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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

R. C. DeYoung, Assistant Director for Light Water Reactors, Group 1, RL
V. A. Moore, Assistant Director for Light Water Reactors, Group 2, RL

STANDARD LETTER TO APPLICANTS CONCERNING MARK III POOL DYNAMIC LOADS AND ANALYTICAL METHODS DEVELOPMENT

At this time, the major portion of the Mark III pool dynamics testing has been completed and the structural design of many Mark III containments is being finalized.

We have provided, as an attachment, a draft of a generic letter requesting CP holders and applicants for plants with Mark III containments to provide their responses to concerns recently expressed by the ACRS and to describe their design provisions to accommodate potential suppression pool hydrodynamic loads. The ACRS comments provided in recent reports on Mark III suggest, in our opinion, a reconsideration of certain objectives of the large-scale Mark III test program currently in progress. With respect to pool dynamic loads, their significance had been identified early in GE's large-scale test program; however, as noted in our SER's for plants with Mark III containments, the review of this issue was deferred pending completion of definitive large-scale testing.

We are thus faced with two milestones that need action for resolution by Mark III designers. We believe that a letter of the type enclosed should be sent to each of the applicants for plants with Mark III containments, including GE (GESSAR). The letter provides suitable background material to assure a clear understanding of the issues at hand, and a list of requested information which we will require to complete our review including a request for the anticipated plant construction schedule. In certain cases slight modifications may be necessary to make it applicable and current to a particular plant. In these instances the LPM should coordinate such change with Bob Cudlin.

Upon receipt of the applicant's responses we would be able to establish a review schedule for each plant which would allow discussions and completion of our review on a timely basis.

Robert L. Tedesco, Assistant Director
for Containment Safety
Division of Technical Review

Enclosure:
As stated
cc: See next page

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

D-9

cc: E. Case
F. Schroeder
A. Giambusso
S. Hanauer
R. Boyd
G. Lainas
J. Kudrick
J. Shapaker
L. Slegers
R. Cudlin
C. Grimes
C. Anderson
J. Glynn
RL B/C's

Attachment

SAMPLE LETTER TO APPLICANT

Gentlemen:

During the construction permit review for your plant, small-scale testing and analytical models have been used to establish the basic performance characteristics of the Mark III containment system. Licensing of your plant proceeded with the recognition that ultimate validation of the design would rely heavily on an empirical basis provided by the General Electric (GE) Company's large-scale Mark III test program. A derivative of early large-scale tests was the observation that containment structures could be subject to significant suppression pool hydrodynamic loads during blowdown. Since resolution of this concern was dependent on finalization of the containment structural design, the availability of additional and definitive test data, and that flexibility was factored into the design, it was left as a post-CP item in our Safety Evaluation Report for your plant.

At this time there have been several developments which now lead to further consideration of the containment design for your plant. First, a major portion of Mark III pool dynamics testing by GE has been completed and data should be available for integration in the structural design. Reference where such information is available is given in Enclosure (1) to this letter. Other information is also available now and should be forthcoming from GE. Therefore we are requesting that you provide us with information on the status of your design with respect to hydrodynamic loads in relation to the construction schedule of affected structures. Second, on several recent occasions we have met with the Advisory Committee on Reactor Safeguards (ACRS), for topical

discussion of the Mark III. In its letters on the Perry Nuclear Power Plant, Units 1 and 2(1), Allens Creek Nuclear Generating Station, Units 1 and 2(2), and River Bend Station, Units 1 and 2(3), the Committee has commented on the progress being made to validate the Mark III design. In particular the Committee emphasizes the importance of developing analytical models, based on a first principles approach, which can be used in conjunction with empirical test results. As these comments are applicable to your plant we are requesting that you discuss your specific plans to be responsive to the concerns of the ACRS. Your response should be in sufficient depth for us to assess your subsequent courses of action on these matters.

Background information is provided in Enclosure (1) to this letter which contains the status of efforts directed at determining pool dynamic loads and a summary of our discussions with GE regarding the objectives of the Mark III test program. In Enclosure (2) we have requested certain information which we will require to complete our review of these aspects of your containment design. For general information we have also provided as Enclosure (3) a description of the various phenomena during the accident sequence which result in dynamic loads. You will observe that certain key phrases have been underlined. These phrases both identify those specific hydrodynamic loads which, as a minimum, should be considered in the development of your structural

(1) Letter, W. R. Stratton, ACRS, to D. L. Ray, AEC, dated December 12, 1974.
(2) Letter, E. A. Mason, ACRS, to D. L. Ray, AEC, dated December 12, 1974.
(3) Letter, W. Kerr, ACRS, to D. L. Ray, AEC, dated January 14, 1975.

design capability and establish the standard nomenclature by which these phenomena should be referenced in your documentation.

You should provide us within seven (7) days after receipt of this letter a schedule for submittal of the requested information. Based on your response we will establish a review schedule which will allow completion of our review in these areas.

Please contact us if you desire additional discussion or clarification of the material requested.

Sincerely,

BACKGROUND

Pool Dynamics

The concern that suppression pool hydrodynamic loads could bear significantly on the structural design of certain parts of the Mark III containment surfaced during the early phases of the large-scale Mark III test program being conducted by the General Electric Company. A series of air tests were performed in March 1974 to scope the range and magnitude of pool dynamic loads. It was recognized that more definitive tests were required and therefore comprehensive tests in 1/3 scale were initiated in the summer of 1974 and are currently still in progress. Parallel efforts to develop analytical models for the various pool dynamic phenomena have been implemented by the General Electric Company, the NRC's consultants, and by several architect/engineers.

The staff has maintained periodic contact with GE regarding the planning and progress of the pool dynamics testing and associated analyses. An outgrowth of this effort was the issuance by the staff of a report entitled, "General Electric Mark III Test Program, Regulatory Evaluation Status Report No. 1"[(4)]. In part, this report expressed the staff's position that due to deficiencies in the number, type, and configuration of air tests, pool dynamic loads could not be specified on the basis of air test data alone. Therefore in responding to the requests of this letter and in the development of your structural design, substantial reliance should not be placed on air test data alone.

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(4) Letter, V. A. Moore, NRC, to I. F. Stuart, GE Company, dated October 7, 1974.

ACRS Concerns

As noted in recent ACRS letters, the Committee has recommended that additional analyses be performed with respect to vent clearing, vent interaction, pool swell, pool stratification, and the methods used to determine dynamic and asymmetric loads on containment structures. In our opinion such recommendations suggest a reevaluation of the current objectives of GE's Pressure Suppression Test Facility (PSTF) program which until now had been considered confirmatory in nature; i.e., the objective was to confirm the basic containment performance characteristics as predicted by existing analytical models. We now find that consideration should be given to the development of improved models for further nfirmation of the adequacy of the Mark III design.

We have discussed these concerns with representatives of the General Electric Company and solicited their response. GE's response[5] was that perhaps all of the theoretical model development on the pressure suppression process has not been fully discussed with either the Committee or us. In this regard, a breakdown of areas of investigation that in GE's opinion addresses the ACRS concerns was prepared. On review, this breakdown still includes a number of areas for which analysis appears to be neither available nor intended. Your response on these matters is necessary especially with regard to items 18, 20 and 22 in the GE letter[5]. We emphasize that an early resolution of the Mark

(5) Letter, G. L. Gyorey, GE Company, to R. L. Tedesco, NRC, dated January 27, 1975.

III program and the ACRS's concerns especially with regard to the phenomena associated with oscillatory behavior is important.

Enclosure (2)

REQUEST FOR INFORMATION

We request that the following information be provided for our review:

1. Provide large size plan and section drawings of the containment which illustrate the structures, equipment, and piping in and above the suppression pool. These drawings should be sufficient to describe all equipment and structural surfaces which could be subjected to suppression pool hydrodynamic loadings.

2. Provide a graphical chronology of all potential pool dynamic loads which identifies the source of the load (i.e., pool swell froth impingement), the time interval over which the load is active, and the structures which are affected. (Reference GESSAR, Response 3.82)

3. For each structure or group of structures provide the anticipated load as a function of time due to each of the pool dynamic loads which could be imparted to the structure.

4. For each structure or group of structures provide the total load as a function of time due to the sum of anticipated pool dynamic loads.

5. Describe the manner in which the pool dynamic load characteristic shown in (4) above is integrated into the structural design of each

structure. Specify the relative magnitude of the pool dynamic load compared to other design basis loads for the structure.

6. Describe the manner by which potential asymmetric loads were considered in the containment design. Characterize the type and magnitude of possible asymmetric loads and the capabilities of the affected structures to withstand such a loading profile. Include consideration of seismically induced pool motion which could lead to locally deeper submergences for certain horizontal vent stacks.

7. Provide justification for each of the load histories given in (3) above by the use of appropriate experimental data and/or analyses. References to test data should indicate the specific test runs and data points and the manner by which they were converted to loads.

8. For those structures subject to pool dynamic loads provide your anticipated schedule for completion of the structural design, procurement of materials and actual construction.

9. Discuss your specific plans to be responsive to the concerns of ACRS. As noted in their letter on the Perry plant[6], the Committee believes that a more basic understanding of certain phenomena such as oscillations, vent interaction, pool swell, and dynamic

(6) Letter, W. R. Stratton, ACRS, to D. L. Ray, AEC, dated December 12, 1974.

and asymmetric loads on suppression pool and other containment structures is required. "The Committee emphasizes the importance of directing the test and analytical programs toward providing not only empirical design correlations but also toward more detailed evaluations of the relevant two-phase phenomena in order to enable the better application of a specific set of scaled tests to a range of actual reactor conditions." If reference is to be made to GE analytical methods development, a finalized breakdown of areas of investigation performed by GE and a time schedule as to their availability is requested. We require that those areas for which analytical results are available, but not yet submitted to the staff, be documented for our review as soon as possible.

DESCRIPTION OF POTENTIAL POOL DYNAMIC PHENOMENA

Following a design basis loss-of-coolant accident in the drywell, the drywell atmosphere will be rapidly compressed due to blowdown mass and energy addition to the drywell volume. This compression would be transmitted to the water in the weir annulus in the form of a compressive wave and propogate through the horizontal vent system into the suppression pool. The pool response to this effect could include a load to the containment wall and floor.

With pressurization of the drywell, the water in the weir annulus will be depressed and forced out through the horizontal vent system into the suppression pool. This movement of pool water can result in a vent clearing reaction force on the weir wall and a water jet impingement load on the containment wall.

Following clearing of the vents an air/steam/water mixture will flow from the drywell through the vents and be injected into the suppression pool, approximately six to eight feet below the surface. A vent flow reaction load will be imparted to the weir wall and a vent flow differential pressure will load the drywell wall. Depending on the characteristics of the suppression system; i.e., the vent area compared to the drywell volume and break flow area, drywell overexpansions could occur. Overventing of the drywell results when the initial vent flow, following vent clearing, evacuates the drywell more rapidly than the volume is replenished by blowdown mass and energy input. If the drywell volume is relatively small compared to the area of the vents,

then there is insufficient capacitance to absorb the transition in venting rates and loads due to drywell overexpansion oscillations can occur on the drywell wall and weir wall.

During vent flow the steam component of the flow mixture will condense in the pool while the air, being non-condensible, will be released to the pool as high pressure (~35 psia) air bubbles. Initial air bubble loads would be experienced by all pool retaining structures; i.e., the drywell wall and containment wall and floor, and could be of an oscillatory mode due to overexpansion and recompression of the bubbles.

The continued addition and expansion of air within the pool causes the pool volume to swell and therefore an acceleration of the surface vertically upward. This response of the pool is referred to as bulk pool swell since the air is confined beneath the pool and is driving a solid ligament of water. Bulk pool swell air bubble and flow drag loads are imparted to the drywell and containment walls and to structures, components, etc., which may be located at low elevations above the normal pool surface. Bulk pool swell impact loads will also result for low elevation structures and components.

Due to the effect of buoyancy, air bubbles will rise faster than the pool water mass and will eventually break through the swollen surface and relieve the driving force beneath the pool. This breakup of the water ligament leads to the upward expulsion of a two-phase mixture of air and water and is referred to as pool swell in the froth mode. Structures which are located at higher

elevations above the initial pool surface (i.e., the Hydraulic Control Unit (HCU) floors) experience a pool swell froth impingement load due to impact of two-phase flow.

In the annular region between the drywell and containment walls, where pool swell occurs, a significant flow restriction exists at the HCU floor level (~20 feet above the normal pool surface); typically 50%-70% of the annulus is blocked by the location of equipment and structures. The volume between the normal suppression pool surface and the HCU level is referred to as the wetwell. During pool swell in the froth mode, passage of the air/water mixture through this restriction generates a two-phase flow pressure drop and produces a wetwell pressurization load on the HCU floors. Froth flow will continue until the fluid kinetic energy has been expended, followed by fallback of the water to the initial suppression pool level. Water fallback loads can be anticipated on all previously mentioned structures and equipment in the annulus.

Following the initial pool swell event the suppression system will settle into a generally coherent phase during which significant vent flow rates are maintained from the drywell to the pool. A resultant effect is the occurrence of high vent flow steam condensation loads, which can be of an oscillatory nature, on pool retaining structures. As the reactor coolant system inventory of mass and energy is depleted, near the end of blowdown, venting rates to the suppression pool diminish allowing recovery of each row of horizontal vents. During phases of low vent mass flux the suppression system behaves in an oscillatory manner, referred to as chugging, whereby

periodic clearing and subsequent recovery of vents occurs since the vent flow cannot sustain bulk steam condensation at the vent exit. The resultant local fluctuations in pressure and water levels generate chugging oscillation loads, predominantly on the drywell wall and weir wall.

It should be further noted that the magnitude and range of any of the hydrodynamic loads discussed above can be aggravated by an asymmetric response of the suppression system, either in the circumferential or radial direction. One possi[illegible] initiator of such response would be seismically induced pool motion which could lead to locally deeper submergences for certain horizontal vent stacks and therefore larger pool swell loads. Full account of this potentiality should be made in establishing hydrodynamic load capabilities for the containment structures design.

Two further pool dynamic loading events, associated with relief valve operations, have been identified in addition to those associated with the design basis loss-of-coolant accident. Pressure waves are generated within the suppression pool when, on first opening, relief valves discharge air and steam into the pool wat[illegible]. This phenomenon yields steam vent clearing loads which are imparted to pool retaining structures. These same structures can also be subject to loads which accompany extended relief valve discharge into the pool (or vent flow from the drywell) if the pool water is at elevated temperatures. This effect is known as steam quenching vibrations.