TECHNICAL EVALUATION OF THE DRESDEN NUCLEAR GENERATING
STATION UNITS 2 AND 3
PLANT-UNIQUE ANALYSIS REPORT

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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 Dresden Nuclear Generating Station Units 2 and 3. The contents of the PUAR were compared against the hydrodynamic load Acceptance Criteria (AC) contained in NUREG-0661. The TER summarizes the audit findings (Table 1), and discusses the nature and status of any exceptions to the AC, identified during the audit (Table 2).

ACKNOWLEDGEMENTS

The cognizant NRC Technical Monitor for this program was Dr. Farouk Eltawila of the Containment Systems Branch (DSI) and the NRC Project Manager was Mr. Jack N. Donohew of the Technical Assistance Program Management Group of the Division of Licensing. Mr. Byron Siegel of Operating Reactors Branch No. 2 (DL) was Lead Project Manager.

List of Acronyms

AC	Acceptance Criteria
BNL	Brookhaven National Laboratory
BWR	Boiling Water Reactor
CO	Condensation Oscillation
DBA	Design Basis Accident
DL	Division of Licensing
DSI	Division of Systems Integration
FSI	Fluid Structure Interaction
FSTF	Full Scale Test Facility
LDR	Load Definition Report
LOCA	Loss-of-Coolant Accident
LTP	Long Term Program
NRC	Nuclear Regulatory Commission
PUA	Plant-Unique Analysis
PUAR	Plant-Unique Analysis Report
QSTF	Quarter Scale Test Facility
RFI	Request For Information
SER	Safety Evaluation Report
SPTMS	Suppression Pool Temperature Monitoring System
S/RV	Safety/Relief Valve
S/RVDL	Safety/Relief Valve Discharge Line
STP	Short Term Program
TAP	Torus Attached Piping
TER	Technical Evaluation Report

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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 is to perform a post-implementation audit of the Dresden plant-unique analysis (Reference 5) against the hydrodynamic load criteria in NUREG-0661.

2. POST-IMPLEMENTATION AUDIT SUMMARY

The purpose of the post-implementation audit was to evaluate the hydrodynamic loading methodologies which were used as the basis for modifying the pressure suppression system of the Dresden Nuclear Generating Station Units 2 and 3. The Dresden PUAR methodologies (Reference 5) were compared with those of the LDR (Reference 3) as approved in the AC of NUREG-0661 (Reference 1). The audit procedure consisted of a moderately detailed review of the plant unique analysis report (PUAR) to verify both its completeness and its compliance with the acceptance criteria. A list of requests for further information was submitted (Reference 6), and answers were obtained at a meeting with the licensee (Reference 7).

Table 1 summarizes the audit results. It lists the various load categories specified in the AC, and indicates plant-unique information through the references, in the right-hand column, to the notes which follow in the text.

LOADS	NUREG-0661 AC SECTION	CRITERIA		NOT APPLICABLE	ALTERNATE APPROACH	NOTES
		MET	NOT MET			
CONTAINMENT PRESSURE & TEMPERATURE	2.1	✓				
VENT SYSTEM THRUST LOADS	2.2	✓				
<u>POOL SWELL</u>						
TORUS NET VERTICAL LOADS	2.3	✓				
TORUS SHELL PRESSURE HISTORIES	2.4	✓				
VENT SYSTEM IMPACT AND DRAG	2.6	✓				1
IMPACT AND DRAG ON OTHER STRUCTURES	2.7	✓				
FROTH IMPINGEMENT	2.8	✓				2
POOL FALLBACK	2.9	✓				
LOCA JET	2.14.1				✓	3
LOCA BUBBLE DRAG	2.14.2				✓	3
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				✓	4
LOADS ON SUBMERGED STRUCTURES	2.14.5				✓	3,4,5
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				✓	3,4,5
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			
<u>T-QUENCHER LOADS</u>						
DISCHARGE LINE CLEARING	2.13.2	✓				
TORUS SHELL PRESSURES	2.13.3	✓				6
JET LOADS ON SUBMERGED STRUCTURES	2.14.3	✓				
AIR BUBBLE DRAG	2.14.4				✓	3,7
THRUST LOADS ON T/Q ARMS	2.13.5	✓				
S/RVDL ENVIRONMENTAL TEMPERATURES	2.13.6	✓				

TABLE 1. (CONTINUED)

DESCRIPTION	NUREG-0661 AC SECTION	CRITERIA		NOT APPLICABLE	ALTERNATE APPROACH	NOTES
		MET	NOT MET			
SUPRESSION POOL TEMPERATURE LIMIT	2.13.8	✓				
SUPRESSION POOL TEMPERATURE MONITORING SYSTEM	2.13.9	✓				8
DIFFERENTIAL PRESSURE CONTROL SYSTEM FOR THOSE PLANTS USING A DRYWELL-TO-WETWELL PRESSURE DIFFERENCE AS A POOL SWELL MITIGATOR	2.16	✓				9
SRV LOAD ASSESSMENT BY IN-PLANT TEST	2.13.9				✓	10

TABLE 1. (CONTINUED)

Notes to Table 1

Number	
1	The Acceptance Criteria do not provide a separate procedure for calculating pool swell impact on spherical structures such as the main vent-to-vent header junction in Dresden. In the PUAR, the spherical junction was modeled as a series of cylinders with axes along the main vent centerline. Acceleration drag, buoyancy and velocity drag were calculated using AC methodology for cylinders. This procedure was found acceptable.
2	For some structures, Region I froth loads were calculated using the high-speed QSTF movies. This alternative is outlined in Appendix A of the AC.
3	Instead of the equivalent cylinder procedure specified in the AC to calculate acceleration drag volumes on sharp cornered submerged structures, the PUAR selected alternate modeling of the structures and used published acceleration volumes. The discussion in Section 3.1 explains why this procedure was found acceptable.
4	To calculate CO and post-chug loads on the torus shell as well as on submerged structures, the 50 individual load harmonics were combined using a random phasing technique instead of the absolute summation specified in the AC. The discussion of Section 3.2 describes why this alternate method was found acceptable.

Number

5 To account for FSI effects during CO and chugging submerged structure loads, the AC suggested adding torus boundary accelerations directly to local fluid accelerations. Instead, the applicant used a method which calculated FSI acceleration fields anywhere in the torus based on knowing the boundary accelerations. This method, which has been accepted during previous PUAR reviews, is discussed in Section 3.3.

6 The analytical model to calculate SRV torus shell loads approved in the AC was modified slightly before being applied to Dresden. The purpose of the modifications was to more closely bound the pressure traces observed in the Monticello tests on which the model is based. These changes have been found acceptable. SRV tests conducted in the Dresden plant further confirm that the analytically obtained loadings are conservative.

7 For SRV air bubble drag loads, the applicant reduced the AC bubble pressure bounding factor of 2.5 to 1.75. This still bounded peak positive bubble pressure and maximum bubble pressure differential from the Monticello test data. Dynamic load factors were derived from Dresden's in-plant SRV test data. These modifications have been found acceptable and are discussed in more detail in Section 3.4.

8 The new SPTMS is acceptable. As stated in Section 1-5.2 of the PUAR, the applicant has committed to perform a separate analysis demonstrating that delayed operator action based on SPTMS readings will not cause the suppression pool temperature to exceed the limit specified in NUREG-0783.

Number

9 In order to reduce torus shell pressures caused by DBA pool swell, a minimum positive pressure difference of 1.0 psi is maintained between the Dresden drywell including the vent system, and the torus air space. According to Technical Specifications, the plant is required to come to shutdown if the main Δp system fails.

10 SRV tests performed in the Dresden plant, were used to confirm that the analytically derived SRV shell loads are conservative and to deduce dynamic load factors for submerged structures.

3. EXCEPTIONS TO GENERIC ACCEPTANCE CRITERIA

Dresden Units 2 and 3 are two of several plants analyzed by NUTECH Engineers, Inc. based on an essentially common hydrodynamic loading methodology (Fermi, Duane Arnold, Monticello and Quad Cities are other plants in this group). The methodology differs from the generic acceptance criteria of NUREG-0661 in four major areas which are listed in Table 2.

In what follows, each of these areas is discussed in detail, and the bases for the resolutions of the differences indicated.

Table 2: Issues Identified During Audit as Exceptions to the Generic Acceptance Criteria

Issue No.	Description	Status	
		Resolved	Open
1.	Use of acceleration drag volumes which differ from those approved in the AC to determine drag on sharp cornered structures.	X	
2.	Phasing of load harmonics used to analyze structures affected by CO and post-chug loads.	X	
3.	FSI methodology used for CO and chugging submerged structure loads.	X	
4.	Use of calibration factors developed from Dresden in-plant tests for use in defining SRV submerged structure drag loads.	X	

3.1 Acceleration Drag Volumes for Sharp Cornered Structures

The Acceptance Criteria 2.14.2 Section 2b in NUREG-0661 states that drag forces on structures with sharp corners (e.g. rectangles and "I" beams) must be computed by considering forces on an equivalent cylinder of diameter $D_{eq}=2^{1/2} L_{max}$ where L_{max} is the maximum transverse dimension. The intent of this criterion is to provide a conservative bound (based on very limited data) that includes non-potential flow effects such as vortex shedding on both the acceleration drag due to hydrodynamic mass and the "standard" drag proportional to velocity squared. Since the dominant load for the Ring Beam (the primary non-cylindrical structure) is acceleration drag, the issue concerns only the hydrodynamic mass or acceleration volume and not the drag coefficient in the Dresden plant-specific case.

The PUAR states that "published" acceleration drag volumes listed in Table 1-4.1-1 are used for sharp edged structures rather than the equivalent cylinder specified in the acceptance criteria. The detailed response to a Request for Information (Item 1) explains that modeling of the actual structures is necessary, and in particular, forces on the web of the ring beam are obtained by modelling the beam by a circumscribed rectangle. In order to evaluate the implications of this modelling, sample calculations were performed on the ring-beam for the post-chug loading condition.

A direct application of the Dresden PUAR methodology leads to an acceleration volume of 17.3 ft^3 for in-plane forces on the maximally loaded ring beam segment. A model that more accurately represents the interference effect but uses acceleration volumes from Table 1-4.1-1 gives a volume of 9.27 ft^3, thus providing a substantial margin for possible non-potential flow effects. For the out-of-plane forces, the PUAR model given an acceleration volume of 59.9 ft^3, while a similar modelling of the structure but using more realistic interference corrections yields a transverse acceleration volume of 53.3 ft^3. While this leaves very little margin for non-potential flow corrections, in the parameter range of CO and post-chug acceleration spectrum where the major energy is concentrated, the flow is expected to be very nearly potential. In addition, the use of single mode dynamic load factors, as explained in response to RFI item 2, provides additional substantial conservatism up to a factor of 2. The conservative application of the AC equivalent cylinder model and interference correction to the hydrodynamic volume alone, while retaining the real volume for the "effective buoyancy" effect, gives an effective acceleration volume of 87.4 ft^3, which yields out-of-plane loads 46% higher than those predicted by the PUAR. Because of the parameter range in the Dresden plants and the conservative application of these loads, the potential non-conservatism on the acceleration volumes is adequately balanced by the conservatisms in the interference corrections and the load application.

On the basis of these comparisons we conclude that while the direct use of "published" acceleration volumes for sharp edge structures may not in general lead to conservative loads, the PUAR methodology for the application of these loads to the relevant structures, has sufficient conservatism to bound any hydrodynamically produced stresses that could arise in these structures.

3.2 CO and Post-Chug Harmonic Phasing

The DBA condensation oscillation and the post-chug load definitions on the torus shell and on submerged structures, accepted in the NUREG-0661, were based on data from a series of blowdowns in the FSTF facility (NEDE-24539), subject to additional confirmatory tests reported in the General Electric Letter Report M1-LR-81-01 of April 1981.

The condensation oscillation load definition as described in NEDO-21888 is based on taking the absolute sum of 1 Hertz components of a spectrum from 0 to 50 Hz. Three alternative spectra are to be calculated with the one producing maximum response used for load definition. The procedure was found acceptable in the supplement to the SER (NUREG-0661), because the demonstrated high degree of conservatism associated with the direct summation of the Fourier components of the spectrum was sufficient to compensate for any uncertainties concomitant with the data available. The post-chug load definition is based on bounding FSTF chugging data but otherwise follows similar procedures to those used in the CO load definition.

The PUAR uses a factor of .65 to multiply the CO and post-chug loads computed on the basis of the absolute sum of the harmonic components. The justification is based on comparisons of measured and predicted stresses in the FSTF facility using statistical studies of different phasing models (References 8, 9, 10, 11). The factor .65 is chosen to give 84% non-exceedance probability with a confidence level of 90%. The PUAR does use an additional spectrum, Alternate 4, for the CO loading, based on test M12 from the supplementary tests reported in the letter report M1-LR-81-01. The information in Table 1-4.1-4 of the PUAR provides additional justification to show that the computed loads (using the .65 factor and Alternates 1 through 3) bound the measured stresses at critical points in the FSTF facility by 11% for axial shell stress to 59% for column force. The use of Alternate 4 in the Dresden plants provides an additional conservatism of about 20% to the shell response. The use of random phasing in the time domain for TAP (Volumes 6 and 7 of the PUAR) coupled with a factor of 1.3 for alternates 1, 2, and 3 and a factor 1.15 for alternate 4 is consistent with the results of Reference 10 and conservatively bounds all FSTF data.

The procedures are a conservative application of the phasing design rules evaluated in Reference 12 and are therefore found acceptable.

3.3 FSI Methodology for CO and Chugging Drag Loads

A detailed discussion of the method used to account for FSI effects on condensation oscillation and chugging submerged structure loads is provided in Reference 13. The methodology described in this note is used to compute acceleration fields across a submerged structure anywhere in the torus resulting from FSI, based on knowing the torus boundary acceleration. The method is presented as an alternative to the NRC Acceptance Criteria suggestion of adding the boundary accelerations directly to the local fluid acceleration to account for FSI effects since the latter is deemed too conservative.

The review of the method outlined in Reference 13 has shown it to be reasonable and acceptable. The equations derived for fluid accelerations and pressure fields are plausible approximations for the conditions prevailing in the suppression pool. Assumed boundary conditions including the driving one at the torus wall are suitable. Overall trends as well as the acceleration fields depicted in the selected results appear reasonable. Therefore, the alternate procedure used to account for FSI effects on submerged structures is considered acceptable in this application.

3.4 Calibration of SRV Drag Loads Based on In-Plant Tests

The staff requested clarification of the detailed procedures used to derive the calibration factors from in-plant tests for SRV submerged-structure loads. On the basis of this response, as well as those provided in other PUAR reviews of NUTECH plants, the staff considers the procedures as an acceptable modification of the AC.

The SRV bubble pressure data from Monticello tests is shown to be bounded using a bounding factor of 1.75 instead of the 2.5 specified in the AC. In the Dresden plants, dynamic load factors are derived on the basis of in-plant tests. A bounding DLF value of 2.5 is then used for all submerged structures.

The staff considers these procedures to be a reasonable application of the in-plant test results, and considers any potential uncertainties associated with the limited data base to be bounded by other conservatisms associated with the design load calculation procedures.

4. CONCLUSIONS

A post-implementation pool dynamic load audit of the Dresden PUAR has been completed to verify compliance with the generic acceptance criteria of NUREG-0661. Four major differences between the PUAR and the AC were identified along with some other minor issues needing additional clarification. Based on additional information supplied by the applicant, as detailed in the previous section, all of these issues were resolved. The review of the Dresden PUAR has been completed with no issues or concerns outstanding.

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) "Dresden Nuclear Power Station Units 2 and 3 Plant-Unique Analysis Report", Vols. 1-7, Prepared for Commonwealth Edison Company by NUTECH Engineers, Inc., May 1983. **

(6) Attachment to Letter from J. R. Lehner, BNL to F. Eltawila, NRC, Subject: Dresden Units 2 & 3 and Quad Cities Units 1 & 2 Request For Information, June 27, 1984.

(7) R. Rybak to H. Denton letter dated August 24, 1984, "Response to Questions concerning Mark I Containment Plant Unique Analysis, NRC Docket Nos. 50-237/249 and 50-254/265".

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

(9) "Evaluation of FSTF Tests M12 and M11B Condensation Loads and Responses", MA12101.04-R001D, prepared by Structural Mechanics Associates for General Electric Company, 1982.

(10) R. P. Kennedy, "Response Factors Appropriate for Use with CO Harmonic Response Combination Design Rules," SMA12101.04-R002D, prepared by Structural Mechanics Associates for General Electric Company, March 1982.

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(12) G. Bienkowski, "Review of the Validity of Random Phasing Rules as Applied to CO Torus Loads", Internal BNL Memo, August 1983.

(13) A. J. Bilanin, "Mark I Methodology for FSI Induced Submerged Structure Fluid Acceleration Drag Loads", Continuum Dynamics Tech. Note No. 82-15, June 1982.*