Lawrence Livermore Laboratory

MARK I 1/5-SCALE BOILING WATER REACTOR PRESSURE SUPPRESSION EXPERIMENT QUICK-LOOK REPORT

Compiled and Edited by William Lai and E. Kejka Collins

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June 3, 1977

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June 1, 1977

MARK I 1/5-SCALE BOILING WATER REACTOR

PRESSURE SUPPRESSION EXPERIMENT

QUICK-LOOK REPORT

FOR TEST NUMBERS 1.3.1, 1.4, 1.5, and 1.6

PERFORMED ON April 26, 1977

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CONTENTS

	<u>Page</u>
1. INTRODUCTION	1-1
2. SUMMARY OF TEST	2-1
2.1 Introduction	2-1
2.2 Air Test Schedule	2-1
2.3 Instrumentation and Associated Error	2-1
2.4 Test Summary	2-4
2.5 Test Evaluation and Typical Results	2-4
2.6 Accuracy of Data	2-14
3. ANALYSIS OF EXPERIMENTAL DATA	3-1
4. CONCLUSIONS	4-1

ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
2-1	Instrumentation Locations for Flow Measurements	2-5
2-2	Instrumentation Locations for Drywell	2-6
2-3	Instrumentation Locations for Torus Displacement	2-7
2-4	Instrumentation Locations for Torus and Ringheader/Downcomer 7.5° Sector	2-8
2-5	Instrumentation Locations for Vent Pipe	2-9
2-6	Instrumentation Locations for Torus	2-10
2-7	Instrumentation Locations for Ringheader/Downcomer	2-11
2-8	Instrumentation Locations for Torus Loads, Ringheader Loads, and Acceleration	2-12
2-9	Drywell Pressure, Test 1.3.1	2-18
2-10	Ullage Pressure, 45°, 7.5° Sector, Test 1.3.1	2-19
2-11	Pressure at 180°, 7.5° Sector, Test 1.3.1	2-20
2-12	Ullage Pressure at Plane 9, 45°, 90° Torus Sector, Test 1.3.1	2-21
2-13	Pressure at Plane 9, 180°, 90° Torus Sector, Test 1.3.1	2-22
2-14	Load at Plane 4, 90°, 90° Torus Sector, Test 1.3.1	2-23
2-15	Load at Plane 4, 270°, 90° Torus Sector, Test 1.3.1	2-24
2-16	Drywell Pressure, Test 1.4	2-25
2-17	Ullage Pressure, 45°, 7.5° Sector, Test 1.4	2-26
2-18	Pressure at 180°, 7.5° Sector, Test 1.4	2-27
2-19	Ullage Pressure at Plane 9, 45°, 90° Torus Sector, Test 1.4	2-28

ILLUSTRATIONS (Continued)

<u>Figure</u>		<u>Page</u>
2-20	Pressure at Plane 9, 180°, 90° Torus Sector, Test 1.4	2-29
2-21	Load at Plane 4, 90°, 90° Torus Sector, Test 1.4	2-30
2-22	Load at Plane 4, 270°, 90° Torus Sector, Test 1.4	2-31
2-23	Drywell Pressure, Test 1.5	2-32
2-24	Ullage Pressure, 45°, 7.5° Sector, Test 1.5	2-33
2-25	Pressure at 180°, 7.5° Sector, Test 1.5	2-34
2-26	Ullage Pressure at Plane 9, 45°, 90° Torus Sector, Test 1.5	2-35
2-27	Pressure at Plane 9, 180°, 90° Torus Sector, Test 1.5	2-36
2-28	Load at Plane 4, 90°, 90° Torus Sector, Test 1.5	2-37
2-29	Load at Plane 4, 270°, 90° Torus Sector, Test 1.5	2-38
2-30	Drywell Pressure, Test 1.6	2-39
2-31	Differential Pressure Across the Vent Line Orifice, 7.5° Sector, Test 1.6	2-40
2-32	Differential Pressure Across Right Vent Line Orifice, 90° Torus Sector, Test 1.6	2-41
2-33	Right Vent Line Pressure Upstream of Orifice, 90° Torus Sector, Test 1.6	2-42
2-34	Ullage Pressure at 45°, 7.5° Sector, Test 1.6	2-43
2-35	Pressure at 180°, 7.5° Sector, Test 1.6	2-44
2-36	Ullage Pressure at Plane 9, 45°, 90° Torus Sector, Test 1.6	2-45
2-37	Pressure at Plane 3, 180°, 90° Torus Sector, Test 1.6	2-46
2-38	Pressure at Plane 4, 180°, 90° Torus Sector, Test 1.6	2-47

ILLUSTRATIONS (Continued)

<u>Figure</u>		<u>Page</u>
2-39	Pressure at Plane 6, 180°, 90° Torus Sector, Test 1.6	2-48
2-40	Pressure at Plane 7, 180°, 90° Torus Sector, Test 1.6	2-49
2-41	Pressure at Plane 9, 180°, 90° Torus Sector, Test 1.6	2-50
2-42	Pressure at Plane 11, 180°, 90° Torus Sector, Test 1.6	2-51
2-43	Pressure at Plane 20, 180°, 90° Torus Sector, Test 1.6	2-52
2-44	Load at Plane 4, 90°, 90° Torus Sector, Test 1.6	2-53
2-45	Load at Plane 4, 270°, 90° Torus Sector, Test 1.6	2-54
2-46	Torus Displacement, Left End, Test 1.6	2-55
2-47	Torus Displacement, Right End, Test 1.6	2-56
2-48	Torus Displacement, Vertical, Test 1.6	2-57
2-49	Torus Displacement, Horizontal, Outward, Test 1.6	2-58
2-50	Torus Displacement, Horizontal, Inward, Test 1.6	2-59
3-1	Variation of Uncorrected Main Load Cell Data with Initial Drywell Pressurization Rate	3-4

TABLES

<u>Table</u>	<u>Page</u>
2-1 Test Matrix for Air Tests (Revision B)	2-2
2-2 Summary of Transducer Accuracy and Uncertainty Specifications for the 1/5-Scale Pressure Suppression Test	2-3
2-3 Initial Test Conditions for Tests 1.3.1, 1.4, 1.5, and 1.6	2-13
2-4 Estimated Measurement Uncertainties for Tests 1.3.1, 1.4, 1.5, and 1.6	2-14
2-5 List of Selected Data Plots for Test 1.3.1	2-15
2-6 List of Selected Data Plots for Test 1.4	2-15
2-7 List of Selected Data Plots for Test 1.5	2-16
2-8 List of Selected Data Plots for Test 1.6	2-17
3-1 Comparison of Peak Values	3-2
3-2 Variation of Peak Pressure at 180° Along the Axis of the 90° Torus	3-5

1. INTRODUCTION

This report is intended as a "quick-look" report summarizing the experimental results obtained from pressure suppression experiment numbers 1.3.1, 1.4, 1.5, and 1.6 that were performed on the Lawrence Livermore Laboratory's 1/5-scale boiling water reactor (BWR) Mark I pressure suppression experimental facility on April 26, 1977. Any analysis or conclusions contained herein are to be regarded as preliminary.

This report is divided into four sections as follows:

- (1) Introduction
- (2) Summary of Tests
- (3) Analysis of Experimental Data
- (4) Conclusions

Section 2 contains a brief description of the general nature of the tests and a summary of the actual tests that were performed on April 26, 1977, and are being reported herein. Sections 3 and 4 contain the preliminary analysis and any empirical conclusions that can be made at this stage of the project, respectively. Information regarding the Pressure Suppression Experiment Program, the test facility, key design parameters, scaling relationship studies, instrumentation, calibration, and data processing will be found in Quick-Look Report No. 1, dated March 16, 1977 (UCID-17446-1).

2. SUMMARY OF TESTS

2.1 INTRODUCTION

The tests conducted on the 1/5-scale BWR Mark I pressure suppression test facility simulate the three-dimensional transient conditions that are encountered in a wetwell pressure suppression system during a hypothetical loss-of-coolant accident (LOCA). Specifically, the nitrogen (N_2)-driven air clearing phase tests discussed here were performed to obtain the air/water-induced dynamic vertical load function and to determine the response of a 90° sector of a 360° torus structure.

2.2 AIR TEST SCHEDULE

The air clearing phase of the pressure suppression tests was begun on March 4, 1977. Table 2-1 contains a listing of the air pressure suppression test matrix (revision B).* It includes the actual date any given test was conducted as well as the number of the Quick-Look Report for that test.

2.3 INSTRUMENTATION AND ASSOCIATED ERROR

A summary of instrumentation used during testing and the expected accuracy is shown in Table 2-2. Both the manufacturer's accuracy specifications and the anticipated accuracy specifications are provided. The location and the type of instrumentation used in this test are identified in Figures 2-1 through 2-8. The excess number of instrumentation ports on the facility allows for flexibility in the location of transducers from test to test.

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*The originally planned pressurization rates were 14.0, 18.6, 23.0, 26.0 psi/sec. In revision A, pressurization rates were changed to 20.5, 27.3, 33.8, 38.2 psi/sec. In revision B, Tests 1.3.1, 2.9 through 2.11, 3.3(b) and 3.4(b) were added, and Test 3.6 was deleted from the test matrix.

Table 2-1. Test Matrix for Air Tests (Revision B)

Test No.	Initial Wetwell Pressure kPa (psia)	Initial Drywell Pressure kPa (psia)	Initial Drywell Overpressure m H ₂ O (in)	Downcomer Submergence m (in)	Torus Water Level m (in)	Initial a/ Drywell Pressurization Rate kPa/s (psi/s)	Imposed Asymmetry	Measurement on 7.5° Sector	Remarks	Date of Test	Quick-Look Report No.
1.0 (a)	20.3 (2.95)	20.3 (2.95)	0	--	--	108 (15.6)	-	-	No water; without orifice	March 4, 1977	QLR No. 1, UCID-17446-1
1.0 (b)	20.3 (2.95)	20.3 (2.95)	0	--	--	121 (17.5)	-	-	No water; with orifice	March 8, 1977	
1.1	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	-	-		March 18, 1977	
1.2	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	-	-	Check out repeatability, 3-D effects	March 25, 1977	QLR No. 2, UCID-17446-2
1.3	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	-	yes		March 30, 1977	
1.3.1	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	-	yes			
1.4	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	141 (20.5)	-	yes			QLR No. 4, UCID-17446-4
1.5	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	233 (33.8)	-	yes	Drywell pressurization rate	April 26, 1977	
1.6	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	263 (38.2)	-	yes			
2.1	20.3 (2.95)	( )	0.12 (4.8)	0.24 (9.6)	Nom.	188 (27.3)	-	yes			QLR No. 3, UCID-17446-3
2.2	20.3 (2.95)	( )	0.18 (7.2)	0.24 (9.6)	Nom.	188 (27.3)	-	yes	Drywell overpressure	April 26, 1977	
2.3	20.3 (2.95)	( )	0.18 (7.2)	0.24 (9.6)	Nom.	188 (27.3)	-	yes			
2.4	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	-	yes	Repeatability		
2.5	20.3 (2.95)	20.3 (2.95)	0	0.340 (13.4)	0.10 (3.8)	188 (27.3)	-	yes			
2.6	20.3 (2.95)	20.3 (2.95)	0	0.15 (5.8)	-0.10 (-3.8)	188	-	yes	Downcomer submergence		
2.7	20.3 (2.95)	20.3 (2.95)	0	0.305 (12.0)	Nom.	188 (27.3)	-	yes			
2.8	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	0.061 (2.4)	188 (27.3)	-	yes			
2.9	20.3 (2.95)	20.3 (2.95)	0	0.305 (12.0)	Nom.	141 (20.5)	-	yes			
2.10	20.3 (2.95)	20.3 (2.95)	0	0.305 (12.0)	Nom.	233 (33.8)	-	yes	Drywell pressurization rate with increased submergence		
2.11	20.3 (2.95)	20.3 (2.95)	0	0.305 (12.0)	Nom.	263 (38.2)	-	yes			
3.1	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	-	yes	Variation of Ah		
3.2	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	-	yes			
3.3 (a)	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	(yes)b/	yes			
3.3 (b)	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	(yes)b/	yes	Asymmetry		
3.4 (a)	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	(yes)b/	yes			
3.4 (b)	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	(yes)b/	yes	Asymmetry		
3.5	20.3 (2.95)	20.3 (2.95)	0	0.24 (9.6)	Nom.	188 (27.3)	-	yes	Repeatability		

a/ Initial drywell pressurization rates changed 17 March 1977 by L. Slegers for NRC-RSR.
b/ The degree of asymmetry to be specified in terms of degree of obstruction in drywell vent.

Table 2-2. Summary of Transducer Accuracy and Uncertainty Specifications for the 1/5-Scale Pressure Suppression Test

Type	Transducers	Range	Transducer Response Time	Manufacturer's Transducer Accuracy (Laboratory Conditions)	Anticipated Transducer Accuracy (Test Conditions)	Expected Uncertainty
Pressure	71	0-69 kPa (0-10 psia)	25 μ s	41 Pa (0.006 psia)	690 Pa (0.1 psia)	3.4% of L_{max+}
	22	0-517 kPa (0-75 psia)	25 μ s	2.59 kPa (0.375 psia)	6.9 kPa (1 psia)	9.6% of L_{max+}
Differential Pressure	3 (annubar)	0-2.5 kPa (0-0.36 psia)	1.7 ms	250 Pa (0.036 psia)	25 Pa (0.0036 psia)	--
	1 (annubar)	0-69 kPa (0-10 psia)	1 ms	6.9 kPa (1 psia)	690 Pa (0.1 psia)	--
	3 (orifice)	0-25 kPa (0-3.6 psia)	1 ms	2.5 kPa (0.36 psia)	250 Pa (0.036 psia)	--
Temperature	38	280-611 K (500-1100°R)	10 ms	1.7 K (3°R)	3.4 K (6°R)	1.2%
Strain Gages	21	0.025 mm (± 1000 μ -in)	1 μ s	0.00025 mm (10 μ -in)	0.0005 mm (20 μ -in)	4% of ϵ_{max}
Load Cells	5	11,000 kg ($\pm 25,000$ lbm)	100 μ s	56.7 kg (125 lbm)	227 kg (500 lbm)	6.5% of L_{max+}
	2	45,000 kg ($\pm 100,000$ lbm)		227 kg (500 lbm)	907 kg (2000 lbm)	18% of L_{max+}
Pool Swell	40	--	1 μ s	--	3.2 mm (1/8 in)	0.5% of PS_{max}
Acceleration	8	25 g	1 ms	0.75 g	0.75 g	--
Displacement	10	10 mm (0.5 in)	1 ms	0.08 mm (0.003 in)	0.25 mm (0.01 in)	--
TOTAL	224					

L_{max+} - maximum expected downward load.

ϵ_{max} - maximum expected strain.

L_{max-} - maximum expected upward load.

PS_{max} - maximum expected pool swell.

12

Light ports and camera ports are included on the torus. Up to six high-speed cameras and two Storz lens television systems are used to view water pool dynamics. Pressures and temperatures are recorded in the drywell, air storage bottles and connecting lines in addition to the torus. Flow measurements in the connecting lines are made using orifice plates and Pitot-static tubes. Direct dynamic load measurement is provided by load cells in the torus and header supports.

2.4 TEST SUMMARY

Test numbers 1.3.1, 1.4, 1.5, and 1.6 of the air clearing experiment series were conducted on the 26th of April, 1977. The primary objective of these tests was to determine the effects of drywell pressurization rates. To facilitate the comparison of results, Test 1.3.1 was performed under the same nominal initial conditions as were used for Test 1.3.

The same vent line orifices were used for all three tests. The initial conditions are listed in Table 2-3.

2.5 TEST EVALUATION AND TYPICAL RESULTS

The total number of transducers used in Tests 1.3.1, 1.4, 1.5, and 1.6 was 177; the eight pool swell transducers are counted as one transducer because their output was sampled and recorded on a single channel. Records of each test were made with six Hycam cameras (1000 frames/sec) and a Storz lens television system. In addition to this, Tests 1.4, 1.5, and 1.6 were also recorded with a Milliken camera. The Hycam camera fiducial failed to function during the tests. One pressure transducer, one thermocouple, and two displacement gauges also failed. A list of the 76 engineering plots selected from these experiments is given in Tables 2-5, 2-6, 2-7, and 2-8 for Tests 1.3.1, 1.4, 1.5, and 1.6, respectively. Locations of transducers (as listed in Tables 2-5 through 2-8) are shown pictorially in Figures 2-1 through 2-8.

NRC-1

INSTRUMENTATION LOCATIONS FOR FLOW MEASUREMENTS

LOCATION	TYPE OF XDCR	TRANSDUCER NO.	LOCATION	TYPE OF XDCR	TRANSDUCER NO.
1	P	91	12	T	37
2	T	35	13	P	
3	A	92	14	ΔP	96
4	T	36	15	A	97
5	P	93	16	T	38
6	ΔP		17	P	98
7	A		18	ΔP	99
8	T		19	A	100
9	P ΔP		20	T	39
10	ΔP		21	P	101
11	A	94	22	ΔP	102

P = Pressure
T = Thermocouple
A = Annubar, ΔP
 ΔP = Diff. Press.

Figure 2-1. Instrumentation Locations for Flow Measurements.

NRC-1

INSTRUMENTATION LOCATIONS FOR DRYWELL

Test No. 1.3.1, 1.4, 1.5, and 1.6

Date April 26, 1977

LOCATION	TYPE OF XDCR	TRANSDUCER NO.
1	P	
	T	
	T _W	
2	P	
	T	
	T _W	
3	P	73
	T	26
	T _W	
4	P	
	T	
	T _W	
5	P	
	T	200
	T _W	
6	P	74
	T	27
	T _W	
7	P	
	T	
	T _W	
8	P	
	T	
	T _W	
9	P	
	T	
	T _W	
10	P	
	T	
	T _W	

P = Pressure
T = Thermocouple, Fluid
T_W = Thermocouple, Wall

Figure 2-2. Instrumentation Locations for Drywell.

NRC-1

INSTRUMENTATION LOCATIONS FOR TORUS DISPLACEMENT

LOCATION	TYPE OF XDCR	TRANSDUCER NO.
1	D	1
2	D	2
3	D	3
4	D	4
5	D	5
6	D	6
7	D	7
8	D	8
9	D	9
10	D	10
11	D	11

D = Displacement

Figure 2-3. Instrumentation Locations for Torus Displacement.

NRC-1

INSTRUMENTATION LOCATIONS FOR
TORUS AND RINGHEADER/DOWNCOMER
7.5° SECTOR

DOWNCOMER		
LOCATION	TYPE OF XDCR	TRANSDUCER NO.
LEFT	P	89
	T	33
	SB	17
	SA	
RIGHT	P	90
	T	34
	SB	18
	SA	
STRUT	P	
	T	
	SB	
	SA	

P = Pressure
T = Thermocouple
PS = Pool Swell
SA = Strain, Axial
SB = Strain, Bending

TORUS		
LOCATION	TYPE OF XDCR	TRANSDUCER NO.
0°	P	
5°	T	
18°	PS	
37°	PS	9
45°	P	75
85°	T	
90°	P	
128°	P	76
135°	T	
140°	P	
155°	P	77
160°	P	78
165°	P	79
175°	T	30
180°	P	80
195°	P	81
200°	P	82
205°	P	83
220°	P	84
235°	P	85
270°	P	
315°	P	86
323°	PS	10
342°	PS	
355°	T	202

RINGHEADER		
LOCATION	TYPE OF XDCR	TRANSDUCER NO.
0°	P	87
	T	31
	SB	16
	SA	
180°	P	88
	T	32
	SB	
	SA	

Figure 2-4. Instrumentation Locations for Torus and Ringheader/Downcomer 7.5° Sector.

INSTRUMENTATION LOCATIONS FOR VENT PIPE

LOCATION	TYPE OF XDCE	TRANSDUCER NO.
LEFT VENT PIPE	S _B	21
RIGHT VENT PIPE	S _B	22

S_B = Strain, Bending

Figure 2-5. Instrumentation Locations for Vent Pipe.

NRC-1

INSTRUMENTATION LOCATIONS FOR TORUS

LOCATION	TYPE OF XDCCR	TRANSDUCER NO.																			
		SECTION																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
12°	P					29			42	7							56				
14°	T	1			4	7			10	40											
18°	PS					1	3			5											
37°	PS					2	4			6											
45°	P		110				30		43	45											
73°	T		110																		
78°	P																				
128°	P				17	31			44	8											
135°	T	2			5	8			11								13			14	
140°	P				18	32															
155°	P	2			19	33			46	47											
160°	P				20	34															
165°	P	3			21	35			48	9											
175°	T	3		11	6	9			12												
180°	P			11	22	13	36	14	49	10											57
195°	P	5			23	37			50	11											
200°	P					38															
205°	P	6			25	39			52	51											
220°	P				26	40															
235°	P					41			54	53											
270°	P																				
315°	P								55	12											
323°	PS								7												
342°	PS								8												

P = Pressure
T = Thermocouple, Fluid
PS = Pool Swell

Figure 2-6. Instrumentation Locations for Torus.

NRC-1

INSTRUMENTATION LOCATIONS FOR RINGHEADER/DOWNCOMER

RINGHEADER									
LOCATION	TYPE OF XDCR	TRANSDUCER NO.							
		SECTION							
		1	2	3	4	5	6	7	8
0°	P	58		61		65			70
	T	15		16		20			25
	SB				7		11		
180°	P			62		66			
	T			17		21			

DOWNCOMER									
LOCATION	TYPE OF XDCR	TRANSDUCER NO.							
		SECTION							
		1	2	3	4	5	6	7	8
LEFT	P	59		63		67			71
	T			18		22			
	SB	1		4		8			13
RIGHT	P	60		64		68			72
	T			19		23			
	SB	2		5					14
STRUT	SA	3							

P = Pressure
T = Thermocouple, Fluid
SA = Strain, Axial
SB = Strain, Bending

Figure 2-7. Instrumentation Locations for Ringheader/Downcomer.

NRC-1

INSTRUMENTATION LOCATIONS FOR TORUS LOADS, RINGHEADER LOADS, AND ACCELERATION

LOCATION	TYPE OF XDCR	TRANSDUCER NO.						
		SECTION						
		1	2	3	4	5	6	7
0°	A	1			3			7
	L							
90°	A				4			
	L				4A, 4B			
180°	A	2			5			8
	L	1	2	3		6	7	
270°	A				6			
	L				5A, 5B			

A = Accelerometer
L = Load Cell

Figure 2-8. Instrumentation Locations for Torus Loads, Ringheader Loads, and Acceleration

Table 2-3. Initial Test Conditions^{a/} for Tests 1.3.1, 1.4, 1.5, and 1.6

PARAMETER	TEST 1.3.1		TEST 1.4		TEST 1.5		TEST 1.6	
	PLANNED	ACTUAL	PLANNED	ACTUAL	PLANNED	ACTUAL	PLANNED	ACTUAL
Pool Temperature	21.7°C (71.0°F)		20.6°C (69.0°F)		20.4°C (68.7°F)		18.5°C (65.3°F)	
Nitrogen Supply:								
Bottle Number	2 and 7		2, 3, 4, 5, 6, and 7		3, 4, and 5		3, 4, and 5	
Total Volume	0.69 m ³ (24.4 ft ³)		1.29 m ³ (45.4 ft ³)		0.42 m ³ (15.0 ft ³)		0.42 m ³ (15.0 ft ³)	
Initial Pressure	5929 kPa (860 psig)		3137 kPa (455 psig)		6067 kPa (880 psig)		6860 kPa (995 psig)	
Supply Line Nozzle Diameter	4.859 cm (1.913 in)		4.859 cm (1.913 in)		4.859 cm (1.913 in)		4.859 cm (1.913 in)	
Vent Line Orifice Diameters:								
Left Hand Vent	24 cm (9.5 in)		24 cm (9.5 in)		24 cm (9.5 in)		24 cm (9.5 in)	
Right Hand Vent	24 cm (9.5 in)		24 cm (9.5 in)		24 cm (9.5 in)		24 cm (9.5 in)	
7.5° Vent	9.22 cm (3.63 in)		9.22 cm (3.63 in)		9.22 cm (3.63 in)		9.22 cm (3.63 in)	
Drywell Pressure	20.3 kPa (2.94 psia)	20.4 kPa (2.96 psia)	20.3 kPa (2.94 psia)	20.3 kPa (2.94 psia)	20.3 kPa (2.94 psia)	20.3 kPa (2.94 psia)	20.3 kPa (2.94 psia)	20.3 kPa (2.95 psia)
Wetwell Pressure	20.3 kPa (2.94 psia)	20.4 kPa (2.96 psia)	20.3 kPa (2.94 psia)	20.3 kPa (2.94 psia)	20.3 kPa (2.94 psia)	20.3 kPa (2.94 psia)	20.3 kPa (2.94 psia)	20.3 kPa (2.95 psia)
Drywell Pressurization Rate	188 kPa/s (27.3 psi/s)	190 kPa/s (27.5 psi/s)	141 kPa/s (20.5 psi/s)	124 kPa/s (18.0 psi/s)	233 kPa/s (33.8 psi/s)	211 kPa/s (30.6 psi/s)	263 kPa/s (38.2 psi/s)	226 kPa/s (32.8 psi/s)

^{a/} Test measurements were made in English units and converted to SI units, rounding off to the appropriate number of significant figures.

The decision was made to range torus pressure transducers to enhance the dynamic pressure signals during vent clearing. As a result, the transducers saturated before the final equilibrium pressures (e.g., Figure 2-11) were reached. The displacement measurements show that the torus movements are in the order of tens of mils or less (Figures 2-46 through 2-50).

2.6 ACCURACY OF DATA

The quality of data reported in Quick-Look Report No. 1, UCID-17446-1, has been maintained in Tests 1.3.1, 1.4, 1.5, and 1.6 (refer to Table 2-4).

Table 2-4. Estimated Measurement Uncertainties
for Tests 1.3.1, 1.4, 1.5, and 1.6.

TYPE	UNCERTAINTY
Pressure	± 1.0 kPa (± 0.15 psia)
Temperature	$\pm 1.6^{\circ}\text{C}$ ($\pm 3^{\circ}\text{F}$)
Differential Pressure	$\pm 15\%$

Table 2-5. List of Selected Data Plots for Test 1.3.1.

PARAMETER	LOCATIONS	FIGURE	PAGE	TRANSDUCER NO.
Pressure	Drywell	2-9	2-18	P73
Ullage Pressure	7.5° Sector	2-10	2-19	P75
Pressure at 180°	7.5° Sector	2-11	2-20	P80
Ullage Pressure	90° Torus, Plane 9	2-12	2-21	P43
Pressure at 180°	90° Torus, Plane 9	2-13	2-22	P49
Load Cell at 90°	90° Torus, Plane 4	2-14	2-23	L4A
Load Cell at 270°	90° Torus, Plane 4	2-15	2-24	L5A

Table 2-6. List of Selected Data Plots for Test 1.4.

PARAMETER	LOCATIONS	FIGURE	PAGE	TRANSDUCER NO.
Pressure	Drywell	2-16	2-25	P73
Ullage Pressure	7.5° Sector	2-17	2-26	P75
Pressure at 180°	7.5° Sector	2-18	2-27	P80
Ullage Pressure	90° Torus, Plane 9	2-19	2-28	P43
Pressure at 180°	90° Torus, Plane 9	2-20	2-29	P49
Load Cell at 90°	90° Torus, Plane 4	2-21	2-30	L4A
Load Cell at 270°	90° Torus, Plane 4	2-22	2-31	L5A

Table 2-7. List of Selected Data Plots for Test 1.5.

PARAMETER	LOCATIONS	FIGURE	PAGE	TRANSDUCER NO.
Pressure	Drywell	2-23	2-32	P73
Ullage Pressure	7.5° Sector	2-24	2-33	P75
Pressure at 180°	7.5° Sector	2-25	2-34	P80
Ullage Pressure	90° Torus, Plane 9	2-26	2-35	P43
Pressure at 180°	90° Torus, Plane 9	2-27	2-36	P49
Load Cell at 90°	90° Torus, Plane 4	2-28	2-37	L4A
Load Cell at 270°	90° Torus, Plane 4	2-29	2-38	L5A

Table 2-8. List of Selected Data Plots for Test 1.6.

PARAMETER	LOCATIONS	FIGURE	PAGE	TRANSDUCER NO.
Pressure	Drywell	2-30	2-39	P73
Orifice ΔP	7.5° Vent Line	2-31	2-40	P96
Orifice ΔP	90° Torus Right Vent	2-32	2-41	P99
Pressure	90° Torus Right Vent	2-33	2-42	P98
Ullage Pressure, 45°	7.5° Sector	2-34	2-43	P75
Pressure at 180°	7.5° Sector	2-35	2-44	P80
Ullage Pressure, 45°	90° Torus, Plane 9	2-36	2-45	P43
Pressure at 180°	90° Torus, Plane 3	2-37	2-46	P111
Pressure at 180°	90° Torus, Plane 4	2-38	2-47	P22
Pressure at 180°	90° Torus, Plane 6	2-39	2-48	P36
Pressure at 180°	90° Torus, Plane 7	2-40	2-49	P14
Pressure at 180°	90° Torus, Plane 9	2-41	2-50	P49
Pressure at 180°	90° Torus, Plane 11	2-42	2-51	P10
Pressure at 180°	90° Torus, Plane 20	2-43	2-52	P57
Load Cell at 90°	90° Torus, Plane 4	2-44	2-53	L4A
Load Cell at 270°	90° Torus, Plane 4	2-45	2-54	L5A
Torus Displacement	Left End	2-46	2-55	D1
Torus Displacement	Right End	2-47	2-56	D10
Torus Displacement	Vertical	2-48	2-57	D3
Torus Displacement	Horizontal, Out	2-49	2-58	D4
Torus Displacement	Horizontal, In	2-50	2-59	D5

NRC TEST NO. 1.3.1

CHAN 31

ENC3D-01
R05/18/77
20:11:03
3492
2.064E-03

CE TIME : 05/18/77U
09.15.48
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

PRESSURE, PSIA (P-73), DRY WELL, 3

Figure 2-9. Drywell Pressure, Test 1.3.1.

NRC TEST NO. 1.3.1

CHAN 11

CE TIME : 04/28/77
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

LOFAU1-01
R05/07/77
17:37:08
3492
2.864E-03

Figure 2-10. Ullage Pressure, 45°, 7.5°
Sector, Test 1.3.1.

24
NRC TEST NO. 1.3.1

CHAN 16

CE TIME : 04/28/77

SA RATE : 0

LOFAU1-02

09.16.08

NCHANS : 15

R05/07/77

LO FREQ : 0.100007 HZ

17:38:00

HI FREQ : 174 HZ

3492

2.864E-03

Figure 2-11. Pressure at 180°, 7.5°
Sector, Test 1.3.1.

LOFAU-03
R05/07/77
17:39:14
3492
2.854E-03

SA RATE : 0
NCHANS : 15

NRC TEST NO. 1.3.1

CHAN 49

LOFAU1-04
R05/07/77
17:40:01
3492
2.864E-03

CE TIME : 04/28/77Z SA RATE : 0
09.16.08 NCHANS : 15
LO FREQ : 0.100007 HZ
MI FREQ : 174 HZ

PRESSURE, PSIA (P-49), TORUS, 9-180 DEG.

Figure 2-13. Pressure at Plane 9, 180°,
90° Torus Sector, Test 1.3.1.

NRC TEST NO. 1.3.1

CHAN 11

ENC10-01
R05/18/77
20:07:47
3492
2.864E-03

CE TIME : 05/18/77U
09.15.48
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

LOAD, LBS. (L-4A), TORUS TRUNION, 4-90 DEG.

Figure 2-14. Load at Plane 4, 90°, 90°
Torus Sector, Test 1.3.1.

NRC TEST NO. 1.3.1

CHAN 13

CE TIME : 05/18/77U

SA RATE : 0

ENC10-01

R05/18/77

20:07:50

3492

2.864E-03

LO FREQ : 0.100007 HZ

NCHANS : 15

HI FREQ : 174 HZ

Figure 2-15. Load at Plane 4, 270°, 90°
Torus Sector, Test 1.3.1.

NRC TEST NO. 1.4

CHAN 31

CE TIME : 05/18/77

SA RATE : 0

ENC3E-01

U05/19/77

10:48:08

3492

2.864E-03

15.47.45

NCHANS : 15

LO FREQ : 0.100007 HZ

HI FREQ : 174 HZ

PRESSURE, PSIA (P-73), DRY WELL, 3

Figure 2-16. Drywell Pressure, Test 1.4.

NRC TEST NO. 1.4

CHAN 11

CE TIME : 04/28/77Z

SA RATE : 0

LOFAU1-01

09.16.08

NCHANS : 15

U05/10/77

LO FREQ : 0.100007 HZ

14:28:35

HI FREQ : 174 HZ

3492

2.864E-03

PRESSURE, PSIA (P-75), TORUS, 7.5 DEG., 45 DEG.

Figure 2-17. Ullage Pressure, 45°, 7.5° Sector, Test 1.4.

NRC TEST NO. 1.4

CHAN 16

CE TIME : 04/28/77Z

SA RATE : 0

LOFAU1-02

09.16.08

NCHANS : 15

U05/10/77

LO FREQ : 0.100007 HZ

14:43:10

HI FREQ : 174 HZ

3492

2.864E-03

Figure 2-18. Pressure at 180°, 7.5°
Sector, Test 1.4.

NRC TEST NO. 1.4

CHAN 43

LOFAU1-03
U05/10/77
14:44:40
3492
2.864E-03

CE TIME : 04/28/77Z

SA RATE : 0

09.16.08

NCHANS : 15

LO FREQ : 0.100007 HZ

HI FREQ : 174 HZ

PRESSURE, PSIA (P-43), TORUS, 9-45 DEG.

Figure 2-19. Ullage Pressure at Plane 9, 45°, 90° Torus Sector, Test 1.4.

NRC TEST NO. 1.4

CHAN 49

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

LOFAU1-04
U05/10/77
14:48:08
3492
2.064E-03

Figure 2-20. Pressure at Plane 9, 180°, 90° Torus Sector, Test 1.4.

NRC TEST NO. 1.4

CHAN 11

ENCIE-01
U05/19/77
10:38:38
3492
2.664E-03

CE TIME : 05/18/77U
15.47.45
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

LOAD, LBS. (L-4A), TORUS TRUNION, 4-90 DEG.

Figure 2-21. Load at Plane 4, 90°, 90°
Torus Sector, Test 1.4.

NRC TEST NO. 1.4

CHAN 13

ENCIE-01
U05/19/77
10:38:41
3492
2.064E-03

CE TIME : 05/18/77J
15.47.45
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ
SA RATE : 0
NCHANS : 15

LOAD, LBS. (L-5A), TORUS TRUNION, 4-270 DEG.

Figure 2-22. Load at Plane 4, 270°, 90°
Torus Sector, Test 1.4.

NRC TEST NO. 1.5

CE TIME : 04/28/77Z

09.16.08

LO FREQ : 0.100007 HZ

HI FREQ : 174 HZ

SA RATE : ' 0

ANCHANS : 15

CHAN 31

ENC3-01

U05/14/77

10:53:49

349

2.864E-03

Figure 2-23. Drywell Pressure, Test 1.5.

NRC TEST NO. 1.5

CHAN_11

LOFAU1-01
R05/13/77
10:59:58
3492
2.854E-03

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

PRESSURE, PSIA (P-75), TORUS, 7.5 DEG., 45 DEG.

Figure 2-24. Uillage Pressure, 45°, 7.5° Sector, Test 1.5.

NRC TEST NO. 1.5

CHAN 16

LOFAU1-02
R05/13/77
11:02:04
3492
2.86E-03

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

PRESSURE, PSIA (P-80), TORUS, 7.5 DEG., 180 DEG.

Figure 2-25. Pressure at 180°, 7.5°
Sector, Test 1.5.

NRC TEST NO. 1.5

CHAN 43

LOFAU1-03
R05/13/77
11:04:01
3492
2.854E-03

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

PRESSURE, PSIA (P-43), TORUS, 9-45 DEG.

Figure 2-26. Ullage Pressure at Plane 9, 45°, 90° Torus Sector, Test 1.5.

NRC TEST NO. 1.5

CHAN 49

CE TIME : 04/28/77Z

SA RATE : 0

LOFAU1-04

09.16.08

NCHANS : 15

11:06:22

LO FREQ : 0.100007 HZ

3492

HI FREQ : 174 HZ

2.864E-03

Figure 2-27. Pressure at Plane 9, 180°,
90° Torus Sector, Test 1.5.

NRC TEST NO. 1.5

CHAN 11

ENC1-01
U05/14/77
10:52:14
3492
2.86E-03

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

LOAD, LBS. (L-4A), TORUS TRUNION, 4-90 DEG.

Figure 2-28. Load at Plane 4, 90°, 90°
Torus Sector, Test 1.5.

NRC TEST NO. 1.5

CHAN 13

ENC1-01
U05/14/77
10:52:17
3492
2.864E-03

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

Figure 2-29. Load at Plane 4, 270°, 90°
Torus Sector, Test 1.5.

NRC TEST NO. 1.6

CHAN 31

ENC3-01
U05/14/77
16:20:57
3492
2.864E-03

CE TIME : 04/28/77
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

Figure 2-30. Drywell Pressure, Test 1.6.

NRC TEST NO. 1.6

CHAN 53

CE TIME : 04/28/77Z

SA RATE : 0

LOFAU1-04

09.16.08

NCHANS : 15

U05/14/77

LO FREQ : 0.100007 HZ

14:28:14

HI FREQ : 174 HZ

3492

2.864E-03

DELTA PRESS., PSID (P-96), 7.5 DEG., ORIFICE, 14

Figure 2-31. Differential Pressure Across the Vent Line Orifice, 7.5° Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 55

LOFAU1-04
U05/14/77
14:28:16
3492
2.864E-03

CE TIME : 04/28/77Z

SA RATE : 0

09.16.08

NCHANS : 15

LO FREQ : 0.100007 HZ

HI FREQ : 174 HZ

DELTA PRESS., PSID (P-99), ORIFICE RT. VENT 18

Figure 2-32. Differential Pressure Across Right Vent Line Orifice, 90° Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 59

CE TIME : 04/28/77Z

SA RATE :

0

09.16.08

NCHANS :

15

LO FREQ : 0.100007 HZ

HI FREQ : 174 HZ

LOFAU1-05

U05/14/77

14:28:22

3492

2.864E-03

Figure 2-33. Right Vent Line Pressure Upstream of Orifice, 90° Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 11

LOFAU1-01
U05/14/77
14:26:20
3492
2.864E-03

CE TIME : 04/28/77Z

SA RATE : 0

09.16.08

NCHANS : 15

LO FREQ : 0.100007 HZ

HI FREQ : 174 HZ

PRESSURE, PSIA (P-75), TORUS, 7.5 DEG., 45 DEG.

Figure 2-34. Ullage Pressure, 45°,
7.5° Sector, Test 1.6.

LOFAU1-02
U05/14/77
14:26:52
3492
2.864E-03

ANCHANS : 15

 

NRC TEST NO. 1.6

CHAN 43

CE TIME : 04/28/77Z

SA RATE :

0

09.16.08

NCHANS :

15

LO FREQ : 0.100007 HZ

HI FREQ : 174 HZ

LOFAU1-03

U05/14/77

14:27:38

3492

2.864E-03

Figure 2-36. Ullage Pressure at Plane 9, 45°, 90° Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 10

ENC1-01
005/14/77
16:17:43
3492
2.864E-03

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

PRESSURE, PSIA (P-111), TORUS, 3-180 DEG.

Figure 2-37. Pressure at Plane 3, 180°, 90° Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 32

LOFAU1-03
U05/14/77
14:27:30
3492
2.864E-03

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

PRESSURE, PSIA (P-22), TORUS, 4-180 DEG.

Figure 2-38. Pressure at Plane 4, 180°,
90° Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 26

CE TIME : 04/28/77Z

SA RATE :

0

09.16.08

NCHANS :

15

LO FREQ : 0.100007 HZ

HI FREQ : 174 HZ

LOFAU2-02

U05/14/77

15:16:23

3492

2.864E-03

Figure 2-39. Pressure at Plane 6, 180°, 90° Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 8

LOFAUI-01
005/14/77
14:26:17
3492
2.864E-03

CE TIME : 04/29/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

Figure 2-40. Pressure at Plane 7, 180°,
90° Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 49

LOFAU1-04
U05/14/77
14:28:10
3492
2.864E-03

CE TIME : 04/28/77Z SA RATE : 0
09.16.08 NCHANS : 15
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

PRESSURE, PSIA (P-49), TORUS, 9-180 DEG.

Figure 2-41. Pressure at Plane 9, 180°, 90° Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 4

LOFAU1-01
U05/14/77
14:26:11
3492
2.864E-03

CE TIME : 04/28/77Z
09.16.08

SA RATE : 0
NCHANS : 15

LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

Figure 2-42. Pressure at Plane 11, 180°, 90° Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 27

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

LOFAU1-02
U05/14/77
14:27:02
3492
2.864E-03

Figure 2-43. Pressure at Plane 20, 180°,
90° Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 11

CE TIME : 04/28/772

SA RATE :

0

09.16.08

NCHANS :

15

LO FREQ : 0.100007 HZ

HI FREQ : 174 HZ

ENC1-01

U05/14/77

16:17:45

3492

2.864E-03

LOAD, LBS. (L-4A), TORUS TRUNION, 4-90 DEG.

Figure 2-44. Load at Plane 4, 90°, 90°
Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 13

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

ENC1-01
U05/14/77
16:17:48
3492
2.854E-03

Figure 2-45, Load at Plane 4, 270°, 90°
Torus Sector, Test 1.6.

NRC TEST NO. 1.6

CHAN 34

CE TIME : 04/29/77

SA RATE : 0

ENC3-01

09.16.08

NCHANS : 15

U05/14/77

LO FREQ : 0.100007 HZ

16:21:01

HI FREQ : 174 HZ

3492

2.864E-03

Figure 2-46. Torus Displacement, Left End, Test 1.6.

NRC TEST NO. 1.6

CHAN 36

ENC3-01
U05/14/77
16:21:03
3492
2.864E-03

CE TIME : 04/28/77Z
09.16.08
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

SA RATE : 0
NCHANS : 15

Figure 2-47. Torus Displacement, Right End, Test 1.6.

NRC TEST NO. 1.6

CHAN 25

CE TIME : 04/28/77Z

SA RATE : 0

ENC2-01

09.16.08

NCHANS : 15

U05/14/77

LO FREQ : 0.100007 HZ

16:20:01

HI FREQ : 174 HZ

3492

2.864E-03

Figure 2-48. Torus Displacement, Vertical, Test 1.6.

NRC TEST NO. 1.6

CHAN 22

ENC2-01
U05/14/77
16:19:56
3492
2.864E-03

CE TIME : 04/28/77Z
09.16.08
SA RATE : 0
NCHANS : 15
LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

Figure 2-49. Torus Displacement, Horizontal, Outward, Test 1.6.

NRC TEST NO. 1.6

CHAN 37

CE TIME : 04/28/77Z
09.16.08

SA RATE : 0
NCHANS : 15

ENC3-01
U05/14/77
16:21:03
3492
2.864E-03

LO FREQ : 0.100007 HZ
HI FREQ : 174 HZ

Figure 2-50. Torus Displacement, Horizontal, Inward, Test 1.6.

3. ANALYSIS OF EXPERIMENTAL DATA

One parameter affecting the magnitude of the vertical loads resulting from a simulated LOCA is the initial drywell pressurization rate. Test 1.4, 1.5, and 1.6 were included in the test matrix to determine the sensitivity of these vertical loads to a variation of the initial drywell pressurization rate. These tests, along with a repeat of the nominal test case, designated test 1.3.1, are the subject of this report.

Higher initial drywell pressurization rates will induce higher flow rates in the vent pipes, and will impart a higher momentum to the fluid ejected from the downcomers. The higher fluid momentum results in higher peak downloads and higher pressures at the time of vent clearing.

Plots of the drywell pressure curve are found as Figures 2-9, 2-16, 2-23, and 2-30. Values of initial drywell pressurization rate were determined from tabular data by taking a constant slope established between the start of the pressure rise in the drywell and a time 0.89 seconds later. This is the same method as described in Quick Look Report UCID-17446-3.

Tables 2.3 and 3.1 list the values of initial drywell pressurization rate for various tests. The approximate initial drywell pressurization rate for test 1.6 is 14% lower than the planned value. However, the variation in initial drywell pressurization rate between the tests is adequate to determine a sensitivity to peak load.

Table 3.1 tabulates appropriate data which confirms that peak down loads increase as initial drywell pressurization rate increases. It should be noted that the data presented are direct measurements and are uncorrected for

Table 3-1. Comparison of Peak Values

	Test 1.4	Test 1.3	Test 1.3.1	Test 1.5	Test 1.6
Approximate Initial Drywell Pressurization Rate	124 kPa/s (18.0 psi/s)	168 kPa/s (24.3 psi/s)	190 kPa/s (27.5 psi/s)	211 kPa/s (30.6 psi/s)	226 kPa/s (32.8 psi/s)
Load Cell 4 (main outboard):					
Peak Download	53.4 kN (12,000 lbf)	66.7 kN (15,000 lbf)	71.2 kN (16,000 lbf)	78.7 kN (17,700 lbf)	84.1 kN (18,900 lbf)
Peak Upload	25.4 kN (5,700 lbf)	26.2 kN (5,900 lbf)	27.1 kN (6,100 lbf)	29.4 kN (6,600 lbf)	31.1 kN (7,000 lbf)
Load Cell 5 (main inboard):					
Peak Download	81.8 kN (18,400 lbf)	102 kN (23,000 lbf)	107 kN (24,000 lbf)	116 kN (26,000 lbf)	125 kN (28,000 lbf)
Peak Upload	40.0 kN (9,000 lbf)	52.0 kN (11,700 lbf)	52.0 kN (11,700 lbf)	54.7 kN (12,300 lbf)	54.7 kN (12,300 lbf)
Peak Pressure at 180°					
7.5° Torus	43.4 kPa (6.3 psia)	51.7 kPa (7.5 psia)	47.6 kPa (6.9 psia)	50.3 kPa (7.3 psia)	52.4 kPa (7.6 psia)
90° Torus, Plane 9	44.8 kPa (6.5 psia)	49.0 kPa (7.1 psia)	49.0 kPa (7.1 psia)	51.0 kPa (7.4 psia)	51.7 kPa (7.5 psia)

effects such as acceleration, motion of the toroidal wetwells as internal pressure increases, etc. Even though the data presented are uncorrected, the trends are clearly exhibited. The magnitude of the peak download obtained from summing the main load cells increased by about 50% as the initial drywell pressurization rate was changed from 124 kPa/s (18.0 psi/s) to 226 kPa/s (32.8 psi/s).

Peak pressure occurring about the time of vent clearing at the bottom of the 90° (plane 9) and 7-1/2° sector toroidal wetwells increased 15% and 20%, respectively. Table 3.2 shows that there is axial variation in peak pressure occurring about the time of vent clearing between similar planes (i.e., compare planes 3, 7, 9, and 11 which are planes containing two downcomers).

Figure 3.1 indicates a nearly linear relationship between peak loads and initial drywell pressurization rate. With the exception of the inboard load cell reading for test 1.4 (124 kPa/sec or 18 psi/sec) the peak uploads vary only slightly with initial drywell pressurization rate.

Tests 1.3.1, 1.4, 1.5, and 1.6 were conducted on the same day as tests 2.1, 2.2, and 2.3. The available volume in the drywell during all seven of these tests was 8.38 m³ (296 ft³) which is 15% lower than the 9.85 m³ (348 ft³) volume used in previous tests. As addressed in Quick Look Report UCID 17446-3, this reduction in drywell volume has insignificant effect on the drywell pressure-time history.

Figure 3-1. Variation of Uncorrected Main Load Cell Data with Initial Drywell Pressurization Rate

Table 3-2. Variation of Peak Pressure at 180°
Along the Axis of the 90° Torus.

Plane	Test 1.3	Test 1.6	No. of Downcomers
1	50.3 kPa (7.3 psia)	---	2
3	48.3 kPa (7.0 psia)	51.0 kPa (7.4 psia)	2
4	47.6 kPa (6.9 psia)	51.0 kPa (7.4 psia)	1
6	44.8 kPa (6.5 psia)	46.9 kPa (6.8 psia)	0
7	46.9 kPa (6.8 psia)	50.3 kPa (7.3 psia)	2
9	49.0 kPa (7.1 psia)	51.7 kPa (7.5 psia)	2
11	49.6 kPa (7.2 psia)	52.4 kPa (7.6 psia)	2
30	---	50.3 kPa (7.3 psia)	2

4. CONCLUSION

An 80% increase in initial drywell pressurization rate results in an increase in peak download as measured from the sum of the main load cells of about 50%. Corresponding peak upload increased about 30%. Peak pressures occurring about vent clearing time at the bottom of the 90° and 7-1/2° sector toroidal wetwells increase 15% and 20%, respectively.

Data from tests 1.3.1, 1.4, 1.5, and 1.6 have little noise on the pressure and load cell plots and the quality of the data remains good.

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