Technical Evaluation of the Oyster Creek Plant Unique Analysis Reports

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ABSTRACT

This Technical Evaluation Report (TER) presents the results of the post-implementation audit of the Plant Unique Analysis Report (PUAR) for the Oyster Creek Nuclear Generating Station. The contents of the PUAR were compared against the hydrodynamic load Acceptance Criteria (AC) contained in NUREG-0661. The TER contains a summary of the audit findings, as well as a more detailed discussion of special issues or exceptions to the AC identified during the audit. Two tables are provided. The first is a checklist of PUAR loads versus AC specifications. The second highlights each special issue or AC exception along with an indication of the type and status of each issue.

ACKNOWLEDGEMENTS

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List of Acronyms

AC	Acceptance Criteria
ADS	Automatic Depressurization System
BNL	Brookhaven National Laboratory
BWR	Boiling Water Reactor
CO	Condensation Oscillation
DL	Division of Licensing
DSI	Division of System Implementation
FSI	Fluid Structure Interaction
FSTF	Full Scale Test Facility
GE	General Electric Company
GPU	General Public Utilities
LDR	Load Definition Report
LOCA	Loss-of-Cooland Accident
LTP	Long Term Program
NRC	Nuclear Regulatory Commission
PUAR	Plant-Unique Analysis Report
QSTF	Quarter Scale Test Facility
RFI	Request For Information
SBA	Small Break Accident
SMA	Structural Mechanics Associates
SRV	Safety Relief Valve
SRVDL	Safety Relief Valve Discharge Line
STP	Short Term Program
TER	Technical Evaluation Report
T/Q	T-Quencher

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1. INTRODUCTION

The suppression pool hydrodynamic loads associated with a postulated loss-of-coolant accident (LOCA) were first identified during large-scale testing of an advanced design pressure-suppression containment (Mark III). These additional loads, which had not explicitly been included in the original Mark I containment design, result from the dynamic effects of drywell air and steam being rapidly forced into the suppression pool (torus). Because these hydrodynamic loads had not been considered in the original design of the Mark I containment, a detailed reevaluation of the Mark I containment system was required.

A historical development of the bases for the original Mark I design as well as a summary of the two-part overall program (i.e., Short Term and Long Term Programs) used to resolve these issues can be found in Section 1 of Reference 1. Reference 2 describes the staff's evaluation of the Short Term Program (STP) used to verify that licensed Mark I facilities could continue to operate safely while the Long Term Program (LTP) was being conducted.

The objectives of the LTP were to establish design-basis (conservative) loads that are appropriate for the anticipated life of each Mark I BWR facility (40 years), and to restore the originally intended design-safety margins for each Mark I containment system. The principal thrust of the LTP has been the development of generic methods for the definition of suppression pool hydrodynamic loadings and the associated structural assessment techniques for the Mark I configuration. The generic aspects of the Mark I Owners Group LTP were completed with the submittal of the "Mark I Containment Program Load Definition Report" (Ref. 3) and the "Mark I Containment Program Structural Acceptance Guide" (Ref. 4), as well as supporting reports on the LTP experimental and analytical tasks. The Mark I containment LTP Safety Evaluation Report

(NUREG-0661) presented the NRC staff's review of the generic suppression pool hydrodynamic load definition and structural assessment techniques proposed in the reports cited above. It was concluded that the load definition procedures utilized by the Mark I Owners Group, as modified by NRC requirements, provide conservative estimates of these loading conditions and that the structural acceptance criteria are consistent with the requirements of the applicable codes and standards.

The generic analysis techniques are intended to be used to perform a plant-unique analysis (PUA) for each Mark I facility to verify compliance with the acceptance criteria (AC) of Appendix A to NUREG-0661. The objective of this study was to perform a post-implementation audit of the Oyster Creek plant-unique analysis (References 5 & 6) against the hydrodynamic load criteria in NUREG-0661.

2. POST-IMPLEMENTATION AUDIT SUMMARY

The purpose of this post-implementation audit is to evaluate the hydrodynamic loading methodologies used to modify the suppression chamber, vent system, internal structures and the torus attached piping of the Oyster Creek Nuclear Generating Station. The methodologies of the Oyster Creek PUAR (References 5 & 6) are compared to those presented in the LDR (Reference 3) which were approved in the AC of NUREG-0661 (Reference 1). The audit procedure consists of a moderately detailed review of the plant-unique analysis report to verify both its completeness and its compliance with the acceptance criteria. A checklist of the various load categories specified in the AC, as shown in Table 1, is used to facilitate this task. Besides providing an overview of the audit, Table 1 supplies plant-unique information through the notes in the right-hand margin which are explained at the end of the table.

The next section of this TER, Section 3, identifies the exceptions to the AC, as well as those special areas, detailed during the Oyster Creek PUAR audit, where additional information was needed.

LOADS	NUREG-0661 AC SECTION	CRITERIA: MET	CRITERIA: NOT MET	NOT APPLICABLE	ALTERNATE APPROACH	NOTES
CONTAINMENT PRESSURE & TEMPERATURE	2.1	✓				
VENT SYSTEM THRUST LOADS	2.2	✓				1
POOL SWELL						
TORUS NET VERTICAL LOADS	2.3				✓	2
TORUS SHELL PRESSURE HISTORIES	2.4				✓	2
VENT SYSTEM IMPACT AND DRAG	2.6	✓				
IMPACT AND DRAG ON OTHER STRUCTURES	2.7	✓				
FROTH IMPINGEMENT	2.8	✓				
POOL FALLBACK	2.9	✓				
LOCA JET	2.14.1	✓				
LOCA BUBBLE DRAG	2.14.2	✓				
VENT HEADER DEFLECTOR LOADS	2.10	✓				

TABLE 1. LOAD CHECKLIST FOR POST-IMPLEMENTATION AUDIT

LOADS	NUREG-0661 AC SECTION	CRITERIA		NOT APPLICABLE	ALTERNATE APPROACH	NOTES
		MET	NOT MET			
<u>CONDENSATION OSCILLATION</u>						
TORUS SHELL LOADS	2.11.1				✓	3
LOADS ON SUBMERGED STRUCTURES	2.14.5	✓				
VENT SYSTEM LOADS	2.11.3	✓				
DOWNCOMER DYNAMIC LOADS	2.11.2	✓				
<u>CHUGGING</u>						
TORUS SHELL LOADS	2.12.1				✓	4
LOADS ON SUBMERGED STRUCTURES	2.14.6	✓				
VENT SYSTEM LOADS	2.12.3	✓				
LATERAL LOADS ON DOWNCOMERS	2.12.2	✓				

TABLE 1. (CONTINUED)

LOADS	NUREG-0661 AC SECTION	CRITERIA		NOT APPLICABLE	ALTERNATE APPROACH	NOTES
		MET	NOT MET			
T-QUENCHER LOADS						5
DISCHARGE LINE CLEARING	2.13.2				✓	6
TORUS SHELL PRESSURES	2.13.3	✓				7
JET LOADS ON SUBMERGED STRUCTURES	2.14.3				✓	8
AIR BUBBLE DRAG	2.14.4				✓	9
THRUST LOADS ON T/Q ARMS	2.13.5				✓	10
S/RVDL ENVIRONMENTAL TEMPERATURES	2.13.6	✓				

TABLE 1. (CONTINUED)

	DESCRIPTION	NUREG-0661 AC SECTION	CRITERIA MET	CRITERIA NOT MET	NOT APPLICABLE	ALTERNATE APPROACH	NOTES
1	SUPRESSION POOL TEMPERATURE LIMIT	2.13.8				✓	11
2	SUPRESSION POOL TEMPERATURE MONITORING SYSTEM	2.13.9	✓				12
3	DIFFERENTIAL PRESSURE CONTROL SYSTEM FOR THOSE PLANTS USING A DRYWELL-TO-WETWELL PRESSURE DIFFERENCE AS A POOL SWELL MITIGATOR	2.16			✓		
4	SRV LOAD ASSESSMENT BY IN-PLANT TEST	2.13.9	✓				13

TABLE 1. (CONTINUED)

Table 1 Notes

1. Since the vent line is reduced in diameter at the vent line-drywell intersection of the Oyster Creek Plant, a thrust load can occur at this reduction. This thrust load was not addressed generically in the LDR but was adequately accounted for in the Oyster Creek analysis.
2. The AC requires the torus net vertical loads and the shell pressure histories to be based on four QSTF tests. Since the decision was made to operate Oyster Creek with 0 Δp between drywell and wetwell, the Oyster Creek vertical loads were based on only a single test. This was the test with the greatest submergence conducted at 0 Δp. Oyster Creek loads were increased to account for the larger statistical variance associated with the smaller number tests. The amount of increase was found acceptable. See Section 3.1 for additional discussion.
3. The AC requires absolute summation of the CO load harmonics for the analysis of structures affected by CO loads. Oyster Creek used a random phasing methodology instead where individual harmonic responses are added assuming random phase angles. Shell stresses and strains are multiplied by 1.3, other responses by 1.15. This methodology was found acceptable. See Section 3.2 for additional details.
4. The post-chug load was defined in the AC as the absolute summation of 50 separate harmonic loads from 1 to 50 Hz. Response above 30 Hz was very small for Oyster Creek structures so the final analysis procedure used for Oyster Creek only absolute summed the responses up to 30 Hz for calculational convenience. The summation up to 30 Hz only was found acceptable for this load.

5. The Oyster Creek SRV system differs from that of most other Mark I plants in two principal ways: Several SRV lines converge to a common header, and plant-unique Y-quenchers are used instead of GE T-quenchers. Therefore, all SRV suppression pool loads in the Oyster Creek PUAR are based on or are modified by plant unique in-plant SRV tests of the Y-quenchers.

6. SRV discharge line clearing loads were calculated in the Oyster Creek PUAR according to AC methodology but modified to account for Oyster Creek's special Y-quencher and for several lines entering a common header.

7. SRV torus shell pressure loads were calculated in the Oyster Creek PUAR according to the guidelines given in the AC for calculations based on in-plant SRV tests. See Section 3.3 for further discussion.

8. Jet loads on submerged structures were calculated using the analytical method of the LDR and approved in the AC but with the specific Oyster Creek Y-quencher geometry.

9. SRV air bubble drag loads were calculated using the LDR analytical model but adapted to the Oyster Creek Y-quencher by development of an empirical factor to bound all test data similar to the one developed for the GE T-quencher. Frequency of bubble oscillation was taken from the SRV shell load analysis.

10. An analytical model was developed to model the sparger arms on the Oyster Creek Y-quencher and calculate water thrust loads on them. To ensure its adequacy, the Oyster Creek model was used to calculate water thrust loads on a GE T-quencher and these were compared to the thrust loads calculated by the generic analytical model from the LDR. Loads calculated by the Oyster Creek model were at least 20% greater than those calculated by the LDR model.

11. The Oyster Creek pool temperature monitoring system which meets AC approval will be incorporated during the next scheduled shutdown of the plant (Cycle 11).
12. The Oyster Creek pool temperature analysis was found acceptable. See Section 3.3 for more discussion on the Pool Temperature Limit analysis for Oyster Creek.
13. The Oyster Creek in-plant SRV tests were conducted using the guidelines given in the AC for the use of such tests in developing a load methodology. Besides the information presented in the PUAR, a separate report dealing with the conduct and measured results of the Y-quencher discharge tests (Reference 7) was also reviewed (Reference 8).

3. SUMMARY OF THE NRC REQUEST FOR INFORMATION REGARDING THE OYSTER CREEK PUAR.

During the post-implementation audit of the Oyster Creek PUAR, various issues were identified as either exceptions to the AC or as areas where additional information was required. To resolve these issues, a request for information (RFI) (Reference 9) was sent to the licensee in order to obtain further details to supplement the information contained in the PUAR. Most of the requested details were presented by the licensee at a meeting in Washington, D. C. on July 14, 1983. This meeting was attended by GPU Nuclear, MPR Associates, as well as NRC and its BNL consultants. More information on a few items was furnished by the licensee at a later date. The material presented at the meeting has been be formally documented.

An overview of the RFI sent to Oyster Creek is presented in Table 2 along with an indication of the type and status of each item. As the table shows, two exceptions to the AC have been identified in the Oyster Creek PUAR. Both of them have been resolved. All items relative to the Mark I LTP have been resolved. For completeness, following Table 2 a brief description of any exceptions to the AC and their justification is provided.

TABLE 2. ISSUES IDENTIFIED DURING POST-IMPLEMENTATION AUDIT

		TYPE OF ISSUE		STATUS OF ISSUE	
ITEM	DESCRIPTION	EXCEPTION TO NUREG-0661 AC	REQUESTS FOR ADDITIONAL INFORMATION	RESOLVED	OPEN
1	Specification of Procedures by Which Operator Will Identify SBA and Insure Manual Operation of ADS.		X	X	
2	Thrust Loads at Vent Line-Drywell Intersection Where Vent Line Diameter is Reduced.		X	X	
3	Torus Net Vertical Loads Based on Single QSTF Test at 0ΔP.	X		X	
4	Number of Load Cases and Exceedance Probability Used to Evaluate Multiple Downcomer Loading.		X	X	

TABLE 2 (CONTINUED)

ITEM	DESCRIPTION	TYPE OF ISSUE: EXCEPTION TO NUREG-0661 AC	TYPE OF ISSUE: REQUESTS FOR ADDITIONAL INFORMATION	STATUS OF ISSUE: RESOLVED	STATUS OF ISSUE: OPEN
5	Random Phasing of Load Harmonics to Analyze Structures Affected by CO Loads.	X		X	
6	Torus Pressures Load Distribution During Pool Swell.		X	X	
7	Method Used to Include FSI Effects for Submerged Structures.		X	X	
8	Details of Post-Chug Submerged Structure Load Calculation.		X	X	
9	Application of Vent System Loads During CO and Chugging.		X	X	
10	Model Used for Post-Chug Load Calculation.		X	X	

TABLE 2 (CONTINUED)

		TYPE OF ISSUE		STATUS OF ISSUE	
ITEM	DESCRIPTION	EXCEPTION TO NUREG-0661 AC	REQUESTS FOR ADDITIONAL INFORMATION	RESOLVED	OPEN
11	Computer Models Used to Calculate Swell and Vent System Loads.		X	X	
12	Further Information on In-Plant SRV Tests and Methodology Used to Develop SRV Loads, as well as Information on the Pool Temperature Monitoring System and Pool Temperature Limits.	x		x	

3.1 Single QSTF Test at 0 Δp. (Item 3 of Table 2).

The LDR (3) and the AC (1) specify a minimum of four QSTF tests as a data base for obtaining net torus vertical loads. Most of the QSTF tests conducted for Oyster Creek and repeated with identical conditions were carried out with a pressure differential (Δp) between the drywell and wetwell. The Oyster Creek PUAR states that Oyster Creek will operate with zero Δp between drywell and wetwell and therefore this condition was the one selected for calculating net torus vertical loads. The PUAR also states that "loads were increased to account for the larger statistical variance associated with the smaller number of tests at the 0 Δp conditions". The RFI asked for the number of tests the loads were based on and the amount the loads were increased, as well as the statistical basis for the increase. The licensee replied that the pool swell loads were based on a single QSTF test at 0 Δp, the one with the greatest submergence to maximize the loads. The licensee further stated that GE has provided generic factors for single test statistics based on doubling the uncertainty for the torus shell load due to having one test instead of four in the data base. Oyster Creek used this doubling of the uncertainty to obtain new margins for their shell loads. The total margin increased from 1.215 to 1.28 for the upload and from 1.096 to 1.192 for the download in Oyster Creek. No increased margins were used for other QSTF single test derived loads.

BNL and its consultants, including those involved in approving the original uncertainty margins for four QSTF tests, reviewed the licensee's arguments and found them acceptable. The conclusion was that doubling the uncertainty was a conservative way to account for reducing the data base from four tests to one.

3.2 Harmonic Phasing for CO Response. (Item 5 of Table 2).

The CO torus shell load is an oscillating load caused by periodic pressure oscillations superimposed upon the prevailing local static pressure. The LDR

defines the load in terms of a rigid wall pressure amplitude versus frequency spectra from 0 to 50 Hz which is to be used in conjunction with a flexible wall coupled fluid structure model. In addition, three alternate sets of spectral amplitudes are provided in the range from 4 to 16 Hz and the alternate which maximizes the response is to be used. The resulting responses from applying the amplitude at each frequency given in the total spectrum to be analyzed are to be summed. The above procedure was found acceptable in the AC because the high degree of conservatism associated with the direct summation of the Fourier components of the spectrum was more than sufficient to compensate for any uncertainties associated with the FSTF data from which the load specification was developed. Direct application of the above methodology to the Oyster Creek torus proved to be too conservative and so an alternate approach based on a study performed in Reference 10 was used. This alternate approach considers a random phasing of the 50 harmonics rather than an absolute summation. Individual harmonic responses are added assuming random phase angles. Results are multiplied by 1.3 for shell stress and strain values and by 1.15 for other responses. This procedure is one of several variations for implementing phasing in the CO load definition discussed in Reference 10 and subsequent SMA Reports (References 11, 12) which account for data obtained after Reference 10 was published. Reference 13 reviews the various design rules and their justification as given in References 10, 11 and 12 and discusses why they are acceptable alternatives to the LDR procedure. The method used by Oyster Creek is one which was found acceptable in Reference 13. It should also be noted that while the design rules of References 10, 11 and 12 were developed from FSTF data, the Oyster Creek plant was selected in these studies as the Mark I example plant on which the design rules were applied. Therefore, the effect of applying the CO phasing methodology has been extensively documented for Oyster Creek.

3.3 Plant Unique SRV System and Pool Temperature Limits. (Item 12 of Table 2).

The Oyster Creek SRV system differs from that of most other Mark I plants in two principal ways: Several SRV lines converge to a common header, and plant unique Y-quenchers are used instead of GE T-quenchers. Information contained in the PUAR and Reference 7 indicated that the Oyster Creek SRV methodology was developed from in-plant tests in accordance with the guidelines of section 2.13.9 of the AC. The RFI (Reference 9) requested additional details on test instrumentation and initial conditions, as well as specific numerical examples of model calibration and extrapolation to design case amplitudes and frequencies. At the July 16, 1983 meeting in Washington, D.C. most of these details were provided by the licensee. Additional information was received in a written communication from MPR Associates (Reference 14) and a conference call involving NRC, BNL, MPR Associates and the licensee. All of this information confirmed that the SRV load methodology used for Oyster Creek did indeed conform to AC guidelines and was developed in a conservative manner. Based on the licensee's statements in References 5 and 14, as well as verbal communications during the above-mentioned conference call, the Oyster Creek methodology for obtaining SRV loads on the torus shell and associated support systems has been found acceptable.

Item 12 of the RFI also pointed out that no discussion had been provided in the Oyster Creek PUAR demonstrating that certain pool temperature limits will not be exceeded during certain SRV discharge transients (Reference 15). The licensee subsequently supplied information addressing this issue at a meeting held on September 28, 1983. The information included a description of the methods used to derive suppression pool temperature response to the selected transients. The methods involved the use of conventional plant transient calculational procedures to develop bulk pool temperature histories

(Reference 16) coupled with the Monticello pool temperature test data base (Reference 17) to derive local temperature. A plant-unique feature which was highlighted at this meeting was the absence of a submerged RHR return in the Oyster Creek plant. This precludes reduction of the local-to-bulk pool temperature difference due to suppression pool circulation. Thus, only the data base which derives from the Monticello test results obtained without RHR operation was employed by the applicant. Although we are not in total agreement with the way in which the applicant employs the Monticello results, we conclude, based on our evaluation of the total computational procedure that local pool temperature will not exceed the limits dictated by the AC during the most severe SRV transients of interest. A detailed description of these findings will be provided in a report which will be issued by the NRC staff in the second quarter of 1984.

The applicant has also supplied us with a Design Report (Reference 18) in which a detailed description of the applicant's Suppression Pool (SPTMS) Temperature Monitoring System is presented. We have reviewed this material and conclude that the proposed SPTMS is designed in accordance with the AC requirements and will provide a reasonable measure of the pool bulk temperature.

4. CONCLUSIONS

A post-implementation pool dynamic load audit of the Oyster Creek PUAR was conducted to verify compliance of the plant unique analysis with the acceptance criteria contained in NUREG-0661. As a result of the audit, several items were identified which required additional information for resolution. A request for information was sent to the licensee in February, 1983. At a meeting with the licensee in July, 1983, most of the outstanding items were satisfactorily resolved and the general conformance of the PUAR with the requirements of the acceptance criteria was confirmed. All issues relative to the Mark I Long Term Implementation Program are closed as of the present date.

5. References

References cited in this report are available as follows:

Those items marked with one asterisk (*) are available in the NRC Public Document Room for inspection; they may be copied for a fee.

Material marked with two asterisks (**) is not publicly available because it contains proprietary information; however, a nonproprietary version is available in the NRC Public Document Room for inspection and may be copied for a fee.

Those reference items marked with three asterisks (***) are available for purchase from the NRC/GPO Sales Program, U. S. Nuclear Regulatory Commission, Washington, D. C. 20555, and/or the National Technical Information Service, Springfield, Virginia 22161.

All other material referenced is in the open literature and is available through public technical libraries.

(1) "Safety Evaluation Report, Mark I Long Term Program, Resolution of Generic Technical Activity A-7", NUREG-0661, July 1980.***

(2) "Mark I Containment Short-Term Program Safety Evaluation Report", NUREG-0408, December 1977.***

(3) General Electric Company, "Mark I Containment Program Load Definition Report", General Electric Topical Report NEDO-21888, Revision 2, November 1981.*

(4) Mark I Owners Group, "Mark I Containment Program Structural Acceptance Criteria Plant-Unique Analysis Applications Guide, Task Number 3.1.3", General Electric Topical Report NEDO-24583, Revision 1, July 1979.*

(5) "Oyster Creek Nuclear Generating Station Mark I Containment Long Term Program Plant Unique Analysis Report - Suppression Chamber and Vent System", MPR-733, prepared by MPR Associates, Inc. for General Public Utilities Nuclear, August 1982.*

(6) "Oyster Creek Nuclear Generating Station Mark I Containment Long-Term Program Plant-Unique Analysis Report - Torus Attached Piping", MPR-734, prepared by MPR Associates, Inc. for General Public Utilities Nuclear, August 1982.*

(7) "Oyster Creek Nuclear Generating Station Test Report - Effect of Modified Discharge Device on Response of Suppression Chamber to Relief Valve Actuation", MPR-550, prepared by MPR Associates, Inc. for Jersey Central Power & Light Co., May 1978.**

(8) C. C. Lin, "Technical Evaluation Report on Oyster Creek In-Plant SRV Test Results", Draft. To be published August 1983.**

(9) Letter from J. R. Lehner, BNL, to F. Eltawila, NRC dated February 25, 1983, Subject: Request for Information Regarding Oyster Creek PUAR.*

(10) "Mark I Containment Program Evaluation of Harmonic Phasing for Mark I Torus Shell Condensation Oscillation Loads", NEDE-24840, prepared by Structural Mechanics Associates for General Electric Company, October 1980.**

(11) Kennedy, R. P., "Response Factors Appropriate for Use with CO Harmonic Response Combination Design Rules", SMA 12101.04-R002D, prepared by Structural Mechanics Associates for General Electric Company, March 1982.**

(12) Kennedy, R. P., "A Statistical Basis for Load Factors Appropriate for Use with CO Harmonic Response Combination Design Rules", SMA 12101.04-R003D, prepared by Structural Mechanics Associates for General Electric Company, March 1982.**

(13) To be published Third Quarter 1983.

(14) "Responses to a Request For Information From the Brookhaven National Laboratory Concerning the Oyster Creek Nuclear Generating Station Mark I Containment Long-Term Program Plant-Unique Analysis Reports", prepared for GPU Nuclear by MPR Associates, Inc., August 1983.*

(15) Letter dated December 9, 1977 from George Lear to I. R. Frinfrock, entitled "Oyster Creek Nuclear Generating Station Unit 1 - Suppression Pool Temperature Transients".

(16) Smith, P. S., Lanese, L. C., "Report on the Effects of Electromatic Relief Valve Discharge on Torus Water Temperature", GPU Service TDR, Rev. 1, March 1981.

(17) Patterson, B. J., "Mark I Containment Program - Monticello T-Quencher Thermal Mixing Test Final Report", GE Report No. NEDE-24542-P, April 1979.

(18) Hwang, J. G., et al., "Design Report - Suppression Pool Temperature Monitoring System Sensor Selection and Placement - Oyster Creek Nuclear Generating Station", NUTECH Report GPN-02-101, Rev. 0, January 19, 1983.