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.....trans the following:

ENCLOSURES:
Mark I Containment Program Status Report.....
(40 cys enc'l rec'd)

ACKNOWLEDGED
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CHARLES W. SANDFORD
EXECUTIVE VICE PRESIDENT

July 31, 1975
IE-75-873

DOCKETED USNRC AUG 2 1975 U.S. NUCLEAR REGULATORY COMMISSION Mail Section

RECEIVED AUG 2 1975 U.S. ATOMIC ENERGY COMMISSION Regulatory Mail Section

Mr. George Lear, Chief
Operating Reactors Branch 3
Division of Reactor Licensing
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Lear:

This is with further reference to your letters of February 15, 1975 and April 17, 1975, the latter pursuant to 50.54(f). Our initial response to these letters was incorporated in our letter of May 9, 1975, which transmitted a preliminary action plan addressing your relief valve and LOCA load concerns.

Since the date of our initial response, General Electric Company, on our behalf, transmitted to Mr. Tedesco (via Mr. Stuart's letter of June 13, 1975) a summary of the proposed Short Term containment program. Mr. Stuart's letter suggested further the desirability of a meeting at the Commission's offices and such occurred on July 17, 1975.

As a result of the July 17 meeting, the Commission requested and we herewith submit (in 37 copies with three attested originals) a "Status Report on the Mark I Containment Program". Also bearing on your inquiries are (1) GE's reference plant analysis, updated and further documented to include the commitments made by Dr. Gyorey and transmitted via letter of June 26, 1975, to Mr. Maccary; and (2) GE's safety/relief valve vent clearing model, transmitted by letter of July 8, 1975 and incorporated in NED-20942F. We ask that items (1) and (2) be incorporated by reference, as though filed in our Docket No. 50-331.

Recognizing the continuing nature of the confirmatory work you have requested (the Short Term Program, for example, cannot be completed until September 1975) we believe that the documents and materials referred to in the previous paragraph (and which are applicable to our facility) are in compliance with the requirements of your letter of April 17, 1975.

8211

The "Status Report" transmitted herewith summarizes the Mark I Short and Long Term Program to date. Our review of this material, together with the previously referenced correspondence, confirms our view that (1) the integrity of our primary containment will be maintained under postulated LOCA loads, including the hydrodynamic loads identified in your letter of April 17, 1975; and (2) the Duane Arnold Energy Center may continue operations under its present license, unmodified, and consistent with our overriding obligation to the Commission and the public to assure the public health and safety.

Iowa Electric Light and Power Company

By Charles W. Sandford
Charles W. Sandford
Executive Vice President

KAM/CWS/ms
Encls.
cc: D. Arnold w/o Enc.
J. Newman
R. Tedesco (NRC)

Sworn and Subscribed to before me on this 31st day of July, 1975.

Marjorie E. McDonald
Notary Public in and for the State of Iowa.

Marjorie E. McDonald
NOTARY PUBLIC
State of Iowa
Commission Expires
September 30, 1976

MARK I CONTAINMENT PROGRAM

STATUS REPORT

INTRODUCTION

This report is a summary of the progress that has been made through July 18, 1975 relative to the reevaluation of the Mark I containments to withstand a loss of coolant accident (LOCA) and the discharge of safety relief (S/R) valves into the suppression pool in light of new information that has been developed by General Electric in their testing in the Pressure Suppression Test Facility (PSTF) and that developed by foreign sources. The report also represents the basis from which conclusions are reached that the Mark I containments will maintain their function during the most probable course of the LOCA event or during S/R valve discharge and therefore continued operation of these BWRs presents no undue risks to the health and safety of the public.

BACKGROUND

To understand the need for reevaluating the Mark I containments it is necessary to review the history of the development of the technical basis for the design. In 1958 testing was begun on the concept of a pressure suppression containment for Humboldt Bay power plant. Subsequent testing was also performed for Bodega Bay power plant. These initial tests were aimed at demonstrating that the concept of pressure suppression was viable for containments and were instrumented to obtain quantitative information for establishing the design pressures of interest for the containment components. This testing simulated the loss of coolant accident (LOCA) with various equivalent pipe breaks up to approximately twice the design basis accident (DBA). The Mark I containment design that is discussed in the plants Safety Analysis Report (SAR) is based on the experimental technology gained from this testing.

From 1962 until November 1972 when GE began testing in its Pressure Suppression Test Facility (PSTF) for the Mark III containment concept, essentially no pressure suppression testing was performed. In the PSTF more sophisticated instrumentation than that used in previous testing was installed in an effort to obtain data which could be used together with the greatly advanced computer capability (from that available at the time of the Humboldt and Bodega Bay testing) to obtain a more detailed phenomonological understanding of the LOCA event. It is from this testing that the dynamic effects of the initial suppression pool swell, which occurs when the drywell air is forced into the pool at the beginning of the LOCA transient, were first identified. In addition to the PSTF test data, other LOCA related dynamic loading information obtained from testing performed by a foreign company indicates that significant random lateral loads can occur on the downcomers toward the end of the blowdown phase of the transient.

From operating plants with pressure suppression containments, the dynamic effects of safety/relief (S/R) valve discharge to the pool have been observed to be significant. For this event there is an initial short duration dynamic oscillatory loading which occurs when the air (non-condensibles) in the discharge pipe between the valve and the submerged discharge point is compressed and ejected into the pool (called vent clearing). It has also been observed that severe random oscillatory loads can occur during discharge of steam to the suppression pool when the pool water temperature is very high. The first of these phemomena will always occur but the latter can be avoided by proper corrective action to prevent the abnormal rise in pool temperature to the threshold value at which the phenomena has been observed to occur. Mark I containments have experienced the vent clearing phenomena since startup testing without loss of containment function.

In the early testing done for Mark I containments, the test facility was subjected to many test runs with simulated primary system pipe breaks up to approximately twice the DBA with no structural damage. Although this provides some confidence that the Mark I containments should also survive the LOCA event in light of the margins incorporated in the design, this conclusion is mitigated by the fact that for practical reasons, structural similitude was not maintained in the full scale Mark I's. Therefore when the details of the LOCA related suppression pool phenomena were understood, GE in early 1975 began an evaluation of the potential impact on the typical Mark I containment using information extrapolated from the PSTF tests and that available from representative foreign testing.

REFERENCE PLANT EVALUATION

In early 1975, GE began a reevaluation of a reference Mark I containment to analyze the effect on containment capability of the new information developed since it was originally designed. In performing this analysis, subjective judgement was used in selecting the new loads which were considered most significant to the capability of the containment to maintain its function during a LOCA event. The emphasis of this effort was to provide a rapid evaluation of the containments capability to obtain assurance that the function was maintained (if the most probable course of events were applied) thus assuring the health and safety of the public while a more in depth analysis was performed during continued plant operation. The screening of the new loading information and the torus and internals design resulted in the conclusions that:

1. The S/R valve discharge dynamic loads were within the capability of the torus shell but that fatigue considerations necessitate an evaluation of end of design lifetime capability.

2. The dynamic load on the torus internals, specifically the drywell to torus vents plus the ring header and column support, must be analyzed to determine the effect of water impingement during the pool swell portion of the LOCA event.

3. The dynamic load on the end of the downcomers must be analyzed to determine the effect of the random impingement toward the end of the blowdown portion of the LOCA event.

The analysis of the new LOCA related loadings was well along on the reference plant when GE made an oral presentation to the NRC staff on April 10, 1975. At that meeting GE reported their preliminary results on the analysis of the specific containment components most directly affected by pool swell, i.e.,

a. the internal ring header which distributes the steam through the downcomers to the suppression pool,

b. the vertical column supports for the ring header,

c. the column clevis itself,

d. the main drywell to ring header vents,

e. the torus to main vent bellows, and

f. the torus shell

The analysis for the lateral downcomer load focused on

a. the internal ring header as a whole, and

b. the individual downcomers.

Of these components it was reported that the critical member was the column supports for the internal ring header. The analysis of the ring header, main vents, and column supports assembly used pool swell impact loads which were extrapolated from data obtained in the PSTF test program. Applying these loads (which have subsequently been shown to be highly conservative) led to the following results and conclusions:

a. the column assembly would not structurally fail although some distortion would be expected to occur.

b. the energy required to actually fail the overall column assembly was higher than that which could reasonably be imparted to the system using realistic assumptions.

c. even if some column assemblies were to fail in tension first order estimates indicated that the main vents to the internal ring header were effective restraints to gross upward movement of the ring header although high localized strains could be expected, thus the downcomers would not lift out of the water and no bypassing of steam would be expected to occur.

Thus, based on the conservatisms believed to be present in the pool swell loads and the structural analysis, it was concluded overall that

1. The containment function (shell or ring header assembly) would be maintained given the DBA and its most probable course, i.e., using realistic assumptions relative to the effect of the pool swell effects and lateral downcomer loads.

2. Based on the fact that the Mark I plants were all designed to the same general criteria it is reasonable to assume that all the Mark Is would most likely respond in a similar manner as the plant studied, however each plant would have to be examined in a similar manner as the reference plant to confirm the judgment.

3. Although the risk of violation of the containment integrity over the short term is low, a detailed structural evaluation would be required to determine the potential for local reinforcements when considering all loads and their combinations for the total plant life time consistent with appropriate structural codes and NRC licensing requirements.

To further confirm the conclusions and judgements discussed with the NRC in the April 10, 1975 meeting, GE agreed to:

a. perform additional analysis of the ring header

b. run pool swell impact tests on larger diameter pipes in the PSTF

c. conduct a clevis test to failure

d. review other loads and the models used in the analysis

e. perform additional analysis of other loads and structures consistent with item (d).

The analysis performed by GE was completed and reported to the NRC in a June 26, 1975 letter from G. L. Gyorey to R. Maccary. Items (d) and (e) above are being performed as part of the Mark I Containment BWR Owner's group Short Term Program which is discussed in the next section of this report.

MARK I CONTAINMENT BWR OWNERS' SHORT TERM PROGRAM

All of the owners of Mark I containments including those with operating licenses as well as those with construction permits met with GE in San Jose on April 23-24, 1975. GE apprised the utilities of the analysis that was in progress for the reference Mark I plant and the conclusions that had been reached from the work completed at that time and reported to the NRC at the April 10, 1975 meeting. Prior to this meeting each utility had received letters (dated approximately February 15 and April 17, 1975) from the NRC requesting additional information on the containment design relative to the new information that had been developed relative to the LOCA related suppression phenomena and the S/R valve discharge dynamics. As a result of the common need to undertake a reevaluation of each of their containments, recognizing that a great deal of the early analysis would be very similar for all the plants, and in an effort to be as responsive as possible in the shortest time possible, the utilities chose to form an owners' group. This ad-hoc organization would enable them to pool their talents, ideas, and experience to develop a uniform approach to the questions and which would result in a strong, widely supported and technically sound program by which they could respond to the requested information.

By letters submitted to the NRC during the week of May 5, each utility with an operating plant committed to a two phase approach to the reevaluation of their Mark I containments. The two phase approach was selected because it would first provide a rapid confirmation of the adequacy of the containment to maintain function under the most probable course of the LOCA event considering the latest information available on key pool dynamic loads. This short term effort is similar to that performed by GE on the reference plant, and is a combination of in-depth analysis of structural response under the key LOCA loads, testing if considered appropriate, and development of fixes if necessary. This program is currently under way, is approximately 30 percent complete, and is scheduled to be completed in September 1975. This Short Term Program is to confirm the judgment, based on the April 10 reference plant analysis, that the other Mark I containments contain significant design margins enabling them to withstand the hypothetical LOCA considering the latest pool dynamic load even though such loads were not originally included in the design basis.

The Short Term Program is flexible and will be modified as the structural analyses identify critical structural elements which need further analysis or testing. At the present time, all the Mark I plants have been categorized into five basic groupings. A plant typical of each of these five groupings is being analyzed in depth considering the key new dynamic LOCA loads that could impact on the containment's capability to maintain its intended function during the course of the LOCA. The key loads being considered for this analysis are pool swell loads on the vent and ring headers, lateral and jet forces on the downcomers, and bubble pressure and froth impingement loads on the torus shell. The Short Term Program also consists of detailed review of the GE PSTF data to determine the loads to be used in this analysis and will incorporate small-scale Mark I model testing to verify the extrapolation of the PSTF data to the Mark I geometry.

As previously indicated the short term evaluation is approximately one-third done, and several structural elements have been identified for further evaluation via the means of full-scale hardware tests. These tests will be completed during the next month and will determine the actual load capability of (1) the containment downcomer to withstand lateral forces, (2) of the vacuum breaker nozzle to withstand pool swell impact loads, and (3) of the ring header support column to absorb the upward pool swell force on the header. Plant modification concepts will be developed based on the information developed during the short term program. If it is determined that additional margin is desirable before completing the Long Term Program for some unique plant's design details, these modifications will have been developed as a result of the Short Term Program and will be available for implementation as early as possible.

The Short Term Program has progessed to the point that a qualitative assessment can be made of Mark I containments, and no substantial differences or new information has been found that would change the original judgment based on the results of the reference plant evaluation. We conclude, therefore, from an engineering judgment standpoint, the Mark I containment will perform its intended function during the course of the LOCA event. It is firmly believed that there is sufficient margin in the design and in the load assumptions that the Mark I containments are capable of maintaining their function under the postulated event and present no danger to health and safety of the public for continued operation while this analysis is completed.

The phase two Long Term Program is being developed to address in depth all of the new pool dynamic loads and the relief valve blowdown loads. This Long Term Program will consist of a combination of testing, analysis, and development of criteria by which the results can be assessed. It also includes development of structural modifications if required to assure that all Mark I containments are capable of meeting NRC requirements with this new information, for their intended 40-year life. This Long Term Program is extensive and will not be completed until approximately the end of 1976.

SIGNIFICANT DEVELOPMENTS SINCE APRIL 10, 1975

Introduction

The results obtained from the Mark I Owners' Group Short Term Program have included:

1. Refinement of "new" loadings orally reported on April 10 and in writing on June 26.
   a. Pool swell
   b. Lateral loads on downcomers
   c. Torus vertical pressure differentials.
2. Characterization of these loads for purposes of short-term evaluation.
3. Establishment of analytical and experimental programs to evaluate the resulting stresses and strains.
4. Development of a philosophy for evaluation of the significance of these effects with respect to maintenance of the containment function.

The second and third aspects for each of the three "new" loadings are summarized under subsequent headings identified by the load designation. The fourth aspect is summarized under a subsequent paragraph entitled "Evaluation."

This overview does not consider in any detail the additional work performed during this period which included:

1. The identification of all loadings present during the LOCA event (see Figure 1).
2. The establishment of conservative estimates of the magnitude of all these loads for use in screening analyses.
3. The performance of screening analyses on all torus components subjected to all loadings to the extent required to provide a basis for judgment as to the significance with respect to the torus function.

MARK I LOCA-RELATED DYNAMIC LOADS

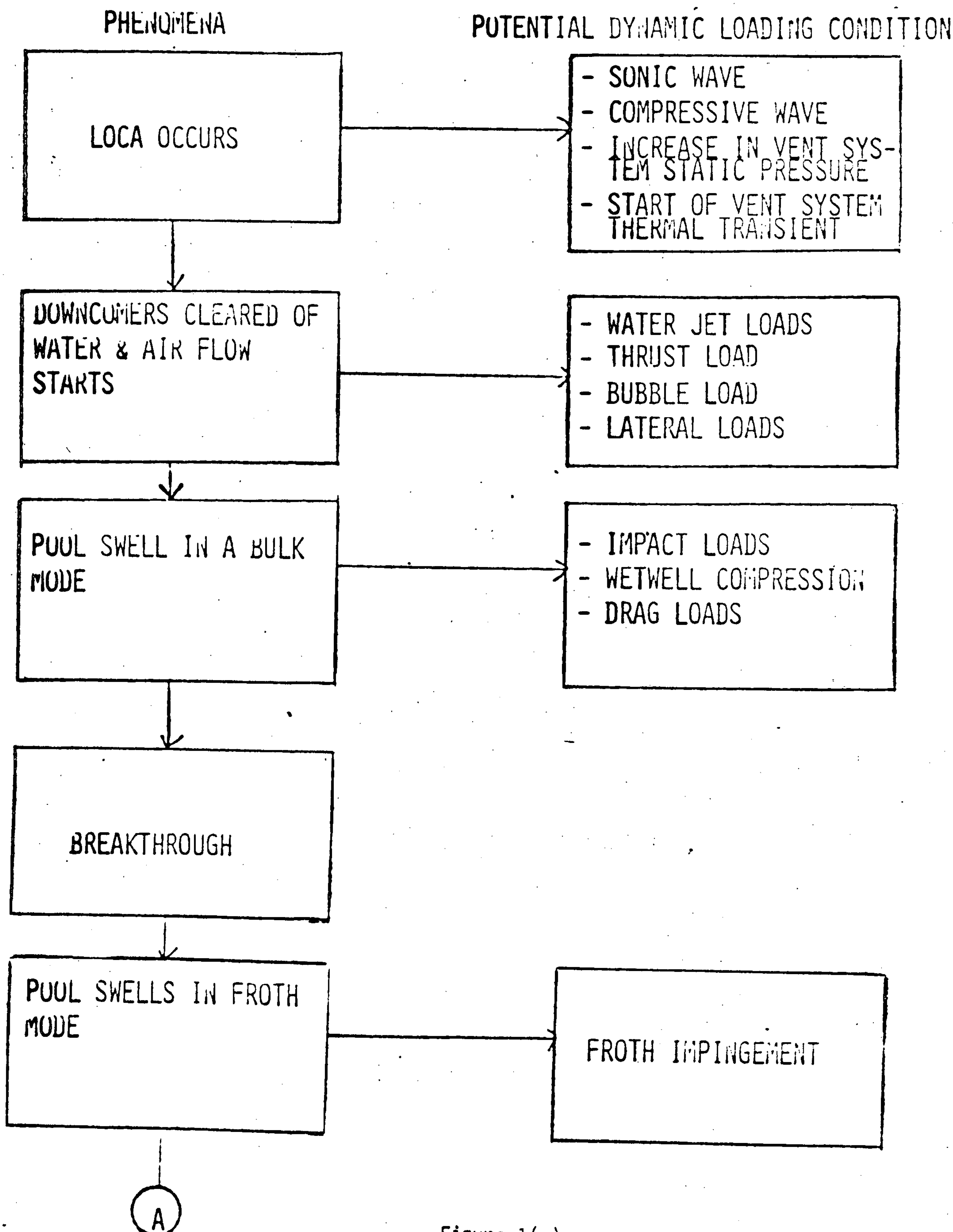

Figure 1(a)

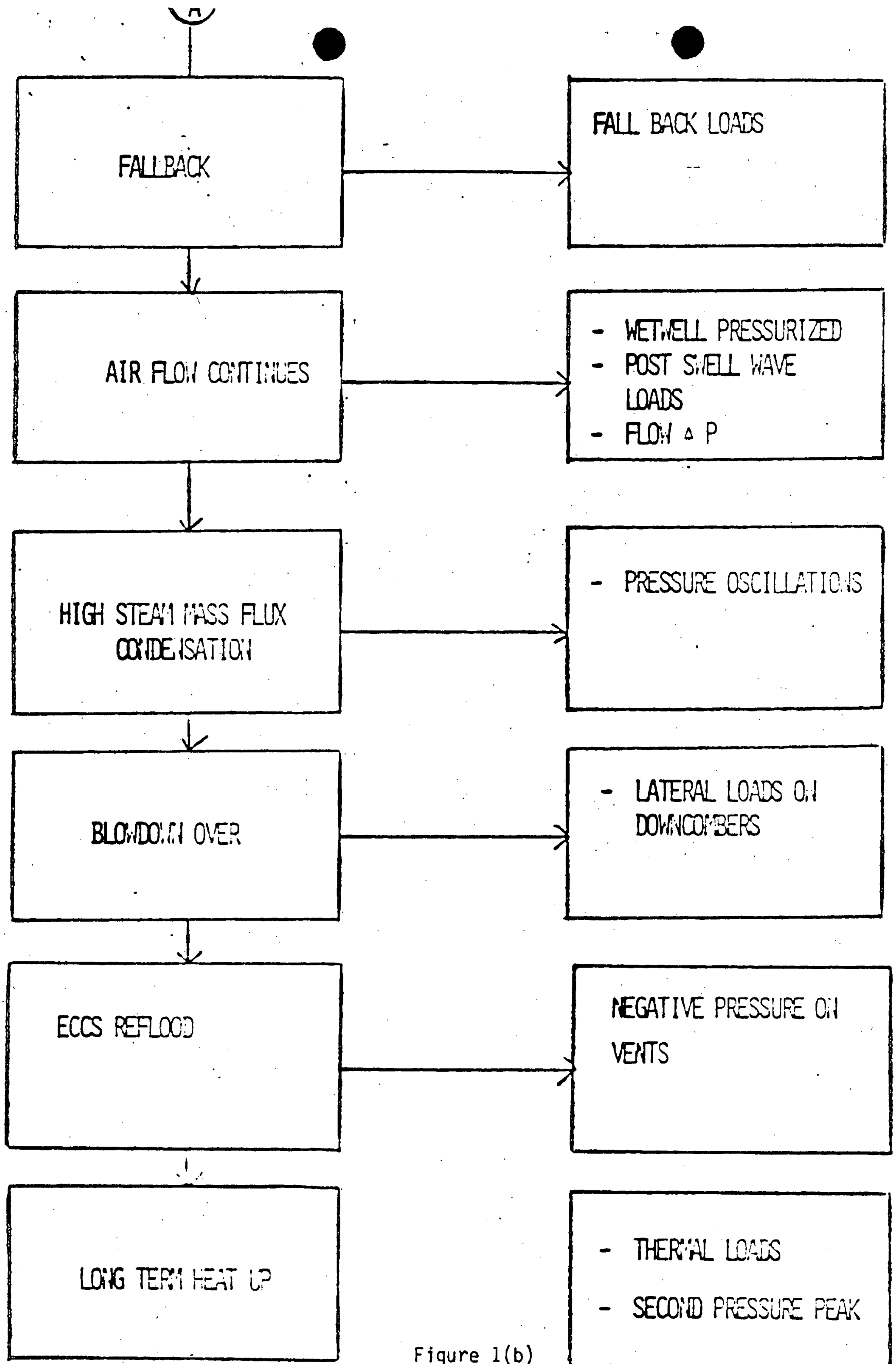
FALLBACK
FALL BACK LOADS
AIR FLOW CONTINUES
- WETWELL PRESSURIZED
- POST SWELL WAVE LOADS
- FLOW Δ P
HIGH STEAM MASS FLUX CONDENSATION
- PRESSURE OSCILLATIONS
BLOWDOWN OVER
- LATERAL LOADS ON DOWNCOMERS
ECCS REFLOOD
NEGATIVE PRESSURE ON VENTS
LONG TERM HEAT UP
- THERMAL LOADS
- SECOND PRESSURE PEAK

Figure 1(b)

As a result of these efforts, the Short Term Program concerns have been reduced to the effects of the three "new" loads on the following structures:

New Loading	Structures
Pool Swell	Ring header, ring header support columns including end connections, vents including bellows connecting to the torus, vent attachment to the drywell.
Lateral Loads	Junction region between a single downcomer and the ring header.
Torus Pressure Differentials	Torus support columns including end connections.

It should be noted that the torus shell has been identified as one of the structures which is not of specific concern. The only possible exception to this conclusion, and one being evaluated, is the region of the torus through which the vents pass. All support column anchorages to the torus shell are by means of stiffening rings or large brackets. The shell stresses adjacent to such structures will be evaluated to confirm the preliminary conclusion that the stresses are too low to be of concern.

Pool Swell

Load Definition

The pool swell loading is being defined in terms of a pressure, averaged over the horizontal projection width of each structure per unit length, acting for a specific duration of time. The time duration is less than the period of the structure, i.e., the effect is that of an impulsive loading rather than static.

The first step is, therefore, that of establishing the impulse which must be considered. The important factors in establishing this quantity are:

1. Shape and striking velocity of the pool surface.

2. Establishment of the hydro-dynamic mass.

For a rigid impacted structure, the impulse per unit length is the product of the velocity and the hydro-dynamic mass.

The General Electric PSTF experiments, which did not necessarily include geometries typical of the Mark I torus, indicated that the pool surface was essentially flat at impact and that the velocity could be reasonably predicted from a simple pool swell model if the effective pool width could be defined. Initial conservative estimates of this velocity applied the assumption that 50 percent of the pool diameter was effective, giving velocity of 35 fps. Electric Power Research Institue designed and built a model which represented the Mark I geometry which was valid for the time periods shortly beyond the time of impact. Their visual tests indicated that the pool surface remained essentially flat at the point of impact, that something more than 80 percent of the pool width was effective, and that the impact velocity was 22 fps maximum. (A conservative value of 24 fps was presented at the July 17 meeting because data analysis was not complete when the presentation was prepared. GE tests of pool surfaces contacting structures had been performed which included 10" and 20" diameter pipes. Their results were utilized with information available from the literature, particularly Ochi and Schwartz, to establish the hydro-dynamic mass.)

Knowing the striking velocity and the hydro-dynamic mass, the impulse was determined for the 58" diameter ring header typical of the Mark I containment.

The experimental data also provided a value for the time duration of the impulse, and information as to the shape of the pressure-time curves which should be considered. However, when the impulse time is short compared to the fundamental frequency at the structure to which the impact is to be applied, the elastic structural response is dependent only upon the magnitude of the impulse, and is independent of the exact shape of the pressure-time curve or of the maximum pressure or duration of the impulse. This is the case for the typical Mark I structure if the response is completely elastic.

The other practical consideration with respect to the Mark I structures is that geometric imperfections (construction tolerances, etc.) will result in the pool impact occurring at slightly different times at different positions along the structure. Therefore, although the pressure-time pulse at any given location will be characterized by a near-step application with exponential decay, the total effect on the structure will be distributed over a longer time period and the sharp peaks will be reduced.

For the reasons discussed in the last two paragraphs, as well as for consistency with GE data, the decision was made to use a parabolic pressure-time history. The next question, within the limit that the total impulse was to be kept consistent, was the decision as to what duration time was to be used. Although the elastic response of a structure is independent of the pulse shape for impulse durations, less than about 40 percent of the response period of the structure inelastic response is dependent upon the duration. Specifically, inelastic deformations are increased by increased duration time. Therefore, it was considered conservative to use the maximum duration time for which the elastic response was essentially independent of the exact shape of the pulse. For a parabolic pulse, and for most pulses of possible interest, the upper limit is essentially such that the pulse duration time, t_0, is 30 percent of the period of the structure. Therefore, we have used

$$t_0 = 0.3/f$$

where f is the frequency (HZ).

To maintain the impulse appropriate to a striking velocity of 22 fps, the maximum pressure, P_{max}, at the parabolic pulse is then

$$P_{max} = 1.23 f$$

For a fundamental frequency at 20 HZ, typical at the ring header assembly in Mark I containments:

$$P_{max} = 24.6 \text{ psi}$$

$$t_o = 0.015 \text{ sec}$$

The values just developed include some consideration of the "real-life" influences which contribute to the decision as to the pressure-time pulse to be considered in the subsequent evaluation. However, the above values continue to use the impulse developed directly from the experimental program. Some of the considerations discussed will also tend to reduce the impulse, but the important factor is component flexibility which has not yet been discussed.

The pressure maximum can be determined from an equation of the form:

$$P_{max} = C \left(1 - \frac{V_f}{V_o}\right) V_o^2$$

where P_{max} = maximum pressure, psi

V_o = pool velocity at impact

V_f = pipe velocity after impact

C = a numerical quantity depending upon dimensions, densities, etc.

The previous analyses have assumed that the pipe is rigid, hence $V_f = 0$.

Two types of pipe flexibilities should be considered in evaluating V_f:

1. Assembly tolerance resulting in clearances in the support columns.

2. Elastic and plastic, if any, disturbance of the structures before and during impact.

The second of these includes both the supports and the ring header, and for the latter includes both beam bending and ovalization effects. To obtain a numerical sensitivity for this effect, at the other limit where the header is considered to be completely free rather than rigid and rigidly supported, the maximum pressure would be reduced to about 1/3 rd of the values presently used. We believe that these effects in the actual structure could reduce the maximum pressure to close to 50 percent of that being used in the analysis. Subsequent evaluations will take credit for such effects, if required and as appropriate.

The present input for a 20 HZ system may be compared to the values as of April 10 as follows:

Quantity	April 10	Present	Ratio
P_{max}	38	24.6	1.5
t_o	.068	.015	4.5
Impulse	1.723	0.227	7.6

(Impulse = 2/3 P_{max} t_o)

This reduction is so great that the pool swell load which was originally considered to be the most significant of the three "new" loads may now be of least significance.

Analytical and Experimental Program

The action plan developed by Bechtel, and which is now under way may be summarized as follows:

1. Elastic analysis of beam models

   Objectives:
   - To aid plant grouping and selection of cases for inelastic analysis, if required.
   - To obtain first-cut prediction of vent system dynamic response.

2. Critical structural element evaluation and tests

   Objectives:
   - To identify critical elements
   - To identify testable items
   - To establish load carrying capacity by tests
   - To develop structural modification schemes
   - To establish dynamic material properties

3. Establish boundary conditions

   Objectives:
   - To provide linear springs for Task 1
   - To provide refined spring constants for Task 4

4. Inelastic analysis of beam models, if required

   Objectives:
   - To obtain preliminary assessment of containment integrity
   - To provide input for Task 6

5. Finite element shell analysis of vent system, if required

   Objectives:
   - To assess significance of shell response
   - To provide input for Task 6

6. Detailed finite element analysis of local areas

   Objective:
   - To make final assessment of containment integrity (vent system supports, and boundaries)

Experimental Program

All of these efforts are being conducted in parallel, including the modeling for Items 4 and 5 in case these efforts are required. As of the July 17 meeting with NRC, the work was 25 percent complete. One of the results of Step 2 has been the identification for the ring header support column end connection details as an item which could be limiting and which is testable. Such tests, as well as tests to determine the strain rate effects on materials of specific interests, are being started.

The results obtained to date have not resulted in any new information which would lead to any different conclusions, i.e. the containment is maintained during the LOCA event.

LATERAL LOADS

Load Definition

Based upon a preliminary and conservative evaluation of available (primarily GE Licensee) data, the original downcomer lateral load was established as an 8.8 kips random load on each downcomer. It was also defined that a total of 20 downcomers could experience that level of load in the same direction at any one time, with the resultant load on all other downcomers being zero.

Since that time the data have been reviewed in detail, and the following have been established:

1. The load on a given downcomer varies at 1 HZ and experiences a total of 250 cycles.

2. The resulting force is dependent upon pool temperature, steam mass flux and percent air.

3. A probabilistic study of common load direction.

Based upon these investigations, it has been concluded that:

1. The peak load to be used for evaluation of an individual downcomer is 5.5 kips.

2. The mean load is 50 percent of the peak load.

3. Probability studies will be used to assess multiple downcomer loading.

The primary factor in reducing the peak load to be applied to any downcomer is the effect of pool temperature. The 5500 lb value is the maximum value to be expected given a LOCA occurs while at normal operating pool temperature and the peak load occurs approximately 35 seconds after LOCA initiation. Only during hot standby at the highest pool temperature could the highest (8800 lb) load occur. Since the plant is typically at hot standby only two to three percent of the time, the 5500 lb value is justified for this evaluation.

Although efforts to further refine this loading are under way, they are not presently expected to be of value to the Short Term Program. Further tests may be required, and these would be performed as part of the Long Term Program.

Analytical and Experimental Programs

The Bechtel structural analysis effort includes consideration of both individual and multiple downcomer loadings. However, preliminary results indicate that the individual downcomer case is the one of most interest.

Since the stresses in the ring headers adjacent to the attachment points of a downcomer are of the most significance, a test of such a configuration, as shown on Figure 2, has been started. The test specimen will also contain a vacuum breaker fitting for possible testing.

TORUS PRESSURE DIFFERENTIALS

Load Definition

The possible significant effects of this loading have been established recently. Two effects which are opposite in direction and separated in time with respect to their peaks have been established. These are:

MARK I-SHORT TERM PROGRAM
TESTING OF CRITICAL STRUCTURAL ELEMENTS

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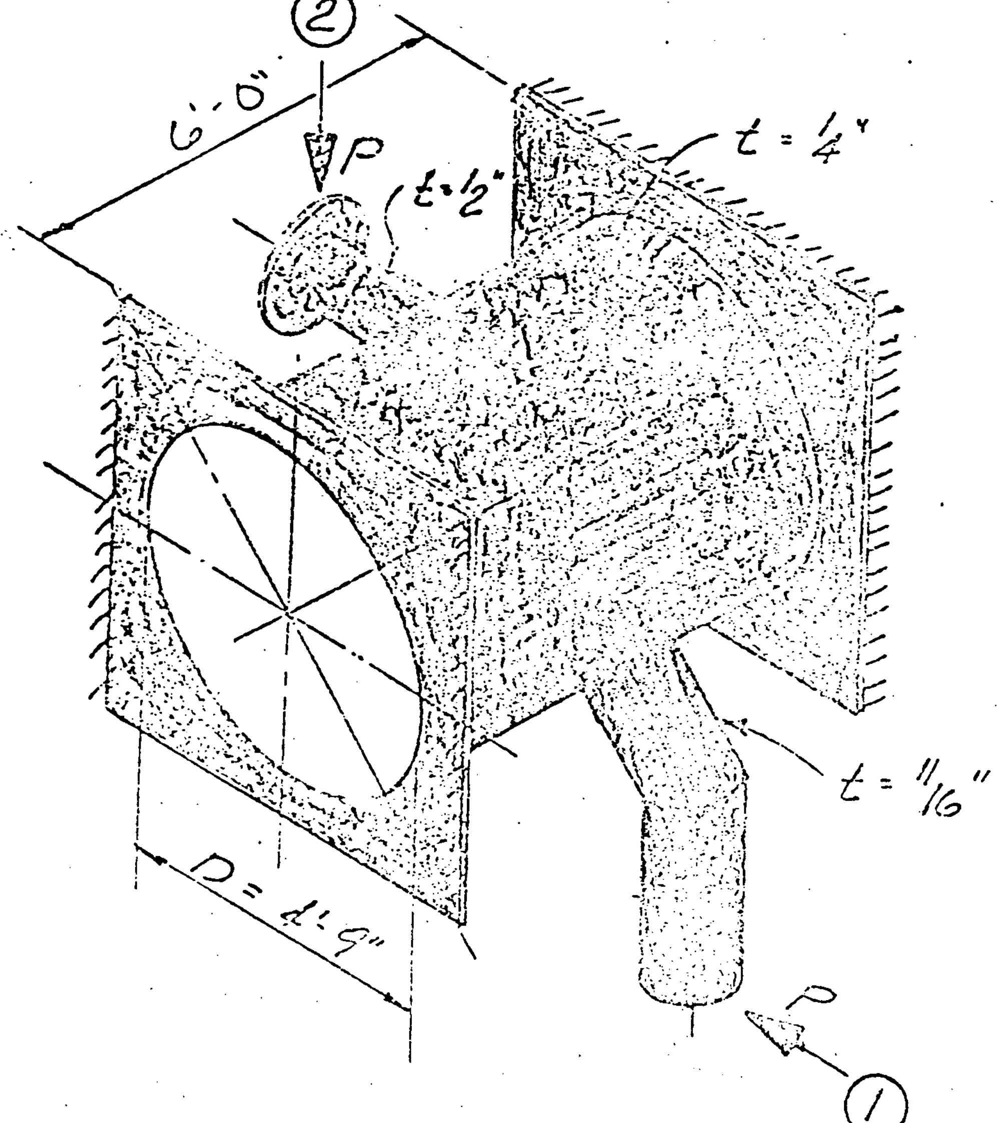
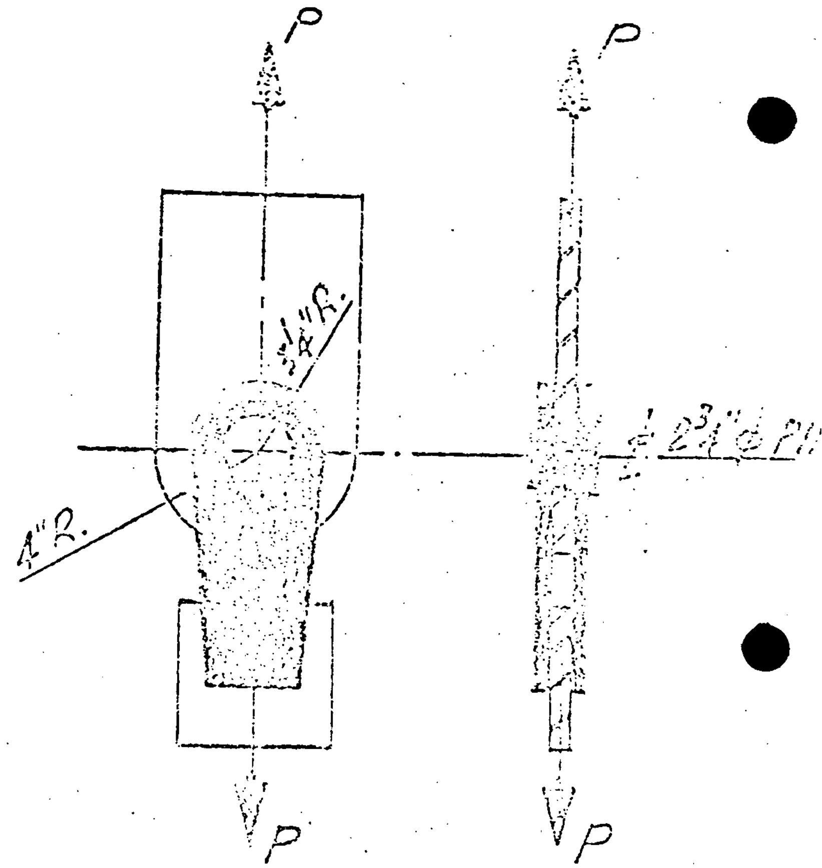


RING HEADER DOWNCOMER TEST № 1
RING HEADER VACUUM BREAKER TEST № 2



RING HEADER PIN CONN.
TEST № 3

Figure 2

1. A resultant downward force on the torus during the initial phase of bubble formation.

2. A resultant upward force on the torus at approximately the time of bubble breakthrough.

Review of available data from the test facility has been used to establish conservative and approximate pressures and effective areas, hence forces, for use in preliminary scoping studies. These are:

1. 17 psi over half the torus area, downward.

2. 10 psi over the entire torus area, upward.

If these loadings are established to be of significance, they will be refined and most probable values established.

The potential problems are entirely within the external torus support columns. The concern is column buckling as a result of the downward force and excessive tension of the columns during the later upward force. This effort is now in the scoping phase.

OVERALL EVALUATION

It is expected that the majority of the structural components will be shown to be in conformance with the Codes and Standards applicable to normal practices within the nuclear industry.

However, since these "new" loadings were not specifically considered at the time of initial design, it is possible that code stress limits will be exceeded in local areas, but the loadings are expected to result in acceptable strain limits. The objective of the Short Term Program is to demonstrate that these effects do not result in loss of the containment function. Therefore, it may be found that some components are stressed to levels higher than is permitted in the design phase but to levels lower than those which would result in loss of the containment function. In the event that the Short Term Program should result in levels above the latter on any specific plant component, the NRC will be immediately notified and action plans to implement any modification will be presented.

The development of existing ASME Code criteria did not consider hydro-dynamic loadings such as those associated with pool swell. The special considerations of NE-3131.2, as applicable to jet impingement and associated reaction effects, are illustrative of the treatment which must be accorded to such hydro-dynamic loads. Therefore there is precedence for providing special rules for loadings other than normal containment pressure.

Should such special evaluations be required during the Short Term Program, the gross failure prevention considerations of Appendix F of the ASME Code will be used to provide guidance in evaluating the results of the Short Term Program.

SCREENING ANALYSIS

Loads were determined to be insignificant if they were either of very small magnitude in themselves (i.e., sonic waves have never been observed in tests, for example) or if the resultant stress on a first order basis was low relative to the strength of the specific member, for example, less than 5000 psi for torus membrance stress due to impact load from level swell. The loads thus considered were:

Thermal Growth	Stresses are not significant relative to time of pool swell since metal temperature changes are on the order of $10^{o}F$.
LOCA Wave Action	Even assuming 2 foot waves, the bending stresses were much lower than lateral vent load stresses.
Growth of Drywell due to Pressure	Less than 500 psi stress during first few seconds.
Torus Shell Stresses due to Bubble Pressure Load	Less than 5000 psi membrane stresses even with conservative bubble pressures assumed.
Fall-back Loads	Vent headers can handle even if lateral columns are assumed to buckle.
Water Jet Loads on Torus	This load is less than 5 percent of torus dead weight and hence insignificant.

The other loads listed in Figure 3 were not significant because they were of such a small magnitude in themselves.

In addition various internal structures have been reviewed in a preliminary manner for pool swell and drag loads. Only the relief valve line over the pool and the vacuum breakers attached to the ring header have significant loads imposed. These will therefore be examined in detail during the remainder of the Short Term Program.

The other items examined were torus baffles, emergency core cooling system suction nozzles, high pressure cooling injection exhaust line, residual heat removal return line, reactor core isolation cooling discharge lines, core spray return lines, the catwalks, the one-inch reactor vessel pipe drain lines, and torus spray header.

The one-inch reactor vessel piping drain lines and core spray test section lines were the highest stressed items. Significant yielding is expected in the former but no failure due to its flexibility. The latter was not stressed sufficiently to fail although stressed beyond yield. To assure that the one-inch line could not impair containment integrity, a gross missile calculation indicated that the torus could tolerate much larger missiles at velocities in excess of the maximum pool velocity. Because of the results of the screening analysis discussed above we can conclude that the typical internal structures of the Mark I containments should not cause loss of either containment or emergency core cooling system function and that these can be addressed during the Long Term Program.

SECONDARY LOADING PHENOMENA NOT LIKELY TO BE SIGNIFICANT

- NEGATIVE PRESSURE ON VENT SYSTEM
- INITIAL DRYWELL COMPRESSION WAVE
- DRYWELL OVER-EXPANSION OSCILLATION
- WATER JET IMPINGEMENT ON TORUS
- POOL SWELL IMPACT, IMPINGEMENT, DRAG LOADS ON SMALL STRUCTURES ABOVE POOL
- FALLBACK LOADS
- POOL SWELL DRAG AND BUBBLE PRESSURE LOADS ON STRUCTURES IN POOL
- ASYMMETRIC MAIN DOWNCOMER CLEARING LOADS
- CONDENSATION OSCILLATION LOAD ON TORUS
- DOWNCOMER LATERAL LOAD DURING AIR CLEARING
- AIR BUBBLE OSCILLATORY LOADS
- CHUGGING

Figure 3

COMPARISON OF OTHER PLANTS WITH REFERENCE PLANT

Vent Header System and Column Supports

A group of 16 BWR nuclear power plants is used for this analytical study. These plants were all of the Mark I generic family of containments. This design used a torus suppression pool contained in an external torus connected to the drywell by a series of vent pipes. For this standard arrangement there was an evolution of design details over the years from 1965 to 1973. These design changes were also related to the age of the design so that the basic classification was by age.

Early plants were considered to be built in the period from 1965 to 1968. The mid-term plants were built from 1967 to 1970 and the late period plants were built from 1969 to 1973. Further classifications were made by considering the number of vents (ten in earliest designs, eight in later designs) and by considering the details of the vent-to-header intersection structures. These intersection structures are illustrated in Figure 4 and vary depending on the intersection shape and stiffening details. One plant had a steel-lined concrete containment and torus and so was listed as a separate group. The plant groupings are given in Table I.

The response of a vent-header system was estimated by first applying the expected peak dynamic pressure to the system as a static loading. The dynamic pressure-time history was arranged for these analyses such that the dynamic load factor (DLF) would be about 1.3. Hence the results of the static approximation X1.3 would estimate the maximum dynamic stresses for that group of plants.

Assuming that all plants had a vertical first mode at about 20 cps then the pressure-time pulse had a peak at 25* psi and was assumed to be parabolic over a time base of 15 milliseconds. This peak pressure was used with the projected area of each vent-header system to give a total static force on each. Only a 1/8 or 1/10 segment needed to be considered tributary to a single vent in each instance.

The maximum static loads calculated were 765 kips for both Peach Bottom and Browns Ferry plants. Most of the force applied to the vent-header system is reacted through the header support columns and the remainder is reacted at the vent-drywell intersection. Hence it was significant that all plants had four support columns per vent except for Browns Ferry which had two support columns per vent. The other support column variable was the pipe diameter. All plants had 6" ϕ Sch. 80 pipe columns except for Oyster Creek and Duane Arnold which had 4" ϕ Sch. 30 pipe columns. Of these two plants the maximum static column load was for Oyster Creek at 148 kips. Converting column loads to stresses and applying the DLF gave the following:

Oyster Creek: 148 kips x 1.3/4.4 = 44 ksi

Browns Ferry: 383 kips x 1.3/8.4 = 59 ksi.

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* These numbers were used to compare the other plants with the reference plant as part of a parametric analysis.

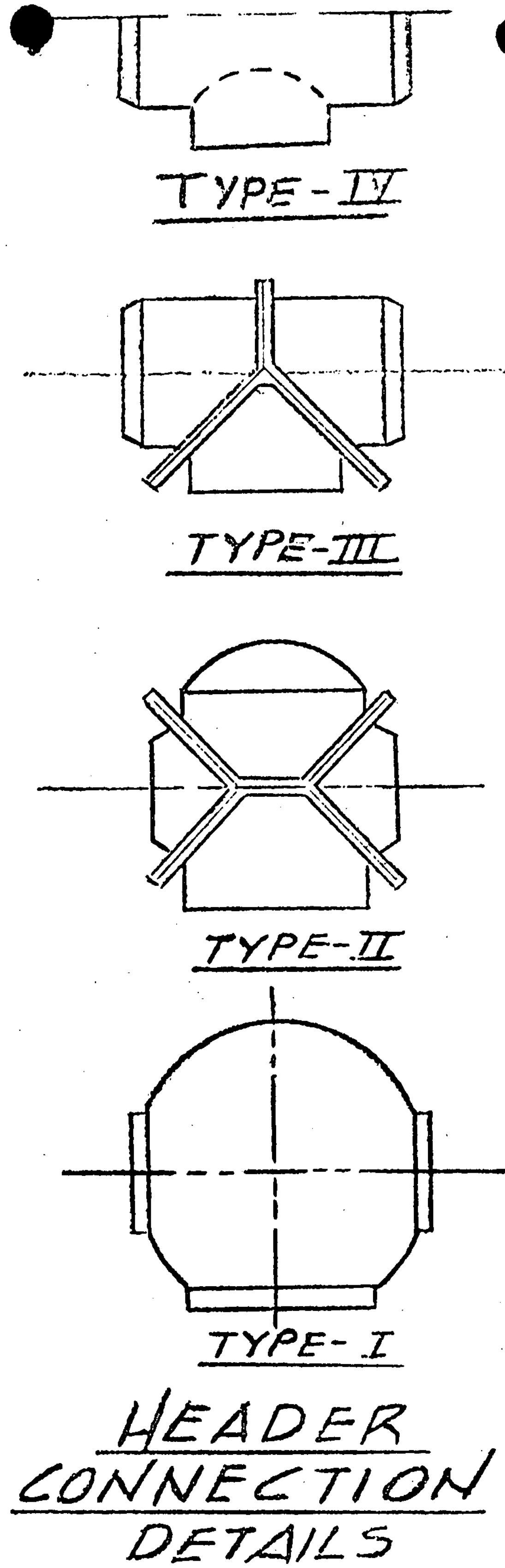

FIGURE 4

Table 1. Preliminary Plant Groupings

Group	Plants	Age/Intersection Type
I	Oyster Creek	Early/Type II
II	Nine Mile Point, #1	Early/Type I
	Dresden, #2 & #3	Early/Type I
	Quad Cities, #1 & #2	Early/Type I
III	Millstone, #1	Mid/Type II
	Monticello	Mid/Type II
	Vermont Yankee	Mid/Type II
	Pilgrim	Mid/Type II
	Peach Bottom, #2 & #3	Mid/Type II
IV	FitzPatrick	Late/Type III
	Cooper Station	Late/Type III
	Duane Arnold	Late/Type III
	Hatch #1 & #2	Late/Type III
	Fermi, #2	Late/Type III
	Browns Ferry	Late/Type IV
V	Brunswick, #1 & #2	Late/Type III

Both plants used ASTM A333 Gr. 1 steel for the pipe columns having a minimum specified yield point of 30 ksi. Applying a dynamic increase factor of 1.4 for high strain rate loading raises the estimated yield point to 42 ksi minimum. The results of the 17 psi peak pressure applied as a static load is shown in Table II for all plants. This demonstrates that the Browns Ferry plant is suitable as the reference plant. These calculations also demonstrate that only one other plant would be expected to be near critical stressing due to the given load impulse definition. That plant, Oyster Creek, is included in the scope of the Mark I Short Term Program to investigate pool swell loading effects.

Vent-Header Intersections

The intersection types are shown in Figure 4 and comprise two types of stiffened connections and two types that are unstiffened. Twelve plants in this study had the stiffened types in their design and three plants had the unstiffened spherical joints. All of these were expected to be inherently less critical in stress behavior, for a given loading, than the unstiffened cylinder intersection. This latter type was unique to the Browns Ferry plant which was used for the reference.

Vent-to-Torus Clearance Gap

For every plant considered in this study the vent pipes pass through the torus shell with a clearance to permit relative motions. The vent-to-torus seal is preserved by an expansion bellows which surrounds the vent pipe and attaches to the torus shell.

Induced displacement of the vent pipe will reduce the available clearance gap. Sufficient motion would imply possible contact between vent and torus at this location. All of the plants studied had clearance gaps greater than 2-1/2 inches except for Browns Ferry which had a gap of one inch. This made Browns Ferry the critical plant for observation of this feature.

Vacuum Breaker Line Arrangements

The vacuum breaker lines and valves have two basic kinds of arrangements in the plants being studied. Six of the plants have the vacuum breaker attached to the vent pipes outside of the torus. Consequently these valves are not themselves subjected to impact from the pool swell phenomenon. However, the remaining ten plants, including Browns Ferry, have the vacuum breaker valve located within the torus. These are typically attached to the vent-to-header intersection structure and are subject to impact from pool swell. Thus Browns Ferry represents another critical feature in this study as the reference plant.

Other Structural Systems

The original reference plant evaluation was restricted to the vent header system which was considered to be most critical to the containment function. Scoping type analyses using bounding loads were made for other structural

Table II. Static Peak Pressure Column Loads

Plant	Approximate Projected Area ft^2	Total Load kips	Support Column Load kips	Support Column Stress ksi
Oyster Creek	242	592	148	33.7
Nine Mile Point	286	700	175	20.8
Dresden	307	752	188	22.4
Quad Cities	307	752	188	22.4
Millstone	291	712	178	21.2
Monticello	284	695	174	20.7
Vermont Yankee	284	695	174	20.7
Pilgrim	291	712	178	21.2
Peach Bottom	312	764	191	22.7
FitzPatrick	301	734	184	21.9
Cooper	259	634	158	18.9
Duane Arnold	207	507	127	28.8
Hatch	284	695	174	20.7
Fermi	278	681	170	20.2
Browns Ferry	311	761	381	45.3
Brunswick	287	702	176	20.9

17 psi peak pressure = 2.448 ksf pressure static
(DLF not applied)

components in the reference plant. The structural response of the components like torus shell walls, miscellaneous piping, baffles, cat walks, etc., were found to be non-critical to the maintenance of containment function. The other plants have roughly similar components which are being subjected to similar structural evaluation in the Short Term Program.

The Browns Ferry torus is supported on cradles which are short and stubby in comparison to the columns which support the torus on the other plants. These external supports will be subjected to extensive structural investigations in the Short Term Program work on the definition of most probable loads and structural modeling of the support systems which is in progress. Based on the information available today, we believe that it is unlikely that support system will jeopardize the containment function for most probable bubble pressure loads.

Other Considerations

A consideration in evaluating the Mark I containments is that the LOCA event for which the containment is designed is of very low probability. The reasons for this low probability have been documented in the various FSARs and other literature. The key reason for the low probability is that, realistically, leaks will occur before the sudden rupture which is postulated as the design basis event. This permits orderly shutdown before piping rupture can occur. Since it is generally accepted that a sudden and complete rupture design basis event is highly probabilistic, it must be recognized that the probability of the event occurring within the specific time span of the Short Term Program is significantly lower than the probability of its occurrence over the plant lifetime.

In addition to the event itself the consequences used as a design basis are probabilistic also. For instance, the maximum flow rates assumed can only occur for breaks very near the vessel.

Thus even though the same assumptions that are used in the FSAR are used to determine the pool driving function for these calculations, these considerations help place the entire event in proper perspective. This coupled with the results of the hydraulic and structural analyses described earlier form the basis for the judgment that continued operation of the Mark I plants is reasonable and prudent during the completion of the Short Term Program.

CONCLUSIONS

Based on the structural considerations discussed above and the fact that all the Mark Is are designed to approximately the same loading conditions* the most significant conclusions determined from the reference plant analyses conducted by General Electric will be in general applicable to the other Mark I containments. The work conducted to date has not uncovered any differences between the various plants so significant as to invalidate the reference plant conclusion that the basic containment function would not be jeopardized given the most probable course of the LOCA event.

* Two plants were designed with a lower pressure torus. However, the torus shell itself has not been found to be one of the critical structural areas of significance to the Short Term Program.