APPENDIX A-3
RESPONSES TO NRC QUESTIONS

DFFR ROUND 3 QUESTIONS

NRC QUESTIONS DATED JUNE 30, 1978, WITH RESPONSES

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QUESTION 020.64

The data base from which chugging loads on downcomers was developed indicates that lateral loads were also observed at vent clearing. These loads were as high as 3.5 kips (See Table 3-3 of NEDE-21078-P). Therefore, it is our position that a design load not less than 3.5 kips be specified for downcomers during vent clearing. This static equivalent load should be used for each plant with a vent natural frequency less than 7 Hz. For a vent natural frequency greater than 7 Hz a higher vent clearing static equivalent load should be specified and justified.

RESPONSE

As indicated in the Application Memorandum for Phases I, II, and III of the 4T test series (NEDE 23678P), no significant lateral loads were observed between the start of the tests and the onset of chugging. However, in the referenced tests (data Table 3-3 of NEDE 21078), static equivalent measurements of lateral loads up to 3.5 kips were observed. These loads are unique to the test setup (Figures 3-1, 3-1A, 3-2 and 3-3 of NEDE 21078); and are not applicable to either the 4T facility or the Mark II containment.

In the test facility where the 3.5 kip static equivalent loads were measured no drywell volume existed except for the air occupying the vent line prior to valve opening. In contrast to the 4T facility or a Mark II containment, the referenced facility vented a very small quantity of non-condensable gas to the pool followed by immediate steam condensation. In these tests without a drywell, the vent pressure typically increased by approximately 1 to 1.5 ATM while the small air volume cleared, then dropped approximately 2 ATM as condensation of the following steam commenced. This loss in vent pressure is evidence of the loss of the bubble at the vent exit and an attendant reentry of water into the vent.

The bubble collapse in the referenced facility (similar to a chugging event) caused the lateral load (during vent clearing) which would not have occurred if a drywell were present. The 4T or Mark II drywell would continue air flow

QUESTION 020:64 - continued

to the bubble at the vent exit that would be gradually diluted with a larger flow of steam which in itself is capable of maintaining a positive bubble at the vent exit. In the absence of a collapsing vent exit bubble, lateral loads would not be expected to occur during the 4T or Mark II vent clearing transients; this was confirmed in the 4T tests. The DFFR methodology is consistent with these results.

The downcomer vents are designed to accommodate the lateral loads occurring during chugging; these loads bound the vent clearing lateral load design consideration for the downcomer vents.

QUESTION 020.65

The data base (NEDE-21078P) from which the chugging load specification for downcomers was developed was obtained with a vent configuration unencumbered by flanges or other protuberances located in the vicinity of the vent exit. It is our position that these load specifications are not applicable to any Mark II plants with vents which are flanged at the vent exit. Either the vent exit flanges should be removed or additional steam tests should be conducted with a vent exit flange.

RESPONSE

Flanges or other protuberances located in the vicinity of the vent exit have been removed from all plants covered by the Mark II program.

QUESTION 020.66

The static equivalent load for a downcomer depends on the natural frequency of the downcomer. The current load specification of 8.8 kips was obtained in a test facility with a downcomer natural frequency of about 7 Hz. This load has not been demonstrated to be conservative for downcomers with a higher natural frequency. For a vent natural frequency greater than 7 Hz, a higher lateral load should be specified and justified. Additional

QUESTION 020.66 - continued

information is needed to establish a static equivalent load for downcomers with a natural frequency greater than 7 Hz. In addition, we require that each Mark II plant provide an evaluation of the downcomers utilizing the dynamic forcing function in Task A.13 in the Mark II supporting program an confirmation of the static equivalent load evaluation. The static equivalent and the dynamic loads for the downcomers described above are based on tests with downcomer diameters of 24 in. or less. Additional information will have to be provided to establish lateral loads for downcomer with a larger diameter.

RESPONSE

Certain plants covered by the Mark II supporting program employ vent systems with natural frequencies greater than 7 Hz. To confirm that the 8.8 kip static equivalent load is adequate for design assessment, all Mark II vent systems will be analyzed for the dynamic forcing function defined in Task A.13 of the Mark II program. Results will be presented for NRC review by applicants on an individual basis.

QUESTION 020.67a Referring to Section 4.3.2 of DFFR (NEDO-21061-P, Rev. 2).

a. It is noted that the force magnitude distribution employed for the probabilistic analysis of multiple downcomer loading is taken from Table 3-6 of NEDE-21078-P. These data were obtained during steam blowdown with significant air admixture (Tests 5 and 7). Thus, they do not correspond to the "worst" loading case (0% air admixture) which yields the 8.8 kip maximum lateral load specification. We require that the multiple downcomer loading be modified so as to be consistent with this worst case distribution.

RESPONSE

The force magnitude distribution data for the 0% air admixture tests is not available for the tests reported in NEDE-21078-P. To conservatively incorporate the effects of 0% air admixture into multiple downcomer analysis, the

QUESTION 020.67a - continued

force per downcomer from Figure 4-10 of the DFFR (NEDO-21061-P, Rev. 2) will be multiplied by the factor 8.8/7.0 = 1.26 for design assessment with a maximum of 8.8 kips per vent. The basis for this factor is that the force magnitude distributions from Table 3-6 of NEDE-21078-P (for which the maximum load is approximately 7 kips) are related to the expected distribution for 0% air admixture tests (for which the maximum load is 8.8 kips according to the ratio 8.8/7.0 = 1.26). This assumes that the force magnitude distribution shifts by the factor 1.26 for the 0% air admixture tests, thereby conservatively incorporating the effects of 0% air on the current DFFR methodology for multiple downcomer loadings.

QUESTION 020.67b (Referring to Section 4.3.2 of DFFR (NEDO-21061-P, Rev. 2)

b. *Since the direction of the combined loads from multiple downcomers is arbitrary, assumption 2 of the analysis is unjustified. We require that the magnitude of the resultant of all forces be employed to define multiple downcomer loads. The analysis and results (Figures 4-10 and 4-10a) should be modified accordingly.*

RESPONSE

The methodology underlying assumption 2 can be shown to be correct, so that no changes in Figures 4-10a are required.

The assumption and its context are as follows:

"4.3.2.4.1 Analysis

"A probabilistic analysis of simultaneous lateral loading on groups of downcomer vents has been performed in the manner of Appendix B of Reference 1. The analysis used these assumptions:

"1. The angle of the chugging force on a single downcomer is random and is uniformly distributed around the horizontal plane.

QUESTION 020.67b - continued

"2. Since the component of the chugging force in a particular direction is of interest, the force magnitude distribution is multiplied by the distribution of the cosine of the angle of the force. ....."

The question is interpreted to be on the assumption that the downcomer group lateral chugging force of interest is the one in a particular direction, not the resultant force.

A static equivalent lateral force is to be calculated at exits of various sized groups of downcomers, due to chugging. The value for each group is to have a predetermined exceedance probability, and is calculated under specific technical assumptions listed in NEDE-21061-P. The structural designer applies the force in each of several directions in the horizontal plane for appropriate downcomer group sizes. The question is whether the probability distribution of group lateral force should be that of the magnitude of the resultant lateral force over many pool chugs (i.e., simultaneous chugs at all downcomers in the group), as advocated in the NRC question, or that the distribution should be that of the lateral force along any one chosen orientation, as defined in the DFFR.

To illustrate why the distribution in only one orientation should be used, consider any one analysis which the structural designer will perform. In the analysis, the chosen group lateral force will be applied in one direction, e.g., $\theta = 0$. A group lateral force value acting in that direction (having the desired exceedance probability) is required. The underlying group lateral force distribution for the probability statement can be formed by considering a series of pool chugs. In the first pool chug, a different random single downcomer lateral force is applied to each downcomer in the group in a random orientation. The single downcomer force distribution is stated, and the orientation distribution is assumed to be uniform around 360°. The resultant of the group lateral force can be found, but will have only a certain component

QUESTION 020.67b - continued

acting in the $\theta = 0$ orientation being analyzed. Repeating this process for each pool chug would build up a histogram of group lateral forces in the $\theta = 0$ orientation. Equivalently, the histogram of group lateral force at $\theta = 0$ could be formed by finding just the $\theta = 0$ component of each single downcomer lateral force, and summing these over all downcomers in the group, for each pool chug. (Rather than carrying out this simulation procedure, the probability distribution of group lateral force at $\theta = 0$ is actually found by convolution, as described below.) The resulting distribution of group lateral force oriented to $\theta = 0$ is then treated in the manner described in NEDE-21061-P to fulfill the desired probability statement for many pool chugs, and the downcomer group lateral force required for the analysis in the $\theta = 0$ orientation is obtained.

The same probability statement applies to downcomer group lateral forces in other orientations to be investigated. Moreover, due to the assumption that single downcomer lateral forces are uniformly distributed in θ, the foregoing analysis at $\theta = 0$ is equally applicable at any other θ; it need not be repeated for the other values of θ; the same group force value is used for analysis in the other orientations.

For information, the convolution method actually used to form the histogram of group lateral force at $\theta = 0$ is described as follows. Two major stages of convolution are used. In the first stage, the distributions of single downcomer lateral force F and of orientation component cos θ are discretized into cells. To find the component in the $\theta = 0$ orientation of each F in the distribution, $F * \cos\theta$ is required (θ being measured from $\theta = 0$). To form the distribution of $F * \cos\theta$ (in place of the distribution of F), $F * \cos\theta$ is found exhaustively for all combinations of F and cos θ cells; at the same time, the probability of each $F * \cos\theta$ product is the product of the probability in each F and cos θ cell, since F and θ values are assumed to occur independently. Collecting $F * \cos\theta$ products into cells and summing the probabilities for each entry gives a histogram of $F * \cos\theta$ for a single

QUESTION 020.67b - continued

downcomer, as required. This is the distribution of single downcomer lateral forces oriented in one chosen $\theta = 0$ orientation. In the second stage, $F * \cos\theta$ values are summed over all downcomers in the group by the same convolution process of forming the sums, over the number of downcomers in the group, of all combinations of $F * \cos\theta$ cells exhaustively, together with the corresponding probabilities found as the products of the probabilities of the participating cells. In this way, a histogram of lateral force of the group of downcomers in the $\theta = 0$ orientation can be formed.

This explanation of how the group lateral force distribution for a particular orientation is found and used clarifies why the group force probability distribution in a particular orientation rather than the resultant group force distribution is appropriate for the application.

QUESTION 020.67c Referring to Section 4.3.2 of DFFR (NEDO-21061-P, Rev. 2)

c. The results shown in Figure 10-4-a implies that a single downcomer will experience an infinite loading. This is obviously incorrect and suggests that the referenced figure is in error. Provide a corrected version of this figure.

RESPONSE

Figure 10-4-a of DFFR Revision 2 (GE Company Proprietary) has been corrected and is provided as Figure 4-53* in the Proprietary Supplement to DFFR Revision 3 (NEDE-21061-P) submitted to the NRC on June 30, 1978. This correction was effected by exchanging titles on the ordinate and abscissa while retaining the orientation of the curve and extending it to the limits of the graph.

QUESTION 020.68

Based on our review of the 4T test reports (NEDE-13442P-01, NEDE-13468P) and the Phase I, II, III Applications Memorandum dated January 1977, it is our position that the specification for maximum pool swell elevation account properly for observed trends with submergence and state of the blowdown fluid.

QUESTION 020.68 - continued

We require that the maximum pool swell elevation specification consist of the maximum of either 1.5 times submergence or that predicted by the pool swell analytical model using a polytropic exponent of 1.2 for wetwell air compression.

RESPONSE

The pool swell analytical model is used to predict bulk pool swell transient velocity and acceleration for purposes of calculating impact and drag loads on structures located within the swell zone. The model is excessively conservative for prediction of maximum pool swell height or wetwell airspace compression. The specification of maximum swell height in NEDO-21061 will be modified to be the greater of:

1. 1.5 vent submergence or
2. the elevation corresponding to the drywell floor uplift differential pressure used for design assessment.

The pool surface elevation corresponding to this maximum wetwell airspace compression will be calculated assuming a polytropic process with an exponent of 1.2.

QUESTION 020.69

Our review and analysis of the data base (4T tests and EPRI results) for upward ΔP suggests that the 2.5 psi specification is inadequate for certain Mark II plants. We require that the current specification be replaced by:

$$\Delta PUP = 8.2 - 44F \text{ (psi)} \qquad 0 < F \leq 0.13$$
$$\Delta PUP = 2.5 \text{ (psi)} \qquad F > 0.13$$

where F is a plant unique parameter defined by

$$F = \frac{\frac{AB \cdot AP \cdot VS}{2}}{VD \cdot (AV)}$$

QUESTION 020.69 - continued

with AB = break area
AP = net pool area
AV = total vent area
VS = wetwell air space volume
VD = drywell volume

RESPONSE

The plant unique parameter correlating pool swell uplift differential pressure on the drywell floor will be calculated by each applicant and provided for NRC review on an individual basis.

QUESTION 020.70

The DFFR (NEDO-21061) methodology for estimating steady state drag loads on submerged structures is unacceptable for those cases where the structures represent significant blockage to the pool water slug motion. We require that the drag coefficients used to compute the loads be modified according to traditional literature references which take account of the effect of blockage.

RESPONSE

Structures such as the bracing that support downcomer vents experience drag loads as a result of the pool water slug motion. The distance between bracing pipes ranges from virtually touching to far apart. The bracing lies in a plane perpendicular to the pool slug motion, i.e., an orientation known in the literature as a side-by-side configuration. The drag coefficients, C_d, for this condition can be analyzed by considering the idealized case of two cylinders located side by side (see Figure 1).

QUESTION 020.70 - continued

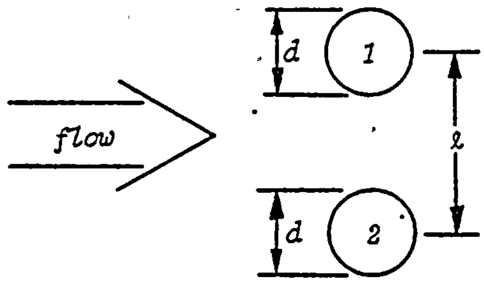

Figure 1

For values of ℓ> approximately 3d, the literature shows no interference effects, and the drag is accurately predicted by considering the cylinders independently of each other. For values of ℓ less than approximately 3d, the effects of the sheer layer interaction between the lower boundary layer of #1 with the upper boundary layer of #2 results in a lowering of the values of C_D (see Figure 1). When ℓ = d (or when the cylinders touch); the C_D can be estimated as that of a flat plate of length 2d.

Another idealized situation called the tandem arrangement is discussed in the literature. Although this arrangement is not directly applicable to vent bracing, it may be representative of other submerged structures located in some suppression pools. The tandem arrangement is illustrated in Figure 2.

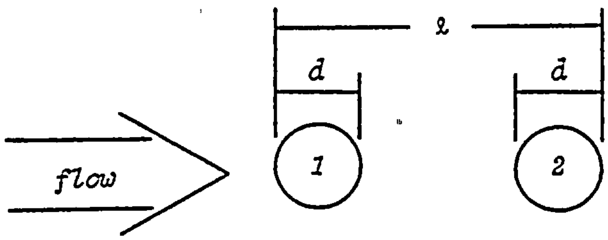

Figure 2

QUESTION 020.70 - continued

The discussion can be simplified by considering three separate regions: a) $\ell \geq$ approximately 30d, no interference, b) approximately 3d $\leq \ell <$ approximately 30d partial interference, and c) d $< \ell <$ approximately 3d mutual interference. For region a), no interference effects exist and the structures can be analyzed independently of one another. For region b) partial interference occurs; only the downstream structure #2 is affected (see Figure 2). The upstream structure #1 does not "see" the downstream one. In all cases of interference, the drag coefficient C_D is less than it would be without the influence of the upstream cylinder. This is because the wake of the upstream cylinder introduces turbulence into the incoming flow; that the downstream cylinder experiences this turbulence hastens the onset of boundary-layer transition of #2, thereby lowering the value of C_D. For region c) mutual interference occurs with C_D for #2 being lower while C_D for #1 is larger. C_D for #1 increases because of deleterious interference effects on the wake formation. However, the maximum increase is about 20% and occurs at about $\ell = d$.

Summarizing the above discussion, for evaluation of submerged structure drag loads the steady-state drag coefficient, C_D, should be treated as follows:

(i) Case 1 (Figure 1):

- For $\ell \geq$ 3d, use steady-state C_D as before.
- For 1.1d $\leq \ell <$ 3d, use steady-state C_D as before.
- For $\ell <$ 1.1d, use steady-state C_D for a flat plate of width 2d normal to flow.

(ii) Case 2 (Figure 2):

- For $\ell \geq$ 30d, use steady-state C_D as before.
- For 3d $\leq \ell <$ 30d, use steady-state C_D as before.
- For $\ell <$ 3d, multiply the steady-state C_D by 1.2, for structure #1; for structure #2 - use C_D as before.

QUESTION 020.70 - continued

Among the more important references used were the following:

1. *C. Dalton and J. M. Szabo, "Drag on a Group of Cylinders" Transactions of the ASME, Journal of Pressure Vessel Technology, pages 152 - 157, Feb. 1977.*

2. *M. M. Zdravkovich, "Review of Flow Interference Between Two Circular Cylinders in Various Arrangements", Transactions of the ASME, Journal of Fluids Engineering, page 16, December 1977.*

QUESTION 020.71

In the response to NRC questions M020.58(4) (NRC questions dated January 14, 1977) it is stated that "Calculations of pool swell for Mark II containments using the analytical model utilize the appropriate calculated drywell pressure response (NEDM-10320) as an input." It is our position that the specification of pressure history is an essential element of the DFFR methodology and that the particular choice cited above has not been demonstrated to be appropriate.

To justify such use, we require that pool swell calculations be made for selected 4T tests using drywell pressure response computed according to NEDM-10320 in lieu of the measured drywell pressure histories. The selected 4T tests are the two saturated liquid blowdowns made during the phase II test series (Runs 36 and 37). The response (pool swell elevation, velocity, bubble pressure) calculated in this manner should be compared with measured values and with similar calculations made using the measured drywell pressure histories.

RESPONSE

For Mark II plant design assessment, the calculated drywell pressure response (NEDM-10320) has been conservatively chosen as input to the Mark II pool swell model. To illustrate this conservatism, the pool swell model calculations were performed for 4T test runs 36 and 37 using the computed drywell pressure response

QUESTION 020.71 - continued

(according to NEDM-10320) as input. These calculations were compared to both the measured 4T pool swell response and the pool swell calculations using the measured 4T drywell pressure histories. The corresponding pool swell elevation, velocity, and bubble pressure are plotted in the attached figures.

The pool surface elevation curves (Figures 1 and 2) show that results using NEDM-10320 drywell pressures yield pool swell elevations which exceed the measured 4T test data, and also exceed the results obtained using the 4T - measured drywell pressure.

The pool surface velocity (Figures 3 and 4) curves illustrate that the maximum velocities calculated using NEDM-10320 pressures are greater (as in run 37) or comparable (as in run 36) to those measured in the 4T tests. Additionally, pool surface velocities using NEDM-10320 input consistently exceed the velocities calculated using the 4T measured drywell pressures.

The bubble pressure curves (Figures 5 and 6) show that bubble pressures calculated using NEDM-10320 drywell pressures provide an upper bound on both the measured 4T data and the calculated values using the measured 4T drywell pressure.

Based on the above results, using the calculated drywell response (using NEDM-10320) for pool swell calculations results in conservatively-predicted pool swell parameters for design assessment.

QUESTION 020.72

The DFFR impact load specification for small structures is inadequate. The current load specification consists of a peak pressure-velocity correlation developed from the Mark III PSTF tests. The peak pressure is used in conjunction with an "average" 7 msec duration to completely define a pressure pulse. The use of the same 7 duration for all situations has not been justified, thus the current specifications are incomplete. We require that the

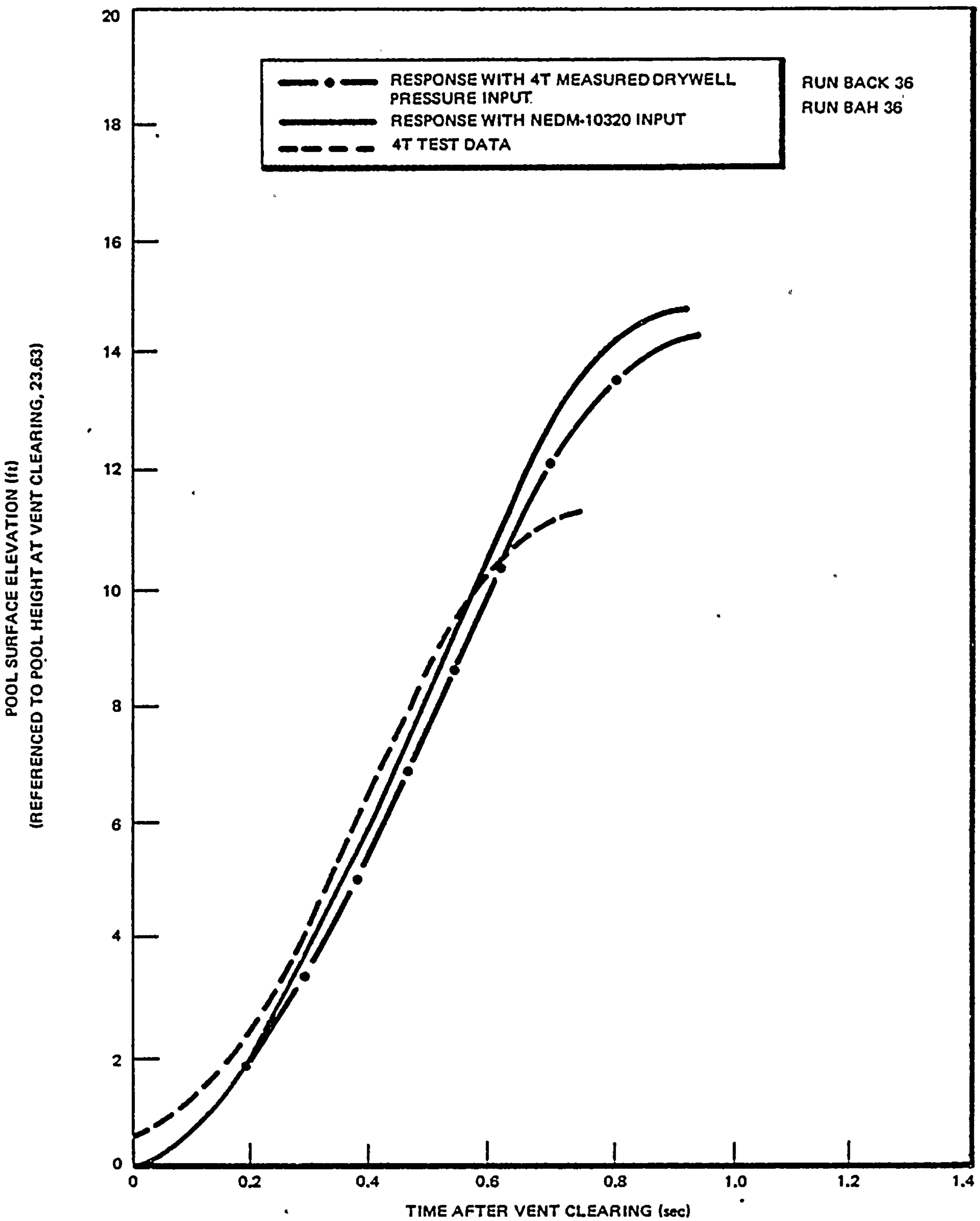

Figure 1. Pool Surface Elevation, Run 36

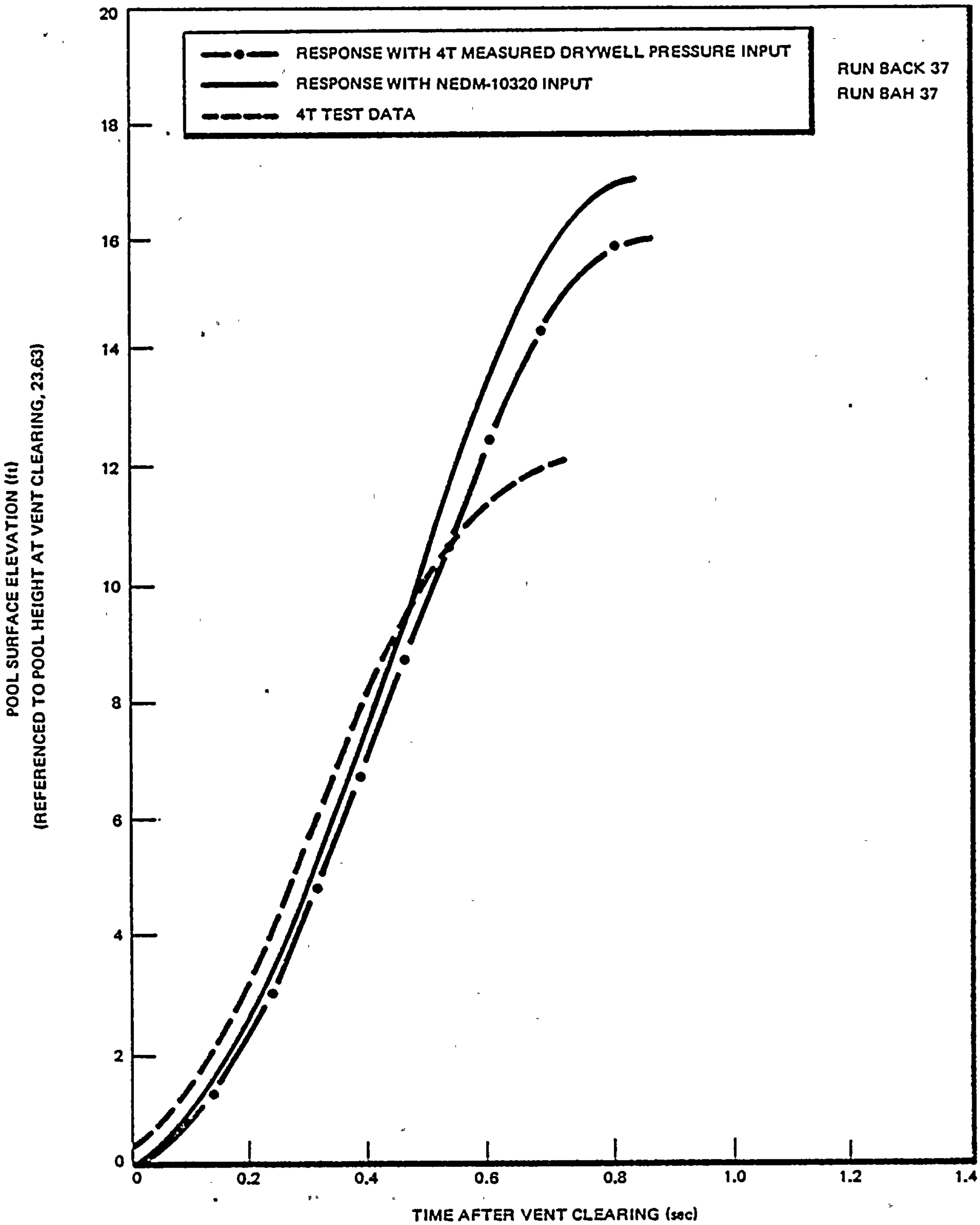

Figure 2. Pool Surface Elevation, Run 37

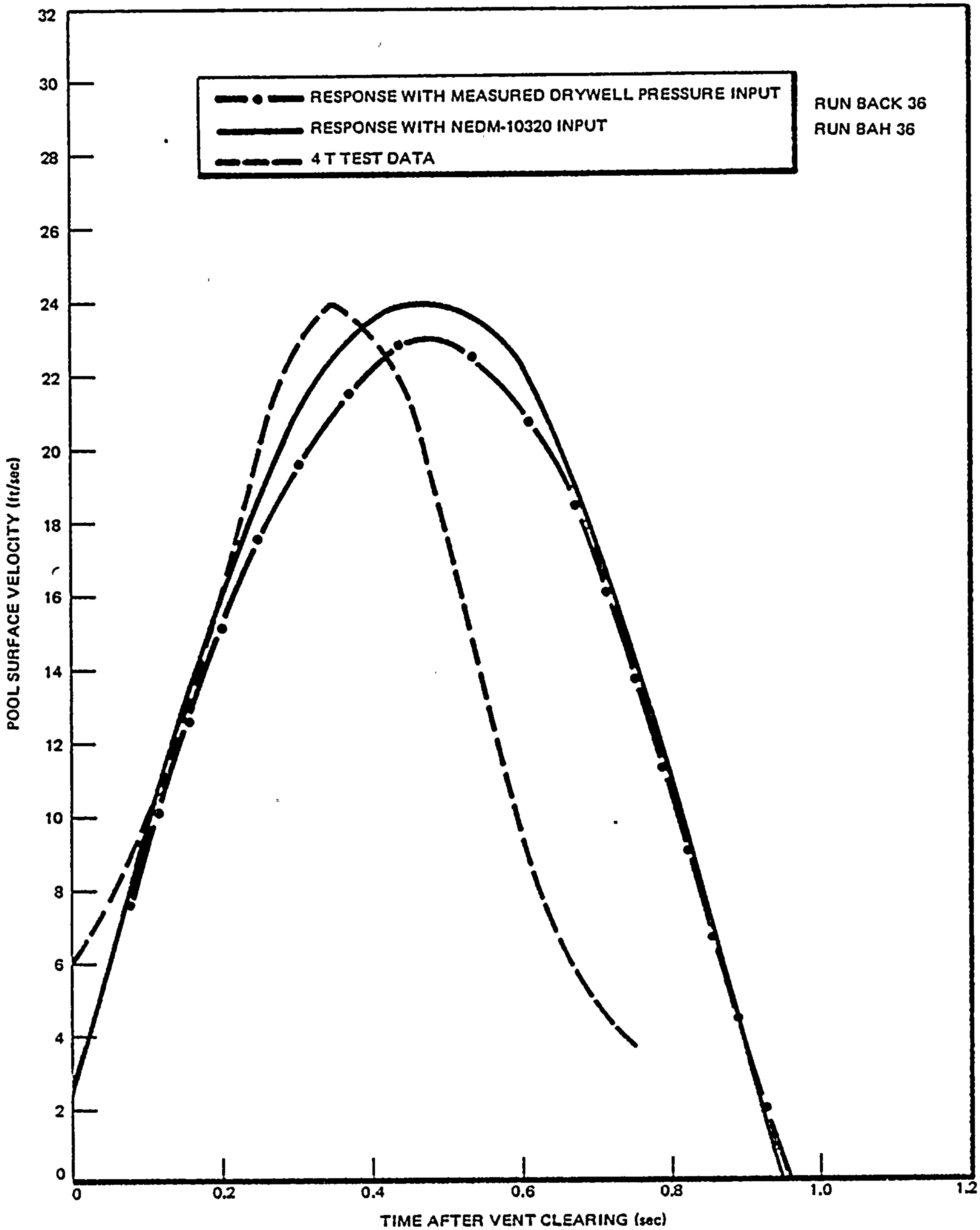

Figure 3. Pool Surface Velocity, Run 36

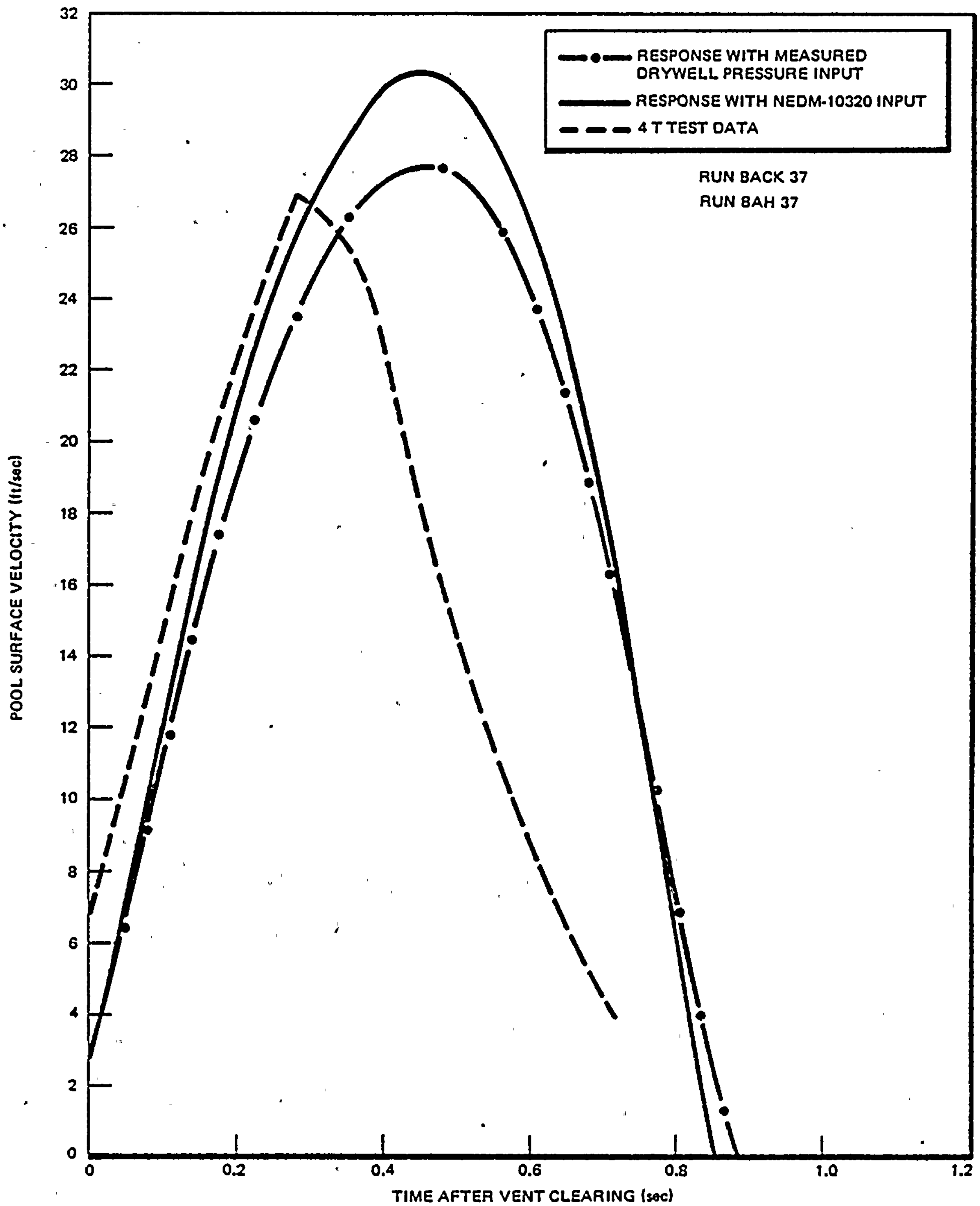

Figure 4. Pool Surface Velocity, Run 37

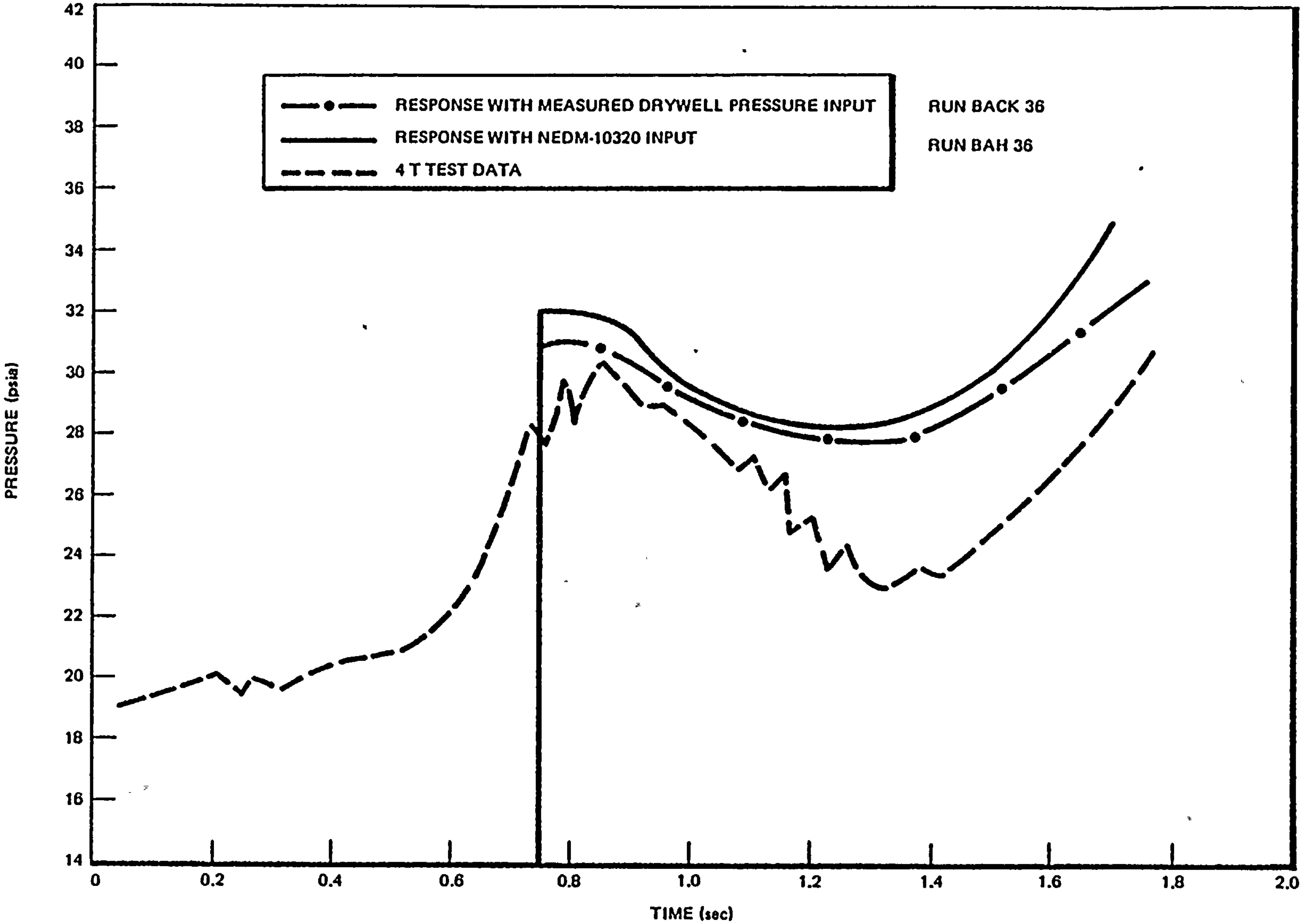

Figure 5. Bubble Pressure, Run 36

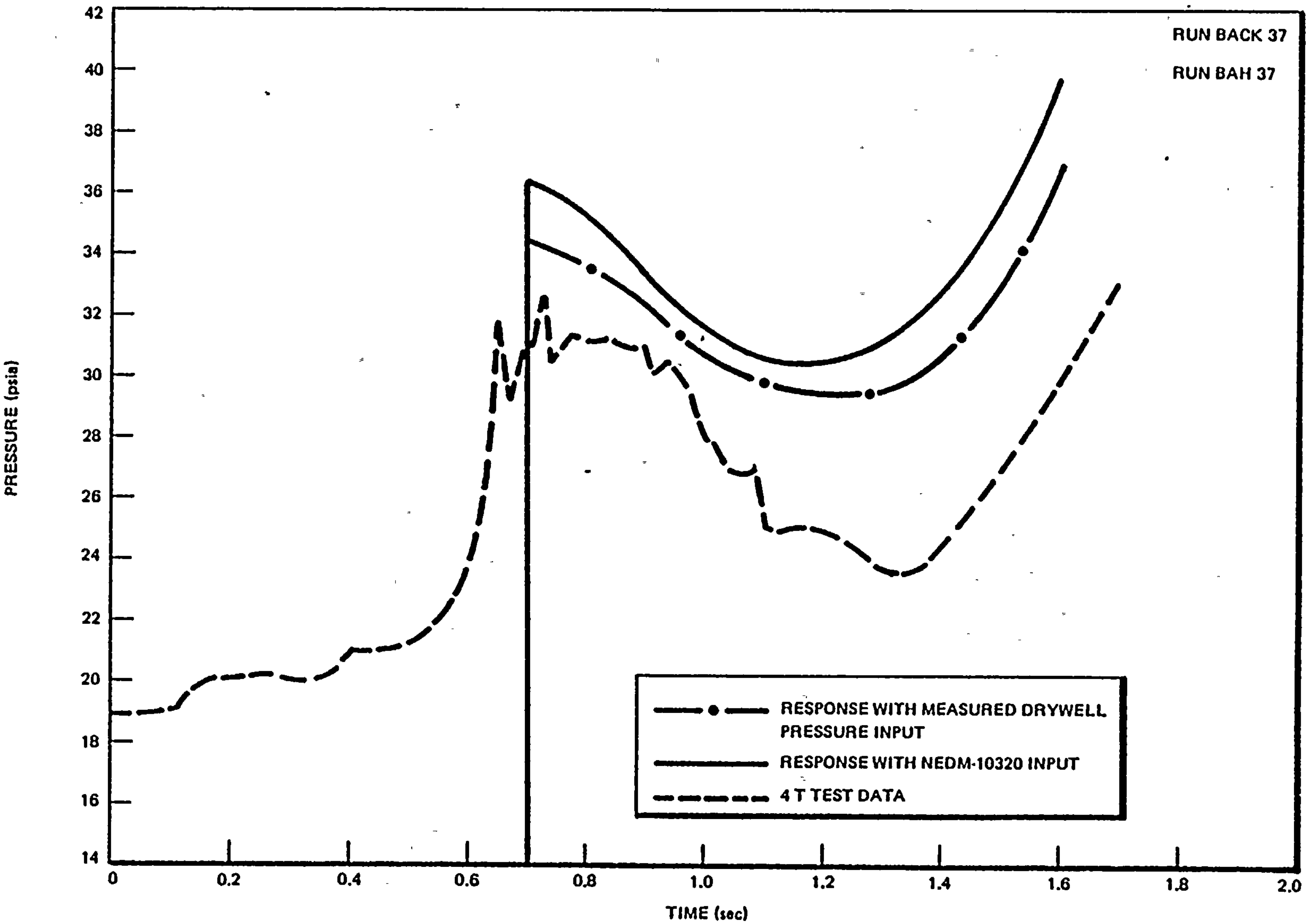

Figure 6. Bubble Pressure, Run 37

QUESTION 020.72

load specification be modified so as to establish a conservative pulse for all Mark II anticipated situations of target geometry, target size, pool flatness and pool approach velocity.

RESPONSE

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 flatness of the approaching pool surface. In the Mark II suppression pool the pool surface is relatively flat; therefore all of the PSTF impact test data using circumferential targets are prototypical of the Mark II conditions. Furthermore, the type and the sizes of the targets tested were also prototypical of the Mark II plants. The load specification in DFFR is therefore a direct application of the test data without any extrapolation.

With regards to the duration of the load, the DFFR specified 7 milli-seconds. The 7 milli-seconds duration was chosen because it is the most representative time duration based on tests using circumferential targets.

The Brookhaven National Laboratory report "Impact Loads on Structures Above Mark II Containment Pools," George Maise, February 2, 1978, indicates that the peak pressure duration is dependent on target geometry and size, pool flatness, and pool approach velocity. The Mark II Owners concur that the concerns raised by the Maise report are technically sound.

The Mark II plants are investigating the effects of the variables mentioned in the Maise report on the structural impact loads and the correspondence between PSTF pool swell and expected Mark II pool swell. The results of these investigations will be used to verify the current DFFR impact pressure methodology described above.

QUESTION 020.73

Based on our review of 14 test reports, application memorandums and the pool swell analytical model report (NEDE-21544-P), it is our position that the specification of pool swell velocity according to the analytical model prediction does not provide sufficient margin to cover uncertainties in the measurements. We estimate this uncertainty to be on the order of ± 10%. Accordingly, we require the addition of a 10% margin to the values predicted by the analyses for pool swell velocity.

RESPONSE

In the report NEDE-21544-P, the pool swell phenomenon was modeled according to two sets of assumptions.

The first set of assumptions, called the "best estimate assumptions," is presented in Section 6.4 of NEDE-21544-P. The objective of these assumptions is to model the pool swell phenomenon to match the 4T test results. In the context of these assumptions, the uncertainty in the computation of the maximum pool swell velocity is approximately ± 10% when compared with the test results.

The second set of assumptions, called the "applications assumptions," is presented in Section 6.7 of NEDE-21544-P. These assumptions are recommended for design calculations. According to these assumptions, the predicted maximum pool swell velocity is higher than the observed maximum velocity from the 4T tests.

The major difference in the two sets of assumptions is in the modeling of the flow from the drywell to the wetwell through the downcomer vents. Under the best estimate assumptions, an air-steam mixture is allowed to flow from the drywell to the wetwell after the expulsion of the air in the vents; in application assumptions only air is allowed to flow through the vents. The latter results in an increased bubble pressure and higher acceleration of the pool surface, thus producing a higher pool swell velocity compared to the results from the 4T tests.

QUESTION 020.73 - continued

The analytical model for predicting the Mark II pool swell phenomenon used the second set of assumptions where only air was allowed to flow from the drywell to the wetwell. This is a very conservative assumption resulting in computed pool swell velocity that is higher than what would be expected in the actual case. Additionally, using the calculated drywell pressure from NEDM-10320 as the forcing function for the pool swell analysis is an added conservatism of the overall pool swell methodology. A quantitative measure of this conservatism is demonstrated in the response to Question M020.71 where the calculated maximum pool swell velocity is 5-10% higher by using as the forcing function the calculated drywell pressure (using NEDM-10320) rather than the 4T-measured drywell pressure. This demonstrates conservatism heretofore not apparent because the model/data comparisons in NEDE-21544-P using "applications assumptions" were performed assuming the measured rather than calculated 4T drywell pressure. Therefore, the current methodology does provide sufficient margin to cover the uncertainties in the computed pool swell velocity.

QUESTION 020.74

The current chugging load specification consists of an oscillatory pressure load derived from a conservative chug in the 4T facility. This load includes the FSI related "ring out" of the test walls. The actual load is an impulsive load resulting from collapse of steam bubbles at the exit of the vents. To confirm that the direct application of the pressure signal to containment walls is conservative, additional information is needed. Wall pressure measurements during a conservative chug at the plane of the vent exit should be used to construct an impulse load at the vent exit. The impulse load specification should be used in the coupled fluid-structure analytical model of the 4T facility described in NEDE-23710-P to confirm the conservative nature of the current chugging wall load specification.

RESPONSE

The concerns expressed in this question have been addressed in the forthcoming report: "Lead Plant Containment Response to Improved Chugging Load Definition," available in July, 1978.

QUESTION 020.75

The supporting program report NEDO-21297 includes an LTP effort to define main vent condensation submerged structure loads. The current DFFR and lead plant program do not include a definition for this load. Either provide a load for steam condensation — submerged structure drag for the STP or justify deferring this item to the LTP.

RESPONSE

The lead plants have developed individual methods for determining these main vent condensation submerged structure loads in their plant specific responses to these questions. A Mark II generic program is currently underway to determine the loads due to steam condensation and will be available about the fourth quarter of 1978. This Program will confirm the adequacy of the lead plant assessments and establish a basis for the remaining plants.