NRC Central

August 16, 1978

Robert M. Lazo, Esq., Chairman
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dr. Richard F. Cole
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dr. Walter H. Jordan
881 West Outer Drive
Oak Ridge, Tennessee 37830

In the Matter of
NORTHERN STATES POWER COMPANY
(Monticello Nuclear Generating Plant, Unit 1)
Docket No. 50-263

Dear Board Members:

In a memorandum dated July 17, 1978, the Office of Nuclear Regulatory Research informed the Office of Nuclear Reactor Regulation of the Staff's preliminary assessment of the results of the Mark I Containment 1/5-Scale Testing Program which was conducted for the NRC by the Lawrence Livermore Laboratory (LLL). A copy of the memorandum is enclosed (Enclosure 1).

The Staff's preliminary assessment of the LLL results indicated that three-dimensional pool swell loads are higher than pool swell loads derived from data obtained in a two-dimensional test facility. This result is contrary to the Staff's conclusions in the Safety Evaluation of the Mark I Containment Short Term Program (STP). The details of the Staff's preliminary assessment are provided in Enclosure 2. As discussed in Enclosure 2, if the three-dimensional effects reported by LLL are shown to be correct, the stresses in the limiting component for one of the Mark I BWR facilities (the Monticello facility) will exceed by less than 10% the structural acceptance criteria established for the "sensitivity case" when a pool swell load uncertainty factor of 1.5 is applied. However, since the STP plant-unique analyses were completed, the data base has increased and the need for so large an uncertainty factor has diminished. In view of this and the fact that the new information obtained from the LLL testing program does not affect the "base case" structural analysis which showed that a safety factor of at least two exists for the weakest structural or mechanical component in the containment for each operating Mark I BWR facility subjected to pool swell loads, the Staff has concluded that no licensing

action is necessary at this time. The Staff expects to complete final assessment of the LLL test results in about two months and will provide the Board with the results of that final assessment.

Sincerely,

Stephen H. Lewis
Counsel for NRC Staff

Enclosures:
As stated

cc w/Enclosures:

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Mr. Russell J. Hatling
Gerald Charnoff, Esq.
Arthur Renquist, Esq.
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ENCLOSURE 1

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

JUL 17 1978

MEMORANDUM FOR: H. Denton, Director
Office of Nuclear Reactor Regulation

FROM: S. Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: LLL 1/5-SCALE MARK I CONTAINMENT TEST DATA

A final report on the air venting test series conducted, at LLL, with the 1/5-scale Mark I Torus Test facility was released to the public in March 1978.

RSR initiated compilation of a Research Information Letter and produced a preliminary table of test results, highlighting the three-dimensional effects.

A Containment Code Review Group meeting was held on July 7, 1978 for the purpose of discussing the LLL results and other containment research programs.

Partial meeting minutes, pertaining to the 1/5-scale Torus research discussion are given in the Enclosure.

The purpose of this transmittal is to inform NRR of the preliminary findings which indicate (a) that the 3-dimensional effects could result in higher loads than measured in a 2-dimensional facility of the same scale; (b) that the vertical loads predicted for the LLL 1/5-scale two-dimensional (7 1/2° sector) test section, using GE's 1/12-scale two-dimensional test data (when extrapolated to 1/5 scale), were higher than actually measured by LLL; (c) that a complete error analysis of the load evaluation in the LLL three-dimensional (90 degree segment) test facility is lacking and, therefore, the conclusion mentioned in (a) above may be premature.

Other research programs (at UCLA and MIT) have verified the air venting loads scaling laws used in extrapolating small scale results to full scale plants.

In order to resolve the issues concerning the present uncertainties of the three-dimensional effects RSR has instructed LLL to undertake

a detailed error analysis. It is our understanding that NRR has asked BNL to provide an independent error analysis of the same data.

S. Levine

S. Levine, Director
Office of Nuclear Regulatory Research

Enclosure: as stated

cc w/encl: R. Fraley (ACRS)
PDR

Enclosure

Partial Minutes of the Containment Code Review Group Meeting Held in Silver Spring on July 7, 1978.

Introduction

A meeting of the Containment Code Review Group was held on July 7, 1978 in Silver Spring, Maryland. The meeting agenda is shown in Attachment I and the list of attendees in Attachment II.

Because of its significance, it was decided to communicate the meeting discussions pertinent to the 1/5-scale torus test program at LLL, prior to the issuance of the full meeting minutes.

Discussion

After LLL's presentation of their test results summary, RES introduced a Table which re-casts these results to highlight the 3-D effects. These effects were demonstrated by showing ratios of the maximum up- and down-load of the 90° torus sector over that in the 7.5° torus sector (see Attachment III). The Table indicates that peak loads measured under identical conditions in the 3-D facility are higher than those in the 2-D facility, even with the error bands considered.

In the ensuing discussion, it was pointed out that the 3-D effects shown in the Table appear contrary to expectation. For example, Professor Lahey indicated that restraining the lateral motion of fluid, by lateral walls

(present in the 2-D wetwell), should enhance vertical motion and, therefore, give higher vertical loads. However, Professor Catton's test result (see Attachment IV) seems to negate that conclusion. As shown in Attachment IV, when an additional vertical baffle was introduced in the middle of the UCLA test chamber to increase fluid confinement, the measured vertical download was lower than those without the baffle.

The second issue raised, concerned the adequacy of the error analysis. The error bands as shown in the Table include the contribution due to pressure measurements as well as due to pressure integration over the wetwell surface. LLL claimed that a proper error analysis of the pressure integration was never performed because of time constraint in meeting the final report completion schedule. In that context BNL questioned the use of the 3rd degree polynominal for fitting the pressure profile, along the torus circumference.

The DOR representative proposed that additional analysis of the 1/5-scale data be performed to gain further understanding of the experimental results (see Attachment V). Such additional analyses could be performed either by LLL or BNL (or both).

The DOR list could be summarized by three basic issues: (1) Understanding of 3-D effects including error analysis, (2) pool swell and header impact loads, and (3) re-casting LLL test data in terms of enthalpy flux for easier comparison with the GE data.

The issue (1) was discussed above. The LLL final report did not dwell on the pool swell and header loads since these do not affect the peak up- and down-loads. It should be recalled that the main purpose of the LLL tests was to establish the influence of 3-D effects on the latter. Nevertheless, a separate evaluation header loads could be undertaken based on the existing LLL test data. RSR will see to it that the LLL peak loads are expressed in terms of the enthalpy flux per DOR request.

LLL 1/5-scale torus air venting test series was completed during May of 1977. At that time RSR indicated that a decision concerning the future use of that facility had to be postponed pending (a) issuance of the final report and its review regarding completeness of information; (b) completion of preliminary studies on the subject of scaleability of the steam venting process.

The latter studies have already indicated, as discussed during this review group meeting, that scaling of steam venting is not feasible, thus questioning the reason for pursuing steam venting tests in smaller than full scale geometries.

Owing to all the concerns raised above in connection with the air venting test results, NRR urged that the 1/5-scale test facility be preserved intact pending the problem resolution.

LLL management wished to have NRC decision by July 1978 (or August at the latest) whether the facility ought to be carefully dismantled or "buried".

ATTACHMENT I

CONTAINMENT CODE REVIEW GROUP

July 7, 1978
11th Floor Conference Room

AGENDA

8:30 a.m. - 12:00 p.m.	Review and discussion of completeness of the 1/5-scale Mark I test results final report.
12:00 p.m. - 1:00 p.m.	Lunch
1:00 p.m. - 2:00 p.m.	Basic Studies at MIT. Review of work scope and results obtained thus far.
2:00 p.m. - 3:00 p.m.	Basic Studies at UCLA. Review of work scope (old) and accomplishments. Review of the proposed (new) work scope.
3:00 p.m. - 3:10 p.m.	Coffee Break
3:10 p.m. - 4:00 p.m.	Review of BEACON code. Accomplishments and future work plans.
4:00 p.m. - 5:00 p.m.	Review of LLL work on BWR wetwell pool dynamics analysis, accomplishments and future work plans.

ATTACHMENT II

CONTAINMENT CODE REVIEW GROUP MEETING

July 7, 1978 Silver Spring, Maryland

List of Attendees

G. Bienkowski	BNL (Princeton)
J. Ranlet	BNL
George Maise	BNL
Fei K. Chiang	NRC/RSR
C. I. Grimes	NRC/DOR
Jerry Goudreau	LLL
Peter Huber	MIT
Ain Sonin	MIT
Ed McCauley	LLL
W. Lai	LLL
Ivan Catton	UCLA
Roy Wells	EG&G
Paul North	EG&G
N. Zuber	NRC/RSR
W. Paulson	NRC/NRR
J. A. Kudrick	NRC/NRR
John Huang	NRC/SD
W. R. Butler	NRC/NRR
Vijay Dhir	UCLA
C. J. Anderson	NRC/NRR
C. K. Chan	UCLA
Douglas M. Norris, Jr.	LLL
William H. McMaster	LLL
Frank J. Tokarz	LLL
Carl E. Walter	LLL
R. T. Lahey	RPI
L. S. Tong	NRC/RSR
S. Fabic	NRC/RSR

TABLE 1

Ratio of Maximum Vertical Loads in the 90° Sector Over 7.5° Sector

Parameters at nominal and constant values[2]	Changing Parameters	Download ratio	Upload ratio
all	none	1.09[1]	1.40[1]
all others	Initial dP/dt in drywell (Psi/sec)		
	20.5	$1.19^{+.14}_{-.12}$	$1.13^{+.26}_{-.22}$
	33.8	$1.16 \pm .12$	$1.22^{+.29}_{-.23}$
	38.2	$1.08^{+.12}_{-.11}$	$1.38^{+.33}_{-.26}$
all others	Drywell initial overpressure (in. H_2O)		
	4.8	$1.13^{+.12}_{-.12}$	$1.21^{+.29}_{-.23}$
	7.2	$1.31^{+.14}_{-.13}$	$1.32^{+.31}_{-.25}$
	7.2	$1.27^{+.14}_{-.13}$	$1.33^{+.32}_{-.25}$

[1] The load ratios shown on Table 1, for tests at nominal conditions, are the arithmatic averages of six repetitive tests at nominal conditions. The uncertainties associate with each download ratio range from $\pm .1$ to $\pm .14$. For the upload ratios, the range is from $^{+.31}_{-.24}$ to $^{+.36}_{-.30}$. The uncertainties given for all other tests are based on the measurement error calculated at tests under nominal conditions.

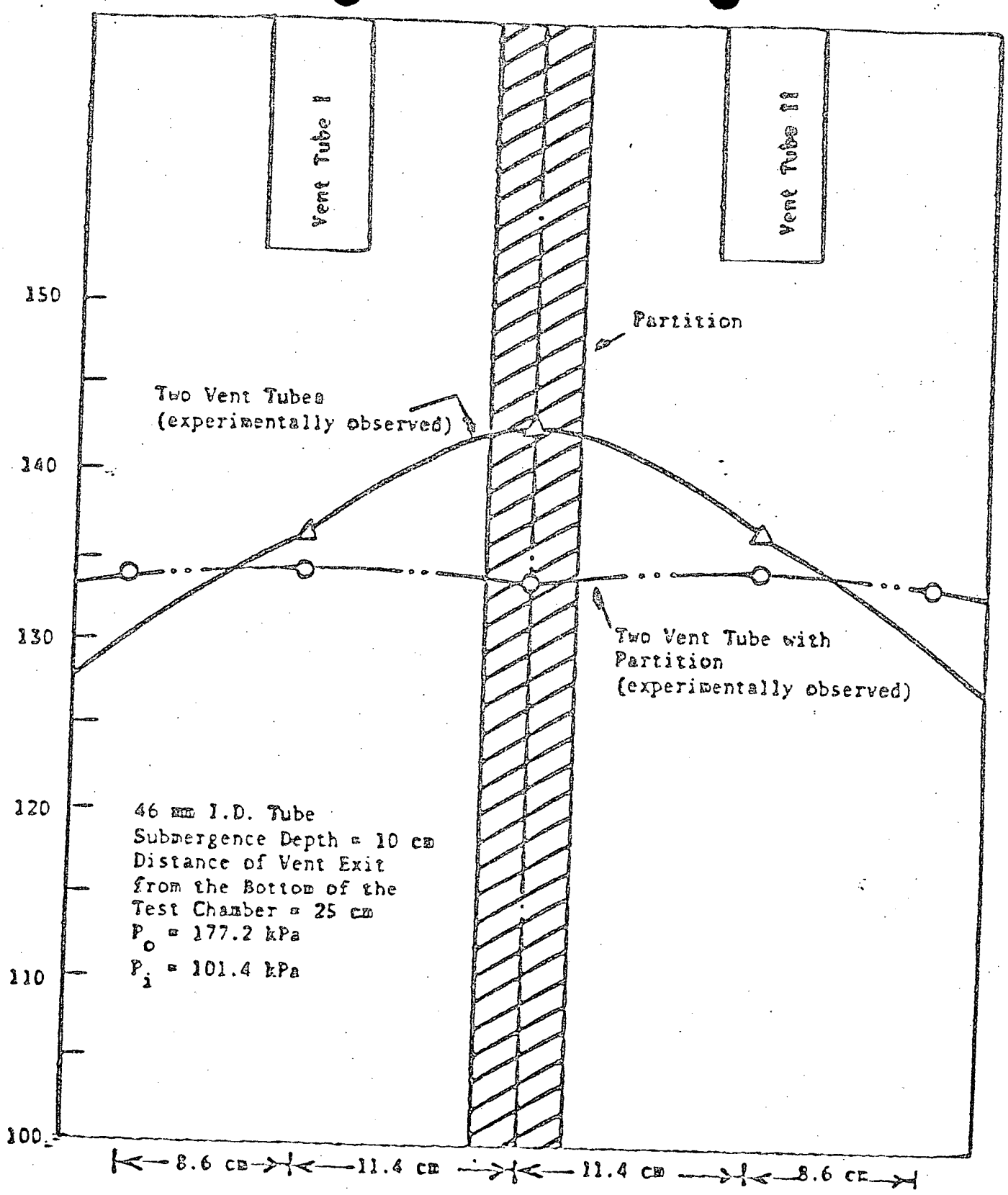
[2] The nominal conditions are:
(1) Torus water level (below centerline) -2.40 in.
(2) Downcomer Submergence -9.6 in.
(3) Initial drywell, wetwell pressure -2.95 Psia
(4) Initial drywell pressurization rate -27.3 Psi/sec
(5) Nominal vent-line orifice diameter (90° sector)-9.5 in
(7.5° sector)-3.63 in

TABLE 1 (cont')

Parameters at nominal and constant values	Changing Parameter	Download ratio	Upload ratio
At increased submergence all other remain nominal and constant. Downcomer submergence is 12.0 in.	Initial dP/dt in drywell (Psi/sec)		
	20.5	$1.22^{+.13}_{-.12}$	$1.28^{+.30}_{-.24}$
	33.8	$1.20^{+.13}_{-.12}$	$1.20^{+.28}_{-.23}$
	38.2	$1.22^{+.13}$	$1.25^{+.29}_{-.24}$
All others	Downcomers submergence (in)		
	13.4	$1.15^{+.13}_{-.12}$	$1.13^{+.26}_{-.22}$
	5.8	$1.30^{+.14}_{-.13}$	$1.19^{+.27}_{-.23}$
	12.0	$1.23^{+.14}_{-.12}$	$1.15^{+.27}_{-.22}$
	9.6	$1.18^{+.13}_{-.12}$	$1.23^{+.29}_{-.23}$
All others	Enthalpy flux expressed in terms of vent pipe orifice diameters for 90° sector		
	10.58 in.	$1.15^{+.13}_{-.11}$	$1.39^{+.32}_{-.27}$
	16.20 in.	$1.06^{+.12}_{-.10}$	$1.50^{+.35}_{-.28}$
All others	Asymmetry[3] (with two values of Enthalpy flux expressed in terms of orifice diameters for 90° sector)		
	9.5 in. (for 90° sec.)	$1.16^{+.13}_{-.12}$	$1.45^{+.34}_{-.27}$
		$1.16^{+.13}_{-.12}$	$1.43^{+.34}_{-.27}$
	16.20 in. " " "	$1.24^{+.14}_{-.13}$	$1.28^{+.30}_{-.25}$
		$1.18^{+.13}_{-.12}$	$1.26^{+.29}_{-.24}$

[3] On Table 1, the entry "Asymmetry (with two values of Enthalpy flux expressed in terms of orifice diameters for 90° sector)" consists of four tests. The first two have nominal orifice and each 45° vent pipe is alternately blocked. The last two are identical to the former two with the exception of no orifice in the vent pipes. The second value of the orifice diameter is therefore the vent pipe (45°) diameter.

ATTACHMENT IV



Effect of Cell Size on Maximum Downward Force

Attachment V

DOR PROPOSED ADDITIONAL LIVERMORE DATA ANALYSES

1. enthalpy flux transients
2. pool surface velocity at header impact (spatial variation)
3. header impact timing
4. submerged pool velocity transients (specific locations)
5. pressure integral with inertial force
6. load integral comparison with load cells corrected for header impact
7. header impact loads and spatial variation
8. analysis of torus acceleration
9. quantification of effects of downcomer clearing
10. local pressure overlays for 7.5° and 90°
11. vent clearing time and velocities
12. axial load variation and typical polynominal functions
13. comparison of load integration techniques (e.g., point to point)
14. volumes of drywell, wetwell airspace, pool, and pool surface areas

ENCLOSURE 2

DISCUSSION OF THE PRELIMINARY ASSESSMENT OF THE LLL MARK I CONTAINMENT TESTING PROGRAM RESULTS

Background

As a result of differences in the design of the torus support systems at Mark I BWR facilities and due to the sensitivity of the predicted structural response of the torus support system to variations in applied loads, the NRC required that each licensee of an operating BWR with a Mark I containment perform a plant-unique analysis of their torus support system and the piping attached to the torus as part of the Mark I Containment Short Term Program (STP). Brunswick Units 1 and 2 were exempted from this requirement since these facilities have a torus encased in concrete which does not depend on columns for external support.

The STP pool swell loads (i.e., during the air clearing phase of the LOCA) on the torus structure and its external supports were based on a series of tests performed in a Mark I Owner's Group one-twelfth (1/12) scale two-dimensional test facility representing a segment of a Mark I containment torus. Based on a staff review of the 1/12 scale test results, it was determined that the structural response of the torus support system and attached piping was sensitive to the magnitude of the upward pressure load. Therefore, in addition to the base case analysis, a sensitivity analysis using the 1/12 scale test data was performed for each facility. This sensitivity analysis was directed toward the upward pressure load considerations, since the torus did not exhibit the same sensitivity to the downward load as to the upward load. The purpose of

the sensitivity analysis was to evaluate the variation in structural response for different upward pressure loads due to uncertainties in the application of data from the experimental program.

The base case structural analysis was performed using the most probable LOCA-related hydrodynamic loads and each licensee was required to demonstrate a factor of safety of at least two for the weakest element in the containment system for its facility. The loads utilized in the sensitivity case structural analysis for each Mark I facility were the base case plant-unique loads multiplied by two additional factors. The first factor is a load correction factor of 0.8 to account for conservatisms in the development of the reference plant load. The second factor is a load factor of 1.5 which was selected to provide a reasonable upper bound for the upward load. The load correction factor of 0.8 was primarily based on the staff's assessment that three-dimensional effects due to unequal downcomer spacing would reduce the torus upward loads by 20%. For the sensitivity case analysis, the structural acceptance criterion was a safety factor of greater than 1.0.

To provide independent confirmation of the suppression pool hydrodynamic loads, the staff initiated a testing program through the Office of Nuclear Regulatory Research. The Lawrence Livermore Laboratory (LLL) was contracted to construct a 1/5 scale three-dimensional model of a Mark I torus and to perform a series of tests to (1) investigate the three-dimensional effects associated with the LOCA hydrodynamic loads on the Mark I contain-

ment suppression chamber, (2) verify the scaling laws utilized in the Mark I containment testing programs, and (3) establish an independent data base for LOCA hydrodynamic loads to confirm the results of testing programs conducted by the Mark I Owners Group.

Following a series of scoping tests, the final LLL test facility arrangement was selected to consist of a 90^{o} sector of a Mark I torus, containing two main vents and twelve downcomer pairs, and a 7.5^{o} two-dimensional torus sector containing a single pair of downcomers.

Construction of the Livermore 1/5 scale test facility was completed in March 1977. Twenty-seven tests were conducted using nitrogen as the pressurizing medium to simulate the conditions of the early pool swell transient. These tests were completed in May 1977. Livermore began the reduction and analysis of the data during the course of the testing. Because of the large quantity of data involved, the data reduction and analyses continued through the summer of 1977. A draft of the final test report was completed by Livermore in October 1977. Publication difficulties delayed the issuance of the final test report and associated supporting documentation until March 1978. A meeting of the Containment Research Review Group was held on July 7, 1978 to discuss the final test report.

For ease of reference, Table A contains a listing of ongoing Mark I containment tests to establish pool swell loads.

Preliminary Assessment of the LLL Testing Program Results

A principal result of the preliminary assessment of the LLL testing program is that the integrated loads on the 90^{o} three-dimensional sector appear to be

higher than the equivalent integrated loads on the 7.5^{0} two-dimensional sector; i.e., three dimensional effects cause the torus loads to increase. This conclusion is contrary to (1) the expected results of the LLL testing program, (2) the preliminary results of the three-dimensional testing program conducted for the Mark I Owners Group by EPRI, and (3) the position taken by the NRC staff for the conduct of the "sensitivity case" analysis portion of the STP plant-unique structural anlayses.

The absolute magnitude of the LLL three-dimensional loads, when scaled up to full scale, are either equivalent (in the case of the torus upward loads) or lower (in the case of the torus downward loads) than those loads which were utilized in the Mark I STP. However, the LLL two-dimensional loads, when scaled up to full scale, are significantly lower than those loads which were utilized in the Mark I STP.

In a memorandum to NRR dated July 17, 1978, RES pointed out that a complete error analysis of the LLL three-dimensional test facility has not yet been completed and, therefore, that it is premature to draw any conclusions regarding the three-dimensional effects at this time. During the meeting of the NRC Containment Code Review Group on July 7, 1978, both the staff and its consultants expressed reservations regarding the calculation techniques used to integrate the loads on the torus for analysis of the LLL 3-D tests and questioned the basis for both the load magnitudes and the conclusions regarding three-dimensional effects.

Current Status

RES has initiated action to have LLL perform a complete error analysis of the LLL test results for both the 7.5^{D} and 90^{D} sectors. In addition, NRR has initiated action to have an independent assessment of the LLL testing program results performed by its consultants. This assessment will include both the results from the three-dimensional testing sector and from the two-dimensional testing sector. It is expected that the above-mentioned analyses will be completed within two months.

NRR has performed a preliminary assessment of the LLL testing program results to determine what impact they may have on the staff's conclusions regarding the Mark I STP, as expressed in the "Mark I Containment Short Term Program Safety Evaluation Report", NUREG-0408, December 1977.

Although the LLL test results indicate that the three-dimensional loads are higher than the two-dimensional loads derived from the same test facility, a direct comparison of the magnitude of the Livermore three-dimensional loads with the magnitude of the STP "base case loads" confirms the adequacy of the most probable loads used for the STP. Consequently, we have determined that, even if the three-dimensional loads calculated by LLL are shown to be correct, this new information does not affect the STP "base case" structural analyses upon which the safety factor of at least two was based. From our review of the methods used by LLL to calculate the three-dimensional loads, we do not see any reason to believe that an improved calculational technique would result in three-dimensional loads that are higher than those currently reported by LLL.

Since the STP "sensitivity case" structural analyses included a load correction factor of 0.8 to account for the anticipated reduction in the torus upward loads due to three-dimensional affects, it could be

affected by this new information. Based on our review of the "sensitivity case" analysis results provided in the plant-unique structural analysis reports for each Mark I BWR facility, we have determined that, if the three-dimensional effects reported by LLL are shown to be correct, the stresses in one component of one of the Mark I BWR facilities will slightly exceed (i.e., by less than 10%) the structural acceptance criteria for the sensitivity case.

It should be noted that the "sensitivity case" structural analysis, in addition to including a load correction factor Of 0.8, included a load factor of 1.5 to account for uncertainties in the STP load definition (a net multiplier factor of 1.2). Subsequently, a large data base has been developed from a number of test facilities, including the LLL testing facility, which demonstrates that the STP most probable loads were appropriate. Consequently, the necessity for including a load factor as high as 1.5 has diminished.

On July 19-21, 1978, a representative from NRR and a consultant from BML visited LLL to review the load integration techniques and to observe trends in the tst data. They concluded that three-dimensional loads reported by LLL are higher than expected because of the methods used to extrapolate the data to areas of reduced instrumentation. Preliminary calculations indicate that the three-dimensional upward load magnitudes would be reduced by about 10% with a better fit of the data. We expect that these load magnitudes will be reduced even further when LLL completes the uncertainty analyses for the three-dimensional test facility, based on the trends observed in the local pressure measurements. They have also developed a rationale which may explain

the differences observed between the loads calculated for the 7.5^{0} sector and the loads derived from GE two-dimensional tests. Our review of this information is continuing.

Conclusion

The preliminary assessment of the LLL testing program results has raised questions regarding the three-dimensional effects associated with the LOCA hydrodynamic loads on the Mark I containment suppression chamber. Since there are a number of questions concerning the preliminary assessment of the LLL testing program results at this time, it is premature to draw any conclusions regarding the three-dimensional effects. A program to resolve this issue has been initiated.

The new information obtained from the LLL testing program does not affect the "base case" structural analysis which formed the basis for the staff's conclusion that a safety factor to failure of at least two exists for the weakest structural or mechanical components in the containment for each operating Mark I BWR facility. Further, we and our consultants believe that the load factors used for the sensitivity cases are still bounding based on our assessment of the LLL data. The actions that we are presently pursuing should confirm our assessment within approximately two months. As a result, the staff has concluded that no licensing actions are necessary at this time.

Table A

Mark I Containment Pool Swell Tests

Sponsor	Size/Geometry	Contractor	Completion Schedule
Mark I Owners	1/12 - 2D sector	GE	March 1976
NRC	1/5 - 90° 3D sector	LLL	October 1977
	1/5 - 2D sector	LLL	
Mark I Owners	1/12 - 90° straight	EPRI	September 1978
Mark I Owners	1/4 - 2D sector	GE(Accurex)	December 1978