independently evaluated during the 4T test program. Appendix "B" of the Phase II and III test report (NEDE-13468P, 11/76) is a discussion of the dynamic load calculation which utilizes strain and accelerometer data. The equivalent static load was determined as the static load applied to the end of the downcomer which would result in the measured bending strain.

Load structure interaction effects on the downcomer were investigaed by changing the downcomer size and bracing configuration for various tests while keeping the other parameters constant. This is further discuessed in the Phase II and III test report. In general, dynamic lateral load increased with downcomer diameter but was unaffected by cantilever length and the equivalent static load also increased with downcomer diameter but decreased with an increasing cantilever length.

R2

The pipe diameter of 24-in. is the parameter affecting the dynamic lateral load. Since the 24-in. diameter is prototypical, the measured load structure interaction is also prototypical and the measured data is therefore directly applicable. Additional material is presented in the "Mark II Lead, Plant Topical Report - Pool Boundary and Main Vent Chugging Loads Justification," NEDO/NEDE 23617-P, July 1977.

QUESTION M130.14

The 4T test applications memorandum states that pool boundary loads resulting from chugging are based on 4T test data in conjuntion with engineering application techniques to account for differences between the 4T facility and the full scale systems. Provide a description of these techniques. In addition discuss load/structure interactions considerations given to pool boundary loads for each Mark II plant.

RESPONSE

The information requested in Question M130.14 is discussed in depth in the report, "Mark II Lead Plant Topical Report - Pool Boundary and Main Vent Chugging Loads Justification," NEDE 23617, which was issued in July, 1977.

QUESTION M130.15

The 4T test report NEDE-13442P-01 does not provide sufficient information related to pool boundary loads. The Final 4T test report should provide a quantitative evaluation of the effect of stiffness of the wetwell wall on pool boundary loads.

RESPONSE

The effect of 4T wall stiffness on boundary loads has been addressed in an extensive study which was performed by Anamet Labs., In., as subcontractors to General Electric. This study concluded that the effect of stiffness primarily was to determine the degree of fluid/structure interaction of the 4T vessel to the chugging loads. Specifically Anamet concluded that the effect of 4T wall stiffness varied with the frequency content of the chugging load. They found:

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1. For the portion of the chugging excitation with a frequency content below ~20 Hz, there is little effect of wall stiffness and the load is transferred to the wall similar to the way a static load would be tranferred to the wall. R2

2. For the frequency range between 20 hz and 50 hz, chugging excites a resonant system reponse in the 4T tank/water system. This produces the 'ring-out' characteristic of most of the 4T chug pressure histories.

3. Above 50 Hz, there is excitation of the 4T structural modes (which define the wetwell stiffness) but the power which is tied up in these modes is less than 10% of the total excitation and therefore they play only a small role in the boundary loads.

The Anamet report "Fluid Structure Interaction 4-T Test Facility," Label No. 1076.57-B describes the 4T FS1 study and was submitted to Re NRC in August 1977.