APPENDIX M - CONTAINMENT REPORT

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APPENDIX M CONTAINMENT REPORT

M.1 INTRODUCTION AND SUMMARY

The purpose of this appendix is to provide technical information concerning the primary containment for PBAPS Units 2 and 3.

This appendix describes the design basis, design evaluation, loads, load combinations, and initial leak rate test of the primary containment (drywell and suppression chamber) vessels for the PBAPS Units 2 and 3.

The data furnished in this appendix refer to the containment vessels of Unit 2 but are equally applicable to the Unit 3 vessels.

The nozzles for Unit 3 are essentially the same as those for Unit 2 with certain exceptions to suit the different equipment layouts.

Section 5.0, "Containment," presents the function and the design bases of the primary containment. This appendix furnishes additional design data for the containment.

The primary containment system consists of a drywell, a pressure suppression chamber which stores a large volume of water, a connecting vent system between the drywell and water pool, isolation valves, containment cooling systems, and other service equipment. The pressure suppression containment system is shown in Figure M.1.1.

The performance criteria and design information regarding the isolation valves, containment cooling systems, and other service equipment are included elsewhere in this FSAR.

The reactor building encloses the reactor and the primary containment. This structure provides secondary containment when the primary containment is in service, and serves as the containment during periods when the primary containment is open. A detailed description of the secondary containment is included in subsection 5.3, "Secondary Containment."

M.2 BASIS FOR CONTAINMENT DESIGN

Paragraphs 5.2.1 and 5.2.2 of the FSAR describe the safety objectives and safety design bases of the primary containment.

Paragraph 5.2.3 gives the detailed description of the primary containment vessels. It discusses the internal and external pressures, temperatures, and other parameters to which the containment is designed. Subsection M.3 of this appendix lists the loads and load combinations used for the structural design of the containment vessels.

The drywell shell, torus, and the penetrations together form the containment and suppression system. Subsection M.4 of this appendix describes the leak rate tests of the containment.

Figures M.2.1 through M.2.3 show the drywell shell stretchout and penetration locations for Unit 2. Unit 3 is similar to Unit 2 except that minor changes in nozzle locations were required. Drawing S-54 shows the suppression chamber penetration schedule and orientation for Units 2 and 3. Figures M.2.5 through M.2.19 show the penetration details of the containment vessels.

Table M.2.1 lists drywell penetrations with their functions and sizes for the Unit 2 containment vessels. Table M.2.2 lists suppression chamber penetrations with their functions and sizes for Units 2 and 3 containment vessels.

TABLE M.2.1

DRYWELL PENETRATIONS***

Number	Req'd. Per Unit	Nozzle Nom. Diam.	Nozzle Schedule	Nozzle Type*	Process Line Size	Services	Remarks
N-1	1	12'-0"				Equipment Access	See Fig. M.2.5
N-2	1	12'-0"				Equipment Access with Personnel Lock	See Fig. M.2.6
N-3	1	24"				Construction Manway	See Fig. M.2.7
N-4	1	24"				Head Access	See Fig. M.2.7
N-5 A to H	8	8'-0"			6'-9"	Vent Line	See Fig. M.2.8
N-6	1	36"				CRD Removal Hatch	See Fig. M.2.9
N-7 A to D	4	44"	t=2"**	2	26"	Steam to Turbine	
N-8	1	8"	80	3	3"	Condensate Drain, Main Steam	
N-9 A,B	2	42"	t=2"	2	24"	RPV Feedwater	
N-10	1	12"	80	3	3"	Steam to RCIC Turbine	
N-11	1	26"	t=1.5"	2	10"	Steam to HPCI Turbine	
N-12	1	36"	t=2"	2	20"	RHR Pump Supply	
N-13 A,B	2	42"	t=2"	2	24"	RHR Pump Discharge	

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* Figure M.2.12 through M.2.17 show nozzle types.

** t indicates minimum wall thickness of nozzle required at the nozzle to shell junction.

*** For Unit 2. Penetrations for Unit 3 are similar.

TABLE M.2.1 (Continued)

	Req'd.		Nozzle		Process		
Number	Per Unit	Nom. Diam.	Schedule	Type*	Line Size	Services	Remarks
N-14	1	22"	t=1.031"	2	6"	Reactor Water Cleanup Pump Supply	
N-15						Deleted	
N-16 A,B	2	28"	t=1.5"	2	12"	Core Spray Pump Discharge	
N-17 Below	1	22"	t=1.025"	2	6"	Reactor Pressure Vessel Head Spray	Unit 2 - See Note Unit 3 Abandoned
N-18	1	3"	80	3	3"	Floor Drains	
N-19	1	3"	80	3	3"	Equipment Drains	
N-20	1	8"	80	3	-	Spare	
N-21	1	3"	80	3	1"	Service Air	
N-22	1	3"	80	3	1"	Instrument Air	
N-23	1	8"	80	3	8"	Closed Cooling Water Supply	
N-24	1	8"	80	3	8"	Closed Cooling Water Return	
N-25	1	18"	80	3	18"	Vent to Drywell	
N-26	1	18"	80	3	18"	Vent from Drywell	
N-27 A to F	6	12"	80	8	1"	Refer to Table 5.2.2	
N-28 A to F	6	12"	80	8	1"	Instrumentation	N-28E Spare
N-29 A to F	6	12"	80	8	1"	Refer to Table 5.2.2	
N-30 A to F	6	12"	80	8	1"	Instrumentation	

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* Figure M.2.12 through M.2.17 show nozzle types.

Note: The RHR head spray pressure boundary was separated from this penetration per ECR 98-03204 for Unit 2.

TABLE M.2.1 (Continued)

		Nozzle					
Number	Req'd. Per Unit	Nom. Diam.	Schedule	Type*	Process Line Size	Services	Remarks
N-31 A to F	6	12"	80	8	1"	Instrumentation	N-31E, F Spare
N-32 A to F	6	12"	80	8	1"	Instrumentation	
N-33 A to F	6	12"	80	8	1"	Instrumentation	N-33E Spare
N-34 A to F	6	12"	80	8	1"	Instrumentation	
N-35 A,B,C (Unit 2)	3	1-1/2"	80	1	3/8"	Spare	
N-35 A,B,D (Unit 3)	3	1-1/2"	80	1	3/8"	Spare	
N-35D (Unit 2)	1	1-1/2"	80	1	3/8"	Tip Purge	
N-35 C (Unit 3)	1	1-1/2"	80	1	3/8"	Tip Purge	
N-35 E to G	3	1-1/2"	80	1	3/8"	TIP Drives	
N-36	1	12"	80	3	4"	CRD Hydraulic Return	Abandoned
N-37 A to D	189	1"	80	-	1"	CRD Insert	See Fig. M.2.10
N-38 A to D	189	1"	80	-	3/4"	CRD Withdraw	
N-39 A,B	2	14"	80	3	12"	Drywell Spray System	
N-40 A,B,C,D	4	12"	80	8	1"	Jet Pump Instr.	
N-41	1	6"	80	3	1"	Recirc. Loop Sample	
N-42	1	4"	80	3	1-1/2"	Standby Liq. Control	
N-43	1	30"	t=1.5"	3	-	Spare	Unit 2 Only
N-44	1	26"	t=1.5"	3	-	Spare	
N-45	1	34"	t=2.0"	3	-	Spare	Unit 2 Only
N-46 (Unit 2)	1	12"	80	3	-	Spare	
N-46 A, B (Unit 3)	2	12"	80	8	-	Instrumentation	
N-46 C to F (Unit 3)	4	12"	80	8	-	Spare	
N-47	1	6"	80	3	1”	ADS Pneumatic Supply	
N-48	1	6"	80	3	-	Spare	

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* Figure M.2.12 through M.2.17 show nozzle types.

TABLE M.2.1 (Continued)

Number	Req'd. Per Unit	Nozzle Nom. Diam.	Nozzle Schedule	Nozzle Type*	Process Line Size	Services	Remarks
N-49 A to F	6	12"	80	8	1"	Refer to Table 5.2.2	
N-50 A to F	6	12"	80	8	1"	Instrumentation	N-50F Spare
N-51 A to F	6	12"	80	8	1"	Refer to Table 5.2.2	N-51F Spare
N-52 A to F	6	12"	80	8	1"	Instrumentation	N-52A to D Spare
N-53	1	12"	80	3	8"	Chilled Water Return A	
N-54	1	12"	80	3	8"	Chilled Water Return B	
N-55	1	12"	80	3	8"	Chilled Water Supply B	
N-56	1	12"	80	3	8"	Chilled Water Supply A	
N-57	1	6"	80	3	1"	Main Steam Sample	
N-100 A,C,D,E B,F	6	12"	80	3	-	Refer to Table 5.2.2	
N-101 A,B,F, C,D,E	6	12"	80	3	-	Recirc. Pump Power	
N-102 A,B 5.2.2	2	12"	80	3, 8		Instr. Spare	Refer to Table
N-103 A,B	2	12"	80	3		A Spare/B Thermocouples	
N-104 A,B,C,D E,F,G,H	8	12"	80	3		CRD Rod Position Ind.	
N-105 A,B,C,D	4	12"	80	3		PWR., Lights, Fans, etc.	

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* Figure M.2.12 through M.2.17 show nozzle types.

TABLE M.2.1 (Continued)

Number	Req'd. Per Unit	Nozzle Nom. Diam.	Nozzle Schedule	Nozzle Type*	Process Line Size	Services	Remarks
N-106 A,B,C,D	4	12"	80	3		Indication and Control	
N-107	1	12"	80	3		Thermocouples	
N-108	1	12"	80	3		Spare	
N-109 A,B	2	3"	80	3		Communication and Lights	N-109B Spare
N-110 A thru H	8					Stabilizer Inspection Manway	16" dimater opening in stabilizer insert plate
N-58	1	26"	t=1.5"	2		Spare	Unit 3 Only
N-150	1	8"				Test Nozzle	

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* Figure M.2.12 through M.2.17 show nozzle types.

TABLE M.2.2

SUPPRESSION CHAMBER PENETRATIONS

Number	Req'd. Per Unit Unit 2/ Unit 3	Nozzle Nom Diam.	Nozzle Schedule	Nozzle Type*	Process Line Size	Services	Remarks
N-200 A,B	2	54"ID				Access Hatch	See Fig. M.2.11
N-201 A to H	8	6'-9"			6'-9"	Drywell to Torus Vents	
N-202 A to M	12	18"	80	4	18"	Drywell Vacuum Breakers	
N-203	1	1"	80	4	1"	Oxygen Analyzer	
N-204 A to F						Deleted	
N-205 A,B	2	20"	80	4	20"	A - Torus Vacuum Breaker/B - Drywell and Torus Purge Supply and Vacuum Relief	
N-206 A,B	2	2"	80	4	2"	Level and Pressure Instrumentation	
N-207 A to H	8	1"	80	4	1"	Vent Line Drain	
N-208 A to M	12	12"	t=0.375	5	12"	Electromatic Relief Valve Discharge	
N-209 A to D	4	1	80	6	1"	Air and Water Temp.	
N-210 A,B	2	18"	80	5	18"	RHR Torus Cooling and Pump Test Line	
N-211 A,B	2	6"	80	4	6"	Containment Cooling to Spray Header (RHR)	
N-212	1	12"	80	5	12"	RCIC Turbine Exhaust	

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*Figure M.2.12 through M.2.17 show nozzle types.

TABLE M.2.2

Number	Req'd. Per Unit Unit 2/ Unit 3	Nozzle Nom Diam.	Nozzle Schedule	Nozzle Type*	Process Line Size	Services	Remarks
N-213 A,B	2	8"	80	7	8"	Const. Drain	
N-214	1	24"	t=0.844	5	24"	HPCI Turbine Exhaust	
N-215	1	4"	80	4		Instrumentation	Unit 3 Spare
N-216	1	4"	80	5	4"	HPCI Min. Recirc.	
N-217 A,B	2	2"	80	4		Spare	N-217 B HPCI and RCIC Vacuum Relief
N-218 A,B,C	3	1"	80	4	1"	Instr. Air (A), Spare (C), O_2 Analyzer (B)	
N-219	1	18"	80	4	18"	Purge Exhaust	
N-220	1	10"	80	4		ILRT Sensors	
N-221	1	2"	80	5	2"	RCIC Vacuum Pump Discharge	
N-222						Deleted	
N-223	1	2"	80	5	2"	Condensate from HPCI Turbine Drain Pot	
N-224	1/0	10"	80	5	10"	Core Spray Test and Flush	Unit 2 Only

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* Figure M.2.12 through M.2.17 show nozzle types.

TABLE M.2.2

Number	Req'd. Per Unit Unit 2/ Unit 3	Nozzle			Process Line Size	Services	Remarks
		Nom Diam.	Schedule	Type*			
N-225	1	6"	80	5	6"	RCIC Pump Suction	Std. Flange on Inner End of Nozzle With Stainless Steel Strainers Typical for N-225 through N-228
N-226 A to D	4	24"	t=0.375	5	24"	RHR Pump Suction	
N-227	1	16"	t=0.375	5	16"	HPCI Pump Suction	
N-228 A to D	4	16"	t=0.375	5	16"	Core Spray Pump Suction	
N-229	1/0	6"	80	5	6"	Core Spray Min. Flow	Unit 2 Only
N-230	1	4"	80	5	4"	RCIC Pump Min. Recirc.	
N-231 A,B	2	3"	80	4		Electrical	Unit 2 Abandoned
N-232	1	10"	80	5		Spare	
N-250	1	8"	-	4		Test Nozzle	Unit 2 – Spare/ Unit 3 – Level Instrument
N-233	1/0	10"	80	5	10"	HPCI & RCIC Test and Flush	Unit 2 Only
N-234	1/2	10"	80	5	10"	Core Spray Test and Flush	
N-235	0/1	4"	80	5	4"	HPCI and RCIC Test and Flush	Unit 3 Only
N-236 A,B	0/2	4"	80	5	4"	Core Spray Min. Flow	Unit 3 Only

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* Figure M.2.12 through M.2.17 show nozzle types.

M.3 CONTAINMENT SYSTEM DESIGN

M.3.1 General

Chicago Bridge and Iron Company (CB&I) designed, fabricated, furnished, installed, and tested the containment vessels and connecting vent piping, including bellows, jet deflectors, penetrations, vessel supports, and other appurtenances. This was accomplished in accordance with Bechtel Corporation specifications.

The information in this report pertaining to the detailed design of the pressure containment system was taken from CB&I's Certified Stress Report, which is on file with the licensee.

Field painting of the drywell and suppression chamber was accomplished under Bechtel specifications.

M.3.2 Design of Drywell, Pressure Suppression Chamber, and Connecting Vent System

M.3.2.1 General Description and Dimensions

The pressure suppression containment system consists of a drywell, a pressure suppression chamber which stores a large volume of water, and a connecting vent system between the drywell and the water pool.

Materials, design, fabrication, inspection, and testing are in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Subsection B (1965 Edition) with all applicable addenda through Summer 1966. The quality assurance requirements as specified in Appendix IX of the ASME code, as applicable to Class B Vessels, were implemented for the Unit 3 vessels insofar as practicable.

The material for the shell of the drywell, suppression chamber, and interconnecting vent system is ASME-SA516 Grade 70 Fire Box quality made to SA-300. The Charpy V-notch impact tests of the material were conducted as specified in N-331.2 with a 20 ft-lb impact as average for each set, in accordance with Article 12, at a maximum test temperature of 0°F. This impact test temperature is based on a lowest service metal temperature of 30°F.

The drywell is a steel pressure vessel with a spherical lower portion and a cylindrical upper portion. The 32 ft 4 in-diameter bolted top closure is made with a double tongue and groove seal which will permit periodic checks for tightness without pressurizing the entire vessel.

Jet deflectors are provided at the inlet of each vent pipe to prevent possible damage to the pipes or bellows assemblies from a jet force which might accompany a pipe break in the drywell, and to prevent overloading any single vent.

The free flow area around the periphery of the jet deflector plate is equal to 1.4 times the area of the 6 ft 9-in diameter vent duct (1.4 x 5150 = 7,210 sq in). The deflectors project approximately 2 ft into the drywell. The vent pipes are enclosed with sleeves and are provided with two-ply expansion bellows to accommodate differential motion between the drywell and suppression chamber.

During erection, the drywell vessel was supported on a steel skirt which was attached to the vessel at Elevation 116 ft 10 1/2 in.

After the initial leak rate and overpressure testing, the Unit 2 drywell was embedded in concrete to Elevation 119 ft 11 in, thereby providing uniformity in the support by following the contour of the vessel. An embedment transition is provided for the shell from Elevation 117 ft 1 5/8 in to Elevation 119 ft 11 in (see Detail A in Figure M.1.1).

For Unit 3, the bottom head of the drywell was embedded in concrete to Elevation 119 ft 11 in prior to the completion of drywell fabrication. This is in accordance with paragraph N-1411 of Section III of the ASME code. The weld seams were checked by the halide detection method to ensure leaktightness since these weld seams would be inaccessible during the initial leak rate test of the containment vessels.

The suppression chamber is a stiffened steel pressure vessel in the shape of a torus below and encircling the drywell. Inside the suppression chamber, also in the shape of a torus, is the vent system distribution header. Projecting downward from the header are 96 downcomer pipes which terminate below the water surface of the pool. Vent header deflectors are located below the header to divert flow away from the header and reduce pool swell impact loads. One deflector is located in each of the eight "non-vent" bays of the torus, where pool swell loads are highest. Each deflector is a pipe section with angles welded to the sides to give a wedge-shaped profile. The deflector is suspended from the vent header support collars at either end of the bay. The deflectors are designed to withstand the combined effects of deadweight, seismic loads, and fluid drag and axial load during a LOCA as defined by General Electric. The design criteria are based on ASME codes together with load combinations and service level assignments negotiated with the NRC. The intersection of the downcomers to the vent header is stiffened to reduce relative motion between the downcomers and the vent header and eliminate weld joint fatigue.

Downcomer tie straps exist between downcomers in each downcomer pair to reduce downcomer motion under the thrust and lateral loads and to minimize resultant stresses in the downcomer-ring header intersection. These ties are welded to the existing collar plate at the bottom of each downcomer.

Vacuum breakers relieve pressure from the suppression chamber to the drywell to prevent a significant pressure differential between the drywell and suppression chamber. These vacuum breakers also prevent a backflow of water from the suppression pool into the vent system and prevent excessive water level oscillation within the downcomer pipes. The vacuum breaker penetrations in the vent header are stiffened to resist LOCA pool swell impact and drag loads.

Access to the pressure suppression chamber from the reactor building is through either of two manholes with double-gasketed bolted covers which can be tested for leakage.

Access to the drywell is through the CRD removable hatch, equipment hatch, personnel air lock, and through the double-gasketed drywell head, all of which have provisions for individual leak testing.

The pressure suppression chamber is supported on 16 pairs of equally spaced columns. Columns support the dead weight of the torus; saddles have additional support points capable of acting with columns to resist dynamic loads. The columns are provided with base plates that are free to slide over lubrite plates. Although free to slide horizontally, the pressure suppression chamber is anchored to the foundation slab to prevent gross vertical uplift. These supports transmit vertical loading to the reinforced concrete foundation slab of the reactor building. Saddles exist between each pair of existing columns to give extra hydrodynamic load support to the suppression chamber.

Lateral loads due to an earthquake are transmitted to the foundation by four symmetrically placed shear keys.

The dimensions of the drywell and pressure suppression system are given in Table M.3.1.

The interior surfaces of the Units 2 and 3 drywells and the Unit 2 torus above the waterline were originally primed with an inorganic zinc coating Carbozinc 11) and finished with a modified epoxy phenolic coating Phenoline 368). The interior surfaces of the entire Unit 3 torus and the Unit 2 torus below the waterline were originally coated with Carbozinc 11 only. Recoating of the above interior surfaces or repairs to the above coatings are performed using compatible qualified materials in accordance with approved procedures which satisfy commitments stated in the Exelon Quality Assurance Topical Report (NO-AA-10, App. C).

M.3.2.2 Applicable Codes and Regulations

The following publications form a part of the applicable codes and regulations used in the design of the pressure suppression containment system:

1. American Society of Mechanical Engineers

   Boiler and Pressure Vessel Code, Section III, Subsection B, 1965 Edition with all applicable addenda through Summer 1966. The torus ring is designed in accordance with ASME Section III with allowable stresses, material, and inspections being in accordance with ASME Nuclear Vessel Code Section III. Material and inspection of welds within 4 in of the torus shell are made in accordance with ASME Nuclear Vessel Code Section III. Material specifications for the containment vessels are tabulated in Table M.3.2.

2. American Institute of Steel Construction

   Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings. The columns and seismic ties are designed in accordance with AISC allowables, with attachment weld designed with ASME allowables. There is no increase in stress when a design basis earthquake is considered.

M.3.2.3 Design Loadings

The loadings considered in the original design of the drywell, suppression chamber, and interconnecting elements are shown in Tables M.3.3 and M.3.4. In addition, the hydrodynamic loads to which the suppression chamber and interconnecting elements are subjected during accident conditions were redefined as part of the Mark I Containment Long-Term Program. A description of the Mark I Program is contained in paragraph M.3.5.

A description of the loads and the various load combinations used in the design are presented in the following paragraphs. A description of the loads identified during the Mark I Program is contained in reference 5.

M.3.2.3.1 Description of Original Design Loads

M.3.2.3.1.1 Pressures and Temperatures Under Normal Operating Conditions

During reactor operation the vessels are subjected to bulk average temperatures up to 145°F at atmospheric pressure. The suppression chamber is also subjected to the loads associated with the 136,000 cu ft of water distributed uniformly within the vessel.

M.3.2.3.1.2 Pressures and Temperatures Under Accident Conditions

The drywell, suppression chamber, and the vent system are designed for a maximum internal pressure of 62 psig coincident with a temperature of 281°F.

M.3.2.3.1.3 Jet Forces

The drywell and closure head are designed to withstand the jet forces listed in Table M.3.3. These listed forces do not occur simultaneously. However, a jet force was assumed to occur concurrently with the design internal pressure of 56 psig and a bulk average temperature of 145°F. The jet forces consist of steam and/or water at 300°F maximum. The drywell is largely enclosed within the structural and shielding concrete. Above the drywell foundation (elevation 119 ft. 11 in.), there is a nominal 2-in gap between the vessel and the concrete except at the closure head and top flanges. Where the drywell shell is backed up by concrete, local yielding may take place due to jet force impingement; however, rupture will not occur(1).

Tests by CB&I showed that a 3 1/8-in deformation occurred before a crack developed at the edge of the loading pad. The specified air gap around the drywell is 1 3/4 in ± 1/4 in which is substantially smaller than the 3 1/8-in deformation observed in the test. Immediately following the impact of the jet, the only significant thermal stresses will be compressive skin stresses on the inside surface of the shell. These compressive stresses would not increase the possibility of rupturing (or cracking).

Followed by the jet and the associated temperature, the thermal membrane stresses and the tensile membrane stresses due to internal pressure and temperature would add to the membrane stresses due to the jet force. Since the thermal stresses are self equilibrating, they are relieved by yielding and do not affect the load-carrying capacity of the shell.

Part of the deformation of the shell would occur in which the stresses remain in the elastic range, but a larger portion of the deformation would take place after a plastic hinge has formed at the edge of the loaded area because the surface bending stresses are substantially greater than the membrane stresses. However, gross deflections occur only after the membrane stresses have reached the yield point.

Where the shell is not backed up by concrete, the primary stresses resulting from the jet force loads do not exceed 0.9 times the yield point of the material at 300°F. However, primary plus secondary stresses permitted are three times the allowable stress values given in Table N-421 of Section III, Subsection B of the ASME Boiler and Pressure Vessel Code.

The suppression chamber and vent system are designed to withstand the vessel blowdown reactions associated with the design basis LOCA. Stresses resulting from these reactions are limited to ASME code allowable stresses.

M.3.2.3.1.4 Gravity Loads to be Applied to the Drywell Vessel

These loads are described in Table M.3.3.

M.3.2.3.1.5 Gravity Loads to be Applied to the Suppression Chamber

These loads are described in Table M.3.4.

M.3.2.3.1.6 Lateral Load - Wind

The drywell vessel which was exposed above grade, prior to construction of the reactor building, was designed to withstand wind loads on the projected area of the circular shape in accordance with the height zones listed. These loads were analyzed in combination with other loads applicable during this stage, with stresses limited to 133 percent of the ASME code allowable stresses.

Height Above Grade (ft)	Wind Load (psf)
0-50	25
50-150	35
150-400	45

CB&I's stress analysis indicates that the stresses in the skirt, during construction, due to wind were less than those due to earthquake and no detailed analysis for wind load was considered necessary.

M.3.2.3.1.7 Seismic Loads

The drywell was designed by a dynamic seismic analysis using a multi-mass mathematical model. The results of this analysis are shown in the form of a graph of the acceleration (g) at various elevations in Figures M.3.1 and M.3.2. The ground acceleration used in developing these curves was 0.05g. A separate set of calculations for 0.12g accelerations was not performed since inspection of the seismic stresses calculated for the 0.05g ground acceleration indicated that the stresses due to the 0.12g acceleration are also very small and well below the applicable allowable stresses for this condition. Other seismic load coefficients used in the containment analysis are listed in Tables M.3.3 and M.3.4.

The calculated seismic stresses for the drywell are extremely low as compared with stresses induced by pressure, and those for the suppression chamber are extremely low as compared with stresses induced by pressure and temperature. Due to this, the use of equivalent static loads derived from the dynamic analysis was considered satisfactory. Torsional response of the drywell was not considered because of the axisymmetrical configuration of the drywell and torus. The contribution from slight eccentricities is an insignificant part of the seismic stresses which in turn form a very small part of the total stresses. The vertical response amplification was also not considered for the same reason.

The earthquake design is based on allowable stresses as set forth in the applicable codes. The one-third increase in allowable stress normally associated with seismic loading was not used.

M.3.2.3.2 Load Combinations Used in the Design of the Drywell and Vent System

Case 1 - Initial leak rate test condition at ambient temperature at time of test (Drywell Cantilevered)

Case 2 - Integrated leak rate test condition at ambient temperature at time of test

Case 3 - Normal operating condition at operating temperature range of 50 to 150°F

Case 4 - Refueling condition with drywell head removed

Case 5 - Accident condition at specified temperature of 281°F

Case 6 - Post-accident flooded condition

In Cases 2 through 6 the drywell is laterally supported.

M.3.2.3.3 Load Combinations Used in the Original Design of the Suppression Chamber

Case 1 - Initial leak rate test condition at ambient temperature at time of test

Case 2 - Integrated leak rate test condition at ambient temperature at time of test

Case 3 - Normal operating condition at operating temperature of 50° to 100°F

Case 4 - Accident condition at specified temperature of 281°F

Case 5 - Post-accident flooded condition

The loads associated with the cases listed in paragraphs M.3.2.3.2 and M.3.2.3.3 are shown in Tables M.3.5 and M.3.6.

M.3.2.4 Design Calculations

M.3.2.4.1 Introduction

A complete set of design calculations for the drywell, suppression chamber, interconnecting elements, nozzle reinforcements, and access openings have been prepared by CB&I and are on file with the licensee. Their analyses have taken into consideration all of the original design loads and load combinations shown in Tables M.3.3, M.3.4, M.3.5, and M.3.6.

A re-analysis of the suppression chamber, vent system, and suppression chamber penetrations was performed as part of the Mark I Containment Long-Term Program as discussed in paragraph M.3.5. A complete set of design calculations for the re-analysis is contained in the Peach Bottom Plant Unique Analysis prepared by Bechtel Power Corporation (Reference 10 and 11).

M.3.2.4.2 Drywell Design - Primary Membrane Stresses

The drywell is designed by membrane theory which is based on the principle that the thin shell resists the imposed loads by direct stresses only. To resist earthquake loads, the stabilizer assembly is provided at Elevation 194 ft 8 in to transfer the seismic load on the internal structure through the shell and into the external concrete shield wall.

The seismic load on the shell and appurtenances is resisted jointly by the shell and by the stabilizer.

The shell acts as a beam of variable cross section fixed at embedment level Elevation 117 ft 1 5/8 in, and simply supported at stabilizer level, Elevation 194 ft 8 in (See Figure M.3.3). The stabilizer assembly is designed for a maximum load of 375 kips due to seismic and jet forces on the internal structure in addition to a stay force on the drywell shell. The magnitude of the stay force corresponds to a 10-mil deflection at the stabilizer level. This deflection is accommodated in the gap between the male and female parts of the stabilizer assembly. The stresses induced in the shell because of the stay force are extremely small, and the earthquake loads do not govern the design of the shell.

M.3.2.4.3 Drywell Design - Maximum Primary Membrane Stresses in the Shell

The maximum primary general membrane stresses in the shell result from the combination of an internal design pressure of 56 psig, the dead load of the shell and appurtenances, lateral and vertical seismic loads, and gravity and live loads on welding pads, which is Case 5, the accident condition. The internal pressure load causes by far the greatest stress.

The maximum stress of 16,712 psi is less than the 17,500 psi allowed by the code. It occurs in the knuckle portion of the drywell. Other stresses computed at other points along the drywell for Cases 1 through 5 are shown in Table M.3.7.

Case 1 is for the initial leak rate test conducted at a pressure of 70 psig, which is higher than the design internal pressure of 56 psig. Since this condition and pressure were temporary, an increase in the allowable membrane stress was used.

In addition to maximum stresses computed for the cylindrical and spherical portions of the drywell, stresses have been computed on the elliptical head of the vessel, taking into account the effect of jet forces, since this portion of the vessel is not backed up by concrete. The maximum stress on the head has been found to be 27,631 psi and results from jet forces combined with the design internal pressure of 56 psig. The design specification allowance for this loading combination is 30,330 psi ($0.9F_y$ @ 300°F).

M.3.2.4.4 Drywell Design - Discontinuity Stresses

Drywell discontinuity stresses at embedment, skirt-to-drywell junction, vent-to-drywell shell junction, and penetration nozzles have been accounted for and stress values included in the CB&I Certified Stress Report. Penetration nozzle design is discussed in paragraph M.3.4. The following gives the actual and allowable stresses at these discontinuities:

Location	Maximum Actual Stress	Allowable Stress
Drywell embedment at accident condition	21,770 psi	3 S_m = 52,500 psi
Skirt-to-drywell junction	29,748 psi	3 S_m = 52,500 psi
Vent-to-drywell Shell junction	9,224 psi	1.5 S_m = 26,250

M.3.2.4.5 Drywell Design - Expansion of the Drywell Containment Vessel and Jet Forces

Design pressure for the drywell permits a relatively thin-walled steel vessel. However, the vessel has relatively little capability to resist concentrated jet forces. Such loads are, however, readily accepted by the massive concrete shield which surrounds the vessel. Accordingly, the space between the steel drywell vessel and the concrete shield outside has to be sufficiently small so that, although local yielding of the steel vessel can occur under concentrated forces, yielding to the extent causing rupture will be prevented. Space has been provided to allow the drywell to expand when in its stressed condition in order for it to function as a pressure vessel. In addition, the vessel is subjected to thermal expansion caused by operating or possible accident condition temperatures significantly higher than ambient.

In order to ensure that a steel shell could deflect up to 3 in locally without failure as a result of a concentrated load, CB&I has conducted a series of tests--- on a steel plate formed to simulate a portion of the drywell vessel. The tests were satisfactory and also provided data on loading required to produce a given deflection, and the strain at various points of the shell. In performing these tests, permanent deformation was not considered as failure.

M.3.2.4.5.1 Drywell Design Pipe Whip Restraints and Drywell Shell Protection

The design criteria for the recirculation line restraints are as follows:

1. For recirculation pipe, the maximum distance between postulated break locations and corresponding restraints is no greater than that distance between the restraint bracket and the containment drywell shell plate.

2. The position of restraint brackets limits excessive motion to assure that a rupture in the recirculation system does not result in cascading pipe failures which would preclude safe shutdown of the reactor.

3. For original recirculation pipe, the pipe ruptures were assumed to occur anywhere in the system and were assumed to be instantaneous circumferential guillotine breaks or longitudinal pipe splits.

   For replacement recirculation pipe, pipe ruptures are postulated in accordance with the criteria contained in Paragraph A.10.3(3) and A.10.7.7(4).

4. The pipe restraints are arranged so as not to interfere with the normal operation of the system, including earthquake motions.

5. The allowable stresses for the restraint brackets and support steel are 150 percent of the AISC code allowables for the materials used. The restraint ring is designed to limit bending stresses within the ultimate strength of the material and to limit the tensile stress to 90 percent of the yield. The recirculation pump restraint cables (wire rope) are limited to 90 percent of their breaking strength.

6. The design loads for the restraint system are the product of the reactor vessel operating pressure times the flow area.

Because of this design criteria, damage to other piping systems and engineered safety systems are not considered. The primary containment design considers what additional protection of the drywell is required to assure that, for the postulated failure of an unrestrained main steam or feedwater line, containment perforation does not occur. The design basis event is the failure of a single main steam or feedwater pipe rupture by instantaneous and complete severance at circumferential butt welds, with the jet reaction force acting normal to the rupture surface and resulting in pipe rotation around a plastic hinge. The force causing pipe movement and deformation around a plastic hinge is the jet reaction resulting from blowdown from the reactor vessel. The areas of the drywell shell potentially requiring protection were then determined by identifying the locations at which each ruptured pipe end could contact the drywell shell when the pipe is rotated around various possible plastic hinge points. A pipe is considered shielded from striking the drywell if, in its rotation, it first strikes another pipe of at least like size and schedule. The extent of additional protection required is determined as follows:

1. The impact energy potential to the drywell wall has been determined as a function of the jet reaction force and the configuration of the pipe with respect to the drywell. No credit is taken for the energy absorbed by pipe deformation on contact with the drywell shell or for the energy dissipated in plastic hinge formation. Conservatively, jet reaction forces have not been reduced due to the throttling effect of partial pipe closure at the plastic hinge joint. The equivalent diameter for the impact area determination is assumed to be the chord of the pipe formed by the inner surface of the plate when the outer circumference of the pipe is tangent to the outer surface of the plate.

2. The energy required for perforation of the drywell shell has been determined based on the material strength and thickness of the potential impact area and an empirical relationship developed from a series of experiments by the Stanford Research Institute using tool steel projectiles. In the empirically derived equation, a window width of eight times the equivalent diameter is assumed for maximum conservatism with the ultimate strength of the containment taken as 70,000 psi. The impact energy thus determined as sufficient to perforate the drywell shell is conservative since it is lower than the energies required for perforation with typical pipe materials.

3. A comparison is made between the energy associated with the pipe's potential impact on the drywell shell and the energy required to perforate the drywell shell, and the areas requiring additional protection are thus determined.

For a portion of the failure cases investigated, no protection was required because:

1. Pipe movement distances to contact the drywell are insufficient to obtain an impact energy exceeding the energy required to perforate the shell thickness.

2. The close proximity of the drywell shell to the piping systems is such that pipe rotation around a plastic hinge is insufficient to result in the ruptured end coming in contact with the shell.

For those areas of the drywell shell identified by the method described as susceptible to perforation as the result of the postulated pipe failure, a protection system was installed such that the protection system and the drywell shell will deform through the 2-in air gap between the drywell and the concrete biological shield without causing breaching of the drywell. This system is quite similar to the system employed by the Boston Edison Company on its Pilgrim plant (Amendment No. 29; Docket No. 50-293). The protection system consists of reinforcing plates arranged to receive the postulated ruptured pipe, to absorb a portion of the impact energy, and to distribute the impact load over an area of the drywell shell such that the combined energy absorption capability of the protection system and the drywell shell is greater than the impact energy of the ruptured pipe. This method of implementation for the spherical portion of the drywell is shown in Figure M.3.4. The amount of additional protection of the drywell shell is shown in Figure M.3.5. The plate thicknesses used eliminated the need for steel members or shapes.

Component sizing and location of the protection system steel members takes into account limitations imposed by the existing structural and piping arrangements as well as requirements for access to perform future in-service inspections.

The existing pipe restraints and spatial separation, plus the additional drywell shielding protection system protects the engineered safety features such as the containment barrier and emergency core cooling systems from the effects of pipe whip in the unlikely event of a double-ended rupture of a main steam, recirculation, or feedwater line. No failure of the primary containment will occur.

M.3.2.4.6 Drywell Design - Flooded Condition

The primary containment was analyzed for its ability to withstand loading from post-accident flooding of the drywell.

Under this condition, the drywell is flooded with water to Elevation 233 ft 0 in. Other loads, such as internal pressure, temperature, and jet forces are not combined with the hydrostatic load since these loads will not occur simultaneously with flooding. However, the vessel was analyzed for earthquake loads combined with the hydrostatic loads and live loads.

Table M.3.8 summarizes the stresses in the shell under the flooded condition and earthquake.

M.3.2.4.7 Drywell Design - Buckling Considerations

The following is a summary of criteria used for buckling:

1. External pressure - ASME Boiler and Pressure Vessel Code formulae.
2. Uniaxial buckling stresses (non-structural members) are limited to the "tubular column allowable" as explained in Welding Research Council Bulletin 69.
3. Unequal biaxial buckling stresses (non-structural members) are limited to a combination of tubular column allowable and equal biaxial allowable as explained in Welding Research Council Bulletin 69.
4. Structural members are in accordance with AISC (Sixth Edition).

The drywell shell must be capable of resisting the compressive stresses resulting from the external pressure, the dead load of the shell and appurtenances, the live load on the access hatch and beam loads, the gravity loads on the weld pads, plus the seismic loads. These loads produce biaxial compressive stresses of varying magnitude at different points along the drywell shell.

The worst condition for drywell buckling is during the refueling condition, Case 4, combined with stresses due to seismic loading. The maximum compressive stress occurs at the drywell embedment.

The stress values at the different points along the shell are summarized in Table M.3.9.

M.3.2.4.8 Suppression Chamber Design - Primary Membrane Stresses

The suppression chamber is supported on 16 pairs of equally spaced columns located on the inner and outer peripheries.

Although the principal stresses computed on the suppression chamber were circumferential, detailed analyses have been performed to determine the magnitude of localized stresses at the point of column and downcomer supports and vents to determine the need for and to provide additional stiffeners and reinforcing as required.

Due to the complexity of the analysis involved in the determination of maximum stresses under various loads and load combinations, CB&I set up a computer program for each of the major loading combinations. These combinations were the initial and final condition at ambient temperature at the time of the acceptance test, and the accident condition at 281°F. In addition, the flooded condition was analyzed. The CB&I calculations for the suppression chamber, including the printout sheets for the computer program, are included in the Certified Stress Report on file with the licensee.

M.3.2.4.9 Suppression Chamber Design - Accident Condition

During the original design analysis the maximum primary membrane stresses in the shell and ring girder result from a combination of downcomer thrusts of 21,000 lb each, a design internal pressure of 56 psig at 281°F or an external pressure of 2 psid, over internal pressure, dead load of shell and appurtenances, the force of the 147,000 cu ft of water in the suppression pool, lateral and vertical seismic loads, and thrust loading on the vent system.

Further analysis was performed (reference 2) and the stresses were determined by computer program at critical points along the girder. The maximum stress of 14.6 KSI for the accident condition is well below the ASME code allowable stresses.

M.3.2.4.10 Suppression Chamber Design - Flooded Condition (Ring Section and Supports)

With the water level at Elevation 233 ft 0 in in the drywell for the flooded condition, a computer analysis showed that the maximum stresses in the support ring are 16,349 psi on the outside and 22,613 psi on the inside.

M.3.2.4.11 Suppression Chamber Design - Buckling Considerations

The suppression chamber shell and its elements have been analyzed to determine their resistance to buckling. The analysis of the shell according to ASME Boiler and Pressure Vessel Code, Section III, Subsection B shows a safety factor of $\frac{2.35}{2.00} = 1.175$ against external pressure.

A re-analysis of the suppression chamber shell due to hydrodynamic loads was performed as part of the Mark I Containment Long-Term Program as described in paragraph M.3.5. Structural WT members were welded to the exterior of the shell to stiffen the shell against buckling.

M.3.2.4.12 Suppression Chamber Design - Support Structure

The suppression chamber support structure was analyzed for operating, accident, and flooded conditions.

Analysis of the support structure under accident conditions has been supplied to the NRC under the PBAPS Units 2 and 3 Docket Numbers 50-277 and 50-278(2). This Plant Unique Assessment (PUA) was submitted to the NRC on September 12, 1977.

The proportion that maximum column stresses are of allowable stresses are as follows:

	Ratio			
	Axial Stress		Combined Stress	
Condition	Outside Column	Inside Column	Outside Column	Inside Column
Operating	0.5100	0.3940	0.5854	0.4638
Flooded	0.6790	0.5035	0.73755	0.5617

The design of stiffeners, column connections, plates, etc, have been analyzed for operating and accident conditions, and stresses are less than the allowable stresses.

Seismic forces and the methods of transmittal of forces were analyzed. The structural steel sections used provide a safe design that conforms to the requirements of the ASME code and the AISC.

M.3.2.4.13 Suppression Chamber Design - Header, Downcomer, and Vent Pipes

These components of the suppression chamber were analyzed and adequately sized for plate thickness and reinforcements as required and in conformance with the ASME code. The maximum stress for the bellows expansion joint due to internal pressure is 15,200 psi compared to an allowable stress of 15,700 psi.

M.3.2.4.14 Containment System Design - Summary

All possible loads, as well as their combinations, have been taken into consideration and the maximum stresses computed are all within the design specifications and the ASME Boiler and Pressure Vessel Code allowable stresses.

M.3.3 Pipe Penetrations

Figures M.2.12 through M.2.17 show the different types of penetrations used in the drywell and torus. The eight types shown, while different from each other in detail, can be classified in three basic categories. Category A penetrations are generally for hot process lines (Type 2). Category B penetrations are for cold process lines and electrical penetrations (Types 3 and 4) and for hot process lines discharging directly in the torus (Type 5). Category C penetrations are for instrumentation in the drywell and torus (Types 1, 6, and 8). Type 7 penetrations are used for drainage in the drywell during construction or for draining the water from the torus.

Category A penetrations for generally hot process lines accommodate relatively large thermal movement, as compared with Category B penetrations for cold process lines which have little or no thermal movement.

M.3.3.1 Category A Penetrations (Type 2)

Category A pipe penetrations (Figure M.2.13) must accommodate thermal movement and must resist relatively high thermal stress. To accommodate large movements due to expansion in high temperature lines, as well as containment shell movement, an expansion bellows is required. These lines are anchored outside the containment to limit the movement relative to the containment. This design assures integrity of the penetration.

The penetration nozzle is welded to the drywell. The process line which passes through the nozzle is free to move axially, with the two-ply bellows joint accommodating the movement. A guard pipe which surrounds the process line is designed to protect the bellows and thereby maintain the penetration seal should the process line fail within the penetration. The two-ply expansion joint permits periodic leak testing of the bellows during normal operation of the plant by pressurizing the annular gap between its two plies.

The design of the penetration takes into account the simultaneous stress associated with internal pressure, thermal expansion, dead loads, seismic loads, and loads associated with a LOCA. A continuous collar around the guard pipe is provided to transfer any load associated with random failures of the process line directly to the vessel without causing any bending moment stresses in the vessel. The penetration nozzle design takes into account the jet force loading resulting from the failure.

M.3.3.2 Category B Penetrations (Types 3, 4, and 5)

For these penetrations (Figures M.2.13 through M.2.15), the lines or their penetration adapters are welded directly to the nozzles. They are tested with the containment system, and the nozzle design is similar to Category A. Guard pipes are not used.

M.3.3.3 Category C Penetrations (Types 1, 6, and 8)

Instrument lines connecting to the reactor coolant pressure boundary and penetrating the primary containment up to and including excess flow check valves meet the design requirements of Group I, Schedule I and seismic Class I as described in Appendix A. The quality assurance program includes thermal and seismic design analyses, fabrication and installation conformance surveillance, and post-erection hydrostatic testing and installation verification by a representative from design engineering. Instrument line routing has been reviewed to ascertain that:

1. The possibility of a loss of more than one redundant subsection of a vital safety system or a loss of more than one functionally independent safety system from an adverse failure of an instrument line is minimized. This will be accomplished by spatial separation and utilization of the biological shield or structural members to the maximum extent practical and will be consistent with the requirement for in-service inspection.

2. Flow limiting devices are located as close to the primary sensing point as practical to minimize the possibility of one line causing failure in another downstream of the devices.

3. Instrument line routing downstream of excess flow check valves is made in protective trays in order to minimize the potential of accidental damage to tubing.

The containment penetrations for these sensing lines are shown in Table M.2.1. The 12-in drywell penetration sleeve contains six equally spaced instrument lines. The manual isolation valves are 1-in, stainless steel, 1,500-lb globe valves and are located as close to the penetration as practical consistent with the need for access to the valve. The excess flow check valves close automatically on flow in excess of 3 gpm. The excess flow check valves are equipped with position indicating switches (open and closed) which energize position indicating lights at local stations and an annunciator in the main control room. Regular monitoring of measured variables and comparison between redundant instruments, together with the position indication, provides operating personnel with sufficient information to identify malfunctioning or inoperative instruments and sensing lines. Operating and/or testing procedures assure the operability of the safety-related instrument lines and their associated orifices and excess flow check valves. The lines are equipped with flow limiting orifices and excess flow check valves of the same size and schedule as the lines. The excess flow check valves can be reset or backflushed using a manually operated bypass on each valve.

M.3.4 Penetration Nozzle Design

CB&I designed the penetration nozzles. The shell stresses, from loads on the nozzles, at the nozzle neck to shell junction were analyzed by the methods outlined in Welding Research Council Bulletin No. 107. A computer program was written to perform the calculations outlined in the computation forms for a spherical and a cylindrical shell.

Unit loads were run on the computer to determine the stresses for various combinations of loads. The stress report by CB&I includes the computer printout sheets listing the stresses for a 1,000-lb radial load, and 1,000 in-lb moment. The stresses in the shell due to unit shear loading on the nozzles were computed by hand computations. Using these coefficients, stresses were determined for combined loading conditions including thermal, earthquake, dead load, and pipe rupture loads.

The size and thickness of the nozzle neck and necessary reinforcement are computed from requirements listed in Section III, Subsection B, of the ASME Boiler and Pressure Vessel Code. The attachments are designed to provide the strength required by the ASME code.

As a result of the re-analysis of the suppression chamber performed during the Mark I Containment Long-Term Program, stiffener plates were added at the torus shell to nozzle junction for all penetrations, 6-in diameter and above.

M.3.5 Re-analysis of Suppression Chamber Design - Mark I Containment Program

A re-analysis of the suppression chamber design was performed during the period 1975-1982 as part of the Mark I Containment Program. The two-phase program was initiated as a result of the discovery of additional suppression pool hydrodynamic loads that were not originally considered in the design of Mark I containments. The hydrodynamic loads will occur during a postulated LOCA or the actuation of a safety relief valve and result from the discharge of water, air, and steam into the suppression pool.

Phase I of the program, called the Short-Term Program, confirmed the adequacy of the containment to maintain its integrity and functional capability when subjected to the loads induced by a postulated LOCA. Based on the latest dynamic load information available, Phase I demonstrated the acceptability of continued operation while a comprehensive Phase II was conducted. Phase I was completed in 1976 with the issuance of the reference 3 and 4 reports. During Phase II of the program, called the Long-Term Program, General Electric Company, in conjunction with the Mark I Owners Group, performed extensive testing and analytical work in order to identify and define the specific hydrodynamic loads to which the containment will be subjected during a LOCA or a safety relief valve actuation. The data gathered during the program through full-scale, subscale, and in-plant tests, and through the use of computer models, has been compiled into a Load Definition Report (reference 5). This report explains the containment phenomena associated with a LOCA and safety relief valve discharge and provides generic procedures for defining the temperature, pressure, and hydrodynamic loads that will act on the suppression chamber shell, vent system, internal structures, and safety relief valve discharge lines.

The Mark I Program Application Guides 1 through 10 (reference 6) provides the detailed procedures necessary to calculate containment design loads for each phase of a LOCA or safety relief valve transient. The guides explain the computer programs used to simulate and interpret the forces described in the Load Definition Report.

The Mark I Program Plant Unique Analysis Application Guide (PUAAG) (reference 7) was developed to assure the consistent application of the structural acceptance criteria by each utility when evaluating each Mark I containment. The PUAAG identifies and classifies the containment structural elements that must be re-analyzed using the Long-Term Program load definitions and acceptance criteria. The PUAAG further describes the load combinations, design and service limits, ASME code criteria, and minimum analysis guidelines that are to be used in the re-analysis of the containment design.

Load definition data unique to the PBAPS is contained in the Plant Unique Load Definition (PULD) (reference 8). The PULD contains time-history plots of LOCA-related loading conditions; specifically, temperature and pressure transients, vent system thrust loads, torus vertical loads, vent system pool swell impact loads, and vent header deflector loads. Refer also to Table 5.2.1 for other principal design parameters.

An evaluation of the generic Mark I Long-Term Program was performed by the NRC as described in NUREG-0661 (reference 9). The NRC concluded in NUREG-0661 that the methods developed for reassessing the design of the suppression chamber would provide a conservative evaluation of the structural response to suppression pool hydrodynamic loading events.

Bechtel Power Corporation utilized the reference 4 through 8 documents to perform a re-analysis of the Peach Bottom suppression chamber design. Structural modifications to the suppression chamber, which were required to assure compliance with NUREG-0661, are described in other sections of the FSAR. A Plant Unique Analysis (References 10 and 11) was prepared by Bechtel Power Corporation and submitted to the NRC.

An addendum to the Plant Unique Analysis report was issued (Reference 11) to summarize the results of the analyses of the external torus attached piping system and associated components. In summary, the addendum report makes provision for the following:

- a review of torus attached piping loadings considered for evaluation.
- an evaluation of torus attached piping including the design loads, acceptance criteria, analysis and fatigue evaluation necessary to meet the original intended safety margin.
- an evaluation of the structural steel which carries the additional reaction loads resulting from the hydrodynamic loads on the piping supports.
- a summary of results of analyses.
- an evaluation of anchorages of the equipment affected by the hydrodynamic loads. The acceptance criteria is described in References 12 and 13.

In response to the NRC Bulletin 96-03, “Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling Water Reactors,” the existing RHR and CS suction strainers were replaced with larger passive suction strainers to ensure the capability of the ECCS to perform its intended safety function.

The strainers have been evaluated for all required loads stipulated in the Code requirements and the Mark I Containment Program. Details from this evaluation have been incorporated in the Plant Unique Analysis.

M.3.6 Containment Loads at Rerate Power Conditions

The containment loads have been evaluated for Power Rerate conditions and found to be acceptable for the containment design. In most cases, the containment loads were bounded by previous analyses or in the few cases where the load increased as a result of rerate, the design was determined to be adequate to accommodate the load increase. The containment pressures and temperature are within their design limits, except that the peak drywell temperature following a Design Basis Accident is calculated to exceed its design temperature of 281°F for a short duration (20 seconds). This is not considered a threat to the drywell structure because the duration is too short for the drywell structure to heat up. Additional information can be found in References 14, 15, 16, 17, and 18.

M.3.7 Containment Loads at Rated Thermal Power

M.3.7.1 Loss of Coolant Accident Loads

The LOCA containment dynamic loads analysis for rated thermal power (RTP) (3951 MWt), including operation in the MELLLA+ domain, is primarily based on the short-term RSLB LOCA analyses and compliance with generic criteria developed through testing programs.

The analyses were performed with break flows calculated using a more detailed RPV model (Reference 19). The NRC approved use of this model for the EPU containment evaluations in Reference 20. These analyses also provide calculated values for the controlling parameters for the dynamic loads throughout the blowdown. The key parameters are drywell (DW) and wetwell (WW) pressures, vent flow rates and suppression pool (SP) temperature. The LOCA dynamic loads considered in the RTP evaluations include pool swell, condensation oscillation (CO) and chugging. For Mark I plants like PBAPS, the vent thrust loads were also evaluated.

The results of the RTP pool swell evaluation confirmed that the original pool swell load definition remains bounding. The containment response conditions for RTP are within the range of test conditions used to define CO loads for the plant. The containment response conditions for RTP are within the conditions used to define the chugging loads. The vent thrust loads at RTP conditions were calculated to be less than the plant-specific values calculated during the Mark I Containment LTP for all but four locations (load components). The four load components that exceeded the plant-specific vent thrust loads originally calculated during Mark I Containment Long Term Program, the PBAPS Analysis of Record (AOR) (Reference 10), are as follows:

1. Vertical load on main vent cap- Exceeded AOR load by 0.12%
2. Horizontal load on main vent cap - Exceed AOR load by 0.05%
3. Horizontal on vent header per miter bend- Exceed AOR load by 2.46%
4. Total vertical load on main vent-Exceeded AOR load by 0.12%

Reconciliation of the above stated mechanical load increases with the AOR structural evaluation was performed (Reference 21). This reconciliation was performed by review of the margins to structural acceptance criteria in the AOR stress report for the containment vent system (Reference 10). A review of Reference 10 showed a maximum stress ratio of 0.87. This means the minimum margin to the allowable stress for the vent system is 13%. The stress analysis of the vent system components considers the contribution of all loads acting on the vent system, including vent thrust loads. All loads on the vent system, except for the increased vent thrust loads at RTP conditions, remain bounded by the AOR loads. Therefore, a conservative assessment was made which assumed that the vent system maximum stress would increase in direct proportion to the increase in the vent thrust loads even though other concurrent loads that contribute to component stress are unchanged at RTP conditions. Since the increase in the vent thrust load component, approximately 2.5%, was much less than the minimum 13% margin between the calculated stress and allowable stress, it was determined that allowable stresses would not be exceeded with the predicted increase in the calculated vent thrust loads at RTP conditions.

The Mark I Containment Program Load Definition Report (LOR) (Reference 5) defines the onset and duration times for chugging based on break size. For the small and intermediate break sizes, chugging lasts for a duration of 900 seconds. Chugging starts five seconds after the break for the intermediate break accident (IBA) event and 300 seconds after the break for the small break accident (SBA) event. Discussion of the chugging duration time is provided in Reference 5. For the load definition, chugging is assumed to end when reactor pressure is reduced to or below the drywell pressure, essentially stopping break flow and therefore vent steam flow. This vessel depressurization for the IBA and SBA events is due to manual initiation of ADS. The load definition of Reference 5 does not include any credit for operation of containment (drywell) sprays. However, emergency operating procedures (EOPs) for PBAPS include direction to initiate DW sprays prior to WW pressure exceeding 9.0 psig. Containment analyses performed for PBAPS EPU (Reference 21) have shown that WW pressure will exceed this DW spray initiation pressure of 9.0 psig before 900 seconds following initiation of the event. Initiation of DW sprays will rapidly reduce DW pressure and stop chugging. Therefore, containment analyses performed for PBAPS RTP confirm that the chugging duration times used in the original PBAPS load combinations remain applicable and bounding for operation at RTP conditions. The basis for these chugging duration times is, however, changed from manual operation of ADS to operation of DW sprays (Reference 21).

M.3.7.2 Safety Relief Valve Loads

The SRV loads include the SRV discharge line (SRVDL) loads, suppression pool boundary pressure loads, and drag loads on submerged structures. The SRV opening setpoint pressure, the initial water leg in the SR VOL, the SR VOL geometry, and the suppression pool geometry influence these loads. The SRV loads were evaluated for two different actuation phases; initial actuation and subsequent actuation. For the initial SRV actuation following an event involving RPV pressurization, the SRV flow rate controlling the SRV loads is dependent upon the SRV capacity and SRV opening setpoint pressure, which are not changed for the EPU increase to RTP. This increase reduces the time between subsequent SRV actuations, however, the RTP analysis confirms that the reflood height used in the original PBAPS analysis remains bounding (Reference 21).

The SRV opening setpoint pressure values, which are in part the basis for the SRVDL loads and the SRV loads on the suppression pool boundary and submerged structures, are not changed. The effect of EPU on the load definition for subsequent SRV actuations was evaluated (Reference 21). Using the same methodology and assumptions as identified in the original analysis of Reference 10, the load definition for subsequent SRV actuations remains bounding and applicable for operation at RTP conditions.

M.3.7.3 LOCA Pressure and Temperature Loads

The Reference 8 load definition report (PULD) provided LOCA-induced pressure and temperature results from the Design Basis LOCA, intermediate break accident (IBA), and small break accident (SBA) events as an input for subsequent use in the Reference 10 structural analysis. The IBA and SBA events were reevaluated at 102% EPU RTP using initial conditions and assumptions consistent with the Reference 8 analysis. The results of the PBAPS RTP analysis show that all drywell and wetwell pressure and temperatures at RTP conditions are bounded by the values of Reference 8 with the exception of the peak WW and SP temperature for the SBA. At RTP conditions, the SBA peak WW and SP temperature is 148°F, which is not bounded by the Reference 8 result of 122°F. The original PBAPS Mark 1 Long Term Program Plant Unique Analysis (Reference 10) determines that the maximum internal pressure and thermal loads for the torus occur during an IBA. The design load combinations with thermal loads are all based on the bounding IBA thermal loads. The Reference 8 result for the IBA is 155°F which bounds the SBA peak WW and SP temperature of l 48°F cited above (Reference 21).

M.3 CONTAINMENT SYSTEM DESIGN

REFERENCES

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M.3 CONTAINMENT SYSTEM DESIGN

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TABLE M.3.1

DRYWELL DESIGN DATA

	Diameter	Height
Spherical section	67' 0"	58' 4 3/8"
Knuckle section	Varies	5' 10 3/8"
Cylindrical section	38' 6" to 32′ 4″	34' 2 1/4"
Top Head (Cylindrical section)	32′ 4 1/16"	6′ 9 7/8″
Top Head (2:1 elliptical)	32' 4 1/16"	8' 2 3/16"
Wall Plate Thickness		
Spherical Shell	0.645" to 1 1/4"	
Spherical Shell to Cylindrical Neck (Knuckle)	2 7/8"	
Cylindrical Neck	Varies, 3/4" to 1 1/2"	
Top Head (Cylindrical section)	1 7/16"	
Top Head (2:1 elliptical section)	1 1/2"	
Vent System		
Number of Vent Pipes	8	
Internal Diameter	6' 9"	

PRESSURE SUPPRESSION CHAMBER DESIGN DATA

Chamber Inner Diameter	31' 0"
Torus Major Diameter	111' 6"
Downcomer Pipes	
Number of Downcomer Pipes	96
Internal Diameter	1' 11 5/8"
Submergence Below Suppression Pool Water Level	4' 0"

TABLE M.3.2

MATERIAL SPECIFICATION FOR THE CONTAINMENT VESSEL

Containment Vessel Components	ASME or ASTM Specification Number and Grade	Title
Plate	SA516 Gr 70 Firebox Quality made to SA-300-O F	Carbon Steel Plates of Intermediate Tensile Strength for Fusion-Welded Pressure Vessels for Atmospheric and Lower Temperature
	SA-240 Type 304	Austenitic Stainless Steel
Pipe	SA-333 Gr 1	Seamless Carbon Steel Pipe for Low Temperature Service
	ASTM A-155 Gr KC70 Class 1	Welded Carbon Steel Pipe. The plate material conforms to SA-516 Gr 70 and the material is impact tested.
	SA-312 Type 304	Austenitic Stainless Steel Seamless Pipe
Forgings	SA-350 Gr LF1 or LF2 for welding	Forged or Rolled Carbon and Alloy Steel Flanges, Forged Fittings, and Valves and Parts for Low Temperature Service (Grade LF-1 or LF-2)
	SA-182, GR F304	Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
Castings	SA-352 Gr LCB	Carbon Steel
	SA-351 Gr CF8	Austenitic Stainless Steel Castings
Bolting	SA-320 Gr L7	Alloy Steel Bolting Materials for Low Temperature Service (Grade L7)
	SA-194 Gr 4 and Gr 8 and Gr 7 SA-193 Gr B7 and B8	Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service
Structural Steel-Shapes and Plates	ASTM A36	Structural Steel for Beams, Columns, Floor Grating Inside the Drywell and Torus
Pipe	ASTM A53 Gr B ASTM A106 Gr B and A120	Welded and Seamless Carbon Steel Pipe for Non-critical Systems

TABLE M.3.3

DRYWELL AND VENT SYSTEM - DESIGN LOADS

a) Maximum Internal Pressure = 62 psig, 281°F under accident condition. 2 psig, temperature range 50°F to 150°F under normal operating condition.

b) Maximum External to Internal Differential Pressure = 2 psid, 281°F under accident condition. 2 psid, temperature range 50°F to 150°F under normal operating condition

c) Dead Weight Loads

  1) Shell and appurtenances

  2) 750 lb per welding pad

  3) Beam seat loads

d) Live Loads

  1) 150 psf on personnel lock floor

  2) Portion of 28-ton load moving through equipment hatches

  3) 1,500 lb on each of any two adjacent pads

e) Refueling Water - Water Surface at Elevation 233 ft 0 in to water seal

f) Weight of Contained Air

g) Wind Load (paragraph M.3.2.3.1.6)

h) Seismic Load - 0.033g Vertical - Horizontal as follows:

  1) Vessel cantilevered from skirt support at Elevation 107 ft 0 in or embedment to Elevation 119 ft 11 in, Figure M.3.1

  2) Vessel supported laterally at Elevation 194 ft 8 in, Figure M.3.2

j) Reactions from drywell to the reactor building refueling expansion bellows.

TABLE M.3.3 (Continued)

k) Jet Forces (Temperature = 300°F)

Spherical Segment 664,000 lb (3.69 sq ft)
Cylindrical Segment and Sphere to Cylinder
Transition 567,000 lb (3.15 sq ft)
Closure Head 32,600 lb (0.181 sq ft)
Jet Deflector 664,000 lb

l) Post Accident Flooding to Elevation 233 ft 0 in

m) Reactions on Penetrations Due to Dead Weight, Piping, and Jet Force

n) Vent Thrusts

o) Thermal Gradients in Shell at Point of Embedment

TABLE M.3.4

SUPPRESSION CHAMBER - ORIGINAL DESIGN LOADS*

a) Maximum Internal Pressure = 62 psig. 281°F under accident condition. 2 psig, temperature range 50°F to 100°F under normal operating condition.

b) Maximum External to Internal Differential Pressure = 2 psid over internal pressure. 281°F for the accident condition, and temperature range 50°F to 100°F for normal operating condition.

c) Dead Weight Loads

    1) Shell and appurtenances

    2) Support reactions from vent system

    3) 250 lb per welding pad

d) Live Loads

    1) Walkways - 75 psf

    2) 750 lb per each of any two adjacent pads

e) 136,000 cu ft Water Normal Operation
147,000 cu ft Water Post Accident

f) Weight of Contained Air

g) Wind

h) Seismic Load - 0.033g Vertical - 0.10g Horizontal

i) Not Used

j) Vent Thrust

k) Jet Force from Downcomer - 21 Kips (Affects Only Header Support Design)

l) Post-Accident Flooding

m) Piping Reactions on Penetrations

*For revised design parameters associated with the Mark I Containment Long-Term program, See Table 5.2.1.

TABLE M.3.5

DRYWELL AND VENT SYSTEM - DESIGN LOAD COMBINATIONS

Loads*

Loading Conditions	Pressure (psi)		(c) Dead Load			(d) Live Load			(e) Refueling Water	(f) Weight of Contained Air	(g) Wind	(h) Seismic		(j) Refueling Expansion Bellow	(k) Jet Forces	(l) Post Accident Flooding	(m) Nozzle Reactions	(n)Vent Thrusts	(o) Thermal Gradient in Shell	Allowable Stresses
	(a) Internal	(b) External	Vessel	Weld Pads	Eqpt.	Uniform	Eqpt.	Weld Pads				Horizontal	Vertical							
1. Initial Leak Rate Test at Ambient Temperature	70		X	X						X		X	X					X		General Primary Membrane = 17,500 psi Prim Memb. + Prim. Bending = 1.5 x 17,500 = 26,250 psi
2. Integrated Leak Rate Test at Ambient Temperature	56		X	X	X					X		X	X					X		Prim. Membrane + Prim. Bending + Secondary Stresses = 3x17,500 = 52,500 psi
		2	X	X	X					X		X	X					X		
3. Normal Operating	2		X	X	X			X				X	X	X			X	X		Above allowable stresses are in accordance with ASME Sec. III, Paragraph N 1310.
		2	X	X	X			X				X	X	X			X	X		
4. Refueling			X	X	X	X	X	X	X			X	X	X						Comprehensive Stresses in shell not to exceed buckling stresses permitted by ASME Sec. III.
5. Accident	56		X	X	X			X				X	X	X	X		X	X	X	With jet force: shell is allowed to yield locally & not allowed to rupture if backed by concrete. If not backed by concrete, primary stresses shall not exceed 0.9 times yield of material at 300°F. Other stresses same as ASME Sect. III, Paragraph N 1310.
		2	X	X	X			X				X	X	X	X		X	X	X	
																X				
6. Post-Accident Flooding			Drywell flooded with water to Elevation 233 ft 0 in										X	X			X			Stresses may go beyond yield stress but shell not to rupture.
																X				Stressed shall be less than Yield stress.

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*For detailed description of loads, see Table M.3.3.

TABLE M.3.6

SUPPRESSION CHAMBER - ORIGINAL DESIGN LOAD COMBINATIONS

Loads*

	Pressure (psi)		(c) Dead Load			(d) Live Load		(e) Water in Pool		(f) Weight of Contained Air	(g) Wind	(h) Seismic		(j) Vent thrust	(k) Jet Force From Downcomer	(l) Post Accident Flooding	(m) Nozzle Reactions	
Loading Conditions	(a) Internal	(b) External	Shell	Vent	Weld Pads	Walkways	Weld Pads	136,000 cu ft	147,000 cu ft			Horizontal	Vertical					Allowable Stresses
1. Initial Leak Rate Test at Ambient Temperature	70		X	X	X		X		X	X		X	X	X				Shell: General Primary Membrane = 17,500 psi Prim. Membrane + Prim Bending = 1.5 x 17,500 = 26,250 psi
2. Integrated Leak Rate Test at Ambient Temperature	56		X	X	X		X		X	X		X	X	X				Prim. Membrane + Prim. Bending + Secondary Stresses = 3x17,500 = 52,500 psi Above allowable stressed are in accordance with ASME Sect. III, Paragraph N1310
		2	X	X	X		X		X	X		X	X	X				
3. Normal Operating	2		X	X	X	X	X	X				X	X	X			X	Support Structure (Columns & bracing): Stresses in accordance with AISC with no increase for seismic loads.
		2	X	X	X	X	X	X				X	X	X			X	
4. Accident	56		X	X	X		X		X			X	X	X	X		X	Shell: Stresses in compression not to exceed ASME Sec. III allowable stresses for buckling. Support Structure: Same as above.
		2	X	X	X		X		X			X	X	X	X		X	
5. Post-Accident Flooding		Suppression Chamber and Vent System Flooded with water to drywell elevation 233 ft. 0 in.														X		ASME Sec. III General Primary Membrane = 17,500 psi

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*For detailed description of loads, see Table M.3.4.

TABLE M.3.7

DRYWELL MAXIMUM PRIMARY MEMBRANE STRESSES

Point*	Case 1 Initial Test Accident	Case 2 Final Test	Case 3 Normal Operating	Case 4 Refueling	Case 5
1	12,284	9,714	-514	-425	9,714
2	21,313	16,712	-1,159	-1,269	16,712
3	18,189	14,282	-1,050	-1,052	14,200
4	19,619	15,592	-1,194	-1,428	15,592
5	19,313	15,901	-1,455	-1,295	15,901
6	19,675	16,328	-1,821	1,678	16,327
7	11,943	10,148	-1,415	1,379	10,147
8	12,372	10,683	-1,922	1,978	10,679
9	13,266	11,817	-3,020	3,273	11,802
10	13,483	12,084	-3,281	3,577	12,066
11	14,490	13,290	-4,464	4,946	13,259
12	14,505	-	-	-	-

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*See Figure M.3.3 for location of stress points.

NOTES:
1. For explanation of cases see paragraph M.3.2.3.2.
2. Values are taken from CB&I calculations.
3. These values are based on estimates of drywell accelerations.
4. Minus signs indicate compressive stresses.

TABLE M.3.8

SHELL STRESSES UNDER FLOODED CONDITION WITH EARTHQUAKE

Stress	Psi
Maximum tensile stress	29,200 psi < 38,000 (= F_y)
Maximum compressive stress	13,066
Critical buckling stress	22,000

Resulting factor of safety for buckling 1.685

TABLE M.3.9

DRYWELL BUCKLING STRESS VALUES

FOR REFUELING CONDITION (CASE 4)

	Maximum Stress (psi)				
Point(1)	Meridional	Circumferential	Maximum Compressive Stress (psi)	Critical Buckling Stress (psi)	Stability Ratio
1	-238(2)	-381	-619	21,400	0.0289
	-265(3)	-425	-690	21,400	0.0322
2	-279	-1,139	-1,418	17,500	0.0812
	-311	-1,269	1,580	17,500	0.0906
3	-377	-948	-1,325	12,300	0.1075
	-419	-1,052	-1,471	12,300	0.1195
4	-1,283	1,201	-1,283	3,350	0.3819
	-1,428	1,341	-1,428	3,350	0.4253
5	-1,165	1,134	-1,165	3,350	0.3470
	-1,295	1,262	-1,295	3,350	0.3855
6	-1,402	1,427	-1,402	3,350	0.4174
	-1,650	1,678	-1,650	3,350	0.4914
7	-1,125	1,167	-1,125	5,590	0.2010
	-1,334	1,379	-1,334	5,590	0.2384
8	-1,542	1,606	-1,542	5,590	0.2755
	-1,910	1,978	-1,910	5,590	0.3412
9	-2,364	2,448	-2,364	5,590	0.4225
	-3,184	3,273	-3,184	5,590	0.5688
10	-2,549	2,635	-2,549	5,590	0.4554
	-3,485	3,577	-3,485	5,590	0.6226

TABLE M.3.9 (Continued)

Point[1]	Maximum Stress (psi) Meridional	Maximum Stress (psi) Circumferential	Maximum Compressive Stress (psi)	Critical Buckling Stress (psi)	Stability Ratio
11	-3,342	3,435	-3,342	5,590	0.5971
	-4,847	4,946	-4,847	5,590	0.8660

NOTE: Minus signs indicate compressive stresses.

(1) See Figure M.3.3 for location of stress points.
(2) Upper number indicates earthquake stress is added to other stresses.
(3) Lower number indicates earthquake stress is subtracted from other stresses.

M.4 INITIAL OVERLOAD AND LEAKAGE RATE TEST

Containment vessels for Peach Bottom Units 2 and 3 were tested by CB&I for their structural integrity by an overload test and for leakage by the reference chamber method as described in the American Nuclear Society's publication ANS 7.60.

Tests showed that the leakage rates for the vessels were less than the 0.2 weight percent per day leakage rate limit as specified in the containment vessel specification (e.g., 0.0072 weight percent per day for the Unit 2 vessels).