Task A-8
Rev. No. 3
June, 1980

1. DESCRIPTION OF PROBLEM

There are 11 BWR facilities with the Mark II containment system in various stages of construction in the United States. None of these domestic facilities with Mark II containments is currently in operation. A reassessment of nuclear power plant facilities with the General Electric Mark II pressure suppression containment design has been required because, during large scale testing of the subsequent Mark III containment system design, new suppression pool hydrodynamic loads associated with a postulated loss-of-coolant accident (LOCA) were identified that had not been explicitly considered in the original design of the Mark II containment system.

These additional loads result from dynamic effects of drywell air and steam being rapidly forced into the suppression pool during a postulated LOCA and from the suppression pool response to safety/relief valve (SRV) operation, which is generally associated with plant transient operating conditions. Since these new hydrodynamic loads had not been considered explicitly in the original design of the Mark II containment, the NRC staff determined that a detailed reevaluation of the Mark II containment system was required. Owners of the Mark II facilities developed a generic program to establish pool dynamic loads for the evaluation of the Mark II facilities. The staff in turn developed a program to review and evaluate the design loads proposed by the Mark II owners.

2. PLAN FOR PROGRAM RESOLUTION

A. Approach

In view of the potential significance of pool dynamic loads, it was determined that a reassessment of the Mark II containment system design would be required. The NRC sent a letter to each of the Mark II owners on April 11, 1975, requesting that they provide information demonstrating the adequacy of their containment design. These letters reflected NRC concerns about the dynamic loads from SRV discharges and the need to evaluate the containment response to the newly identified dynamic loads associated with postulated design basis LOCA events.

The domestic Mark II containment owners formed an ad hoc Mark II Owners Group to develop responses to these NRC requests. The Utility owners recognized that the additional evaluation would be very similar for all plants. Formation of the Mark II Owners Group was beneficial because it established a uniform program for responding to the NRC inquiries as quickly as possible.

A program was established by the Owners of Mark II plants to define pool dynamic loads for their use in the assessment of

these plants. A program with several phases* was developed consisting of: (1) a lead-plant program (LPP) designed to establish conservative pool dynamic loads for use in the licensing evaluation of the lead Mark II plants, and (2) a long term program (LTP) designed to support a reduction in selected conservatively prescribed loads and to provide confirmatory data for certain pool dynamic loads. The LTP tasks relate primarily to the steam loads (i.e., Condensation Oscillation (CO) and chugging pool boundary loads and vent lateral loads). The air load related issues were resolved during the LPP, and are discussed in NUREG-0487 Section III.B.

The experimental and analytical subtasks comprising the Mark II owners' generic programs, (i.e., LPP, and LTP), are described in Supplement 1 to NUREG-0487, "Mark II Containment Lead Plant Program Load Evaluation and Acceptance Criteria."

The staff review of the above cited Mark II owners programs is being conducted as part of the TAP A-8 technical review program. We have reviewed the Mark II Owners' LPP and issued the Mark II Containment Lead Plant Program Load Evaluation and Acceptance Criteria Report (NUREG 0487) in October 1978. That report included an evaluation of the Mark II Owners' proposed methodology

*An Intermediate Plant Program (IPP) was previously proposed but was subsequently dropped because it was not necessary. The IPP tasks have been factored into the Lead and the Long Term Program.

for establishing pool dynamic loads for the lead Mark II plants and a description of the bases for load methodologies that we find acceptable for use in the individual plant unique assessments. Since that report was issued, the Mark II owners submitted additional reports in which they proposed alternative load methodologies for use in the evaluation of Mark II plants. We have completed our evaluation of these alternative load specifications. The pool boundary condensation and chugging loads remain open items in the LPP. We anticipate resolution of these remaining LPP items by August 1980. The Mark II owners have made substantial progress towards completion of a number of the LTP tasks. The staff plans to complete our review of the LTP program by April 1981.

The pool dynamic loads developed in this generic program form the bases for the plant unique evaluation of Mark II pool dynamic loads. The resulting plant unique evaluation using these generic dynamic loads for each plant will be performed as a part of the Operating License review for each plant.

Related NRC generic review programs include: the review of Mark I Pool Dynamic Loads (A-7); the review of Safety Relief Valve (SRV) Loads for the Mark I, II and III containments, (A-39); the review of load combinations and stress limits, (B-6); the review of Mark III Pool Dyanmic Loads (B-10); and the

review of selected plant unique Mark II pool dynamic loads programs.

B. End Product

The end product of the Mark II owners' program consists of a number of topical reports which describe the pool dynamic loads and provide the experimental and analytical bases to support the load specifications. A list of these reports is provided in Supplement 1 to NUREG-0487.

The staff issued several reports in 1978 related to our review of pool dynamic loads for the Mark II containment design. These included: (1) "A Technical Update on Pressure Suppression Type Containments In Use In U.S. Light Water Reactor Nuclear Power Plants," NUREG-0474, and (2) "Mark II Containment Lead Plant Program Load Evaluation and Acceptance Criteria," NUREG-0487. Future reports we plan to issue include:

(1) A Supplement to NUREG-0487 in June 1980 consisting of an evaluation of the alternative LPP load methodologies;

(2) A letter report in August 1980 consisting of an interim evaluation of the interim condensation and chugging loads;

(3) The LTP load criteria are scheduled to be released as a letter report in December 1980 and;

(4) A NUREG report in April 1981 containing an evaluation of the Mark II Long Term Program.

C. Tasks

The A-8 tasks include a task to address each of the significant Mark II LOCA related pool dynamic loads to be addressed in the Long Term Program (LTP). These tasks include: Task 1 - Chugging Loads on Containment Boundaries; Task 2 - Condensation Oscillation Loads on Containment Boundaries; Task 3 - Main Vent Lateral Loads and; Task 4 - Confirmation of Air Clearing - Pool Swell Loads. The following discussion for each load task includes the following information: load origin, lead plant load specification, proposed LTP load modification, and the program for load resolution.

Task 1 Chugging Loads on Containment Boundaries Load Origin

As the steam flux continues to decrease during a blowdown, the steam-water interface oscillates about the vent exit until a random and erratic motion results from the growth and rapid collapse of steam bubbles. These bubble growth and collapse events, varying in intensity and duration, cause associated pressure loads on the containment and are referred to as chugging events.

Lead Plant Load Specification

The original lead plant chugging load specification was based on a conservative time history obtained from observations of wall pressures in the first phases of the GE (4T)* tests (GE/Mark II Owners Task A.1).

The chugging load was specified so as to bound these early 4T tests. The specifications are given in NUREG-0487 for both uniform and asymmetric loading conditions. As a result of observations in the extended 4T tests and in large scale multivent tests, the staff expressed the concern that the lead plant load was not conservative. The lead plants are proposing an interim chugging load to address the staff concerns.

Load Modification Proposal for the Long Term Program

The Mark II Owners noted that the chugging measurements obtained from 4T and used for the lead plant specification are affected by the properties of the 4T facility. They decided, as a result of fluid-structure interaction (FSI) studies, that direct application of the observed 4T loads was a very conservative procedure. It is the aim of the GE/Mark II Owners Task A.16, the improved chugging task, to establish the magnitude of this conservatism and to develop an 'improved' chugging specification of reduced but still conservative magnitude.

*The 4T test facility simulates a single cell of a full-scale Mark II containment.

To develop the new chugging specification several compnents are required: a forcing function at the vent exit must be inferred from wall pressure measurements made during chugging tests; Fluid Structure Interaction (FSI) effects in the test facility as well as in the Mark II containment buildings must be understood and extracted; loads from the vent sources must be applied in a conservative and statistically correct manner.

A generic, improved load methodology has been developed by Bechtel for the Mark II owners. This methodology relies on test data obtained from the GE 4T tests to describe the vent source function.

Program for Load Resolution

Preliminary results from full-scale multivent tests conducted in Japan and Germany show an apparent high degree of vent synchronization, as well as some high pressure amplitudes. The staff has indicated the need for consideration of the results of these tests in the establishment of a conservative "improved" load.

The most pertinent full-scale, multivent data to date has come from the JAERI tests conducted in Japan. The JAERI tests are sponsered by the Japanese government in support of their Mark II plants and are conducted in a facility that is a prototypical sector of a Mark II containment.

The Mark II owners are relying primarily on the original 4T and the extended 4T tests and the Creare scaled multivent tests to establish the conservative nature of the "improved" chugging loads. They have agreed to review the results of the JAERI tests, as this data is made available to them, to address the staff's concerns related to 1) Fluid Structure Interaction Effects (FSI), 2) load magnitude and frequency and, 3) statistical arguments related to load magnitude and synchronization. Confirmation of the 'improved' chugging load is to include comparisons between calculations and observations of the full scale tests.

Other programs are being conducted which can add to the understanding of chugging. While these programs are not included in the generic Mark II program, these programs will be followed as part of the LTP generic load confirmation. These include:

1) The GKSS Large-Scale Steam tests in Germany, which can provide additional information with regard to elevated pool temperature effects, air content effects and degree of event coupling during chugging.

2) The GKM-II-M tests conducted for PP&L by KWU in Germany which model a specific Mark II plant 'single cell' as accurately as possible. A

more detailed evaluation of the GKM-II-M tests is planned in support of the PP&L Susquehanna license review. This test program parallels the generic 4T extended tests.

3) The Burns & Roe 'improved' chugging load program for WPPSS-2. A more detailed evaluation of this program is planned in support of the WPPSS-2 license review. This program parallels the generic improved chugging program.

Task 2 Condensation Oscillation Loads on Containment Boundaries

Load Origin

During the course of a LOCA blowdown, after the stable condensation at high steam flow and before the chugging experienced at low steam flow, there occurs a period of intermediate flow when the steam-water interface at the vent exit has a regular sinusoidal type of motion. This phenomenon, referred to as condensation oscillation (CO), causes sinusoidal-like pressure fluctuations on the containment boundary.

Lead Plant Load Specification

The lead plant condensation oscillation specification was based on observations of CO related wall pressures obtained during the 4T tests (GE/Mark II Owners Task A.1). The specification can be found in NUREG-0487 Appendix D.

As a result of preliminary observations in the full-scale vent tests conducted in Germany and Japan during 1979, questions arose regarding the conservative nature of the lead plant CO load. The lead plants are proposing that an interim CO load be applied.

Load Modification Proposed for the Long-Term Program

In reviewing the original 4T tests the staff noted that they were conducted with a vent length significantly longer than that typical of a Mark II plant. Since the sinusoidal pressure fluctuations of CO have been associated with vent acoustics, the question of vent length influence on CO, particularly regarding frequency content, was of concern. A question also arose whether the mass flow in the original 4T tests was high enough to bound the corresponding parameters in all Mark II plants. To resolve these questions concerning vent length effects as well as bounding mass flow and other plant parameters during CO, the Mark II Owners have conducted additional tests in a modified 4T facility using a vent length prototypical of Mark II plants.

A revised CO load is under development by the Mark II owners to reflect the results of these tests.

Program for Load Resolution

The extended 4T tests conducted by GE/Mark II are expected to resolve questions on the effect of vent length on CO loading. The test matrix has been examined by the staff and its consultants to ensure that the tests will cover the bounding Mark II conditions with respect to vent steam mass flux, vent steam quality and percentage of vent air. The 4T facility has been modified so that vent length is prototypical of Mark II plants. Bends have been removed, such that the vent consists of a straight downcomer from the drywell. This is the case in an actual plant. The tests, about 25 in number, simulate both steam and liquid breaks.

Other programs are being conducted which can add to the understanding of CO loads. Other programs that will be followed as a part of the LTP generic load confirmation include:

1) The JAERI full scale multivent tests.
2) The GKM-II-M tests which model a single cell of the Susquehanna Mark II plant.
3) The GKSS tests which contain pool temperature variations as well as variations in air content.

Task 3 Main Vent Lateral Loads

Load Origin

Lateral loads on the downcomers occur because of the asymmetry of the steam condensation with respect to the vent centerline. The loads may be due either to the asymmetric collapse of steam bubbles near the vent exit or to the impact on the vent caused by rapidly inflowing water. For the Mark II type geometry, the lateral loads have been observed to be impulsive and random in both direction and magnitude.

Lead Plant Specifications

The Mark II Owners proposed a lateral load specification for the lead plants in terms of a static equivalent load observed in a foreign licensee test on a single prototypical downcomer. Upon review, the staff determined that the magnitude of the static equivalent load should be adjusted according to the downcomer natural frequency for a certain frequency range. Beyond that range, or for downcomers braced in a non-prototypical manner, the staff required a dynamic structural analysis of the downcomer response on a plant specific basis. The static equivalent load specification represented an upper bound of all observed loads. Details of the lead plant specification can be found in NUREG-0487 Appendix D.

Load Modification Proposal for the Long-Term Program

Both the staff and the Mark II Owners regarded the lead plant specification as an interim bounding specification which would be supplanted by a more realistic dynamic load specification developed by the Mark II Owners during the course of the Long-Term Program. The staff also stated in NUREG-0487 that it would require a dynamic evalution of downcomer response to lateral chugging loads for all plants during the LTP to provide additional confirmation that the static load specification is conservative.

The Mark II Owners have proposed a 'Dynamic Forcing Function' approach in which the loads are applied dynamically on the vents as an alternative to the lead plant specification. The approach is documented in the General Electric report NEDE-24106-P, and has been reviewed by the staff. NEDE-24106-P deals with loads on a single downcomer. A methodology for applying the Dynamic Forcing Function Method to a multivent system has also been proposed by the Mark II Owners in a letter report from R. H. Bucholz (GE) to J. F. Stolz (NRC) dated April 9, 1980.

Program for Load Resolution

The staff's preliminary review of the 'Dynamic Forcing Function Model' produced questions regarding the 4T specific nature of the dynamic model, since the model

was developed from 4T test data. Task B.13 of the Mark II owners program includes an independent verification of the dynamic model using test results from other full scale tests. The results of this verification are included in the report "Dynamic Lateral Loads On Mark II Main Vent Downcomer - Correlation of Independent Reference Data," NUREG-24797-P, March 1980." Other related programs that will be followed as a part of the LTP generic lateral load confirmation include:

1) The JAERI full scale multivent tests.
2) The extended 4T tests.
3) The GKSS multivent tests.
4) The GKM-II-M single vent tests.

Task 4 Confirmation of Air Clearing-Pool Swell Loads

Load Origin

At the start of the blowdown, the downcomers are cleared of water and a mixture of air and steam from the drywell passes through the downcomers and the non-condensible air forms a blanket of relatively uniform thickness across the entire pool below the vent exits. The water above this blanket is accelerated upward by continuing expansion of the air until increasing pressure in the air space above the pool slows the motion and breakup of the water slug eventually occurs. Drag, impact and pressure

loads occur on wetwell structures and boundaries during this phase of the LOCA.

Lead Plant Specification

Load specifications for the wetwell and its components during pool swell were developed using the General Electric Pool Swell Analytical Model (PSAM). The PSAM was qualified by a series of comparisons between predictions and experimental results as well as with independent analytical comparisons. The staff found the PSAM provisionally acceptable for developing conservative Mark II pool swell loads. Specific details on acceptability and lead plant specifications can be found in NUREG-0487 Appendix D.

Long-Term Program Loads Confirmation

To provide additional confirmation of the conservatism of the lead plant specifications in the area of air clearing and pool swell loads, the staff and its consultants will conduct confirmatory calculations with the PSAM.

The results of the JAERI and GKSS large scale tests results will be compared with the appropriate PSAM calculations. Pending its availability the EPRI single cell tests will also be included in this confirmation program.

We anticipate completion of the generic Mark II Long Term Program in the first quarter of 1981. However, the

related foreign full scale test will run into 1982. The NRC requires that the Mark II owners follow these tests and notify the NRC of any required changes in the Mark II load specifications. In addi-tion, our consultants at BNL will monitor these test programs and notify the staff of significant variations from the LTP load specifications.

3. BASIS FOR CONTINUED PLANT OPERATION AND LICENSING PENDING COMPLETION OF TASK

As discussed in Section 1, the safety issues addressed by this task are the loads on BWR Mark II containments resulting from the dynamic effects of drywell air and steam being rapidly forced into the suppression pool during a postulated LOCA. The dynamic loads resulting from safety relief valve actuation are being considered in Task A-39.

This matter is of present concern only for plants under construction and undergoing review for operating licenses, since there are no domestic BWR plants with the Mark II containment system now in operation and no further applications to construct a facility of this type are anticipated. The first Mark II plant scheduled to go into operation (La Salle) has a projected fuel loading date of November 1980.

The staff's generic Lead Plant Program load evaluation report was published October 1978. A supplement to this report identifying

acceptable alternative loads is scheduled to be published June 1980. In addition, a letter evaluation report for the interim CO and chugging loads is scheduled for August 1980.

The above lead plant load reports specify conservative pool dynamic loads. The staff finds the loads in these reports acceptable for licensing of the Mark II plants.

In summary, there currently are no domestic operating plants using a Mark II containment. All the generic review efforts associated with the lead plants are scheduled to be completed prior to the time of licensing the first plant. However, should these LPP generic efforts not be complete, plant licensing still could proceed based upon a plant unique analysis which demonstrates the capability of the containment to safely withstand conservatively derived dynamic loads. Accordingly, we conclude that while this task is being performed, there would be no safety hazard from operating BWR Mark II facilities. Moreover, new plant licensing activities can proceed prior to completion of this task with reasonable assurance of protection of the health and safety of the public, provided an analysis is performed which demonstrates the capability of the containment of the plant being licensed to safely withstand conservatively determined pool dyanmic loads.

4. NRR TECHNICAL ORGANIZATIONS INVOLVED

A. Division of Safety Technology, Generic Issues Branch

(1) The Generic Issues Branch has overall lead responsibility for the review and evaluation of the Mark II o[illegible]s' generic LPP, and LTP tasks associated with establishing pool dynamic loads for the Mark II containment system.

(2) Manpower Requirements:

FY 1980 - 5.0 man-months

FY 1981 - 7.0 man-months

Total - 12.0 man-months

B. Division of Systems Integration, Containment Systems Branch.

(1) The Containment Systems Branch will provide personnel to assist in the review and evaluation of the Mark II owner's LPP and LTP tasks and the review of related foreign test programs.

(2) Manpower Requirements:

FY 1980 - 8.0 man-months

FY 1981 - 3.0 man-months

Total - 11.0 man-months

5. TECHNICAL ASSISTANCE

A. Brookhaven National Laboratory

(1) Title:

Mark II Containment LOCA Pool Dynamic Loads (A3319)

(2) Responsible Branch:

Div. of Safety Technology, Generic Issues Branch

(3) Scope:

The contractor and his consultants are to provide expert technical assistance in the review of the Mark II owners' LPP, and LTP experimental and analytical subtasks related to the definition of the Mark II pool dynamic loads.

(4) Funding:

FY 1980 - $183,000

FY 1981 - $138,000

FY 1982 - $ 46,000

6. INTERACTIONS WITH OUTSIDE ORGANIZATIONS

A. Mark II Owners' Group

(1) Title:

The Mark II owners' Lead Plant Program (LPP), and Long Term Program (LTP)

(2) Scope:

The subtasks associated with the Mark II owners' LPP and LTP generic load definition program consist of a number of experimental and analytical programs. These subtasks are described in NEDO 21297, "Mark II Containment Supporting Program Report" March 1978 and NUREG-0487." Mark II Containment Lead Plant Program Load Evaluation and Acceptance Criteria", Octrober 1978.

7. ASSISTANCE REQUIREMENTS FROM OTHER NRC OFFICES

A. Office of Nuclear Regulatory Research, Division of Reactor Safety Research, Analysis Development Branch

(1) BWR - Pressure Suppression Pool Dynamic Loads

(2) Scope:

(a) RES has established a program at Lawrence Livermore Laboratory (A0116) to maintain foreign laison for containment systems research. They are following the Mark II large scale multivent tests of JAERI in Japan and GKSS in Germany.

(b) A program is underway at MIT (B6167) to investigate steam condensation loads and fluid structure interaction (FSI) effects.

(c) A program is underway at Lawrence Livermore Laboratory (A0116) to calculate the dynamic response of BWR pressure suppression pool containment structures. Task 2 of this program includes the study of fluid structure interactions in test facilities.

(d) The NRC was a participating member in the Marviken containment tests that were conducted in Sweden.

8. POTENTIAL PROBLEMS

A. Our review schedules for the LTP is contingent upon receipt of documentation describing the related Mark II owners' supporting analytical and experimental subtasks and their response to our questions in a timely manner. Delay in receipt of this

information from the Mark II Owners Group will affect our review schedule.

B. Large scale Mark II related tests are currently in progress in Germany and Japan. The timely availability of information related to those tests could affect our review schedule.