# MARK I CONTAINMENT PROGRAM

## PROGRAM ACTION PLAN

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# SECTION I

# INTRODUCTION

# I. INTRODUCTION

This Program Action Plan provides a detailed description of project management information in an integrated format for the Mark I Containment Program. The Program Action Plan defines the objectives of the Program, gives Program task descriptions and displays the integration of the activities leading to a definition of loads for final reevaluation of the containment structure by the individual utilities. This report includes for reference purposes, a brief summary of the historical background related to the reevaluation program for Mark I containments.

The technical approach followed in the Mark I Containment Program is summarized and key decision-making milestones are identified. The pressure suppression loads are described and the technical tasks which establish load magnitudes are explained in the context of their interrelationship and their support of final load determination. The testing activities contained in this Program and their integration with analytical activities are also summarized. The expected followup activities which individual Mark I Owners may enter into upon completion of load definitions for the Mark I Containment Program are identified. A fundamental objective of this Program is to quantify more precisely and to confirm the various Loss-of-Coolant Accident and Safety Relief Valve loads for application to Mark I Containment plants. Both non-mitigation base loads and mitigated (by operational changes, design modifications or addition of devices) loads are currently included in the Program.

Since the Mark I Containment Program is expected to be continually modified on the basis of newly acquired test data and analyses and the key decisions that follow from this additional information, the Program Action Plan has been constructed in a flexible format which permits an update of the information as required.

# SECTION II

# BACKGROUND

## II. BACKGROUND

### 1. MARK I CONTAINMENT - GENERAL SYSTEM DESCRIPTION

The Mark I containment is a vapor suppression system which houses the BWR vessel, the reactor coolant recirculating loops and other branch connections of the Nuclear Steam Supply System (NSSS). It consists of a drywell, a vapor suppression chamber which contains a large volume of water, a vent system connecting the drywell and the water pool, isolation valves, containment cooling systems, and other service equipment. For most Mark I plants, the vapor suppression chamber is a steel pressure vessel in the shape of a torus; it is located below and encircles the drywell. The suppression chamber is on supports which transmit vertical and seismic loading to the reinforced concrete foundation slab of the reactor building. The drywell-to-wetwell vents are connected to a vent header contained within the airspace of the suppression chamber. Projecting downward from the vent header are the downcomer pipes, which are nominally 24 inches in diameter and terminate approximately 4 feet below the water surface of the pool. The pressure suppression chamber in relation to the steel drywell is shown in Figure II-1. Figure II-2 shows a typical cross-section through the suppression chamber.

In the highly unlikely event of an NSSS piping failure within the drywell, reactor water and steam are released into the drywell atmosphere. As a result of increased drywell pressure a mixture of drywell atmosphere, steam, and water is forced through the vent system into the pool of water which is stored in the suppression chamber. The steam vapor condenses in the suppression pool. The drywell atmosphere is initially transferred to the suppression chamber and pressurizes the chamber. At the end of the blowdown the chamber is vented to the drywell to equalize the pressures between the two vessels. Cooling systems are provided to remove decay heat from the reactor core, the drywell, and the water in the suppression chamber; this provides continuous cooling of the primary containment under the postulated accident conditions.

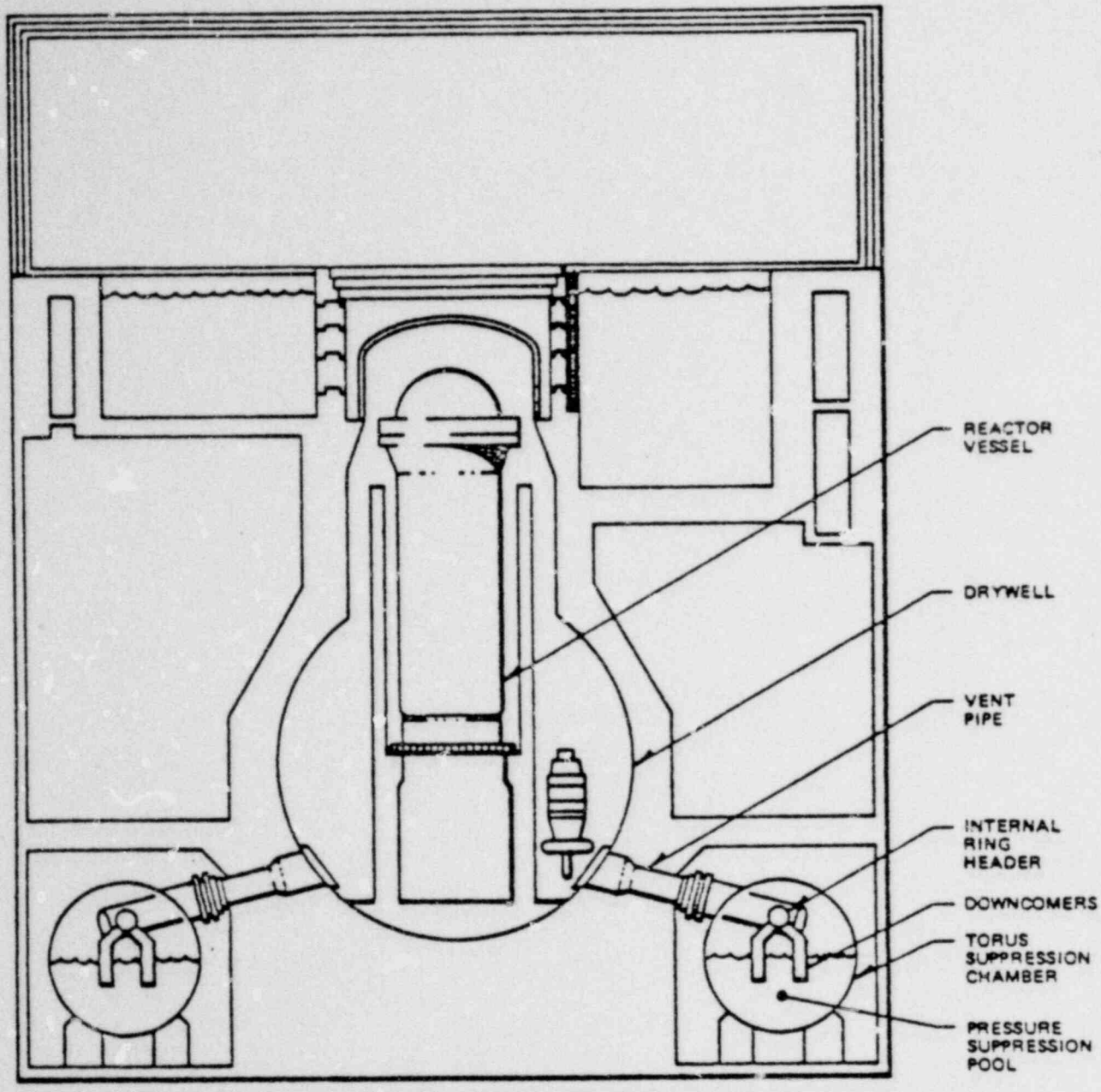


Figure II-1. Mark I Containment

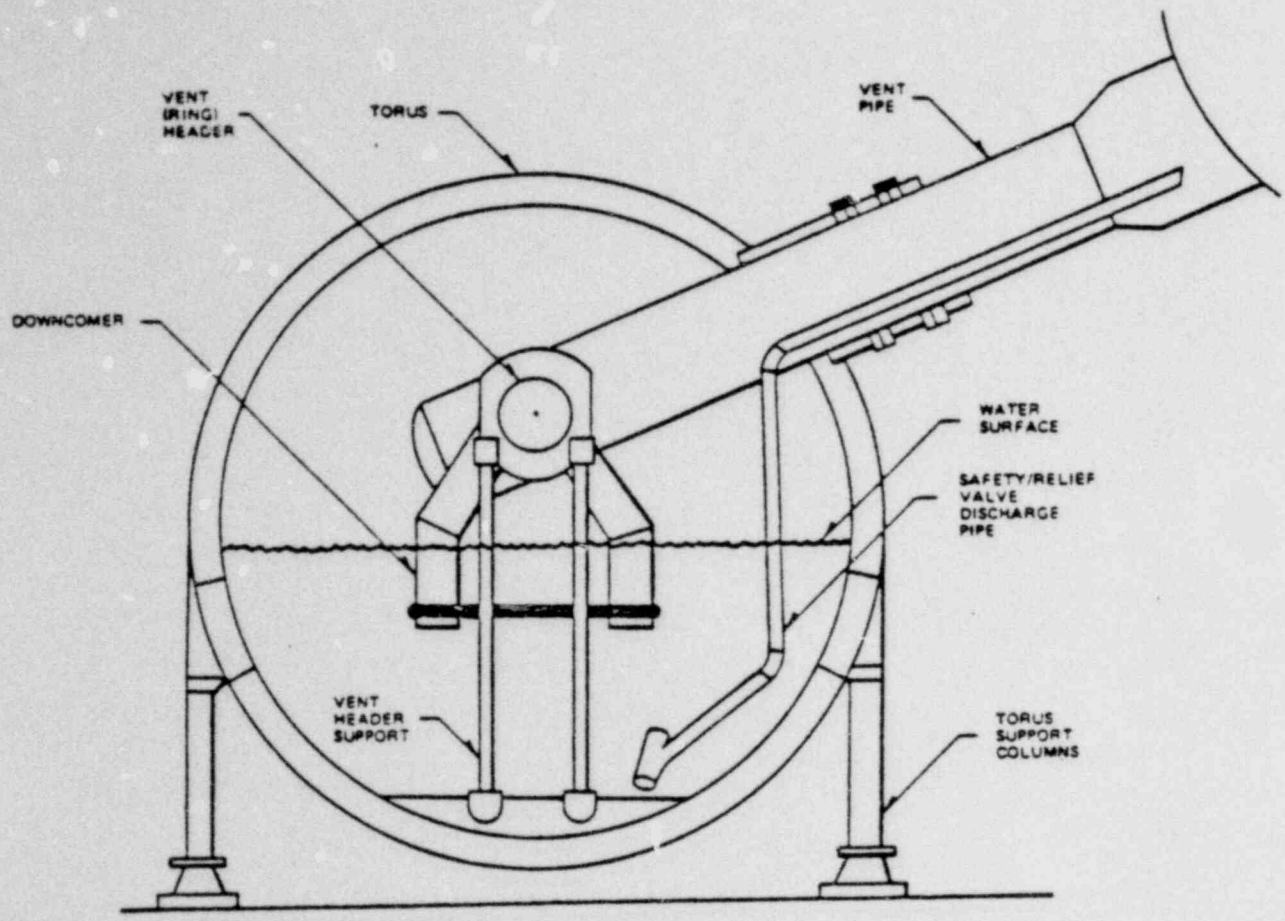


Figure II-2. Composite Section through Suppression Chamber

## 2. HISTORICAL DEVELOPMENT OF MARK I CONTAINMENT PROGRAM

In February and April 1975, the NRC requested that the utilities with a Mark I containment provide additional information on the capability of its structure. The February 1975 letters reflected concerns about the dynamic nature of safety relief valve (S/RV) discharge, while the April 1975 letters indicated the need to evaluate the containment structure for newly identified dynamic loads associated with the Loss-of-Coolant Accident (LOCA). On April 23, 1975, the domestic Mark I containment owners met and formed an ad-hoc Owners Group to respond to these NRC requests for additional information. Note, the utilities currently in the Mark I Owners Group are shown in Table II-1. Recognizing that the additional evaluation work would be very similar for all plants, this organization was formed to pool the available talents, ideas, and experience so that a uniform and technically sound program could be established to respond to the NRC requests in the shortest time possible. The Mark I Owners Group organization is given in Figure II-3. The organizational hierarchy is designed to coordinate the opinions of all Mark I Owners into a cohesive program.

A two-phase program was established and identified to the NRC in letters submitted during the week of May 5, 1975. The Phase I effort, called the Short Term Program (STP), would provide a rapid confirmation of the adequacy of the containment to maintain its integrity under the most probable course of the postulated Loss-of-Coolant Accident considering the latest available information on the key suppression pool dynamic loads. The first phase would thus demonstrate the acceptability of continued operation during the performance of Phase II, called the Long Term Program (LTP), where detailed testing and analytical work would be performed to define the specific design loads against which the containment is assessed to establish conformance to established acceptance criteria.

The initial portion of the Phase I task of evaluating the integrity of the containment vent system and vent system supports is documented in a

TABLE II-1

MARK I UTILITIES AND PLANTS

| UTILITY NAME | PLANT NAME |
|---|---|
| Boston Edison Company<br>Boston, Massachusetts | Pilgrim |
| Carolina Power & Light Company<br>Raleigh, North Carolina | Brunswick 1,2 |
| Commonwealth Edison Company<br>Chicago, Illinois | Dresden 2,3<br>Quad Cities 1,2 |
| Detroit Edison Company<br>Detroit, Michigan | Fermi 2 |
| Georgia Power Company<br>Atlanta, Georgia | Hatch 1,2 |
| Iowa Electric Light & Power Company<br>Cedar Rapids, Iowa | Duane Arnold |
| Jersey Central Power & Light Company<br>Morristown, New Jersey | Oyster Creek |
| Nebraska Public Power District<br>Columbus, Nebraska | Cooper |
| Niagara Mohawk Power Corporation<br>Syracuse, New York | Nine Mile Point |
| Northeast Utilities Service Company<br>Berlin, Connecticut | Millstone |
| Northern States Power Company<br>Minneapolis, Minnesota | Monticello |
| Philadelphia Electric Company<br>Philadelphia, Pennsylvania | Peach Bottom 2,3 |
| Power Authority of the State of New York<br>New York, New York | Fitzpatrick |
| Public Service Electric and Gas<br>Newark, New Jersey | Hope Creek |
| Tennessee Valley Authority<br>Knoxville, Tennessee | Browns Ferry 1,2,3 |
| Yankee Atomic Electric Company<br>Westboro, Massachusetts | Vermont Yankee |

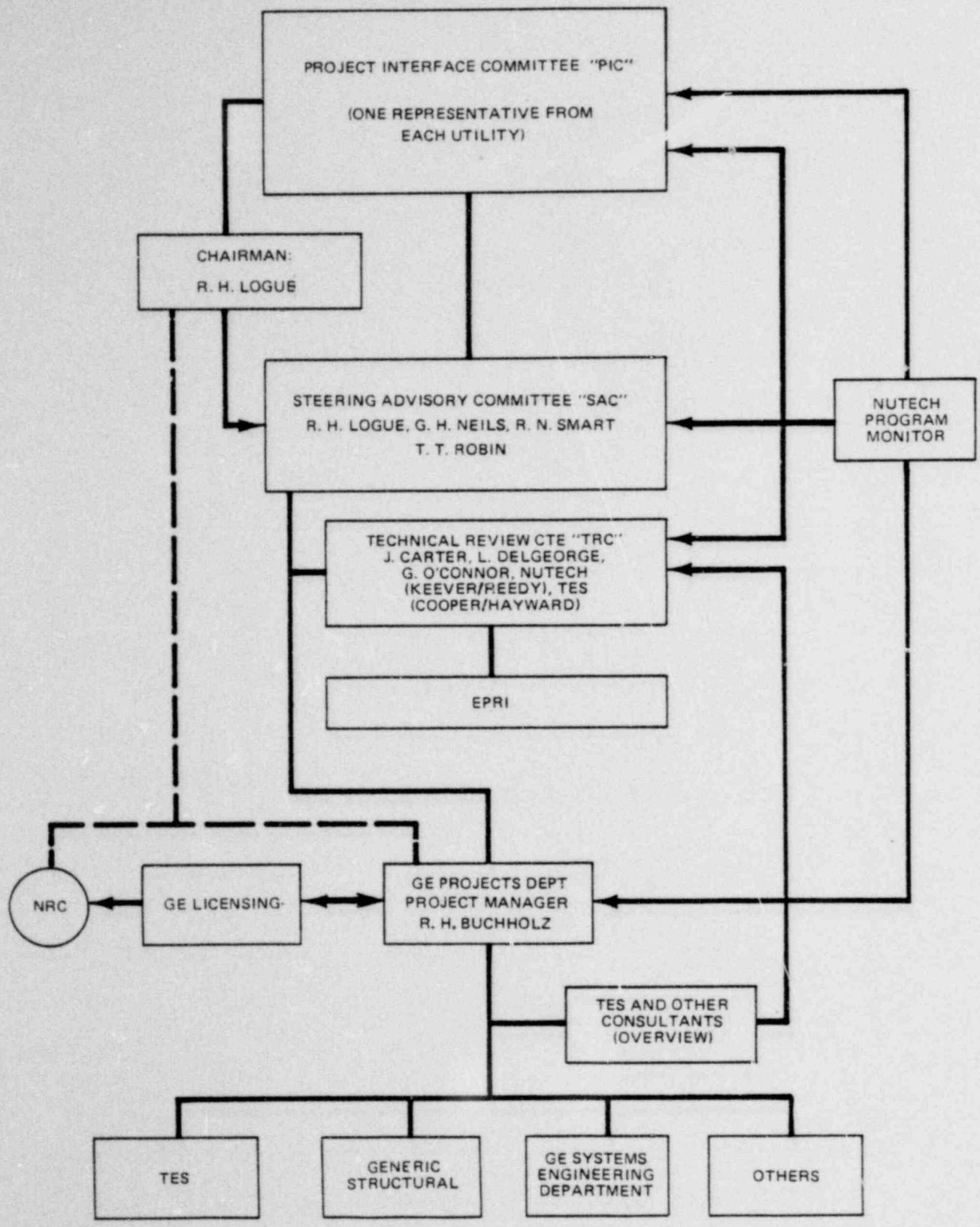


Figure II-3. Mark I Owners Group Organization

five-volume report which was submitted to the NRC in September 1975 (Short-Term Program Report NEDC-20989). Addendum 1 to this report, which was submitted to the NRC in December 1975, documented an evaluation of LOCA-related hydrodynamic loads on S/RV discharge piping and testing performed on a representative vent bellows assembly. Additional information was provided in response to NRC questions; responses were transmitted by General Electric for the Mark I Owners Group in a letter dated September 9, 1976.

In addition to the generic reference plant evaluation presented in the Short-Term Program Report, a plant unique analysis of the external support system for the toroidal pressure suppression chamber and the externally attached piping was also performed by each utility with an operating Mark I plant and submitted on their docket. The loading information used for these evaluations is presented in Addenda 2 and 3 to the Short Term Program Report - submitted to the NRC in June 1976 and August 1976, respectively.

This additional plant-unique analysis was performed in accordance with the approach described in NUTECH Report MKI-02-012, (Rev. 2), which was transmitted to the NRC in July 1976. This NUTECH report also identified the acceptance criteria against which each plant's support system and external piping was assessed. Additionally, each utility has indicated that the torus water volume will be maintained to as near the minimum as practical; also, each utility has committed to control the normal pressure in the drywell to at least 1.0 psi greater than the air space pressure in the torus as an interim operating condition. Scaled sensitivity tests showed that this action would result in reduced net loading on the torus support system. Several utilities have also increased the capability of key structural members to provide additional margin of safety.

Throughout the Short Term Program, periodic meetings were held with the NRC staff and status reports submitted to apprise them of program results.

The Short Term Program was completed in late 1976. The results of the Short Term Program show that there is no undue risk to the health and safety of the public and the Long Term Program could proceed as planned. The remainder of this document describes the details of the Long Term Program, henceforth called the "Mark I Containment Program".

# SECTION III

# MARK I CONTAINMENT PROGRAM SUMMARY

# III. MARK I CONTAINMENT PROGRAM SUMMARY

## 1. GENERAL STRUCTURE

The objective of the Mark I Containment Program is to demonstrate that all Mark I containments have acceptable structural margins throughout their design life when compared to criteria acceptable to the NRC. This Program consists of testing and analysis of both structural and hydrodynamic phenomena; also it addresses the effect of structural/hydrodynamic phenomena on containment loads. It includes the establishment of Structural Acceptance Criteria against which the results of structural evaluations can be assessed. The Program includes an evaluation of the need for structural modifications and/or load mitigation devices, to assure adequate structural margins. Key elements of the Program are:

1. Load Definition Report (LDR) - Documentation of the design basis hydrodynamic pressure suppression loads and their possible combinations.

2. Structural Acceptance Criteria - Identification of the acceptance criteria against which the structural evaluation results will be assessed. They will consider current requirements and increased knowledge gained since original design, including specific test support as required.

3. Plant Unique Analyses - Specific structural evaluation of each plant by using the loads defined in the LDR in conjunction with the established Acceptance Criteria.

The "Plant Unique Analyses Reports" will be submitted by each utility to NRC for review and approval. This approval of plant-unique analysis reports with any required structural modifications and/or load mitigation devices and Safety Evaluation Reports completes the Program. Periodically

during the progress of the Program, the Mark I Owners Group will meet with the NRC to apprise them of progress and of key Program decisions. Five key decision points were identified at the outset of the Mark I Containment Program.

| Decision Point | Description |
|---|---|
| #1 | Early decision on the feasibility of structural modifications or need for load mitigation on the basis of preliminary information. |
| #2 | Firm decision on the feasibility of structural modifications or need for the load mitigation, if information available at time of Decision Point #1 did not indicate this clearly. |
| #3 | Selection of load mitigation operational techniques and/or device(s) for further development, if load mitigation was determined to be required (Decision Points #1 or #2). |
| #4 | Establishment of structural modifications for plant-unique implementation, if structural modifications were determined to be required (Decision Points #1 or #2). |
| #5 | Specification of the physical configuration of load mitigation devices for plant-unique implementation, if a decision to implement devices was made at Decision Point #3. |

A detailed description of these decision points, current status and relative timing is given in Section III.5.

## 2. PRESSURE SUPPRESSION HYDRODYNAMIC LOADS

Hydrodynamic loads to which the pressure suppression system can be subjected are due primarily to the following phenomena: (1) Safety Relief Valve (S/RV) discharge, and (2) Loss-of-Coolant Accident (LOCA).

### 2.1 Safety/Relief Valve Discharge

Actuation of a safety relief valve produces a dynamic loading on components and structures in the suppression pool region. When a relief valve lifts, the effluent reactor steam causes a rapid pressure buildup in the discharge pipe due to compression of the column of air initially occupying the pipe and a subsequent acceleration of the water slug in the submerged portion of the pipe. During this process, the pressure in the pipe builds to a peak as the last of the water is expelled. At this point, the compressed air between the water slug and the effluent vapor begins to leave the pipe. As the compressed air exits the discharge line, it immediately begins to expand, displacing the water and propagating a pressure disturbance throughout the suppression pool. The dynamics of expanding a compressed air bubble result in pressure oscillations (similar to that of a spring-mass system) arising from the bubble expansion coupled with inertial effects of the moving water mass. The magnitude of the pressure disturbance in the suppression pool decreases with increasing distance from the point of discharge, resulting in a damped oscillatory load at every point on the torus wall below the water surface. This load produces oscillatory stresses in the torus shell.

There are several S/RVs in the plant, each having different discharge line characteristics, but the above general description is applicable. Additional types of actuation to be considered are:

Consecutive actuation (one value actuating several times),

Multiple actuation (two or more valves actuating simultaneously),

Multiple consecutive actuation (two or more valves actuating several times).

## 2.2 Loss-of-Coolant Accident

The various phenomena that can occur during the course of a postulated loss-of-coolant accident in a Mark I pressure suppression containment system can result in dynamic loads on the torus and its associated structures. With a postulated instantaneous rupture of a steam or recirculation line, the escaping steam/water mixture would cause a very rapid increase in drywell pressure and temperature. As the drywell pressure increases, the water initially in each downcomer accelerates into the pool and each downcomer clears of water. During this water clearing process, a jet can form in the suppression pool which may cause water jet impingement loads on the structures within the suppression pool and on the torus. Immediately following downcomer clearing, a bubble of air from the drywell starts to form at the exit of the downcomers. Since initially the bubble pressure is essentially equal to the drywell pressure at the time of clearing, the bubble pressure is transmitted through the suppression pool water and results in a downward load on the torus.

When the air-steam mixture flows from the drywell through the vent system, the bubble initially formed expands and decompresses. Continued injection of drywell air and expansion of the air bubble results in a rise of the suppression pool surface. Structures close to the pool surface experience loads as the rising pool surface impacts the lower surface of the structure. As the suppression pool surface rises, the air in the upper half of the torus is compressed and causes a net upward load on the torus.

As the pool surface rises, the air bubble passes through the water ligament and there is a breakup of the water slug. The subsequent pool swell evolves into a two-phase "froth" of air and water. The pool swell transient associated with drywell air venting to the pool typically lasts for 3 to 5 seconds.

Following air carryover, there will be a period of decreasing steam flow rate through the vent system. This time period has been subdivided into three phases: 1) high mass flux, characterized by nearly steady-state condensation; 2) medium mass flux, characterized by periodic variations in condensation rate; and 3) low mass flux chugging, characterized by intermittent condensation.

During steam condensation, the downcomers experience a lateral loading caused by random movement of the steam-water interface. The magnitude of this load varies with steam mass flux and suppression pool temperature. The maximum lateral loads in a design basis LOCA will occur toward the end of blowdown.

Shortly after a LOCA, the Emergency Core Cooling System (ECCS) pumps have automatically started to pump condensate water and/or suppression pool water into the reactor pressure vessel. This water floods the reactor core and subsequently cascades into the drywell from the break. Because the drywell will be full of steam when the vessel floods, the introduction of water causes steam condensation and drywell depressurization.

Following vessel flooding, suppression pool water is continuously recirculated through the core by the ECCS pumps. The energy associated with the core decay heat will result in a slow heatup of the suppression pool. To control suppression pool temperature, operators activate the Residual Heat Removal (RHR) heat exchangers. After several hours, the heat exchangers terminate the suppression pool temperature increase.

## 2.3 Summary of Loading Phenomena

The following is a listing of the various loads which may be experienced by the containment system due to S/RV discharge and LOCA phenomena:

S/RV

- Water clearing loads
- Air clearing loads
- Steam flow condensation loads
- Submerged structure loads - velocity and acceleration drag loads
- Thrust loads on S/RV discharge lines
- S/RV discharge line internal pressure
- Pool stratification effects

LOCA

- Drywell pressurization
- Vent system thrust and pressurization loading
- Downward air bubble pressure load
- Pool swell liquid impact and drag loads
- Upward air compression load
- Submerged structure loads - velocity and acceleration drag loads
- Froth impingement loads
- Pool fallback loads
- Post-swell wave loads
- Steam flow condensation loads on torus walls
- Lateral condensation loads on downcomers
- Containment design pressure loads
- Drywell depressurization
- Asymmetrical effects
- Pool thermal stratification effects

# 3. LOAD CLASSIFICATION AND QUANTIFICATION

## 3.1 Load Classification

All the pressure suppression loads given in Section III.2.3 were reviewed during the Short Term Program to establish their relative significance. The loads were classified with respect to severity on the structure and the level of confidence in the load quantification (aided by STP test results). The emphasis of the remaining Mark I Containment Program is to perform the tests and analyses which are considered necessary to provide a strong technical basis for the loads that could most significantly affect structural capability. The loads which are to receive primary attention include:

A. Pool swell loads
   Downward bubble pressure
   Upward air compression loads
   Pool swell impact loads
B. Condensation loads
   Wall loads
   Lateral vent loads
C. Safety relief valve loads on internals and walls
D. Seismic slosh
E. Asymmetric torus loads
F. Pool thermal stratification
G. Submerged structure loads

## 3.2 Load Quantification

For each load listed in Section III.3.1, the initial bases (at the beginning of the Mark I Containment Program) and tasks planned in the Program to supplement the current bases are indicated as follows:

3.2 Load Quantification (Continued)

A. Pool Swell Loads

Components Affected:

(1) Torus shell and piping external supports and welds

(2) Vent header, vacuum breaker, catwalks, bellows, S/RV discharge lines, vent header columns

Initial Bases:

(1) Bodega tests, 1/12 Scale 2-D GE tests

(2) 1/10 Scale 2-D (EPRI), Pressure Suppression Test Facility (PSTF) tests

Program Tasks:

(1) 2.5*
Review current data and establish preliminary bounding values for pool swell loads

(2) 5.3
Flexible cylinder tests to account for vent header fluid/structure interaction

(3) 5.5, 5.8
Use 1/4 Scale Pool Swell 2-D Test and 1/12 Scale 2-D Test results to verify scaling methods and expand load definition basis

(4) 5.6
Pool swell tests to account for 3-D effects

* Refers to Mark I Containment Program Task (See Section V)

(5) 5.9
Develop 2-D and 2-1/2-D pool swell models to simulate pool swell phenomena

(6) 5.14
Develop methods to compute drag loads on submerged structures

B. Condensation Loads

Components Affected:
(1) Downcomers
(2) Torus shell
(3) External supports
(4) Internal structures

Initial Bases:
(1) Foreign data
(2) 4T Mark II test data

Program Tasks:
(1) 2.6
Evaluate potential chugging loads based on existing data

(2) 5.2
Use 4T Mark II test data to develop an understanding of the basic chugging phenomena and determine the qualitative effect of temperature on chugging

(3) 5.10
Monitor pressure suppression tests and analytical efforts in other organizations

(4) 5.11
Perform Full Scale 3-D 8 Vent Tests to quantify condensation loads

(5) 5.13
Develop chugging models based on existing data

(6) 5.15
Develop analytical techniques and supporting experimental basis to define hydrodynamic/structural interaction

(7) 5.16
GE Licensee Test at Mark I downcomer submergences for early assessment of chugging loads

(8) 5.17
Evaluation of condensation oscillation loads

C. Safety Relief Valve Loads

Components Affected:
(1) Torus shell
(2) S/RV lines
(3) Submerged structures
(4) External supports

Initial Bases:
(1) Quad Cities in-plant test data
(2) Analytical Models (NEDE-20942-P)

Program Tasks:
(1) 2.1
Review the current data and determine bounding values

(2) 5.1
Evaluate Monticello Test data for:
a) direct measurement of torus shell stresses
b) direct measurement of external support structures
c) direct measurement of S/RV loads

(3) 6.2
S/RV subscale mitigation effects

D. Seismic Slosh Loading

Components Affected:
(1) Downcomer and submerged structures
(2) Torus shell and external supports

Initial Bases:
(1) Analytical methods
(2) Mark III Seismic Slosh Tests

Program Tasks:
(1) 5.4
Conduct a scaled test for Mark I geometry

E. Asymmetric Loading

Components Affected:
(1) Potentially all to various degrees

Initial Bases:
(1) Scoping calculations presented in NEDC-20989
(2) Judgment

Program Tasks:
(1) 5.6
Evaluate test results of 1/12 Scale and 1/30 Scale 3-D Tests
(2) 5.13
Monte Carlo simulation of multivent loadings

3.2 Load Quantification (Continued)

F. Pool Stratification During S/RV Discharge

| | | |
|---|---|---|
| Components Affected: | (1) | None. Concern is pool temperature stratification effects on loads |
| Initial Bases: | (1) | Quad Cities in-plant test data |
| Program Tasks: | (1) | 2.1<br>Review existing data and establish bounding temperature distribution results |
| | (2) | 5.1<br>Evaluate pool temperature measurements from Monticello data |

G. Submerged Structures

| | | |
|---|---|---|
| Components Affected: | (1) | Internals structures; i.e., ring girders, S/RV discharge lines, vent header support columns |
| Initial Bases: | (1) | Standard drag loads calculations |
| Program Tasks: | (1) | 5.14<br>Tests and analytical developments |

# 4. MARK I CONTAINMENT PROGRAM TASKS

## 4.1 General

The objective of the Mark I Containment Program is to verify that all Mark I containments are structurally adequate for their plant life based on established criteria. This will be accomplished through the multiple approach of a detailed definition of hydrodynamic phenomena, together with comprehensive structural evaluations and development of load mitigation approaches, as required. Also included is the establishment of Structural Acceptance Criteria against which the results of structural evaluations can be assessed.

From the analytical and experimental investigation of Mark I containment phenomena, a complete set of design basis loads will be established. The twin objectives of the phenomena investigation are to: (1) provide a definition of Mark I LOCA and S/RV related phenomena and, aided by testing and analytical activities, establish with a high level of confidence that all pressure suppression loads have been properly accounted for; and (2) provide realistic but yet conservative, design basis loads for the individual Mark I plants.

Supporting structural evaluations will consider: (1) fluid/structure interaction effects, (2) Generic Structural Evaluation; and (3) Structural Acceptance Criteria.

Figure III-1 shows the total Mark I Containment Program as currently structured on a time scaled basis. Detailed task descriptions are provided in Section V. A summary of the planned Program actions by major work packages (1.0, 2.0, 3.0, etc.) follows.

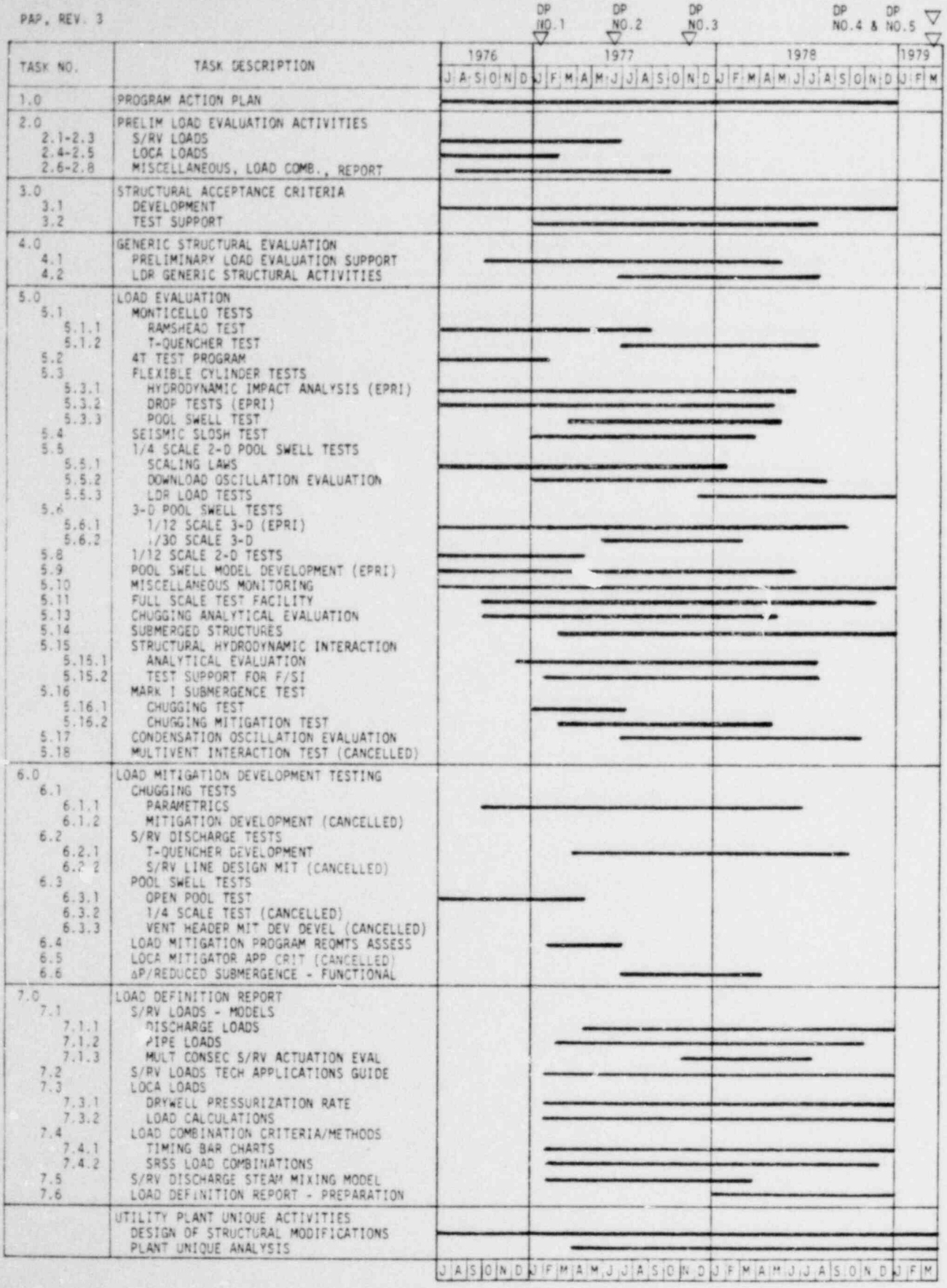


FIGURE III-1. MARK I CONTAINMENT PROGRAM SCHEDULE

## 4.2 Task Description

Task 1.0 - Program Action Plan (See Introduction to this report)

Task 2.0 - Preliminary Load Evaluation Activities

This activity will contain a preliminary assessment of all key hydrodynamic loads associated with LOCA and S/RV phenomena for initial structural evaluation activities. Loads defined in this task will be based upon best available test data/correlations and analytical methods at the time. Best engineering judgment, wherever necessary, will be used to define reasonably conservative load magnitudes. The results of the activity will be applied to Generic Structural Evaluation (Task 4.0) and will assist the utilities in performing preliminary structural evaluations of their torus and making an assessment for potential structural modification. The results of these comparisons will then be used to assess the scope of the remaining Program Action Plan.

Task 3.0 - Structural Acceptance Criteria

The Code rules used at the time of the design of the operating Mark I plants did not address many of the newly-identified loads. Acceptance criteria for application to this Mark I Containment Program plant-unique analyses is therefore needed. Short Term Program results (loads and structural evaluation reports), feedback from specific testing and from composite plant evaluation will contribute to development of the final criteria.

Task 4.0 - Generic Structural Evaluation

The primary objective of this task is to establish generic indications of structural response to defined loads for the most critical components from the Mark I plants. Limiting structural elements, identified from the review of STP plant unique analyses reports, plus structural evaluation for available pool swell, chugging and S/RV loads, are to be incorporated in this evaluation.

Task 5.0 - Load Evaluation

Several separate tests are to be included in the Program to further clarify the loads resulting from hydrodynamic effects from a postulated LOCA, and from S/RV discharge. Load evaluation tests are summarized in Table III-1. Also included as supportive to the test programs are analytical tasks related to flexible cylinder water impact, analytical pool swell model development, specific chugging analytical evaluations (near term) and generalized structural/hydrodynamic interaction evaluations (long term).

Task 6.0 - Load Mitigation Development Testing

The primary objective of this activity is to provide quantitative evaluation for development of mitigating devices for suppression pool loads, by performing small scale screening tests and by selection of mitigation devices for more extensive, larger scale load determination tests. A summary of these load mitigation tests is given in Table III-2.

Task 7.0 - Load Definition Report (LDR)

The LDR will contain the final design basis loads and represents the fundamental output to the Mark I Owners Group. All Mark I activities contribute directly or indirectly toward the establishment of design basis magnitude for all pressure suppression pool loads.

Table III-1

LOAD EVALUATION TEST PROGRAMS

| Task No. | Description | Performing Agency/Facility | Scale | Phenomena Being Tested | Testing Fluid | Date for Completion of Testing | Comments |
|---|---|---|---|---|---|---|---|
| 3.2.1 | Column Buckling Test | TES/TES | N/A | Dynamic Load Capacity | N/A | February 1977 | ---- |
| 3.2.2 | Ring Header/Vent Pipe Intersection Test | Bechtel/ Anamet | N/A | Load Capability | N/A | April 1978 | ---- |
| 5.1.1 | Monticello S/RV Ramshead Test | GE/NSP | Full | S/RV Discharge Loads | Air/Steam | July 1976 (Complete) | ---- |
| 5.1.2 | Monticello S/RV Quencher Test | GE/NSP | Full | S/RV Discharge Loads | Air/Steam | December 1977 (Complete) | ---- |
| 5.2 | 4T High Temperature Tests | GE/GE | Full | Chugging Wall and Vent Loads | Steam | July 1976 (Complete) | Mark II Configuration |
| 5.3.2 | Flexible Cylinder Tests | EPRI/DSI | 1/6 & 1/3 | Fluid/Structure Interaction-Vent Header | Water | July 1977 (Complete) | ---- |
| 5.3.3 | Flexible Cylinder Tests | GE/NSC | 1/4 | Fluid/Structure Interaction-Vent Header | Air/Water | November 1977 (Complete) | ---- |
| 5.4 | Seismic Slosh | GE/SWRI | 1/30 | Seismic Slosh Loads/ Vent Uncovering | Water | July 1977 (Complete) | ---- |
| 5.5.1 | 1/4-Scale 2-D Test | GE/NSC | 1/4 | Pool Swell Scaling Laws | Air | November 1976 (Complete) | ---- |
| 5.5.2 | 1/4-Scale 2-D Test | GE/NSC | 1/4 | Download Oscillation | Air | October 1977 (Complete) | ---- |
| 5.5.3 | 1/4-Scale 2-D Test | GE/NSC | 1/4 | LDR Loads | Air | August 1978 | Plant unique matrix |

Table III-1

LOAD EVALUATION TEST PROGRAMS

(Continued)

| Task No. | Description | Performing Agency/Facility | Scale | Phenomena Being Tested | Testing Fluid | Date for Completion of Testing | Comments |
|---|---|---|---|---|---|---|---|
| 5.6.1 | 1/12-Scale 3-D Test | EPRI/SRI | 1/12 | Pool Swell Loads | Air | June 1978 | ---- |
| 5.6.2 | 1/30-Scale 3-D Test | GE/SWRI | 1/30 | Torus/Cylinder Geometry | Air | September 1977 (Complete) | Qualitative Supplement to 5.6.1 |
| 5.8 | 1/12-Scale 2-D Test | GE/GE | 1/12 | Pool Swell Scaling Laws | Air | October 1976 (Complete) | ---- |
| 5.11 | Full Scale 3-D Test | GE/Braun | Full | Chugging | Steam | June 1978 | ---- |
| 5.13 | 1/12-Scale 3-D Test | GE/NUTECH | 1/12 | Chugging | Steam | September 1977 (Complete) | Qualitative multivent effects |
| 5.14 | Submerged Structures | GE/WYLE | 1/3 | Steady State and Transient Drag Loads | Air/Steam | June 1977 (Complete) | Revised test report transmitted November 28, 1977 |
| | | GE/NSC | 1/4 | Submerged Loads | Air | January 1978 (Complete) | ---- |
| | | GE/SWRI | N/A | Components of Drag | Water | February 1978 | ---- |
| 5.15.2 | Structural/Hydrodynamic Interactions | GE/Aerotherm | 1/12 | Fluid/Structure | Steam | February 1978 | Flat plate only |
| 5.16.1 | Reduced Submergence | GE/ GE Licensee | Full | Chugging | Steam | April 1977 (Complete) | Testing at Mark I submergence levels |
| 5.16.2 | Chugging Mitigation | GE/ GE Licensee | Full | Chugging | Steam | May 1977 (Complete) | Testing mitigator at Mark I submergence |

Table III-2

LOAD MITIGATION DEVELOPMENT TEST PROGRAM

| Task No. | Description | Performing Agency/Facility | Scale | Phenomena Being Tested | Testing Fluid | Date for Completion of Testing | Comments |
|---|---|---|---|---|---|---|---|
| 6.1.1 | Chugging Parametrics | GE/NUTECH | 1/12 | Chugging | Steam | March 1977 (Complete) | Scoping parametrics |
| | | GE/Creare | 1/12,1/6, 1/4 | Chugging | Steam | July 1977 (Complete) | Scaling parametrics |
| 6.1.2 | Chugging Mitigation | GE/NUTECH | 1/12 | Chugging | Steam | March 1977 (Complete) | Scoping mitigation |
| | | GE/Creare | 1/6 | Chugging | Steam | September 1977 (Complete) | Mitigation screening |
| 6.2.1 | S/RV | GE/NUTECH | 1/12 | S/RV Discharge Loads | Steam | June 1977 (Complete) | Mitigation confirmation |
| | | GE/NUS | 1/4 | S/RV Discharge Loads | Steam | April 1978 | Quencher parametrics |
| 6.3.1 | Pool Swell Screening | GE/NUTECH | 1/12 | Pool Swell Downloads | Air | September 1976 (Complete) | Screening tests |
| 6.3.2 | Pool Swell Mitigation | GE/NSC | 1/4 | Pool Swell | Air | November 1977 (Complete) | Qualification tests |
| 6.3.3 | Vent Header Device | GE/NSC | 1/4 | Pool Swell | Air | November 1977 (Complete) | Vent impact mitigation |

## 5. KEY DECISION POINTS

Based upon STP results and early Program results, it is probable that structural modifications may be necessary on several plants in order to meet the anticipated acceptance criteria to be set for the long term. Early decisions on plant modification are clearly advantageous. After a careful review of the Program's objectives, five key decision points were identified and are described below. A logic chart showing the interplay between these key decision points is shown in Figure III-2.

### Decision Point #1

For pool swell, S/RV and chugging loads, it may have become obvious very early in the Program that decisions on Program direction could have been made without the benefit of further screening testing or analysis. Decision Point #1 recognized the need to evaluate this possibility and provided a definite point very early in the program for evaluation of alternatives, based upon the STP load magnitudes, STP plant-unique analyses, and preliminary structural acceptance criteria. This decision point could have led to one of the following conclusions:

1. It will be feasible to design adequate structural modifications; or
2. Load mitigation (devices or operational change) will be required; or
3. Present design is adequate, but load definition will be further justified.

Tasks required to arrive at Decision Point #1 were:

1. Plant-unique analyses for upward and downward load (STP reports),
2. Preliminary results from Generic Structural Evaluation (Task 4.0) from preliminary chugging loads (Task 2.0),
3. Preliminary Structural Acceptance Criteria established (Task 3.0),

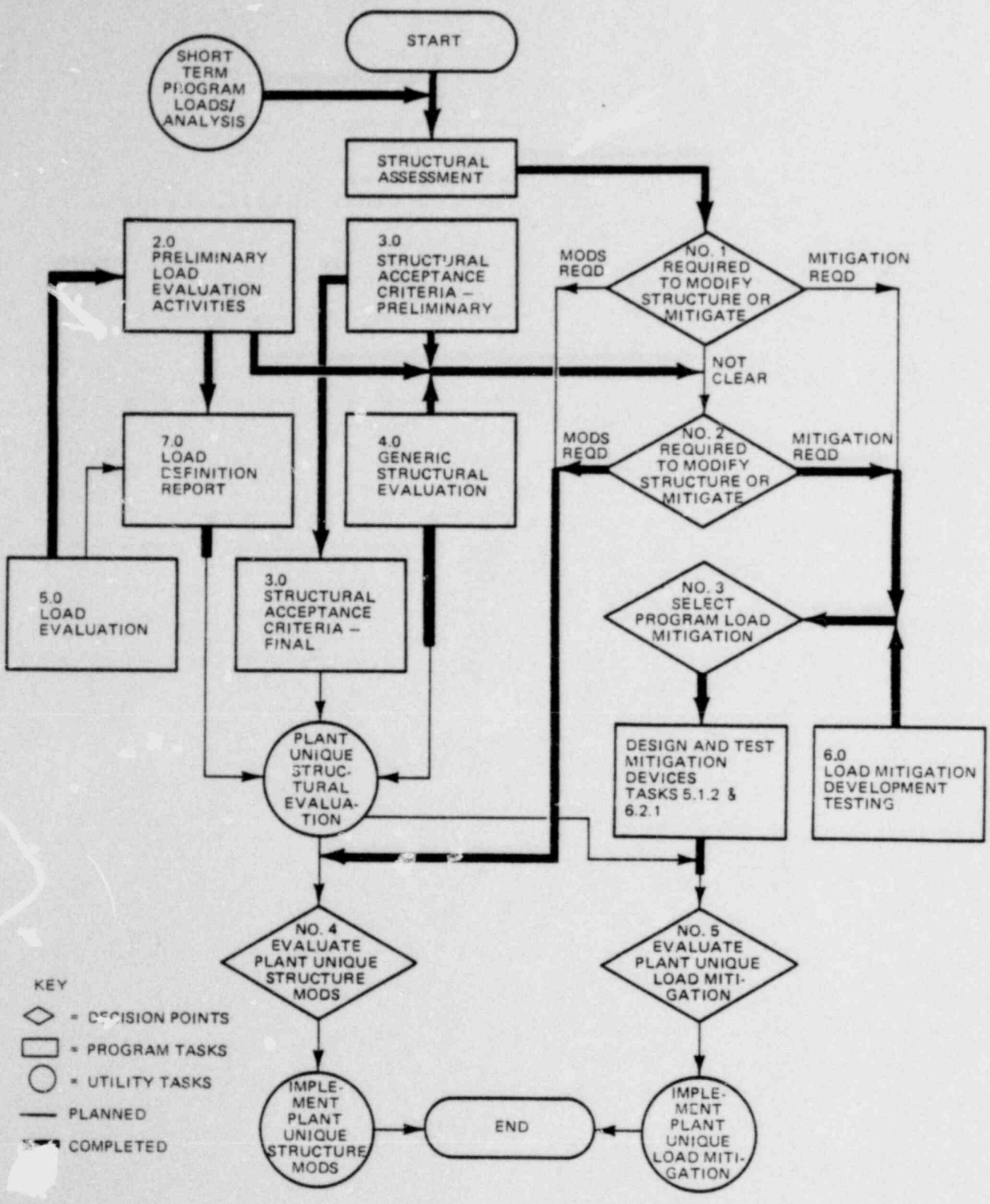


Figure III-2. Program Logic Diagram

4. Preliminary load mitigation feasibility (Task 6.0 - preliminary results as available).

Decision Point #1 Date: January 1977
(Complete. Results not conclusive; go to Decision Point #2.)

Decision Point #2

Available information gathered for Decision Point #1 was not conclusive with respect to feasibility of adequate structural modification or load mitigation, and additional efforts were required. This effort led to Decision Point #2, which established, on a more complete basis, the decision attempted in the Decision Point #1 time period with respect to feasibility of designing adequate structural modifications or employing load mitigation devices or operational changes. The same conclusions as those for Decision Point #1 were the potential results; namely:

1. It will be feasible to design adequate structural modifications; or
2. Load mitigation (devices or operational techniques) will be required; or
3. Present design is adequate, but load definition must be further justified.

Tasks required to arrive at Decision Point #2 were:

1. Tasks of Decision Point #1,
2. Completion of preliminary load evaluation activities (Task 2.0 and reduced submergence testing - Task 5.16),
3. More complete results from Generic Structural Evaluation (Task 4.0),
4. Mitigation program assessment (Task 6.4).

Decision Point #2 Date: June 1977

(Complete. Load mitigation devices or operational technique such as drywell/wetwell pressure differential required; some structural modification may also be required.)

Decision Point #3

Decision Point #3 will be the point at which to select promising mitigating devices or operating techniques, or both (for LOCA-related and/or S/RV loads) for large-scale load evaluation tests designed to produce assurance that mitigation is indeed a practical program alternate.

Tasks required to arrive at Decision Point #3 were:

1. Tasks of Decision Point #2,
2. Continuation of the Generic Structural Evaluation (Task 4.0) and plant unique assessments of structural margins,
3. Chugging load mitigation development tests (Task 6.1),
4. Review and analysis of available S/RV load mitigation development tests (Task 6.2.1),
5. 1/4 scale pool swell load mitigation development tests (Task 6.3),
6. LOCA mitigation application criteria (Task 6.5),
7. $\Delta P$/reduced submergence functional assessment (Task 6.6),
8. Structural Acceptance Criteria (Task 3.0).

Decision Point #3 Date: November 1977

(Complete. The use of $\Delta P$ and reduced downcomer submergence were defined as the pool swell load mitigation techniques, if required. Vent header mitigation would be by a vent deflector (pipe or wedge) if required by any individual utility. T-quencher tests for S/RV mitigation will be continued. No further LOCA pool swell or condensation mitigation testing will be done.)

Decision Point #4

Decision Point #4 will assess on a plant unique basis what degree of structural modification (potentially in combination with load mitigation) will be required. A plan for potential implementation of modifications based on use of LDR and preliminary structural analysis will be finalized. The Decision Point #4 evaluation does not represent the final plant unique stress report for the containment system. The final stress report will be committed

to on an individual utility basis after NRC approval of the LDR.

Tasks required to arrive at Decision Point #4 are:

1. Final Load Definition Report (Task 7.0), including effects of load mitigation,
2. Structural Acceptance Criteria (Task 3.0),
3. Generic Structural Evaluation (Task 4.0),
4. Plant unique structural assessment (Utility/AE task) for structural modifications.

Decision Point #4 Date: March 1979

Decision Point #5

Evaluation of the need for load mitigating devices on a plant unique basis will be made at Decision Point #5. At Decision Point #5, a plan for potential implementation of load mitigation devices will be finalized.

Tasks required to arrive at Decision Point #5 are:

1. Tasks of Decision Point #3 (as required),
2. Tasks of Decision Point #4 assessment,
3. Plant unique structural assessment (Utility/AE task) including load mitigation effects on loads.

Decision Point #5 Date: March 1979

# SECTION IV

# UTILITY PLANT UNIQUE ACTIVITIES

## IV. UTILITY PLANT UNIQUE ACTIVITIES

Some additional activities are being performed on a plant unique basis by the Mark I Owners; additional work will follow after the issuance of the final LDR. These followup activities will bring the Mark I Containment Program to a final conclusion. GE will provide support for interpretation and application of the LDR loads and load combinations.

Specific activities include:

### IV-1 PLANT UNIQUE ANALYSIS

Based upon the hydrodynamic loads defined in the Preliminary Load Evaluation Activity (Task 2.0) and the LDR (Task 7.0), each utility will perform the structural evaluation of its plant to show the Structural Acceptance Criteria is met

### IV-2 STRUCTURAL MODIFICATION/LOAD MITIGATIONS

Each utility will decide the necessity of structural modifications, load mitigation and the type of design to be implemented in order to meet the Structural Acceptance Criteria. The LDR will incorporate the effect of operational techniques and/or mitigation devices on the loads for use by the utilities for reevaluation. Implementation will be scheduled by individual utilities and is dependent on approval of the LDR by NRC.

Figure IV-1, which follows, summarizes these events graphically.

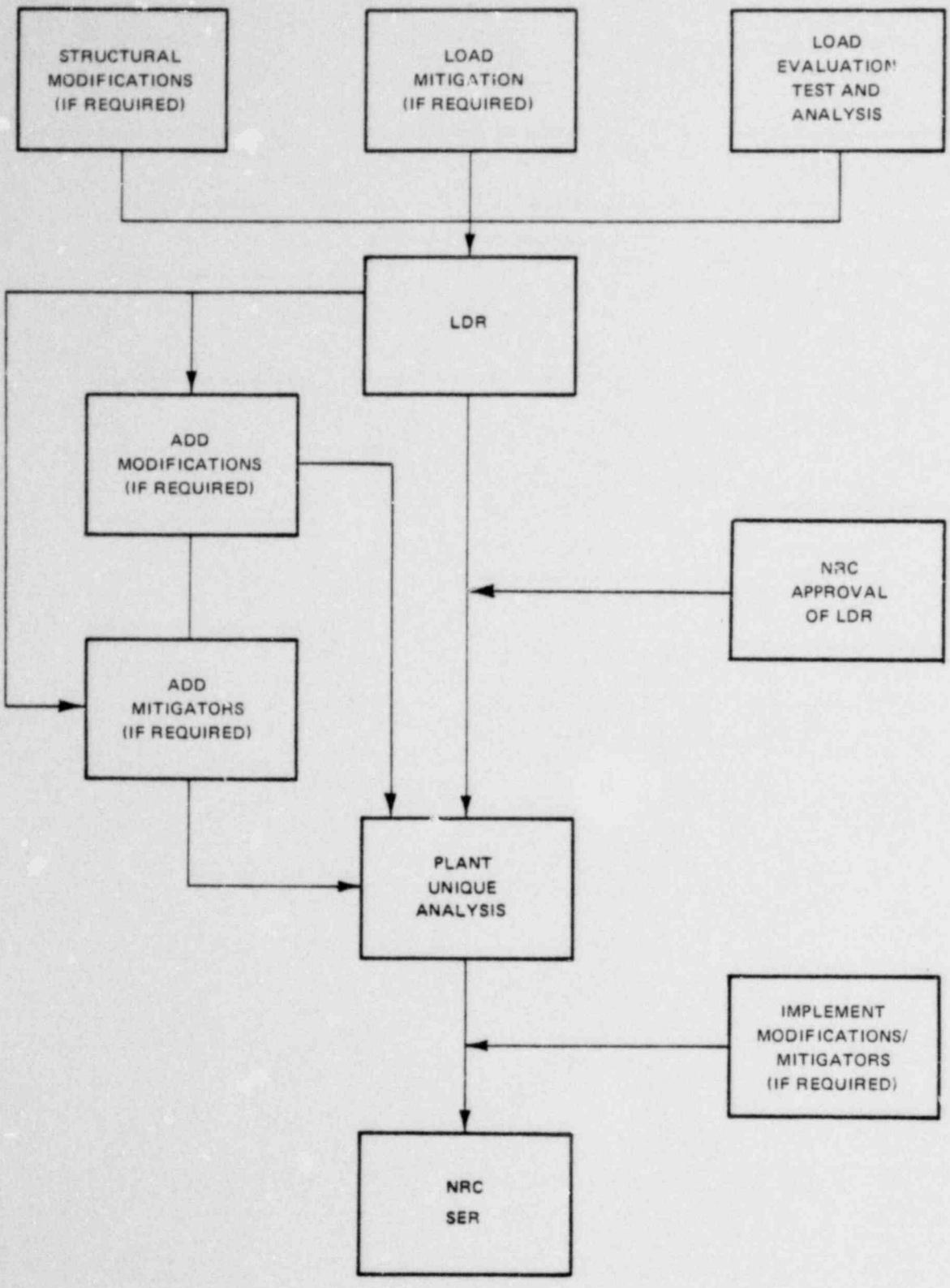


Figure IV-1. Utility Plant Unique Activities

# SECTION V

# DETAILED DESCRIPTION OF ACTIVITIES

# V. DETAILED DESCRIPTION OF ACTIVITIES

This Section contains a description of Mark I Containment Program activities. The description includes objectives, task description, and targeted completion dates. It is to be noted that completion dates shown in this Section are best estimates based on the scope of work defined for each task. Also note that several tasks are subdivided into phases. At the discrete junctures delineated in the applicable task descriptions, the decision to proceed with the ensuing phase will depend on the technical need for that effort in the Mark I Containment Program.

TASK NUMBER: 1.0

TITLE: PROGRAM ACTION PLAN

DESCRIPTION: This document provides an integrated source of information regarding the Mark I Containment Program plan. It is used in communication to NRC, utility management, and all other organizations associated with the Program. It defines the Program in terms of specific tasks, and identifies objectives, task descriptions and scheduled key milestones. Also, it shows the logic for integration of the individual tasks into the determination of the Load Definition Report for Mark I containments.

| TARGET DATES: | | |
|---|---|---|
| | Issue Program Action Plan (Rev. 0) | October 1976 (Complete) |
| | Issue Program Action Plan (Rev. 1) | February 1977 (Complete) |
| | Issue Program Action Plan (Rev. 2) (After Decision Point #2) | August 1977 (Complete) |
| | Issue Program Action Plan (Rev. 3) (After Decision Point #3) | February 1978 (Complete) |

TASK NUMBER: 2.0

TITLE: PRELIMINARY LOAD EVALUATION ACTIVITIES

OBJECTIVE: To establish to the best extent possible early in the Program, the magnitude of the more significant suppression pool dynamic loads. The loads resulting from this study are intended to serve as a basis for an iterative design assessment of potential structural modifications (Task 4.0), using the structural acceptance criteria being developed in Task 3.0; these loads will also help guide the selection of testing for load verification. These loads are not to be interpreted as necessarily equivalent to Load Definition Report (LDR) loads (Task 7.8), since the LDR loads will have factored into them the data from the many tests being performed in Task 5.0.

DESCRIPTION: This task will concentrate on those loads required for evaluation of the representative structural systems selected in Task 4.0 (Generic Structural Evaluation). Where variability in design requires plant unique analyses under Task 4.0 it may be necessary to use generic load values with engineering judgment in this preliminary analysis.

The loads generated in Task 2.0 will be based on test data and analytical models available at the time. These initial loads are intended to be conservative because of the preliminary nature of the data and models. If the first structural evaluation with the loads developed in this task indicates that extensive plant modifications are potentially required, iterations will be made to:

1. Refine the loads by a more detailed analytical effort and comparison with test data,

TASK NUMBER: 2.0 (Continued)

2. Improve the structural models,

3. Determine where both load and structural margins exist,

4. Reevaluate the acceptance criteria.

In some cases the loads will be reduced by review of the assumptions. In other cases the initial evaluation will indicate that additional effort must be expended on defining the loads experimentally or analytically. The structural capability can be improved through more detailed models and reevaluation of assumptions. There will be iteration between Tasks 2.0, 3.0 and 4.0 to assess overall margins. (Margins will not be added in series.)

On the second iteration, when the above evaluation factors have been considered, it will be likely that a decision can be made on selecting mitigation and/or a structural fix.

TASK NUMBER: 2.1

TITLE: S/RV LOADS - METHODOLOGY

OBJECTIVE: Develop analytical models to predict S/RV discharge characteristics and to calculate the associated hydrodynamic loads due to S/RV discharge through a ramshead discharge device.

DESCRIPTION: Develop analytical models and procedures to calculate loads on S/RV lines, torus, and on submerged structures due to S/RV discharge through a ramshead discharge device. Any expansion of the existing analytical models will be on a preliminary basis and will not necessarily be verified. Loads for the following types of the S/RV air clearing transient will be determined to the maximum practicable extent: pipe clearing, bubble oscillation, clearing of the ramshead in single, multiple, and consecutive valve actuations.

The current analytical models will be compared to Monticello data. Multipliers will be established and/or correlations made where test results indicate further modification of S/RV models is required. The multipliers and/or correlation will be established for varying discharge conditions - including consecutive actuation.

TARGET DATE: April 1977 (Complete) - Documentation will be included in Task 2.8.

TASK NUMBER: 2.2

TITLE: S/RV LOADS - PLANT DATA AND GROUPING

OBJECTIVE: Review plant geometric data to establish the range of pertinent parameters needed to develop a parametric method by which individual plants may obtain S/RV loads. Identify those plants where specific analyses will be required due to uniqueness of S/RV discharge line routing or discharge device.

DESCRIPTION: Review the S/RV discharge line geometry and valve characteristics and establish the necessary parameter ranges needed to produce a parametric method which will predict plant unique S/RV loads using a ramshead discharge device. The review will include an examination of the following parameters which influence the S/RV pipe pressure and the torus wall loads produced by the S/RV air clearing transient: reactor pressure, S/RV flow capacity, S/RV discharge line (DL) diameter and length, S/RVDL submerged length, type of end fitting, and location of discharge point.

TARGET DATE: May 1977 (Complete) - Documentation will be included in Task 2.8.

TASK NUMBER: 2.3

TITLE: S/RV LOADS - PLANT UNIQUE CALCULATIONS

OBJECTIVE: Develop and apply a parametric method to obtain calculated plant unique S/RV discharge loads.

DESCRIPTION: For the range of parameters identified in Task 2.2, develop a parametric method which predicts dynamic loads associated with S/RV actuation and discharge through a ramshead device. These dynamic loads will include: S/RVDL pipe pressure, S/RVDL pipe reaction loads at the ramshead during the expulsion of the S/RVDL water leg, water jet loads on submerged structures due to air bubble oscillations. These loads will be calculated for the appropriate combination of first and consecutive valve actuation, and for single and multiple valve action cases.

COMPLETE

TARGET DATE: June 1977 (Complete) - Documentation will be included in Task 2.8.

TASK NUMBER: 2.4

TITLE: LOCA LOADS - PLANT GROUPING

OBJECTIVE: Review plant geometric data and group the Mark I plants to minimize the effort of calculating LOCA loads. Identify the need for plant unique analyses for subsequent utility/AE evaluations.

DESCRIPTION: Plant unique pool swell loads have been calculated for vertical and impact cases in the Short Term Program assuming no mitigation. The other loads associated with pool swell were established on a high and low bound bases (i.e., worst and best geometry) or do not vary significantly from plant to plant. The loads take into consideration the following parameters: drywell, wetwell and suppression pool volumes; initial pressure and temperature in the drywell, wetwell and suppression pool; vent system flow area; primary system break area; and details of the suppression pool and torus geometry.

COMPLETE

TARGET DATE: February 1977 (Complete) - Documentation will be included in Task 2.8.

TASK NUMBER: 2.5

TITLE: LOCA LOADS - CALCULATIONS

OBJECTIVE: Establish preliminary LOCA loads.

DESCRIPTION: Using current test data and analytical methods, procedures will be developed to calculate the preliminary hydrodynamic loads on the containment system for the following conditions: Design Basis Accident (DBA); an Intermediate-size Liquid Break (IBA) which actuates Automatic Depressurization System (ADS); and a Small Steam-line Break (SBA). The loads will be calculated assuming no mitigation devices have been installed. Current reactor vessel blowdown models will be used to establish effects on LOCA loads. Representative comparative analyses will be made to determine the effect of type of break (main steam or recirculation line) on pool swell loads. Preliminary indications are that the DBA of the recirculation line gives the highest initial drywell pressurization rate and thus the worst pool swell loads.



TARGET DATE: February 1977 (Complete) - Documentation will be included in Task 2.8.

TASK NUMBER: 2.6

TITLE: MISCELLANEOUS LOADS - CALCULATIONS

OBJECTIVE: Identify and calculate miscellaneous loads associated with a LOCA in a bounding manner assuming no mitigation devices have been installed.

DESCRIPTION: Using currently available analytical methods, data and procedures, the following containment system dynamic loads will be addressed:

1. Evaluate seismic effects in the suppression pool - magnitude and frequency of loads induced by seismic slosh on the torus and internals.

2. Steam condensation pressure oscillation loads.

3. Vent system thrust loads.

4. Drag loads.

COMPLETE

TARGET DATE: May 1977 (Complete) - Documentation will be included in Task 2.8.

TASK NUMBER: 2.7

TITLE: LOAD COMBINATION CRITERIA

OBJECTIVE: Develop preliminary bar charts for loads showing time sequence assuming no mitigation devices are installed.

DESCRIPTION: For the matrix of break types discussed in Task 2.5 bar charts for various containment structures will be developed. These bar charts will define the time period over which a particular loading condition exists, and will thus define which of the loads need to be combined for the purposes of structural evaluation. Load combinations will be based on a mechanistic evaluation of the NSSS and the containment response to a LOCA.

COMPLETE

TARGET DATE: February 1977 (Complete) - Documentation will be included in Task 2.8.

TASK NUMBER: 2.8

TITLE: REPORT PREPARATION

OBJECTIVE: To document the preliminary loads for internal use in the Generic Structural Evaluation, and for preliminary plant unique analyses by the individual utilities.

DESCRIPTION: Identify the loads to be used for initial evaluation activities. This internal report will provide sufficient preliminary loading information to allow the containment designer to perform early evaluations of the various structures which form the containment system. The information derived from Tasks 2.1 through 2.7 will be incorporated into this report. Guidance will be provided to assist in the interpretation of these loads for the generic or plant unique structural evaluations.



| TARGET DATE: | | |
|---|---|---|
| | Issue Final Report Draft for Utility Review | July 1977 (Complete) |
| | Issue Final Report | September 1977 (Complete) |
| | NEDM-21688-P, "Mark I Containment Program Preliminary Load Evaluation Report (PLER), Volumes I and II", August 1977 | |

TASK NUMBER: 3.0

TITLE: STRUCTURAL ACCEPTANCE CRITERIA

OBJECTIVE: To develop structural acceptance criteria and plant modification guidelines for Mark I containments to which the structural evaluations and/or modifications will be made.

DESCRIPTION: Develop and justify, with specific testing if required, structural acceptance criteria and plant modifications for Mark I containments. Preliminary information is to be utilized in making judgments on the capability of existing structures to withstand the loads defined in other tasks of the Mark I Program. Final documentation in the form of a Plant Unique Analysis Application Guide will be used by the utilities in making plant unique evaluations.

In preparing structural acceptance criteria to evaluate the acceptability of the existing Mark I containment systems or to provide the basis for any modifications required to withstand newly defined loads, it is the intent that the structural design criteria of the ASME Section III Code Addenda (Summer 1977) be applied to the maximum extent practical. When complete application of such criteria results in hardships or unusual difficulties without a compensating increase in the level of quality and safety, alternative structural acceptance criteria will be considered. Possible alternative criteria include those which were applicable at the time of initial construction or those which are developed as a result of this program. Approval of additional plant-specific alternative criteria may be requested for application by the individual utilities during the performance of plant unique analyses.

TASK NUMBER: 3.0 (Continued)

Structural elements to be considered include the torus shell and supports, the vents and connecting bellows, the vent ring header with downcomers and supports, internal and external piping with associated components and supports, and applicable pumps and valves. Loadings to be considered include those defined by Tasks 2.0 and 7.0 of the Mark I Containment Program.

Activities to complete this task are described in Subtasks 3.1 and 3.2.

TASK NUMBER: 3.1

TITLE: STRUCTURAL ACCEPTANCE CRITERIA - DEVELOPMENT

OBJECTIVE: To provide all structural acceptance criteria efforts other than those involving testing (see Task 3.2).

DESCRIPTION: The activities are described in the following subtasks.

TASK NUMBER: 3.1.1

TITLE: EVALUATION OF BACKGROUND INFORMATION

DESCRIPTION: The Mark I Containment Short Term Program (STP) efforts, including the STP plant unique analyses, identified the need for further review and understanding of the bases for existing structural design criteria. Such an evaluation provides a basis for the application of existing criteria to future investigations and assists in the identification of the need for alternative criteria.

The subactivities to be conducted are as follows:

1. Preparation of a state-of-the-art summary on the static and dynamic buckling of columns. The literature on this subject has been reviewed, specifically including the background of the column equations now in the Code. Based upon the early status of this effort, it was recommended that a column test program be conducted, see Task 3.2.1. This summary and the results of the test program will form the background for the development of alternative column rules under Task 3.1.2.

2. Preparation of a summary on containment system component design rules and classification. During the period in which the Mark I containments have been in existence there have been considerable changes in requirements and improvements in knowledge. In fact, the Winter 1976 and Summer 1977 Addenda to the Code include major revisions of consequence to this effort.

The various Code editions and Addenda have been reviewed with respect to Class MC vessels, linear component supports, and Class 2 piping. Emphasis has been placed upon load categorization relative to the various allowable stresses, the specific stress limits and design rules, and the classification of components and the definition of boundaries between components. In addition to providing background information, this summary will be referenced in preliminary internal versions of the Plant Unique Analysis Application Guide (Task 3.1.3).

3. Consideration of additional development needs. As other Program tasks are completed, information may be developed which indicates the need for further in-depth background reviews or additional test programs.

TARGET DATE:

| | |
|---|---|
| Column Buckling Report TR-2778(a), "Mark I Containment Program, Structural Acceptance Criteria, Activity 3.1.1, Short Term Loading of Columns", February 25, 1977 | March 1977 (Complete) |
| Issue Preliminary Rules and Classification Report | March 1977 (Complete) |
| Issue Final Report Draft for Utility Review-Rules and Classification Report | February 1978 |
| Issue Final Report-Rules and Classification Report | April 1978 |

TASK NUMBER: 3.1.2

TITLE: ALTERNATIVE CRITERIA DEVELOPMENT

DESCRIPTION: When application of existing Code criteria results in hardships or unusual difficulties without a compensating increase in the level of quality and safety, alternative structural acceptance criteria will be considered. An example of such possible alternative criteria is the rules for buckling of columns. The present Code rules were developed for statically loaded columns so they may be overly conservative for dynamic load application. The review of column buckling conducted under Task 3.1.1 indicates that available data may be insufficient to provide a firm basis for alternative rules. Therefore, a test program is to be performed, as is described under Task 3.2.1. The results of that test program and other data which do exist will be used to develop alternative column design rules.

The general design criteria for Class MC containment vessels are based upon the criteria for Section VIII, Division 1, Pressure Vessels. These criteria follow a "design by rule" procedure in which detailed load information and analysis are not required, as contrasted to a "design by analysis" procedure in which detailed loads are defined and analyses performed. Such procedures should be retained when evaluating the ability of the containment structure to withstand essentially static maximum containment pressures, but are not logical when loads are defined in detail and extensive stress analyses are performed. This situation is similar, as are the safety consequences, to that with ASME Class 2 vessels where either the "design by rule" procedures of NC-3300 or the "design by analysis" procedures of NC-3200 are permitted. The allowable stress values for

TASK NUMBER: 3.1.2 (Continued)

primary stresses in Class MC vessels are 110 percent of those used for Class 2 vessels designed to NC-3300. The allowable stress values for primary stresses in Class 2 vessels designed to NC-3200, and the allowable for primary-plus-secondary stresses in both Class MC vessels (Summer 1977 Addenda) and Class 2 vessels designed to NC-3200, are the same as those used for Class 1 vessels. It will be proposed that the basic allowable stress values to be used for evaluating operating condition, primary stresses, in regions where detailed loads are defined and analyses performed, be those applicable to Class 2 vessels designed to NC-3200.

| TARGET DATES: | | |
|---|---|---|
| | Allowable Stress Selection Recommendation | May 1977 (Complete) |
| | Issue Preliminary Evaluation Letter Report-Alternative Column Rule Report | October 1978 |
| | Issue Final Report Draft for Utility Review - Alternative Column Rule Report | November 1978 |
| | Issue Final Report - Alternative Column Rule Report | December 1978 |

TASK NUMBER: 3.1.3

TITLE: PLANT UNIQUE ANALYSIS APPLICATION GUIDE

DESCRIPTION: The Plant Unique Analysis Application Guide will ensure that the structural acceptance criteria are applied consistently by those evaluating each of the specific containments for the utilities. It will be a self-contained document except for references to Section III of the ASME Code, possibly to other codes and standards, and to the Load Definition Report prepared under Task 7.0. It will include:

1. Code classification of the structural elements making up the containment system,

2. Reference to the loads and load categorizations contained in the Load Definition Report and Code categorization of these,

3. Reference to Code and Standard rules, procedures, and criteria to be followed for all structural elements,

4. Alternative structural acceptance criteria developed under Task 3.1.2,

5. When required, descriptions of the analytical models or procedures to be followed.

The Plant Unique Analysis Application Guide will be the final version of preliminary guides used throughout the Program by the utilities and General Electric and their subcontractors. The preliminary internal versions will provide guides to structural design criteria and to structural element classification primarily by reference to the rules and classification

report prepared under Task 3.1.1. Later internal versions will incorporate more detailed information as it is developed under this or other Program tasks. For example, revisions will be prepared at the appropriate time to incorporate:

1. Categorization of the loads and load combinations defined by Task 2.0,

2. The selection of allowable stresses to be recommended under Task 3.1.2,

3. Guidance with respect to non-pressure retaining members,

4. Experiences with the General Structural Evaluation performed under Task 4.0,

5. The publication of applicable Code Addenda,

6. Alternative design rules developed under Task 3.1.2,

7. Additional load information developed under Tasks 5.0, 6.0, and 7.0,

8. Experiences with the application of existing versions of the Guide,

9. Changes in regulatory requirements,

10. The results of analytical/test efforts described in Task 3.1.5 which are intended to justify service level assignments.

TASK NUMBER: 3.1.3 (Continued)

| | | |
|---|---|---|
| TARGET DATE: | Issue Preliminary Plant Unique Application Guide, Rev. 0 | May 1977 (Complete) |
| | Issue Interim Structural Acceptance Criteria Package | February 1978 |
| | Issue Final Report Draft for Utility Review - Plant Unique Application Guide | June 1978 |
| | Issue Final Report - Plant Unique Application Guide | October 1978 |

TASK NUMBER: 3.1.4

TITLE: PLANT MODIFICATION CRITERIA - DEVELOPMENT

OBJECTIVE: To develop plant modification criteria applicable to containment vessel and component support modifications.

DESCRIPTION: Section XI of the ASME Code does not include criteria for the modification of containment vessel and component supports. Subsections IWE and IWF will eventually contain appropriate criteria but in the interim IWA-7210 requires that an Owner's Specification be prepared which specifies the applicable edition of the Construction Code to be used. Drafts of the necessary IWE and IWF Subsection articles on "replacements" of the Code will be prepared under this task. A close liaison will be maintained with the appropriate Code Subcommittee to allow submittal of the Subsections to the January Code Meetings.

TARGET DATES:

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report - Plant Modification Criteria Report | October 1977 (Complete) |
| Submittal of IWE and IWF Subsections for Code Incorporation | January 1978 (Complete) |
| Issue Final Report Draft for Utility Review - Plant Modification Criteria Report | June 1978 |
| Issue Final Report - Plant Modification Criteria Report | July 1978 |

TASK NUMBER: 3.1.5

TITLE: JUSTIFICATION OF SERVICE LEVEL ASSIGNMENTS

OBJECTIVE: To justify the service level assignments contained in the Plant Unique Analysis Application Guide (Task 3.1.3) considering the dynamic nature of the various loadings.

DESCRIPTION: The justification activities are described in the subtasks which follow.

TASK NUMBER: 3.1.5.1

TITLE: VENT HEADER 2-D RING ANALYSIS

OBJECTIVE: To demonstrate analytically that when an idealized Mark I vent header is subjected to short duration dynamic loads, the reserve margin between ASME Code allowable dynamic load and actual failure is greater than the margin between ASME Code allowable static load and the static failure load.

DESCRIPTION: This task will consider the effect of pool swell impact on an idealized Mark I vent header by conducting static and dynamic linear elastic and nonlinear collapse analyses. Then, the reserve margin between ASME Code allowable loads based on elastic stress limits and actual static and dynamic collapse loads based upon instability or strain limit criteria will be established.

TARGET DATE:

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report | November 1977 (Complete) |
| Issue Final Report Draft for Utility Review | March 1978 |
| Issue Final Analysis Report | May 1978 |

TASK NUMBER: 3.1.5.2

TITLE: LIMIT ANALYSIS OF THE DOWNCOMER – RING HEADER INTERSECTION

OBJECTIVE: To utilize the results of the Short Term Program downcomer - ring header intersection test to determine the collapse load of this intersection. These results will be compared with those determined by using stress analysis results and Code allowable stresses to justify the service level assignment for the intersection.

DESCRIPTION: The test data will be used to determine a limit (collapse) load, based on the procedures in ASME Section III Appendix II. For Class MC vessels, NE-3228.2 allows a maximum of 2/3 of the limit load determined by the tests to be used directly as an allowable lateral load on the downcomer. The allowable load determined on a limit basis will be compared with that determined using stress analysis results and Code allowable stresses, to justify the assigned service level limit for the intersection.

TARGET DATE:

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report | February 1978 |
| Issue Final Report Draft for Utility Review | April 1978 |
| Issue Final Analysis Report | June 1978 |

TASK NUMBER: 3.1.5.3

TITLE: BASIC TORUS SHELL ANALYSIS

OBJECTIVE: To demonstrate analytically that the basic torus shell could withstand peak pressures in excess of the static failure pressure during a postulated pool swell transient. This demonstration will be used to justify the assigned service level assignment for load combinations involving pool swell, such as S/RV and pool swell.

DESCRIPTION: A preliminary study will be carried out using the "Bigg's Technique". The Bigg's Technique can be used to determine maximum plastic response of an elastic - perfectly plastic single degree of freedom system, subject to an idealized (triangular, square, etc.) impulsive load. The pool swell positive pressure transient will be idealized as a triangular pulse load. The torus will be represented in terms of its frequency and yield pressure characteristics. The analysis will provide an indication of maximum (plastic) strain under the specified transient. Assuming indication that peak pressure capacity significantly exceeds static failure value, the analysis will proceed to a more detailed evaluation utilizing the work accomplished by Costantino for the AEC in the early 1960s. The Costantino method will allow for the consideration of the biaxial stress field characteristic of the torus shell. This technique will be applied to a single torus cylindrical segment. The pool swell positive pressure transient will again be idealized as a triangular impulse. The analyses will predict the peak pressure which the torus shell can sustain without failure.

TASK NUMBER: 3.1.5.3 (Continued)

TARGET DATES:

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report | * |
| Issue Final Report Draft for Utility Review | * |
| Issue Final Analysis Report | * |

*To be established in March 1978. Proposal in review phase.

TASK NUMBER: 3.2

TITLE: TEST SUPPORT

OBJECTIVE: To provide test data required in support of development of structural acceptance criteria.

TASK NUMBER: 3.2.1

TITLE: COLUMN BUCKLING TEST

OBJECTIVE: To determine the increase in column static load capacity when subjected to short duration dynamic loads.

DESCRIPTION: The state-of-the-art on column buckling evaluated under Task 3.1.1 confirmed that the behavior of relatively short columns subjected to short duration overloads is not well defined, but confirmed the earlier judgment that appreciable short-time overloads could be sustained. A test program was developed consisting of a pilot program and a second more complete program of investigation. The results of this test are to be evaluated under Task 3.1.2.

Initial testing consists of a short series of scoping tests designed to provide early confirmation of the existence of the anticipated capacity increase. Specifically, Phase I will provide the information on:

1. The existence of an overload factor for short duration loading,

2. The sensitivity of load duration,

3. The effect the water and torus mass has on the response of the column.

Potential Phase II testing will consist of testing three typical geometries; pipe, rolled and built-up wide flange section fabricated from carbon steel. The tests will also establish the effect of plant unique variations on the short duration load capacity of the test specimen. These variations include:

TASK NUMBER: 3.2.1 (Continued)

1. Slenderness ratios - over the spectrum of current Mark I designs and most probable modifications,

2. Load duration,

3. Load eccentricities - simulating as-built conditions and applied moments to the columns,

4. End connections - simulating pipe columns pinned at the bottom and wide flange columns with sliding supports.

Prior to any further testing, a scaling report will be issued that relates the test specimens to the Mark I prototype columns for the above parameters. NRC concurrence with the relationships contained in the scaling report will be obtained before initiation of further testing.

| TARGET DATES: | | |
|---|---|---|
| | Prepare Draft Specification | October 1976 (Complete) |
| | Perform Scoping Tests | February 1977 (Complete) |
| | Issue Preliminary Evaluation Letter Report - Scoping Tests | April 1977 (Complete) |
| | Issue Preliminary Evaluation Letter Report - Scaling Analysis | July 1977 (Complete) |
| | Issue Final Report Draft for Utility Review - Scaling Analysis | December 1977 (Complete) |
| | Issue Final Report - Scaling Analysis | March 1978 |
| | Obtain NRC Concurrence with Scaling Analysis | April 1978 |

TASK NUMBER: 3.2.2

TITLE: RING HEADER – VENT PIPE INTERSECTION TEST

OBJECTIVE: To perform a test on a prototypical vent pipe - ring header intersection to permit a determination of the allowable load on both a limit basis and a Code allowable stress basis. It is intended to utilize test data in conjunction with the limit analysis provisions of the Code to justify an increase in capacity over normal Code allowable stress limits.

DESCRIPTION: This task will involve performance of a test on a full scale model of a ring header - vent pipe intersection. The test specimen will be loaded by end moments representative of the critical pool swell loading condition.

The test specimen will be instrumented sufficiently to permit determination of allowable load both on a limit basis (per Appendix II and NE 3228.2) and using Code allowable stresses.

The test data will be used to predict the limit load and maximum load associated with allowable stress limits. Demonstrations that the limit load significantly exceeds the maximum allowable load will be used to justify an increase in Code service level assignment.

TARGET DATE:

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report | May 1978 |
| Issue Final Report Draft For Utility Review | June 1978 |
| Issue Final Report | July 1978 |

TASK NUMBER: 4.0

TITLE: GENERIC STRUCTURAL EVALUATION

OBJECTIVE: The primary objective of this task is to provide an overall engineering assessment of the structural margins applicable to the key components for the spectrum of Mark I plants. Then, when applying loads, identify what is necessary to correct the situation by further work to (1) reduce loads by some mitigation process, or (2) modify the component structurally. Combinations of both of the above may be the optimum solution in some cases.

DESCRIPTION: This activity is divided into Preliminary Load Evaluation Support (Task 4.1) and Load Definition Report (LDR) Structural Support (Task 4.2). These activities are described in the following subtasks.

TASK NUMBER: 4.1

TITLE: PRELIMINARY LOAD EVALUATION SUPPORT

DESCRIPTION: This subtask will evaluate the critical components of the Mark I containment utilizing the loading information contained in the Preliminary Load Evaluation Report (PLER). This evaluation will identify the structural capability of the components and where necessary, define potential structural modification concepts and/or load mitigation ratios to meet the preliminary structural acceptance criteria. The output of the following subactivities will appropriately be factored into Decision Point #2.

Torus Shell Fatigue Evaluation

The preliminary test data that was obtained from the Monticello S/RV test will be used to evaluate the fatigue effects on the torus shell and related components for a 40-year plant for the cyclic loading imposed by S/RV actuations. The S/RV actuation history of the Monticello plant will be projected over the remaining plant life to obtain the total number of expected actuations. This analysis will serve as a guide in performing individual plant unique analyses.

Review Plant Unique Analyses Reports

Review the applicable portions of all the Plant Unique Analyses prepared for the Short Term Program to determine the capability of the reported structural components.

Torus Structure Model Development Study

Select a torus and develop a generic $180^{o}$ torus segment finite-element model. Determine the feasibility of utilizing this model, as opposed to smaller segment models, in the analysis of the torus to the dynamic loads contained in the PLER.

TASK NUMBER: 4.1 (Continued)

Review Structural Acceptance Criteria

Review, comment and participate in the development of the Structural Acceptance Criteria, Task 3.0.

Vent Header System Model Development and Analysis

Representative vent header systems will be selected and categorized based upon the main vent-to-ring header geometry. Detailed finite-element models will be developed which allow dynamic analysis of the vent header system. The PLER will provide the input loads.

TARGET DATE:

| | |
|---|---|
| Issue Vent Header Model Report Draft for Utility Review | March 1977 (Complete) |
| Issue 180° Model Report Draft for Utility Review | April 1977 (Complete) |
| Perform Torus Shell Fatigue Evaluation | May 1977 (Complete) |
| Review Plant Unique Analyses | May 1977 (Complete) |
| Complete 180° Model Analysis Feasibility Study | June 1977 (Complete) |
| Issue Vent Header Analysis Report Draft for Utility Review | September 1977 (Complete) |
| Issue Final Vent Header Model Report | April 1978 |
| Issue Final Vent Header Analysis Report | April 1978 |
| Issue Final 180° Model Report | May 1978 |

TASK NUMBER: 4.2

TITLE: LDR GENERIC STRUCTURAL ACTIVITIES

DESCRIPTION: Throughout the remainder of the Mark I Containment Program following Decision Point #3, various structural evaluations will be required on a generic basis. These evaluations will be required in support of making various Program decisions as well as providing generic input to the individual utility's plant unique analysis. The currently identified ongoing activities are identified in the subtasks which follow.

TASK NUMBER: 4.2.1

TITLE: REVIEW STRUCTURAL ACCEPTANCE CRITERIA

OBJECTIVE: To provide technical support toward the development of the Mark I Structure Acceptance Criteria.

DESCRIPTION: This effort will require ongoing review, evaluation, and consultation on development of structural acceptance criteria, as well as analytical and consulting support in presentation and justification of the Structural Acceptance Criteria, component classifications, and service level categories to the Nuclear Regulatory Commission. Participation in this activity will be as dictated by the demands of Task 3.0 - Structural Acceptance Criteria of the Mark I Containment Program.

TARGET DATE: As Required by Task 3.0 - Structural Acceptance Criteria Development

TASK NUMBER: 4.2.2

TITLE: ANALYSIS OF TYPE I AND TYPE III VENT PIPE-RING HEADER INTERSECTIONS

OBJECTIVE: To develop the Type I and Type III vent pipe-ring header intersection flexibilities and stress indices which will be used in plant unique analyses by individual Architect Engineers.

DESCRIPTION: Using vent system finite element models developed during Phase I of the Generic Structural Evaluation, the flexibility coefficients and stress indices for the Type I and Type III vent-ring header intersections are to be calculated. The flexibilities and stress indices for the Type II intersections were previously developed and presented in "The Mark I Vent System Evaluation" dated September 1977 (Task 4.1). The flexibility coefficients and stress indices for the Type I, II, and III vent-ring header intersections are to be compiled in a user application guide. This guide will describe how the coefficients and indices are to be applied for plant unique vent header analyses.

TARGET DATE:

| | |
|---|---|
| Issue Preliminary Evaluation Letter Guide | May 1978 |
| Issue Final Guide Draft for Utility Review | June 1978 |
| Issue Final Guide | July 1978 |

TASK NUMBER: 4.2.3

TITLE: ANALYSIS OF SUBMERGED STRUCTURES

OBJECTIVE: To evaluate submerged structure loads derived using the Task 5.4 analytical models. Evaluate the effect the load definition has in terms of structural stress.

DESCRIPTION: The structures to be considered will include the ring girder, the ring header support columns, ECCS nozzles, return lines and supports, and the catwalk supports. The load methodology to be utilized will be defined in the appropriate submerged structure models of Task 5.14. Where appropriate, a simple, yet conservative approach to the structural analysis may be taken. Additionally, consideration will be given to the potential load combinations and their time phasing in order that a realistic "total" load assessment can be made. The analytical results will be evaluated against the Mark I Containment Program Structural Acceptance Criteria.

TARGET DATE:

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report | April 1978 |
| Issue Final Report Draft For Utility Review | May 1978 |
| Issue Final Report | June 1978 |

TASK NUMBER 4.2.4

TITLE: COORDINATE ARCHITECT ENGINEER (AE) REVIEW OF PRELIMINARY LOAD DEFINITION REPORT (PLER)

OBJECTIVE: To utilize AE comments on the PLER load definitions to ensure that LDR load definitions are compatible with AE requirements for structural analyses.

DESCRIPTION: Comments on the format of the PLER load definitions will be requested from each of the Mark I Utility AEs. These comments will be reviewed and categorized in order that they may be appropriately factored into the various LDR load definition formats. This will ensure that, to the degree possible, the LDR load definitions are compatible with the input parameter requirements of the AE structural models which will be utilized in performing the plant unique analyses.

TARGET DATE: Issue Preliminary Evaluation Letter Report — April 1978

TASK NUMBER: 5.0

TITLE: LOAD EVALUATION

OBJECTIVE: The objective of this task is to provide an adequate technical data base necessary to establish final design basis values for the hydrodynamic loads on Mark I containment structures resulting from a postulated LOCA and S/RV discharge. Included will be loaded determinations with and without load mitigation (operational changes and mitigation devices) to the degree required by Decision Point #3.

DESCRIPTION: The activities planned to accomplish the above objectives are described in the following subtasks.

TASK NUMBER: 5.1

TITLE: MONTICELLO TESTS

OBJECTIVE:

1. To measure pressures and temperatures in the torus and S/RV piping associated with single, multiple and consecutive valve actuations. The measurements will be used to verify the analytical model for prediction of the loads produced by S/RV discharged through a ramshead and a T-quencher.

2. To measure the structural response of the torus, S/RV piping, supports and acceleration of the base mat and pedestal associated with single, multiple and consecutive valve actuations. These measurements will be used to evaluate the structural response of various structural elements in conjunction with other loads acting simultaneously with the S/RV loads.

DESCRIPTION: In-plant testing will provide S/RV actuation data (single, multiple and consecutive valve) to support ramshead and T-quencher analytical model for predicting loads on the torus, torus internals, and the safety relief valve lines. In addition, measurements of the structural response of the torus shell, supports, S/RV lines and supports will be made for use in evaluating the structural response of the affected components. Various activities included in this task are described in the following subtasks.

TASK NUMBER: 5.1.1

TITLE: MONTICELLO RAMSHEAD TEST

OBJECTIVE: To acquire necessary data for developing the containment loads resulting from S/RV ramshead discharge into the Monticello Mark I suppression pool.

DESCRIPTION: In-plant S/RV discharge load testing will be performed in the Monticello torus. Data measurements during the test include: (1) Containment Load Phenomena (torus shell strains, displacements and accelerations, pressure inside torus pool, torus pool temperatures, discharge air bubble formation); (2) Relief Valve Line Discharge Phenomena (pressures inside the pipe, discharge pipe temperatures, water level rise in line, vacuum breaker flow rates or position indicator with valve flow characteristics, S/RV pipe strains and deflections, ramshead support strains, accelerations and deflections, to determine the reactions of the discharge loads); and (3) Structure/Accelerations (torus basemat and torus supports, pedestal). Test data consisting of about 10,000 traces for the 37 test runs recorded on PCM tapes and Wyle Analog tapes will be reduced into time-history graphs and tabulations of phenomena and structural data including calculated principal stresses, etc. The preliminary test data report will include the general test plan, identification of instrumentation and test results. Typical data on the phenomena, S/RV piping and torus structural responses will be included. The final test report will include the test objectives, test matrix and limits, sensor and instrumentation system, test results, discussion of effects of major parameters, summary and conclusions.

TASK NUMBER: 5.1.1 (Continued)

| | | |
|---|---|---|
| TARGET DATE: | Issue Test Plan<br>NEDC-20997, "In-Plant Safety/Relief Valve Discharge Load Test - Monticello Plant", October 1975 | October 1975<br>(Complete) |
| | Complete Test | July 1976<br>(Complete) |
| | Complete Data Reduction (Hydrodynamic) | November 1976<br>(Complete) |
| | Issue Preliminary Test Data Report | January 1977<br>(Complete) |
| | Complete Data Reduction (Structure) | May 1977<br>(Complete) |
| | Issue Final Report<br>NEDC-21581-P, "Final Report - In-Plant Safety/Relief Valve Discharge Load Test - Monticello Plant", August 1977 | August 1977<br>(Complete) |

COMPLETE

TASK NUMBER: 5.1.2

TITLE: MONTICELLO T-QUENCHER TEST

OBJECTIVE: To acquire data to assist the development of containment loads resulting from S/RV T-quencher discharge into the Monticello Mark I suppression pool.

DESCRIPTION: In-plant S/RV discharge load testing will be performed in the Monticello torus. Testing will be performed to assist in subsequent definition of Mark I containment loads resulting from both single, consecutive and multiple valve actuations discharging through the mitigator. Measurements will include pool pressures; pipe water level, temperatures and pressures; torus shell and support column strains; and mitigator and support strains and accelerations. Testing will also be performed to assess T-quencher thermal mixing capability both in a quiescent pool and with RHR pumps operating. To the extent practicable, torus instrumentation will be located to allow correlation of hydrodynamic loading and structural response. Use will be made of existing data acquisition and data reduction equipment supplemented as required. Upon completion of testing, all data will be reduced and evaluated and a test report written.

TARGET DATE:

| | |
|---|---|
| Issue Test Plan | August 1977 (Complete) |
| Complete In-Plant Testing | December 1977 (Complete) |
| Issue Preliminary Evaluation Letter Report | December 1977 (Complete) |
| Complete Thermal Mixing Test | March 1978 |
| Issue Final Report Draft for Utility Review | May 1978 |
| Issue Final Report | July 1978 |

TASK NUMBER: 5.2

TITLE: TEMPORARY TALL TEST TANK (4T) TEST PROGRAM

OBJECTIVE: Use data to attempt to establish reasonable bounding values for Mark I downcomer loads and torus wall loads during low steam flow chugging. Account for downcomer flexibility effects on chugging loads.

DESCRIPTION: The loads measured in this program will be available for early use in performing generic structural evaluations in Task 4.0. Specifically, the downcomer lateral loads in the Phase II testing will be derived from the measured lateral acceleration and bending moment. An equivalent static load will be developed from the 4T and other pertinent test data which takes the cantilever length of the downcomer into consideration. This static load will be applied to the Mark I downcomer to determine vent header to downcomer attachment capability. The suppression pool boundary loads generated in Phase II (hot pool effects from Phase III) will be treated statistically to establish bounding torus loads. Where possible, parametric factors applicable to the Mark I geometry (such as pool area to vent area ratio) will be used in establishing these loads.



TARGET DATES:

| | |
|---|---|
| Test Completed (Mark II) | July 1976 (Complete) |
| Data Reduction (Mark II) | September 1976 (Complete) |
| Issue Final Report (to Mark I) - Phase II/III Test NEDE-13468P, "Mark II Pressure Suppression Test Program, Phase II and III Tests", October 1976 | January 1977 (Complete) |

TASK NUMBER: 5.3

TITLE: FLEXIBLE CYLINDER TESTS

OBJECTIVE: Quantify the influence of fluid/structure interaction for the pool swell impact loads upon the flexible vent header inside the Mark I torus.

DESCRIPTION: A combined experimental and analytical approach has been taken to quantify the vent header fluid/structure interaction effects. The activities involved are described in the following subtasks.

TASK NUMBER: 5.3.1

TITLE: HYDRODYNAMIC IMPACT ANALYSIS (EPRI)

DESCRIPTION: Hydrodynamic impact analysis of rigid and flexible cylinders will be performed to assess the importance of fluid/structure interaction at the ring header. Various fluid/structure analysis techniques will be utilized to determine the response of simple mathematical models of the ring header subjected to water impact.

TARGET DATE:

| | |
|---|---|
| Complete Rigid Cylinder/Water Impact Calculations | June 1977 (Complete) |
| Complete Flexible Cylinder/Water Impact Calculations | February 1978 |
| Compare Analysis with Small Scale Tests (Task 5.3.2) | February 1978 |
| Issue Final Report Draft for Utility Review | April 1978 |
| Issue Final Report | June 1978 |

TASK NUMBER: 5.3.2

TITLE: DROP TESTS (EPRI) — FLEXIBLE/RIGID CYLINDERS

DESCRIPTION: Small-scale drop tests (about 1/6 and 1/3 scale) will be conducted to verify analytical calculations (Task 5.3.1) and to quantify anticipated fluid/structure interaction load reductions experienced by flexible structures. The test facility will be designed to drive horizontal cylinders (both rigid and flexible) into a pool of water at constant velocities from about 6 to 24 fps. Measurements to be taken include impact pressure, forces, strains and accelerations.

TARGET DATE:

| | |
|---|---|
| Complete Test Facility | January 1977 (Complete) |
| Complete 1/6 Scale Tests | April 1977 (Complete) |
| Issue Preliminary Evaluation Report-1/6 Scale Test | May 1977 (Complete) |
| Complete 1/3 Scale Tests | July 1977 (Complete) |
| Issue Preliminary Evaluation Letter Report-1/3 Scale Test | September 1977 (Complete) |
| Issue Final Report Draft for Utility Review | February 1978 |
| Issue Final Report | April 1978 |

TASK NUMBER: 5.3.3

TITLE: POOL SWELL TEST - FLEXIBLE/RIGID CYLINDER

OBJECTIVE: The test program is designed to provide an assessment of the flexibility effects on vent header impact loads under test conditions which accurately simulate pool swell hydrodynamic behavior.

DESCRIPTION: This task will utilize the 1/4 Scale 2-D Facility to simulate the hydrodynamic loading phenomena, including any mitigating effects of pool swell bubbles on vent header loads. Included will be testing of both a rigid and a flexible vent header model. An assessment of the potential for load reduction to be realized from consideration of flexible cylinder effects will be made on the basis of these tests in conjunction with the more qualitative assessment from analysis of Task 5.3.2 flexible and rigid cylinder pool impact test data.

The flexible and rigid test data will be used to develop transient pressure distribution vs. circumferential and longitudinal vent header position to support an assessment of vent header structural capabilities. Use of other available test data, such as EPRI 1/12 scale 3-D tests, may be used to supplement Task 5.3.3 data. This assessment of vent header loads is designed to assist utilities in the definition of plant unique test configurations for Task 5.5.3 1/4 scale pool swell testing.

TARGET DATE:

| | |
|---|---|
| Evaluate 1/4 Scale 2-D and Drop Test Facilities for Comparative Suitability of Testing Vent Headers | May 1977 (Complete) |
| Design and Fabrication of Scoping Scale Models | October 1977 (Complete) |
| Complete Scoping Tests | November 1977 (Complete) |

TASK NUMBER: 5.3.3 (Continued)

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report (TRC Meeting Minutes) | November 1977 (Complete) |
| Issue Final Report Draft (Test) for Utility Review | March 1978 |
| Issue Vent Header Structural Assessment Report | March 1978 |
| Issue Final Report (Test) | May 1978 |

TASK NUMBER: 5.4

TITLE: SEISMIC SLOSH TEST

OBJECTIVE: Use a 1/30 scale Mark I torus model to evaluate simulated earthquake excitations.

1. Determine the wave shape and wave height,

2. Determine the slosh pressure loads at the limiting locations on the torus and drag loads on the downcomers due to slosh.

DESCRIPTION: A 1/30 scale 3-D model of the Mark I suppression pool will be designed and fabricated. Tubular sections will be cut from plastic tubing and bonded together to form the Mark I torus. Geometrically scaled smaller plastic tubing will be used to form the downcomers. The tank will be rigidly mounted on a flat plate seismic shaker. Instrumentation will be installed for determining liquid wave height and slosh load measurements at critical locations. A typical earthquake acceleration/displacement time history (both horizontal and vertical) will be generated for driving the seismic simulator.

An analytical model will be developed to predict the wave profile and slosh loads on the limiting structures. The mathematical model will be verified with the small scale test results. The mathematical model can then be used to calculate the slosh heights and loads for individual plants.

The test data will be recorded on analog tape. Excitation and response time histories will be plotted for ready comparison of results.

TASK NUMBER: 5.4 (Continued)

| TARGET DATE: | | |
|---|---|---|
| | Fabricate Scale Model | March 1977 (Complete) |
| | Develop Analytical Model | April 1977 (Complete) |
| | Perform Simulated Earthquake Test | July 1977 (Complete) |
| | Issue Preliminary Evaluation Letter Report | September 1977 (Complete) |
| | Issue Final Report Draft for Utility Review | October 1977 (Complete) |
| | Issue Final Report | March 1978 |

TASK NUMBER: 5.5

TITLE: 1/4 SCALE 2-D POOL SWELL TESTS

OBJECTIVE: To establish pool swell load information for scaling verification, determination of reference plant loads and plant unique parameter sensitivities.

DESCRIPTION: A 1/4 Scale 2-D Test Facility will be fabricated. It will include a drywell and wetwell with vent header and two downcomers. The specific activities in the test program are discussed in the following subtasks.

TASK NUMBER: 5.5.1

TITLE: 1/4 SCALE 2-D TEST - SCALING LAWS

OBJECTIVE: Demonstrate the validity of the hydrodynamic scaling relationships for pool swell by direct comparison of 1/4 scale and 1/12 scale data.

DESCRIPTION: The task involves construction of a 2-D, 1/4 scale model of the Mark I torus. The facility is scaled to the reference plant geometry but has been designed in such a way that the internals can be readily modified to other geometries and test conditions. This portion of the 1/4 scale 2-D test program will provide pool swell data for the same conditions as the 1/12 scale testing during December 1975 and January 1976. Comparison of the results (velocities, pressures, etc.) will be performed to assess the accuracy of the fundamental scaling laws involved.

Tests will be conducted at both zero and positive drywell overpressure conditions to compare to the loads observed in 1/12 Scale Tests. Any differences between the earlier 1/12 scale results and the 1/4 scale data will be evaluated.



TARGET DATE:

| | |
|---|---|
| Initiate Design | April 1976 (Complete) |
| Approve Final Design | August 1976 (Complete) |
| Complete Tests | November 1976 (Complete) |
| Issue Preliminary Evaluation Letter Report | December 1976 (Complete) |
| Issue Final Report Draft for Utility Review | May 1977 (Complete) |
| Issue Final Test Report<br>NEDE-21627-P "Mark I 1/4 Scale Pressure Suppression Pool Test Program: Scaling Evaluation", January 1978 | January 1978 (Complete) |

TASK NUMBER: 5.5.2

TITLE: DOWNLOAD OSCILLATION EVALUATION

OBJECTIVES: Identify the significant test facility phenomena affecting measured download oscillations and define test conditions and facility modifications, if required, to properly simulate the LOCA air clearing phenomena.

DESCRIPTION: This phase of the 1/4 scale 2-D Part 2 test program is divided into two test series.

Series 1 - Facility Sensitivity

The first test series is designed to evaluate facility sensitivity parameters and clarify facility response and interaction phenomena which may be observed in scaling law tests (Task 5.5.1). This subtask includes modal analyses, structural evaluations of the torus supports and the vent header with facility modifications as required, including installation of the variable stiffness support beam and incorporation of bubble pressure measurement capability.

Series 2 - Facility Fluid/Structure Interaction

The second test series is devoted to identification of the source of fluid/structure interaction and determination of correspondence to prototypical conditions.

TASK NUMBER: 5.5.2 (Continued)

| | | |
|---|---|---|
| TARGET DATE: | Complete Series 1 Facility Sensitivity Test | May 1977 (Complete) |
| | Complete Series 2 Facility Fluid/Structure Interaction Tests | October 1977 (Complete) |
| | Issue Preliminary Evaluation Letter Report | October 1977 (Complete) |
| | Issue Final Report Draft for Utility Review | May 1978 |
| | Issue Final Report | August 1978 |

TASK NUMBER: 5.5.3

TITLE: LDR LOAD TESTS

OBJECTIVE: To provide the necessary 2-D experimental basis for definition of plant unique LDR pool swell loads.

DESCRIPTION: The 1/4 Scale Test Facility (QSTF) has a 93 in. diameter torus which is "1/4 scale" for the reference plant. However, this 93 in. diameter is 26.27% scale for FitzPatrick, 28.02% scale for Monticello, etc. By using these scale factors and adjusting torus width, vent system configuration, drywell volume, pressure, pressurization rate, etc. and using Moody's scaling laws, the QSTF can be employed to perform scaled plant unique tests. The plant unique break areas and vent resistances will be modeled.

The Task 5.5.3 program is divided into two test series, Series 1 - Generic Sensitivity Tests and Series 2 - Plant Unique Tests.

Series 1 - Generic Sensitivity Tests

The Generic Sensitivity Test series has the objectives of providing data on the sensitivity of pool swell to both vent system resistance and the distribution of vent resistance (capacitance); and providing data on pool swell load sensitivities to variations in plant operating conditions such as water level and $\Delta P$.

Series 2 - Plant Unique Tests

The 1/4 Scale Facility will be configured to provide scaled plant unique pool swell tests for all Mark I plants.

TASK NUMBER: 5.5.3 (Continued)

These tests will provide a direct 2-D simulation of all plant unique geometric and hydrodynamic parameters important for pool swell. Downcomer submergence, operating $\Delta P$ and other plant unique information will be specified by individual Mark I utilities.

| | | |
|---|---|---|
| TARGET DATE: | Complete Testing (Series 1 - Generic) | March 1978 |
| | Complete Testing (Series 2 - Plant Unique)* | August 1978 |
| | Issue Final Report Draft for Utility Review | October 1978 |
| | Issue Final Report | December 1978 |

* Plant unique preliminary evaluation letter reports to be issued for each plant unique test series.

TASK NUMBER: 5.6

TITLE: 3-D POOL SWELL TESTS

OBJECTIVE: To establish 3-D effects on pool swell surface velocity, vent header impact and up/down loading on the torus.

DESCRIPTION: Perform 1/12 scale 3-D cylindrical tests simulating a $90^{o}$ sector of a torus, with supporting 1/30 scale cylinder/ $360^{o}$ torus comparative tests. Specific test programs are discussed in the following subtasks.

TASK NUMBER: 5.6.1

TITLE: 1/12-SCALE 3-D TESTS (EPRI)

OBJECTIVE: To establish 3-D LOCA pool swell and hydrodynamic loading phenomena including pool swell transient surface shape, vent header loading, impact and sweep timing, net up/down loading on the torus and downcomer clearing time. To investigate effects of asymmetric vent flow.

DESCRIPTION: Three-dimensional pool swell effects will be quantified by performing dynamic tests on a 1/12 scale Mark I multiple downcomer model. The model wetwell is a clear plastic straight-circular cylinder and simulates a 90° sector of the torus. The model contains two vent pipes and twelve pairs of downcomers. The vent system support is isolated from that of the torus to allow separate load measurements. The wetwell is instrumented with distributed pressure transducers so that the load on the torus can be confirmed by spatial pressure integration. Proper scaling of the vent flow resistance is accomplished by a separate flow characteristic experiment. Dynamic tests will be performed and compared with those from 2-D tests to provide the 3-D correction factors. These tests will quantify load attenuation due to irregular spacing of downcomers, as well as determine the possibility of measuring horizontal (i.e., circumferential) and vertical pool submerged velocities.

TARGET DATE:

| | |
|---|---|
| Complete Facility | April 1977 (Complete) |
| Complete Initial Visual (Movie) Tests | August 1977 (Complete) |
| Issue Preliminary Evaluation Letter Report | November 1977 (Complete) |

TASK NUMBER: 5.6.1 (Continued)

| | |
|---|---|
| Complete ΔP and Submergence Parametric Tests | March 1978 |
| Complete Load Definition Tests | April 1978 |
| Complete Asymmetric Mass Distribution Tests | May 1978 |
| Complete Parametric Tests | June 1978 |
| Issue Final Report Draft for Utility Review | July 1978 |
| Issue Final Report | September 1978 |

TASK NUMBER: 5.6.2

TITLE: 1/30 SCALE 3-D TESTS

OBJECTIVE: To qualitatively assess comparative open tank pool swell hydrodynamic behavior in a cylinder and $360^{o}$ torus.

DESCRIPTION: A 1/30 scale cylinder model similar to the EPRI 1/12 scale model (Task 5.6.1) will be constructed. This 1/30 scale cylinder will be tested in conjunction with a 1/30 scale $360^{o}$ torus (from Task 5.4 Seismic Slosh Tests) for pool swell and assess any visual differences in pool behavior.

TARGET DATE:

| | |
|---|---|
| Complete Tests | September 1977 (Complete) |
| Present Preliminary Evaluation | October 1977 (Complete) |
| Issue Final Report Draft for Utility Review | December 1977 (Complete) |
| Issue Final Report | February 1978 |

NEDC-23752 - "A Comparison of 1/30 Scale $360^{o}$ Torus and Straight Cylinder Open Tank Pool", February 1978

TASK NUMBER: 5.8

TITLE: 1/12 SCALE 2-D TESTS

OBJECTIVE:

1. Provide a statistically adequate data base at 1/12 scale to evaluate hydrodynamic scaling.

2. Provide scoping tests to support the investigation of the downward load anomaly observed between the December 1975 and January 1976 1/12 scale test series.

DESCRIPTION: An improved data base at 1/12 scale will be provided to aid in the evaluation of scaling laws when compared against 1/4 scale test data. A series of about 32 runs will be made at both reference conditions and with drywell pressure differential. Control of initial conditions will be improved by consideration of air temperature and humidity conditions.

Also, the scoping tests for the effects of structural flexibility on torus pressure forces will be analyzed in conjunction with Task 5.5.1 results.

| | | |
|---|---|---|
| TARGET DATE: | Complete Tests | October 1976 (Complete) |
| | Issue Final Report NEDE-21492P, "Mark I 1/12 Scale Pressure Suppression Pool Swell Test Program - Phase IV Tests", March 1977 | April 1977 (Complete) |

TASK NUMBER: 5.9

TITLE: POOL SWELL MODEL DEVELOPMENT (EPRI)

OBJECTIVE: Develop 2-D computer programs to simulate the pool swell phenomena. Validate these programs against available test data and qualify them for application to loads prediction.

DESCRIPTION: The single cell (VENT3/SURGE) computer programs will be developed to simulate the hydrodynamic response in the wetwell resulting from the postulated LOCA during the period from initial drywell pressurization and vent clearing to the point of bubble breakthrough. The models developed will be used to: 1) quantify vertical pool velocities on structures above the initial water level; 2) investigate timing of downcomer clearing; and 3) investigate up-and-down loads on a generic torus. These models will be verified against 1/12 Scale 2-D and 1/4 Scale 2-D test results. A final report will be issued which will give the analytical bases for the model development and the comparisons to test data used in code validation.

In addition, the capability of the single cell codes to predict approximate flow field velocity and acceleration characteristics and water clearing period will be investigated to support submerged structure loads (Task 5.14).

TARGET DATE:

| | |
|---|---|
| Complete Single-Cell VENT3/SURGE Code | June 1977 (Complete) |
| Incorporate Improved VENT 3-Extended (3-D) Bubble Model | September 1977 (Complete) |
| Validate VENT3/SURGE for Torus Loads (EPRI) | February 1978 |

TASK NUMBER: 5.9 (Continued)

| | |
|---|---|
| Validate VENT3/SURGE Code for use in LDR for Torus Loads (GE) | April 1978 |
| Issue Final Report Draft for Utility Review (EPRI) | April 1978 |
| Issue Final Report (EPRI) | June 1978 |

TASK NUMBER: 5.10

TITLE: MISCELLANEOUS MONITORING

OBJECTIVE: To monitor for any pertinent information of test and analytical activities going on outside of the present Mark I Program.

DESCRIPTION: Pressure suppression efforts going on in other organizations and facilities (i.e., 1/4 scale 3-D tests at Livermore, LOFT program in Idaho, Marviken tests, and others) may yield information of use to the Mark I Program. Appropriate technical personnel will monitor the reports, establish contacts, and make periodic visits as required.

TARGET DATE:

| | |
|---|---|
| Meeting with KWU (Germany) | October 1976 (Complete) |
| Meeting with Marviken (Sweden) | November 1976 (Complete) |
| Review of Livermore Test (Washington) | January 1977 (Complete) |
| Meeting with LOFT (Idaho) | January 1977 (Complete) |
| Presentation to ACRS | July 1977 (Complete) |
| Review Livermore Preliminary Test Reports (1/5 Scale Pool Swell) | September 1977 (Complete) |
| Presentation to ACRS | November 1977 (Complete) |
| Other Monitoring Activities | As Required |

TASK NUMBER: 5.11

TITLE: FULL SCALE TEST FACILITY

OBJECTIVE: To define hydrodynamic loads and dynamic structural response from medium and low mass flux steam condensation phenomena on a representative torus sector in a Full Scale Test Facility (FSTF).

DESCRIPTION: A Full Scale, 3-D 8-Vent Test Facility simulating a representative Mark I containment will be designed and constructed. The facility will consist of a wetwell, drywell, steam supply, vent system, instrumentation, data acquisition system and other auxiliary equipment. The wetwell envelope will be large enough to house up to four downcomer pairs in a 22-1/2 degree sector of a Mark I containment torus. The drywell, steam supply and vent system will be scaled as required to produce representative plant steam condensation conditions for a design basis Loss-of-Coolant Accident. Irstrumentation will be installed to measure steam flow, drywell temperature and pressure, vent flow and pressure, wetwell wall pressures, accelerations, strains and displacements, downcomer accelerations, wall pressures, water level and temperature, local ring header strains and torus support column strains.

The test program will investigate the containment medium and low mass flux steam condensation loads and structural response for a typical geometry over a range of representative Mark I parameters.

TASK NUMBER: 5.11 (Continued)

| TARGET DATE: | | |
|---|---|---|
| | Finalize Test Matrix | December 1977 (Complete) |
| | Complete Site Construction | February 1978 |
| | Complete Testing | June 1978 |
| | Issue Last of Preliminary Evaluation Letter Report Series | June 1978 |
| | Issue Final Report Draft for Utility Review | September 1978 |
| | Issue Final Report | November 1978 |

TASK NUMBER: 5.13

TITLE: CHUGGING ANALYTICAL EVALUATION

OBJECTIVE: The initial objective of this task is to attempt to develop an analytical model, formulated through the evaluation of existing technology, to predict chugging loads in a BWR Mark I or Mark II containment. An alternate objective will be to provide short-term prediction capability through basic physical understanding of chugging. This capability will be improved upon through correlation and calibration with additional test data, and can be used in the planning and direction of necessary test programs, should the analytical modeling efforts not be totally satisfactory.

DESCRIPTION: The analytical model development is divided into four activities:

1. Single-vent chugging
2. Multiple-vent chugging
3. S/RV plus chugging combinations
4. 4T-facility fluid/structure interaction

The first three activities listed are closely interrelated. The fourth is separate.

1. Single-Vent Chugging

In this portion of the task, all available relevant chugging test data will be assembled, reduced to common units and presented in a format useful for correlation with the analytical model. In a parallel task, a "first principles" analytical model will be developed based upon the application of laws of hydrodynamics, heat transfer, and thermodynamics. Bench-scale tests may be used to develop basic understanding. After the initial phase of

model development, the adequacy of the models will be verified with a prediction of 4T test results. The predicted results will be compared to actual test results and the model will be adjusted accordingly.

2. Multiple-Vent Chugging

In parallel with the single-vent efforts, a model will be developed for the prediction of multiple-vent loads on the containment boundary using single-vent chugging forces as an input. The model will use potential flow theory and simple assumptions to permit superposition of pressure derived from existing single vent test data. The fundamental physical model described in "single-vent chugging" will also be expanded to include multiple-vent effects.

A small (1/12 scale) multiple-vent test program will be conducted to qualitatively investigate chugging phasing, attenuation of the chugging load with pool-to-vent area maintained constant. These tests will provide insight into the degree of participation of each single cell to the overall containment load. The test facility will consist of a twelve-vent wetwell, steam supply, drywell vent system and associated equipment in approximate 1/12 scale. Measurements will be made of wetwell free space pressure, pool pressures at the torus wall and pool temperature. High speed movies will be taken of each test.

3. S/RV Plus Chugging Combinations

It is possible that S/RV air clearing loads and chugging loads could occur together in the event of a small pipe

break. In phase, addition of these loads is excessively conservative due to the random nature of both signal types and because the presence of S/RV discharge air bubbles will increase the compressibility of the wetwell fluid which may attenuate the chugging load. Combined chugging and S/RV loads will be evaluated by a Monte Carlo statistical analysis using chugging and S/RV pressure traces from existing test data, without any credit for attenuation due to the presence of air bubbles. The output will be a probability distribution of the combined loads. The fundamental physical model for chugging will be extended to address the combination of the chugging signal with the presence of an S/RV signal. If this effort is successful, the results will be factored into the Monte Carlo predictive model.

4. 4T Fluid/Structure Interaction

In order to understand the facility effects on the test data, a study will be made of the 4T Test data. This will include a modal survey of the 4T Test Facility with and without fluid, tests with a simulated steam bubble collapse, and an analytical model to correlate the test results and to understand the facility influence on the pressure measurements.

The signature of the chugging phenomenon will be isolated from the structural response, and the chugging forcing function will be identified. The objective of this scope of work is to develop and assess the chugging pressure forcing function, in order to identify the significance of fluid/structure interaction on the data. It is not planned to isolate the chugging signal from all 4T chugging traces.

TASK NUMBER: 5.13 (Continued)

| TARGET DATE: | | |
|---|---|---|
| | Issue Preliminary Report - Modal Survey of 4T (in Final Report) | April 1977 (Complete) |
| | Issue Preliminary Report - Preliminary Single Cell Model (in Final Report) | April 1977 (Complete) |
| | Issue Preliminary Report - Preliminary Results from Monte Carlo Simulation (Without Final Multivent Model) (in Final Report) | May 1977 (Complete) |
| | Issue Preliminary Report - Preliminary Multivent Model (in Final Report) | July 1977 (Complete) |
| | Issue Preliminary Report - Preliminary Results from Monte Carlo Simulation Based on Multivent Model (as Required) | August 1977 (Complete) |
| | Complete Multivent Tests | September 1977 (Complete) |
| | Issue Final Report Draft for Utility Review (Single Cell, Multivent and Load Combination Models) | October 1977 (Complete) |
| | Issue Final Report Draft for Utility Review - Multivent Test | March 1978 |
| | Issue Final Report - (Single Cell Multivent and Load Combination Models) | March 1978 |
| | Issue Final Report - Multivent Test | May 1978 |

TASK NUMBER: 5.14

TITLE: SUBMERGED STRUCTURES

OBJECTIVE: The primary objective of this task is to define loads on submerged structures in the suppression pool due to:

1. Main vent air clearing bubbles (LOCA)
2. Main vent water clearing
3. S/RV air clearing bubbles
4. S/RV water clearing
5. Main vent steam condensation loads.

The program has been based on development of submerged structure loads from the present Mark I downcomers and S/RV ramshead discharges. The program will be supplemented to include submerged structure loads due to downcomer reduced submergence and the S/RV T-quencher device as selected at Decision Point #3.

DESCRIPTION: This program is divided into four parts as defined below. Assessment of the need for continuation will be made after completion of each part to assure that the anticipated results of the next test series are technically required.

Part 1 - Theoretical Models

This task involves formulating theoretical models to predict both the velocity and acceleration components of S/RV ramshead and postulated LOCA loads due to submerged jets, air clearing bubbles, and steam condensation. The initial models will predict loads associated with the original discharge devices. A numerical model (Task 5.9) will be used for predicting the main vent air bubble loads. Consideration will be given to develop additional models or a bounding load technique to predict loads associated with the S/RV T-quencher.

Consideration will be given to testing as an alternative to model revisions. In addition to the model development effort, extensive consultation and a detailed literature review will be conducted to ensure the models reflect the existing technology in the field of submerged structure loads.

Part 2 - PSTF 1/3 Scale Tests

This part of the program consists of conducting load measurements during the 1/3 scale Mark III tests scheduled in the Pressure Suppression Test Facility (PSTF). Load measurements due to main vent clearing, air bubble formation, and steam condensation will be measured on instrumented sheath pipes mounted on PSTF baffle walls.

Part 3 - Simple Geometry Square Tunnel Tests and Mark I 1/4 Scale Tests

Tests will be run in controlled velocity and acceleration fields to support model (Part 1) verification of loads on submerged structures. The test will be carried out in a blowdown-type facility being constructed with a square tunnel and using instrumented simple geometry structures mounted in the test section. Additional tests will utilize the Mark I 1/4 scale pool swell facility and will measure submerged loads on simple structures. Those measurements will be planned based on experience gained from PSTF tests described in Part 2. The test results will also be used to verify the numerical model (Task 5.9).

Part 4 - Model/Data Evaluation

The last part of the program will be a comprehensive model/data evaluation of all available test data from the above tasks.

TASK NUMBER: 5.14 (Continued)

The results will then be incorporated into the models which predict loads on submerged structures due to postulated LOCAs, S/RV actuations, and main vent chugging. A Topical Report will summarize the results of this final effort.

TARGET DATE:

Part 1 - Theoretical Models

- LOCA (with Reduced Submergence) and S/RV Ramshead

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report | June 1977 (Complete) |
| Issue Final Report Draft for Utility Review | July 1977 (Complete) |
| Issue Final Report<br>NEDE-21472, "Analytical Model for Liquid Jet Properties for Predicting Forces on Rigid Submerged Structures", September 1977<br>NEDO-21471, "Analytical Model for Estimating Drag Forces on Rigid Submerged Structures Caused by LOCA and Safety Relief Valve Ramshead Air Discharges", September 1977 | February 1978 (Complete) |

- S/RV T-quencher (Model or Methodology)

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report | * |
| Issue Final Draft Report for Utility Review | * |
| Issue Final Report | * |

- Main Vent Steam Condensation (Chugging)

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report | June 1977 (Complete) |
| Issue Final Report Draft for Utility Review | April 1978 |
| Issue Final Report | June 1978 |

* To be established upon method of approach development.

TASK NUMBER: 5.14 (Continued)

Part 2 - PSTF 1/3 Scale Models

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report | June 1977 (Complete) |
| Issue Final Report Draft for Utility Review | July 1977 (Complete) |
| Issue Final Report NEDE-21606-P, "Mark III One-Third Area Scale Submerged Structure Tests", October 1977 | September 1977 (Complete) |

Part 3 - Simple Geometry Tests and 1/4 Scale Tests

| | |
|---|---|
| Complete Tests | February 1978 |
| Issue Preliminary Evaluation Letter Report | April 1978 |
| Issue Report Draft for Utility Review | May 1978 |
| Issue Final Report | July 1978 |

Part 4 - Data Evaluation

| | |
|---|---|
| Issue Final Report Draft for Utility Review | October 1978 |
| Issue Final Report | December 1978 |

TASK NUMBER: 5.15

TITLE: STRUCTURAL HYDRODYNAMIC INTERACTION

OBJECTIVE: To provide analytical or semi-empirical models to quantify the effects of structural hydrodynamic interaction phenomena on dynamic loads.

DESCRIPTION: Obtain structural hydrodynamic computer models currently available from industry/university sources. Apply models to Mark I geometry for quantification of effects of fluid/structure interaction on loads to be used in Task 7.0 (Load Definition Report). Verify application with small scale tests. Activities required to complete this task are described in the following subtasks.

TASK NUMBER: 5.15.1

TITLE: ANALYTICAL EVALUATION

OBJECTIVE: Develop a method which permits assessment of Fluid/Structure Interaction (F/SI) effects on loads and structural responses in support of application of the Task 7.0 Load Definition Report.

DESCRIPTION:

Phase I - Available Analytical Models

Perform a systematic survey of fluid/structure interaction computer code capabilities currently available from industry/university sources. Provide a set of representative fluid/structure interaction problems to agencies judged to have the most promising computer code capabilities and use results from these codes to provide a technical evaluation for potential application to Mark I load descriptions.

Utilizing the most promising of the available computer codes, assess the effect of fluid/structure interaction on load descriptions to be provided in Task 7.0.

Phase II - Data Assessment

A three-dimensional hydrostructural computer code, selected from the the Phase I survey, will be utilized for application of the condensation loads to the Mark I configuration. This computer code will represent the vent-bubble as a point source in the fluid. The fluid will be treated as an acoustic medium coupled with a structural dynamics model. This computer code will be compared with 1/12 scale test data (Task 5.15.2).

TASK NUMBER: 5. 5.1 (Continued)

Using the analytical chugging load specification developed in Task 5.13 as the source imput, the degree of F/SI in FSTF will be evaluated. If the F/SI experimental results from Tasks 5.15.2 and 5.11 test data are judged to be small enough to allow a bounding load definition, this task will be terminated. If the F/SI experimental effects from Task 5.15.2 and Task 5.11 test data are large, development and verification requirements for this program will be reassessed.

TARGET DATE:

Phase I - Available Analytical Models

| | |
|---|---|
| Complete Survey of Available Computer Codes | July 1977 (Complete) |
| Issue Final Report Draft (Phase I) for Utility Review | November 1977 (Complete) |
| Issue Final Report (Phase I) NEDE-21773, "Fluid Structure Interaction Capability Survey, Phase I", January 1978 | January 1978 (Complete) |

Phase II - Data Assessment

| | |
|---|---|
| Program Specification and Issue of Subcontract for Code Documentation | January 1978 (Complete) |
| Completion of Code Documentation | March 1978 |
| Assessment of F/SI Effects | July 1978 |

TASK NUMBER: 5.15.2

TITLE: TEST SUPPORT FOR FLUID/STRUCTURE INTERACTION

OBJECTIVE: Evaluate the fluid/structure interaction due to the steam vent chugging phenomena by determination of values of wall pressure response for rigid and flexible structures. Identify the significant parameters affecting these values.

DESCRIPTION: The 1/12 Scale Multivent Chugging Test Facility (previously used in the Task 5.13 Chugging Analytical Task) will be modified to perform chugging tests measuring the response of various flexible, segment flat plate models (in comparison to rigid flat plate models). The flat plates will be positioned as chord segments in the lower regions of the 1/12 scale circular cylinder test facility. Instrumentation on the flat plates will include pressure transducers, accelerometers and displacement gages for both rigid and flexible tests. Tests will be performed with both rigid a . flexible chord plates to permit evaluation of fluid/structure interaction effects on a directly comparable basis.

At the conclusion of these tests, the order of magnitude effects of fluid/structure interaction on measured loads in the 1/12 Scale Facility will be assessed based on available chugging test data from the test facility, the available analytical models used in development of the flexible segment flat plate test specifications, and the generic model developed in Task 5.15.1.

| | | |
|---|---|---|
| TASK NUMBER: | 5.15.2 (Continued) | |
| TARGET DATE: | Complete Facility Design and Modifications | December 1977 (Complete) |
| | Complete Flat Plate Chord Tests | February 1978 |
| | Issue Preliminary Evaluation Letter Report | March 1978 |
| | Issue Final Report Draft (Test Results) for Utility Review | May 1978 |
| | Issue Final Report (Test Results) | July 1978 |

TASK NUMBER: 5.16

TITLE: MARK I SUBMERGENCE TEST

OBJECTIVE: To obtain representative chugging wall and indications of downcomer lateral loads for downcomer submergences typical of Mark I containments.

DESCRIPTION: The activities which accomplish the above objective are described in the following subtasks.

TASK NUMBER: 5.16.1

TITLE: CHUGGING TEST

OBJECTIVE: To obtain representative chugging wall loads for nominally 4 feet submergences typical of plants with Mark I containments (about 1.2 meters) for preliminary evaluation activities in Tasks 2.0 and 4.0; and to obtain sufficient data to define a curve of chugging load versus submergence.

DESCRIPTION: Tests will be run at a GE Licensee facility where chugging tests have previously been run. It is planned to use initial conditions identical to previously run tests, except submergences will be 2.0, 1.2 and 0.6 meters. In the initial test series, two blowdowns will be performed at each of these submergences. It may be desirable to run additional blowdowns in a subsequent series, depending on the consistency of the test data. The test matrix is planned such that, using prior submergence data, the test will result in curve of chugging wall load versus vent submergence. Downcomer lateral strains will be recorded and downcomer lateral loads will be assessed. Submergence will be reduced by reducing water level as opposed to cutting the downcomer pipe.

Upon completion of the initial test series, an additional three tests will be conducted to evaluate the effect of pool temperature on chugging wall loads. These tests will be conducted at constant 1.2 meter submergence and initial conditions consistent with those previously tested.

TASK NUMBER: 5.16.1 (Continued)

| | | |
|---|---|---|
| TARGET DATE: | Complete Test Facility Reactivation (Instrumentation Rework and Installation) | February 1977 (Complete) |
| | Complete Testing | April 1977 (Complete) |
| | Issue Preliminary Test Report to Utilities for Review | June 1977 (Complete) |
| | Final Report to be incorporated in Task 5.16.2 | |

COMPLETE

TASK NUMBER: 5.16.2

TITLE: CHUGGING MITIGATION TEST

OBJECTIVE: To assess containment wall loads produced by condensation phenomena for a single downcomer at a typical Mark I submergence with mitigation device attached to the end of the downcomer.

DESCRIPTION: Tests will be run to obtain condensation loads in the GE Licensee test facility for a submergence typical of a Mark I containment with a load mitigation device installed at the end of the downcomer. With the exception of the device, the same facility, instrumentation, flexible wall and initial conditions will be utilized as in the previous testing performed in Task 5.16.1. Testing will be conducted at variable initial pool temperatures. A total of three blowdowns will be carried out at a submergence of 1.2 meters, and the resulting chugging wall loads will be compared to those produced in the previous testing in Task 5.16.1 at the same submergence. Selection of the load mitigation device to be tested will be based upon an expedited review of test data and the application of engineering judgment.

Lateral downcomer restraint strains will be recorded, and downcomer lateral loads will be evaluated. The resulting lateral loads will be compared to those developed in Task 5.16.1 to assess effects of addition of a mitigator device.

TASK NUMBER: 5.16.2 (Continued)

| | | |
|---|---|---|
| TARGET DATE: | Complete Testing | May 1977 (Complete) |
| | Issue Final Report Draft for Utility Review - Mitigator Testing | July 1977 (Complete) |
| | Issue Final Report Draft for Utility Review - Downcomer Lateral Loads | September 1977 (Complete) |
| | Issue Final Report - Downcomer Lateral Loads | January 1978 (Complete) |
| | NEDL-23715, "Results of the Single-Pipe Condensation Tests in the GKM II Test Stand - Summary Description of the Strut Loads in Tests No. 1-14, Volume III", September 1977 | |
| | Issue Final Report - Mitigation/ Non-Mitigation Wall Loads | April 1978 |

TASK NUMBER: 5.17

TITLE: CONDENSATION OSCILLATION EVALUATION

OBJECTIVE: Develop an understanding of condensation oscillation phenomena and define analytical/experimental programs to determine generic Mark I condensation oscillation loads.

Develop analytical model for condensation loads; provide experimental verification; and predict plant unique condensation oscillation loads.

DESCRIPTION: Phase I - Phenomenon Identification

During the medium steam mass flux flow regime phase of the Loss-of-Coolant Accident, unstable condensation can occur at the downcomer exit producing pressure oscillations within the pool boundaries. Existing data from 4-T and GE Licensee tests will be examined to further characterize the load. A phenomenological model of condensation oscillation will be constructed and areas identified where further understanding is required.

Analytical modeling of the condensation oscillation phenomenon will: (1) identify system geometric and thermodynamic variables which fix the amplitude and frequency of condensation oscillation; (2) determine scaling laws relevant to the physics of condensation oscillation; and (3) facilitate the design, execution, and data reduction of sub-scale and full-scale tests.

The analytical models of chugging phenomenon (developed under the Mark I Containment Program Task 5.13) will provide the basis for development of a condensation oscillation first principles model. The modeling effort will use as input data obtained from previous tests, the literature

survey and data obtained from sub-scale pilot experiments. The latter sub-scale pilot experiments will be carried out to confirm the validity of the various analytical model elements, as required.

Phase II - Analytical/Experimental Models

The Phase I model for analytical prediction of condensation loads will be expanded to include all identified parameters which influence condensation oscillation phenomena. The continuation of this analytical investigation will be closely coupled to pilot experiments at Aeronautical Research Associates of Princeton (ARAP) bench top condensation facility. Parameters which will be investigated experimentally include: pool subcooling, air content in the steam flow, vent length and vent friction. The model will be empirically adjusted by use of results from both pilot experiments and from the more extensive tests program described below.

The model developed as a result of the analytical investigations will be adjusted by use of experimental results including FSTF data. The test results adjusted for the effects of fluid/structure interaction (Task 5.15) will be compared to the analytical predictions as a final full scale verification of the model. The analytical model, after verification using FSTF data, will be used to predict plant unique condensation oscillation loads. Parameters covering all existing Mark I plants will be considered in the predictions.

TASK NUMBER: 5.17 (Continued

Upon completion of the basic analytical development of the model, a parallel study will be initiated to conceptually identify various techniques which might be used to mitigate the condensation oscillation phenomena.

| TARGET DATE: | | |
|---|---|---|
| | Complete Phase I Evaluation Report | February 1978 |
| | Complete Phase II Model Development | April 1978 |
| | Complete Conceptual Mitigation Studies | May 1978 |
| | Complete Plant Unique Predictions | July 1978 |
| | Issue Final Draft Report for Utility Review | August 1978 |
| | Issue Final Report | October 1978 |

TASK NUMBER: 5.18

TITLE: MULTIVENT INTERACTION TEST

OBJECTIVE: To determine multivent interaction effects on chugging loads on a basis decoupled from fluid/structure interaction effects. The information developed will be applied to the FSTF measured loads for use in the Load Definition Report (LDR) (Task 7.0).

DESCRIPTION: Tests will be conducted to determine the multivent effects in chugging loads in the facility used for Task 6.1. Loads will be determined at about 1/10 scale with 1, 3 and 7 vents and at about 1/6 scale with 1 and 3 vents. Existing test tanks and instrumentation will be used. Based on these tests, it is expected that the 8 vent FSTF test will result in bounding load predictions by showing that there is no multivent reinforcement of chugging loads. Test variations will be included for multivent chugging effects related to submergence, mass flux, drywell volume and pool temperature in sufficient degree to support resolution of the FSTF test matrix required for final load definition.

Results will be correlated with existing multivent models (Task 5.13) and then coordinated with fluid/structure interaction studies (Task 5.15) to provide a technique for application of measured FSTF loads to plant unique applications.

TASK NUMBER: 6.0

TITLE: LOAD MITIGATION DEVELOPMENT TESTING

OBJECTIVE: To provide quantitative evaluation of different mitigating devices (for LOCA and S/RV loads) for the purpose of identifying potential devices for development and, potentially, plant unique implementation. The task also identifies those program changes that will be incorporated subsequent to Decision Point #2 with regard to mitigated containment loads.

DESCRIPTION: This activity is divided into subtasks described in the following pages.

TASK NUMBER: 6.1

TITLE: CHUGGING TESTS

OBJECTIVE: To evaluate the effects of varying plant parameters on resulting chugging loads and to identify downcomer devices that mitigate chugging loads.

DESCRIPTION: This activity is divided into two subtasks which are described in the following pages.

TASK NUMBER: 6.1.1

TITLE: CHUGGING TESTS - PARAMETRICS

OBJECTIVE: To obtain the effect of various parameters on wetwell chugging wall loads and to develop scaling relationships for extrapolation to full scale, using a straight downcomer configuration for base case data.

DESCRIPTION: Scoping tests will be conducted to provide quick-look flow visualization and plant parameter sensitivity information. The tests will be conducted in a steel/Plexiglas facility with minimal instrumentation.

Based upon the results of the scoping tests, additional tests will be conducted to assess more extensively the influence of various parameters on wetwell chugging wall loads. Increased parameter variation and instrumentation capability will be included. Parameters to be studied include vent-to-wall clearance, vent submergence, wetwell pressure, wetwell airspace volume, steam air content and wetwell pool temperature. Testing of important parameters will be conducted at more than one scale.

Formulation of empirical and analytical scaling bases will be attempted for potential use in mitigation design and planning for large scale testing. Some testing will be conducted to provide a preliminary assessment of downcomer lateral loads on a comparative basis for variations in downcomer structural configuration and stiffness.

TASK NUMBER: 6.1.1 (Continued)

| TARGET DATE: | | |
|---|---|---|
| | Complete Scoping Tests | March 1977 (Complete) |
| | Issue Preliminary Evaluation Letter Report - Scoping Tests | May 1977 (Complete) |
| | Issue Final Report Draft for Utility Review - Scoping Tests | August 1977 (Complete) |
| | Issue Final Report - Scoping Tests NEDE-24505, "Preliminary Evaluation of Chugging and Chugging Loads Mitigation Devices Using a Semi-Scaled Facility. Volume 1. Standard Downcomer Parametric Tests", October 1977 | December 1977 (Complete) |
| | Complete Parametric Tests | July 1977 (Complete) |
| | Issue Preliminary Evaluation Letter Report - Parametric Tests | October 1977 (Complete) |
| | Issue Final Report Draft for Utility Review - Parametric Tests | April 1978 |
| | Issue Final Report - Parametric Tests | June 1978 |

TASK NUMBER: 6.1.2

TITLE: CHUGGING TESTS - MITIGATION DEVELOPMENT

OBJECTIVE: To identify a device or modification to existing downcomers which significantly reduces the consequences of the chugging load on the containment wall and the downcomer itself.

DESCRIPTION: Scoping tests similar to those of Task 6.1.1, but with selected downcomer devices, will be conducted to provide quick-look flow visualization and mitigator performance comparison information. The scoping tests will be followed by more extensive testing. For each test phase, tests will be conducted to evaluate the relative performance of various chugging load mitigation devices. The chugging wall loads measured for each mitigation scheme will be compared to the performance of the standard downcomer base case tested in Task 6.1.1 for the same initial conditions. An assessment of installation of a downcomer device on lateral loads will be made.



The mitigation devices will be selected primarily on the basis of expected capability for mitigating chugging loads, but consideration will also be given to expected capability for other LOCA loads.

TARGET DATES:

| | |
|---|---|
| Complete Scoping Tests | March 1977 (Complete) |
| Issue Preliminary Evaluation Letter Report - Scoping Tests | May 1977 (Complete) |
| Issue Final Report Draft for Utility Review - Scoping Tests | August 1977 (Complete) |

TASK NUMBER: 6.1.2 (Continued)

| | |
|---|---|
| Issue Final Report - Scoping Tests<br>NEDE-24505, "Preliminary Evaluation of Chugging and Chugging Loads Mitigation Devices Using a Semi-Scaled Facility. Volume II. Tests of Load Mitigation Devices", October 1977 | December 1977 (Complete) |
| Complete Mitigation Tests | September 1977 (Complete) |
| Issue Preliminary Evaluation Letter Report - Mitigation Tests | October 1977 (Complete) |
| Issue Final Report Draft - (Mitigation Tests) for Utility Information | February 1978 |

CANCELLED

TASK NUMBER: 6.2

TITLE: SAFETY RELIEF VALVE DISCHARGE TEST

OBJECTIVE: To develop an S/RV discharge load mitigation plan that will reduce the air-clearing loads for first and subsequent actuation and provide stable condensation over all operating conditions.

DESCRIPTION: The activities planned to accomplish the above objective are described in the following subtasks.

TASK NUMBER: 6.2.1

TITLE: S/RV DISCHARGE T-QUENCHER DEVELOPMENT

OBJECTIVE: To design, develop and test an effective S/RV discharge load mitigation device suitable for installation in Mark I containments.

DESCRIPTION: A prototype load mitigation T-quencher device will be designed to reduce the air clearing containment loads for single, consecutive and multiple S/RV actuations while producing stable condensation over the full operating range of plant conditions. The mitigation potential of the prototype quencher relative to the standard ramshead will be established by small scale testing. Additional small scale out-of-plant parametric testing will be performed, as necessary, to assess the effects of varying plant geometries and initial conditions.

To assess installation suitability for Mark I plants, conceptual Mark I quencher piping and support system designs will be provided. To adapt the prototype T-quencher device for Mark I plants, the loads definition specification for the prototype T-quencher will incorporate loads determined by improved models (Tasks 7.1.1 and 7.1.2) and full-scale loads determined from the Monticello T-quencher test (Task 5.1.2). A generic design for the T-quencher arms will be prepared. The generic design will not include the complete T-quencher assembly. The design document will include the hardware drawings and the specification for the T-quencher arms. The T-quencher hole pattern will be specified in these documents.

TASK NUMBER: 6.2.1 (Continued)

TARGET DATE:

| | |
|---|---|
| Issue Preliminary In-Plant Test Package | May 1977 (Complete) |
| Complete Confirmation Tests | July 1977 (Complete) |
| Issue Preliminary Evaluation Letter Report - Confirmation Testing | July 1977 (Complete) |
| Issue Final Report Draft for Utility Review - Confirmation Testing | August 1977 (Complete) |
| Issue Final In-Plant Test Package<br>"Generic Test Requirements for Determination of SRV Discharge Loads Utilizing Either Ramshead or Mitigator" | September 1977 (Complete) |
| Issue Final Report Draft for Utility Review - Scaling Analysis for Initial S/RV Discharge Loads | November 1977 (Complete) |
| Issue Final Report Draft for Utility Review - Conceptual Design/SRV Quencher Supports | November 1977 (Complete) |
| Issue Final Report - Confirmation Testing<br>NEDE-24504, "Small-Scale Tests of a Revised Mark I Safety Relief Valve Discharge T-Quencher", October 1977<br>NEDE-24506, "Small-Scale Mark I Safety Relief Valve Discharge Load Mitigation Tests", August 1977 | January 1978 (Complete) |
| Issue Final Report - Scaling Analysis for Initial S/RV Discharge Loads<br>NEDC-23713, "Scaling Analysis for Modeling Initial Loads due to Reactor Safety Relief Valve Discharge", February 1978 | February 1978 |
| Issue Final Report - Conceptual Design/S/RV Quencher Supports | March 1978 |
| Complete Parametric Testing | April 1978 |

TASK NUMBER: 6.2.1 (Continued)

| | |
|---|---|
| Issue T-Quencher Arm Drawings and Hardware Specs to Utilities for Review | April 1978 |
| Issue Preliminary Evaluation Letter Report - Parametric Testing | May 1978 |
| Issue T-Quencher Arm Drawings and Spec | May 1978 |
| Issue T-Quencher Load Definition Spec to Utilities for Review | May 1978 |
| Issue Final Report Draft for Utility Review - Parametric Testing | July 1978 |
| Issue T-Quencher Load Definition Spec | July 1978 |
| Issue Final Report - Parametric Testing | September 1978 |

TASK NUMBER: 6.2.2

TITLE: S/RV DISCHARGE - S/RV LINE DESIGN - MITIGATION

OBJECTIVE: To evaluate and develop analytical methods for reducing air clearing loads to either complement installation of S/RV discharge line mitigators or eliminate the potential need for such mitigators.

DESCRIPTION: Equipment and/or arrangement modifications as well as operational procedure changes will be evaluated to accomplish the noted objectives. Evaluations will include such items as optimum vacuum breaker size, pipe line geometry, optimum S/RV setpoints, S/RV discharge sequencing and reduced submergence, based on use of analytical models developed in Tasks 2.0 and 7.0.

TASK NUMBER: 6.3

TITLE: POOL SWELL TESTS

OBJECTIVE: Screen a wide range of candidate mitigation concepts and select one or more devices that offer significant mitigation for pool swell loads.

DESCRIPTION: The activities planned to accomplish the above objective are described in the following subtasks.

TASK NUMBER: 6.3.1

TITLE: POOL SWELL TESTS - OPEN POOL

OBJECTIVE: Screen a wide range of candidate mitigation concepts to indicate which devices offer potential for pool swell mitigation.

DESCRIPTION: A wide range of pool swell mitigation concepts will be screened in 1/12 scale open tank tests. Pool swell download and pool motion (via high speed movies) will be taken to establish relative performance between straight downcomers and different mitigation concepts. These tests are expected to establish:

1. Whether or not mitigation of pool swell loads is possible with modified downcomer designs.

2. Which types of mitigators provide the highest potential for pool swell mitigation.

TARGET DATE:

| | |
|---|---|
| Complete Screening Tests | September 1976 (Complete) |
| Issue Final Report | April 1977 (Complete) |

NUTECH Report GEN-08-009, "Small-Scale Mark I Pool Swell Loads Mitigation Screening Tests, Phase I (Rev. 1)", September 1976

NUTECH Report GEN-08-034, "Small-Scale Mark I Pool Swell Loads Mitigation Screening Tests, Phase II, Vol. I", March 1977

TASK NUMBER: 6.3.2

TITLE: POOL SWELL TESTS - 1/4 SCALE

OBJECTIVE: Define one or more devices that offer significant mitigation for pool swell loads and will also reduce chugging loads. These devices would be appropriate for further subscale and full scale testing, as required, prior to installation of the mitigation device in an operating Mark I plant.

DESCRIPTION: The 1/4 scale testing is divided into two test series as follows:



Series 1 - Confirmation of Mitigation Potential

The best devices evaluated during the subscale open pool screening tests (Task 6.3.1) will be retested to confirm potential, any adverse characteristics (e.g., high vent resistance), and impact on the overall plant. For this evaluation, a number of devices will be selected and fabricated for 1/4 scale testing. The selected devices will be flow calibrated in the 1/4 Scale Facility first to establish their vent resistance, and then, with correctly sized flow orifices, to establish the proper 1/4 scale enthalpy flow into the pool. The selected devices will be tested at reference conditions.

The performance of the selected devices at reference conditions will be evaluated in terms of peak download, download impulse, peak upload, vent header impact velocity and vent impact force. The test conclusions will provide a basis for further testing of mitigation devices in Series 2.

Series 2 - Optimization of Mitigation Device

The devices selected for testing in this phase will be chosen on the basis of their demonstrated overall mitigation capability.

TASK NUMBER: 6.3.2 (Continued)

Performance of the selected devices will be tested as in Series 1 tests.

| TARGET DATE: | | |
|---|---|---|
| | Select Devices for Confirmation Testing | March 1977 (Complete) |
| | Complete Confirmation Testing | June 1977 (Complete) |
| | Issue Preliminary Evaluation Letter Report - Confirmation Testing | July 1977 (Complete) |
| | Issue Final Report Draft for Utility Review - Confirmation Testing | September 1977 (Complete) |
| | Issue Final Report - Confirmation Testing<br>NEDE-24518 - "Confirmation of Mitigation Potential", January 1978 | January 1978 (Complete) |
| | Select Devices for Optimization Testing | October 1977 (Complete) |
| | Complete Optimization Testing | November 1977 (Complete) |
| | Issue Preliminary Evaluation Letter Report - Optimization Testing | December 1977 (Complete) |
| | Issue Final Report Draft for Utility Information - Optimization Testing | March 1978 |

TASK NUMBER: 6.3.3

TITLE: VENT HEADER MITIGATION DEVICE DEVELOPMENT

OBJECTIVE: Design and test one or more deflector-type devices that reduces pool swell impact loads on the vent header system.

DESCRIPTION:

1. Design of Device

Develop conceptual designs for vent header impact load mitigation devices for pool swell loading. The devices will mitigate by specifically altering pool swell behavior in the vent header vicinity. Stress analysis of vent header mitigator device in-plant structural support techniques will be made. Consideration of practicality (both schedule and cost) of vent header device installation will be a primary feedback to the designs selected.

2. Testing of Device

Pool swell impact tests of promising devices will be tested in the 1/4 scale 2-D Test Facility.

TARGET DATE:

| | |
|---|---|
| Complete Conceptual Designs | November 1977 (Complete) |
| Complete 1/4 Scale 2-D Tests | November 1977 (Complete) |
| Issue Preliminary Evaluation Letter Report | December 1977 (Complete) |
| Issue Final Report Draft for Utility Information (in Conjunction with Task 6.3.2) | March 1978 |

TASK NUMBER: 6.4

TITLE: LOAD MITIGATION PROGRAM REQUIREMENTS ASSESSMENT

OBJECTIVE: To review general concepts of containment LOCA load mitigation, assess their feasibility and develop a program description that would, if implemented, lead to an optimum containment load definition.

DESCRIPTION: Modifications to the existing vent/downcomer system will be considered. The general concept of modifying or making an attachment to the existing downcomers will be evaluated in combination with a pool swell vent header load mitigation device. This concept of containment modification will then be compared in terms of feasibility to other potential mitigation schemes involving other plant modifications. After optimization of the mitigation technique(s) is established, the task will identify specific activities which must be performed should a decision to implement load mitigating scheme in existing plants be reached. The various areas of the containment which must be investigated to implement load mitigation will be identified. Required supporting testing and analysis to determine the effect of the load mitigation scheme on the overall containment performance will be indicated. This task will be completed prior to making the decision to incorporate LOCA load mitigating concepts in individual plants. The testing and investigations which are identified by this task will be performed under a separate task if the decision is reached to implement load mitigation.

| TARGET DATE: | | |
|---|---|---|
| | Establish Recommended Mitigation Scheme | May 1977 (Complete) |
| | Issue Mitigation Program Description (for Input to Decision Point #2) | June 1977 (Complete) |

TASK NUMBER: 6.5

TITLE: LOCA MITIGATOR APPLICATION CRITERIA

OBJECTIVE: Develop criteria to be used in: (1) selection of mitigation device; and (2) fabrication and installation of mitigation device in Mark I plants.

DESCRIPTION:

1. Selection

The rationale and basis for selection of a particular mitigation device will be developed. Included will be optimization of mitigation load reduction efficiency for different LOCA loads consistent with Mark I Owners' requirements specified prior to Decision Point #3. The numerous mitigation activities will be integrated, including the correlation of the results from full scale chugging (Task 5.16), chugging mitigation development tests (Task 6.1), pool swell mitigation tests (Task 6.3), condensation load evaluations (Task 5.17), chugging and pool swell modeling activities (Tasks 5.13 and 5.9), and the results of generic structural evaluation (Task 4.0). Also to be included in the selection process is a feedback from (2) below relating to fabrication, cost and ease of installation.

2. Fabrication/Installation

Fabrication and installation considerations related to implementation of a load mitigation device will be evaluated. Designs for attachment to present downcomer configurations will be developed; structural criteria and operational restrictions will be identified. An applications report will be generated to provide generic justification for implementation of a LOCA mitigation device in Mark I plants.

TASK NUMBER: 6.6

TITLE: ΔP/REDUCED SUBMERGENCE - FUNCTIONAL ASSESSMENT

OBJECTIVE: To assess the plant operational restrictions and limitations on implementation of drywell/wetwell pressure differential and reduced downcomer submergence, over the life of the Mark I plants.

DESCRIPTION: Pool swell tests in Tasks 5.5.2 and 5.8 have demonstrated that the use of drywell/wetwell pressure differential is a viable and effective technique for reduction of pool swell loads. The continued use of this technique, originally developed in the Short Term Program, for the life of the Mark I plants will be assessed with regard to plant operational parameters and equipment requirements.

Testing has also demonstrated that reducing downcomer submergence decreases pool swell loads resulting from a postulated LOCA. This task will establish the minimum downcomer submergence for acceptable operation of the plant by consideration of appropriate design and operating conditions. Consideration will be given to the effects of reduced submergence on post-LOCA drawdown, post-LOCA pool waves, post-LOCA pool thermal limit, non-accident pool thermal limit, ECCS pump NPSH requirements, condensation effectiveness, suppression pool stratification and seismic induced waves.

Evaluations of condensation effectiveness and pool stratification will be based on measurements taken in the full scale test of Task 5.11. This study is therefore conditional pending the results of these tests. The condensation effectiveness and pool stratification effects will be addressed in the final report for Task 5.11.

TASK NUMBER: 6.6 (Continued)

These evaluations will be conducted for the cases of both standard and modified (for mitigation) downcomers.

| | | |
|---|---|---|
| TARGET DATE: | Issue Final Draft for Utility Review (Reduced Submergence) | January 1978 (Complete) |
| | Issue Final Report (Reduced Submergence) | June 1978 |
| | Issue Final Draft for Utility Review ($\Delta P$) | March 1978 |
| | Issue Final Report ($\Delta P$) | May 1978 |

TASK NUMBER: 7.0

TITLE: LOAD DEFINITION REPORT

OBJECTIVE: Document pressure suppression hydrodynamic loads for the use of the utilities in performing plant unique analysis.

DESCRIPTION: Test data and analytical models generated by the Program activities will be used to refine loads to a practicable confidence level for use by the utilities in the evaluation of their plants. In defining loads, test data which incorporates an error and uncertainty analysis and analytical models which are properly validated against test data will be used.

This activity is divided into six subtasks which are described as follows:

TASK NUMBER: 7.1

TITLE: S/RV LOADS - MODELS

OBJECTIVE: To develop improved models for prediction of S/RV actuation loads in a format which is amenable for input into utility/AE finite-element structural models.

DESCRIPTION: Refinement of the ramshead S/RV models used in Task 2.0 and the development of a methodology to predict T-quencher device S/RV loads as required by Decision Point #3 fall into the following categories.

TASK NUMBER: 7.1.1

TITLE: DISCHARGE LOADS

OBJECTIVE: To develop or refine existing S/RV models by calibrating them against Monticello and other test results.

DESCRIPTION: The ramshead S/RV models used in Task 2.1 will be verified and refined as necessary after a detailed comparison with Monticello Test data (Task 5.1.1) and other applicable tests.

Analytical or empirical models will be developed for the S/RV T-quencher discharge device. Calibration of these models will be accomplished by comparison with the applicable test data from Task 5.1.2. The development of the T-quencher models will be parallel to the ramshead model development as required by Decision Point #3. The necessary documentation will be provided to ensure licensability of the final models.

TARGET DATE:

| | |
|---|---|
| Identify all Differences between Predictions and the Monticello Data (Ramshead) (in Final Report) | May 1977 (Complete) |
| Complete Calibration/Modification of Models (Ramshead) (in Final Report) | July 1977 (Complete) |
| Issue Final Report Draft for Utility Review - Ramshead Model | September 1977 (Complete) |
| Issue Final Report - Ramshead Model | October 1978 |
| Develop T-quencher Models | March 1978 |
| Issue Final Report Draft for Utility Review - T-quencher Model | September 1978 |
| Issue Final Report - T-quencher Model | December 1978 |

TASK NUMBER: 7.1.2

TITLE: PIPE LOADS

OBJECTIVES: To provide a detailed method of computing pressures and forces on the S/RV discharge line during the water clearing transient. This task defines necessary refinements to the pipe pressure model contained in Task 2.1.

DESCRIPTION: The water clearing transient occurs in the short period of time immediately following the S/RV actuation. Shock and pressure waves move back and forth in the S/RV discharge line (DL) creating transient forces on the piping. Line pressure increases due to the time required to expel the water plug in the submerged end of the S/RV line. Analysis of these phenomena is required to design the S/RV piping, piping supports, and discharge device restraints.

Development of a ramshead and a T-quencher model will be as required by Decision Point #3.

The existing methodology will be improved to include the following:

- Non-uniformly distributed S/RVDL pipe frictions,
- Non-constant S/RVDL flow areas,
- Water clearing through a T-quencher devices,
- Water clearing through a ramshead devices,
- Vacuum breaker performance with a T-quencher device.

TASK NUMBER: 7.1.2 (Continued)

- Calculation of thrust (including thrust on the discharge device) during the water clearing transient,

- Wall condensation modeling.

Documentation of the final models will be provided for use in licensing. This documentation will include appropriate model/data comparisons.

| TARGET DATE: | | |
|---|---|---|
| | Complete Model Development and Test Data Comparisons for Ramshead | November 1977 (Complete) |
| | Issue Final Ramshead Report Draft for Utility Review | January 1978 (Complete) |
| | Issue Final Ramshead Report | February 1978 |
| | Complete Model Development and Test Data Comparisons for T-quencher | May 1978 |
| | Issue Final T-quencher Report Draft for Utility Review | August 1978 |
| | Issue Final T-quencher Report | October 1978 |

TASK NUMBER: 7.1.3

TITLE: MULTIPLE CONSECUTIVE S/RV ACTUATION EVALUATIONS

OBJECTIVE: For each Mark I plant, determine the number of S/RVs that will be reactuated after the initial S/RV actuation and closure transient. On a generic basis, develop a method of analysis to facilitate assessment of the structural integrity of each containment when subject to the loading from the number of S/RVs predicted to reactuate.

DESCRIPTION: This task is divided into the following three phases:

Phase I -

This phase of the program covers the period from the first written notice of a Mark III reportable condition under 10CFR21 on October 11, 1977 through the meeting with the NRC and the Mark I Owners on October 27, 1977.

General Electric, with the help of the Mark I Owners and their AEs, developed a preliminary evaluation of the subsequent actuations with ramshead discharges. These evaluations included:

a) Preliminary parametric study using most probable S/RV and MSIV operating times,

b) A typical plant unique study,

c) Evaluation of shell stresses and torus support column loads on a plant unique basis.

Phase II -

This phase of the program covers the period from the Mark I Owners/NRC meeting on October 27, 1977 through the TRC/NRC/GE working session on November 29, 1977.

General Electric performed evaluations of the subsequent actuations with ramshead discharge which factored in the comments and recommendations arising from Phase I results. The evaluations included:

a) Preliminary screening analysis,

b) Selected plant unique transient analysis,

c) Development of conservative design basis criteria e.g., hot pop multipliers, attenuation curves, etc.

Phase III -

This phase of the program covers the period from the November 29, 1977 NRC working session through the completion of the program.

During this phase of the program, General Electric will coordinate the Mark I Owners' plant unique transient and structural analysis. This effort shall include:

a) Collection and analysis of S/RV set point variation data. Development of realistic S/RV set point distributions for use in plant unique transient analysis

TASK NUMBER: 7.1.3 (Continued)

b) Performance of plant unique transient analysis to predict number and timing of valves discharging during subsequent actuation, if requested by individual Mark I utilities.

c) Preparation of guidelines for use in plant unique structural evaluations; i.e., shell stress and column load attenuation curves, multipliers, load combination techniques, etc.

d) Coordination of NRC comments or responses to plant unique assessment letters and planning for any necessary follow-on activities.

| | | |
|---|---|---|
| TARGET DATE: | Phase I | October 1977 (Complete) |
| | Phase II | November 1977 (Complete) |
| | Phase III | * |

* To be established based on NRC requirements.

TASK NUMBER: 7.2

TITLE: S/RV LOADS - APPLICATION GUIDE

OBJECTIVE: To develop procedures which will allow the individual utility/AE's to calculate plant unique S/RV loads through utilization of the models developed in Task 7.1.

DESCRIPTION: A technical applications guide will be developed which will allow the calculation of plant unique S/RV loads for all of the affected structures, discharge lines, torus shell, and submerged structures. The models developed in Task 7.1 will be utilized in establishing procedures for both ramshead and T-quencher equipped discharge lines to the degree required by Decision Point #3.

In order that plant unique loads may be calculated, the following parameters which influence S/RV loads will be addressed: reactor pressure, S/RV flow capacity, S/RV discharge line (DL) diameter and length, S/RVDL submerged length, type of end fitting, and location of discharge point. Justification of the loads used in the procedure will be made by reference to the applicable analytical model/test data correlation produced in Task 7.1.

TARGET DATE:

| | |
|---|---|
| Issue Final Application Guide Draft for Utility Review | September 1978 |
| Issue Final Application Guide (contained in Load Definition Report) | December 1978 |

TASK NUMBER: 7.3

TITLE: LOCA LOADS

OBJECTIVE: To perform LOCA-related methodology analysis required for calculation of LOCA loads.

DESCRIPTION: This task has been divided into the following two subtasks:

TASK NUMBER: 7.3.1

TITLE: DRYWELL PRESSURIZATION RATE

OBJECTIVE: To revise calculations using improved input in the existing model for calculating drywell pressurization rate.

DESCRIPTION: This task will be divided into two phases:

Phase 1

Revise the vessel blowdown for existing Mark I containment and pressure model to include subcooling and inventory effects. Compare the model results with LOFT, Humboldt Bay and Bodega Bay tests to confirm modeling assumptions. Define the vent system loss coefficient based on testing performed by EPRI in the 1/12 scale 3-D Test Facility. Perform calculations for a range of Mark I containment conditions to bracket parameters for use in Mark I Containment Program tests and preliminary structural analyses. Specific analyses will be accomplished to:

1. Establish maximum initial pressurization rate,
2. Develop sensitivity of pressurization to fL/D,
3. Establish limit fL/D for chugging and pool swell mitigator,
4. Establish drywell peak pressure.

Phase 2

Perform plant unique containment pressure and temperature analyses. The input parameters used will reflect the plant intentions regarding vent submergence and drywell to wetwell differential pressure.

| | | |
|---|---|---|
| TASK NUMBER: | 7.3.1 (Continued) | |
| TARGET DATE: | Complete Phase I Calculations | August 1977 (Complete) |
| | Final Documentation (in Load Definition Report) | December 1978 |

TASK NUMBER: 7.3.2

TITLE: LOAD CALCULATIONS

OBJECTIVE: Develop methodology to calculate plant unique LOCA loads.

DESCRIPTION: Using plant unique geometry and data available from various tests, techniques for calculating loads will be established for the drywell, vents, bellows, vent header, downcomers, submerged structures and the torus for different sized line breaks. Methods for correcting differences between the test data base and individual plant condition, if any, will be discussed.

The various analytical and experimental items in the Mark I Containment Program will have provided improved methods and extended data base for the specification of the LOCA loads (over those used in Task 2.5).

Specifically, updated information for suppression pool boundary condensation loads and downcomer lateral loads will be gained from Tasks 5.11, 5.13, 5.15, 5.16, 5.17 and 6.1. New information gained from Tasks 5.3, 5.5, 5.6, 5.8, 5.9 and 6.3 will be used to update the pool swell phenomena associated loads. Velocity and acceleration fields predicted by the pool swell model in Task 5.9 (and others) will be coupled to the model of Task 5.14 to predict submerged structure loads. Effects due to seismic events that are predicted by the model in Task 5.4 will also be included.

| | | |
|---|---|---|
| TARGET DATE: | Complete Development of LOCA Load Calculation Methodology | September 1978 |
| | Final Documentation (in Load Definition Report) | December 1978 |

TASK NUMBER: 7.4

TITLE: LOAD COMBINATION CRITERIA/METHODS

OBJECTIVE: Develop criteria for use in analyzing loading combinations.

DESCRIPTION: This task has been divided into the following subtasks:

TASK NUMBER: 7.4.1

TITLE: TIMING BAR CHARTS

DESCRIPTION: The analytical and experimental work performed during the execution of the Mark I Containment Program, plus a review of the response of the Nuclear Steam Supply Systems to a full spectrum of transients and accidents will provide additional insight into the time-phasing relationships between the various LOCA and S/RV loading conditions. Using this information, the bar charts (Task 2.7) developed in the Preliminary Load Evaluation task, will be reviewed and amended as necessary to form the final definition of load combinations. The final definition will be based on a mechanistic evaluation of the S/RV discharge events and LOCA. There will be a series of bar charts covering all significant structures.

TARGET DATE:

| | |
|---|---|
| Complete Bar Chart Development for LDR | May 1978 |
| Issue Bar Charts for Utility Review | July 1978 |
| Final Documentation (in Load Definition Report) | December 1978 |

TASK NUMBER: 7.4.2

TITLE: SRSS LOAD COMBINATIONS

OBJECTIVE: The objectives of this activity are defined as follows:

1. Develop a technical basis for justifying the use of SRSS load combination methods in Mark I containment analyses,
2. Identify all significant dynamic loads, including pool dynamic loads, which can be combined by the SRSS method,
3. Quantify applicability limits, such as frequency content and response duration, of the SRSS method for response combinations.

DESCRIPTION: The identification and initiation of the specific activities needed to fulfill the above objectives will be accomplished after reassessment of the NRC position on the use of the SRSS load combination technique for Mark I Plants. The Staff review of the philosophy, criteria, and justification contained in report NEDO-24010-P, "Technical Bases for the Use of Square Root of the Sum of the Squares (SRSS) Method for Combining Dynamic Loads for Mark II Plants", will determine the necessary path which the Mark I Program must take to ensure timely justification of this technique.

TARGET DATE:

| | |
|---|---|
| Issue Preliminary Evaluation Letter Report | * |
| Issue Final Draft for Utility Review | * |
| Issue Final Report | * |

*To be established after assessment of NRC position on NEDE-24010-P and Mark I Program schedule.

TASK NUMBER: 7.5

TITLE: S/RV DISCHARGE STEAM MIXING MODEL

DESCRIPTION: Based upon the available test data, develop/modify an analytical model for predicting thermal mixing in the suppression pool during relief valve discharge. This model will be capable of justifying the assumptions made between bulk pool temperatures and local temperatures at the S/RV discharge device for plant unique geometries. In addition, the model will be capable of confirming the adequacy of pool temperature monitoring systems. The model will be done assuming a ramshead discharge device. The need for a T-quencher model is being assessed.

TARGET DATE:

| | |
|---|---|
| Develop Ramshead Methodology | June 1977 (Complete) |
| Issue Final Ramshead Report Draft for Utility Review | October 1977 (Complete) |
| Issue Final Ramshead Report | March 1978 |

TASK NUMBER: 7.6

TITLE: LOAD DEFINITION REPORT - PREPARATION

DESCRIPTION: This activity will document the final design basis loads for all Mark I plants. This will include the coordination and integration of all the hydrodynamic loading information generated by the Containment Program tasks into a single coherent document. This Load Definition Report, plus the criteria established in Task 3.0 and the knowledge and procedures developed from Task 4.0, will enable the Mark I Owners and their A/Es to conduct final plant unique analyses.

| TARGET DATE: | | |
|---|---|---|
| | Issue Report Objective and Outline | February 1978 |
| | Issue Final Report Draft for Utility Review | October 1978 |
| | Issue Final Report | December 1978 |

# APPENDIX A

## LIST OF ORGANIZATIONS SUPPORTING THE MARK I CONTAINMENT PROGRAM

APPENDIX A

LIST OF ORGANIZATIONS SUPPORTING THE

MARK I CONTAINMENT PROGRAM

(In Addition to Mark I Owners Group and General Electric)

| Task No. | Description | Supporting Organization |
|---|---|---|
| 1.0 | Program Action Plan | |
| 2.0 | Preliminary Load Evaluation Activities | Nuclear Services Corporation<br>NUTECH<br>Teledyne Engineering Services |
| 3.0 | Structural Acceptance Criteria | Bechtel Power Corporation<br>Teledyne Engineering Services<br>Engineering Decision Analysis Co., Inc. |
| 4.0 | Generic Structural Evaluation | Bechtel Power Corporation<br>Teledyne Engineering Services |
| 5.1 | Monticello Tests | Data Acquisition<br>Hewlett Packard<br>Northern States Power Co.<br>NUTECH<br>Sensometrics<br>Teledyne Engineering Services<br>Trendtec<br>Western Piping and Engineering<br>Wyle Laboratories |
| 5.3 | Flexible Cylinder Tests | Acurex/Aerotherm<br>Developmental Sciences, Inc.<br>EDS Nuclear<br>Electric Power Research Institute<br>Engineering Decision Analysis Co., Inc.<br>Lockheed<br>MARC Analysis Research Corporation<br>Science Applications, Inc.<br>Southwest Research Institute |
| 5.4 | Seismic Slosh Test | Southwest Research Institute<br>Teledyne Engineering Services |
| 5.5 | 1/4-Scale 2-D Pool Swell Tests | Acurex/Aerotherm<br>Nuclear Services Corporation<br>NUTECH<br>Teledyne Engineering Services |

APPENDIX A

LIST OF ORGANIZATIONS SUPPORTING THE

MARK I CONTAINMENT PROGRAM

(Continued)

| Task No. | Description | Supporting Organization |
|---|---|---|
| 5.6.1 | 1/12-Scale 3-D Test | Electric Power Research Institute<br>Stanford Research Institute |
| 5.6.2 | 1/30-Scale 3-D Test | Southwest Research Institute |
| 5.9 | Pool Swell Model Development | Electric Power Research Institute<br>JAYCOR |
| 5.11 | Full-Scale Test Facility | C.F. Braun<br>Chicago Bridge & Iron<br>EDS Nuclear<br>Kaiser Steel<br>Nuclear Services Corporation<br>NUTECH<br>Teledyne Engineering Services<br>Wyle Laboratories |
| 5.13 | Chugging Analytical Evaluation | Aeronautical Research Associates of Princeton<br>Anamet Laboratories<br>CDC Computer<br>EDS Nuclear<br>NUTECH<br>R. M. Parsons<br>Teledyne Engineering Services |
| 5.14 | Submerged Structures | Acurex/Aerotherm<br>Nuclear Services Corporation<br>Southwest Research Institute<br>Teledyne Engineering Services<br>Wyle Laboratories |
| 5.15 | Structural Hydrodynamic Interaction | Acurex/Aerotherm<br>Anamet Laboratories<br>Del Mar Technical Associates<br>Engineering Decision Analysis Co., Inc.<br>MARC Analysis Research Corporation<br>Nuclear Services Corporation<br>Pacifica Technology<br>Physics International<br>Teledyne Engineering Services |

APPENDIX A

LIST OF ORGANIZATIONS SUPPORTING THE

MARK I CONTAINMENT PROGRAM

(Continued)

| Task No. | Description | Supporting Organization |
|---|---|---|
| 5.16 | Mark I Submergence Test | GE Licensee (Germany) |
| 5.17 | Condensation Oscillation Evaluation | Aeronautical Research Associates of Princeton<br>Teledyne Engineering Services |
| 6.1 | Load Mitigation Testing - Chugging | Creare<br>NUTECH<br>Scientific Services |
| 6.2 | Load Mitigation Testing - S/RV Discharge | Bechtel Power Corporation<br>EDS Nuclear<br>NUS Corporation<br>NUTECH<br>Scientific Services<br>Teledyne Engineering Services<br>Wyle Laboratories |
| 6.3 | Load Mitigation Testing - | Acurex/Aerotherm<br>Bechtel Power Corporation<br>Nuclear Services Corporation<br>NUTECH<br>Scientific Services<br>Teledyne Engineering Services |
| 6.4 | Load Mitigation Program Requirements Assessment | Nuclear Services Corporation<br>Teledyne Engineering Services |
| 6.5 | LOCA Mitigator Application Criteria | Teledyne Engineering Services |
| 7.1 | S/RV Loads - Models | Nuclear Services Corporation |
| 7.5 | S/RV Discharge Steam Mixing Model | NUS Corporation |

In addition, many consultants from universities and industry have been hired on an individual basis.

# APPENDIX B

APPENDIX B

LIST OF EFFECTIVE PAGES - LATEST REVISION

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