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

April 19, 1994

Docket No. 52-003

APPLICANT: Westinghouse Electric Corporation

FACILITY: AP600

SUBJECT: SUMMARY OF MEETING TO DISCUSS THE EVALUATION OF CONTAINMENT PERFORMANCE

On March 28 and 29, 1994, representatives of the U.S. Nuclear Regulatory Commission (NRC) and its contractors, and Westinghouse Electric Corporation (Westinghouse) and its contractors, met in the Westinghouse office in Monroeville, Pennsylvania, to discuss the evaluation of containment performance for the AP600, and to obtain information needed for an NRC confirmatory analysis. Enclosure 1 is a list of attendees.

Westinghouse began the meeting with a presentation on the operation of, and design basis for, the passive containment cooling system. Next, Westinghouse presented preliminary information pertaining to the containment severe accident function. Westinghouse ended the meeting on March 28 with a presentation on the containment design specification and the containment structural design and analysis.

On March 29, Westinghouse completed its presentation on the containment structural design and analysis, and discussed the analyses of capacity for severe accidents and the seismic margin. At this time, the attendees discussed the information that would be required for the staff's contractors to perform a confirmatory analyses of containment buckling and severe accident responses. During the meeting, some proprietary information was presented and discussed. Enclosure 2 contains the nonproprietary version of the information presented by Westinghouse.

The following actions will be taken as a result of the meeting:

1. Westinghouse will review the proprietary classification of the drawings of the containment vessel and provide the results of their review to the staff.

2. Westinghouse will provide additional details on the containment design transients, associated with the passive containment function, in Appendix D to the SSAR.

DF03

4. For the buckling evaluation of the containment shell, Westinghouse should consider the residual stress effect on the tangent modules.

Original Signed By

Kristine M. Shembarger, Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal, NRR

Enclosures:
As stated

cc w/enclosures:
See next page

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TCheng, 7H15			

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DATE:	04/6/94	04/6/94 KMS	04/19/94	04/19/94

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WESTINGHOUSE AP600
CONTAINMENT PERFORMANCE MEETING
MEETING ATTENDEES
MARCH 28 and 29, 1994

Name	Organization
R. Orr	Westinghouse
D. McDermott	Westinghouse
J. Wills	Westinghouse
D. Lingren	Westinghouse
J. Scobel	Westinghouse
T. Ahl	CBI (Westinghouse consultant)
K. Shembarger	NRC/NRR
T. Cheng	NRC/NRR
D. Smith	NRC/NRR
G. Bagchi	NRC/NRR
D. Terao	NRC/NRR
F. Fanous	Ames (NRC consultant)
L. Greimann	Ames (NRC consultant)

Enclosure 1

AP600 Containment Meeting

Meeting with the NRC

March 28 and 29, 1994

Enclosure 2

AP600 Containment Meeting
March 28 and 29, 1994
Agenda

Introduction	R. Orr
Purpose of meeting Transmittal of design information to NRC consultants SSAR and RAI status for Section 3.8.2	
Containment Design Basis Function	D. McDermott
Containment Severe Accident Function	J. Scobel
Containment Design Specification	R. Orr
Containment Structural Design and analysis	T. Ahl
Analyses of capacity for severe accidents	T. Ahl
Seismic Margin	R. Orr
Information for independent analyses	

WESTINGHOUSE AP600 CONTAINMENT VESSEL

CONTAINMENT DESIGN AND ANALYSIS PERFORMED BY CBI

- CBI CONTAINMENT CONFIGURATION SKETCHES

- MATERIAL PROPERTIES

- CONTAINMENT SHELL - FREE FIELD AND GROSS STRUCTURAL DISCONTINUITIES ANALYSIS

- LOCAL EFFECTS ANALYSIS AT MAJOR PENETRATIONS AND ATTACHMENTS

CONTAINMENT SHELL - FREE FIELD AND GROSS STRUCTURAL DISCONTINUITIES ANALYSIS

- DESIGN CASE - 45 PSIG at 280 DEGREES F.
- SERVICE LEVEL C CASE at 320 DEGREES F.
- SEVERE ACCIDENT CAPACITY ASSESSMENT at 70 DEGREES F
- STRESS EVALUATION DUE TO REPRESENTATIVE THERMAL GRADIENTS
- BUCKLING ANALYSIS AT SEVERE ACCIDENT PRESSURE
- SEISMIC MODELING

Table 3.8.2-1

Load Combinations and Service Limits For Containment Vessel

Load Description		Load combination and service limit									
		Test	Design	A	A	C	C	C	D	A	C
Dead	D	x	x	x	x	x	x	x	x	x	x
Live	L	x	x	x	x	x	x	x	x	x	x
Wind	W			x							
SSE	E_s					x	x		x		
Tornado	W_t							x			
Test pressure	P_t	x									
Test temperature	T_t	x									
Operating pressure	P_o			x							
Normal reaction	R_o			x			x	x		x	x
Normal thermal	T_o			x			x	x		x	x
Design pressure	P_d		x		x	x			x		
External pressure (2.5 psid)	P_e									x	
External pressure (3.0 psid)	T_o										x
Accident thermal	T_a		x		x	x			x		
Accident thermal reactions	R_a		x		x	x			x		
Accident pipe reactions	Y_r								x		
Jet impingement	Y_j								x		
Pipe impact	Y_m								x		

Notes:

1. Service limit levels are per ASME-NE.

2. Where any load reduces the effects of other loads, that load shall be taken as zero, unless it can be demonstrated that the load is always present or occurs simultaneously with the other loads.

STRESS-STRAIN CURVE (UNIAXIAL)

Assume elastic-perfectly plastic material properties.

Ignoring strain-hardening is conservative.

Yield strain, $\varepsilon_Y = \frac{\sigma_Y}{E} = \frac{60000}{29.5 \times 10^6} = 2.0339 \times 10^{-3}$ in/in.

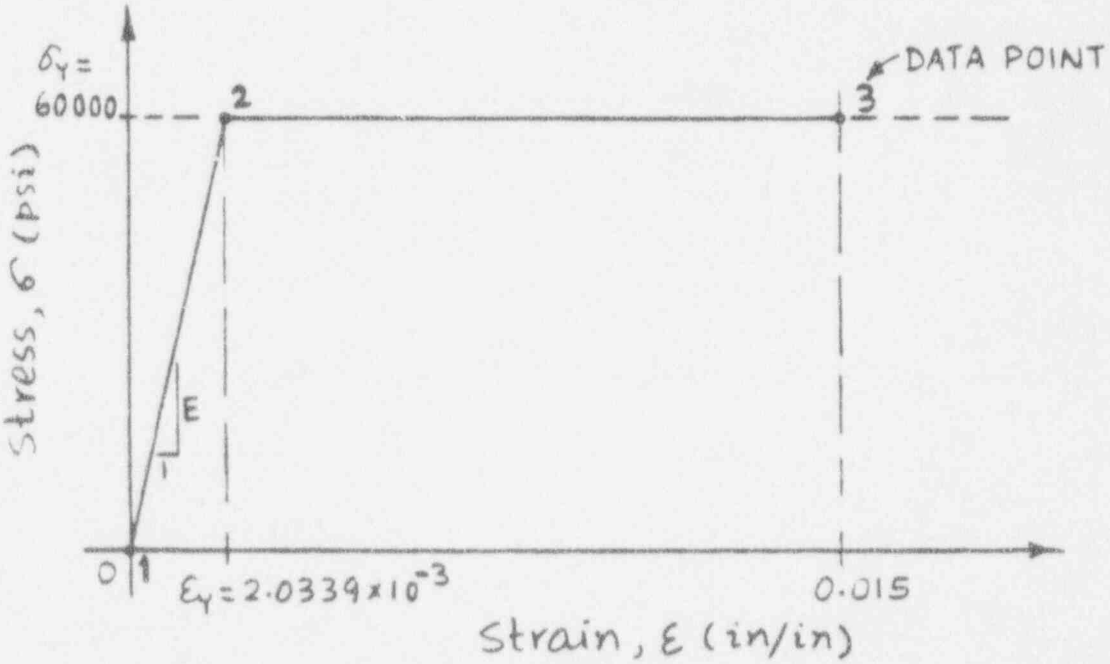

FIG. 3-2: STRESS-STRAIN CURVE FOR ANALYSIS

NOTE:

Effective stress at data point 3 has been modified by 'BOSOR5' program internally in order to obtain a minimum tangent modulus of 0.001E = 29500 psi. (σ_{eff} at data point 3 used in 'BOSOR5' is 60382 = 60000 + 29500[0.015 - 0.0020339].) This is normally done to improve the rate of convergence. This 'negligible' strain hardening will not have any significant effect on the results.

SUBJECT	OFFICE	REVISION		REFERENCE NO
BUCKLING CAPACITY EVALUATION	CBI NOE-A			902657
TASK #3, CBI PHASE 3 STUDY	MADE BY: RSR / VERIFIED BY: TJA	MADE BY	VERIFIED BY	SHT 3-5 OF ___
AP600, WESTINGHOUSE	DATE: 12/17/91 / DATE: 2/18/92	DATE	DATE	

AP600 CONTAINMENT VESSEL

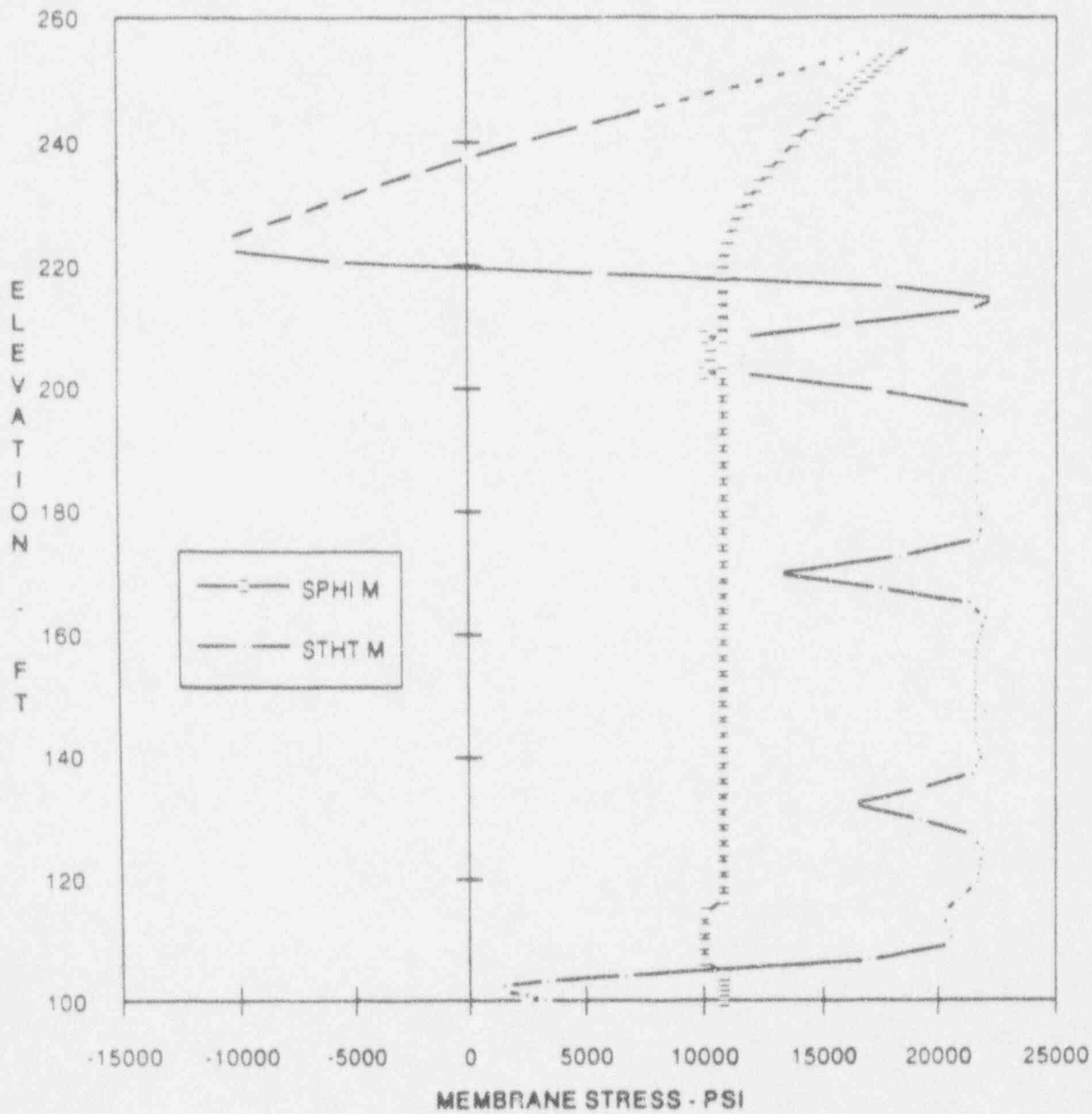

FIGURE 2 CONTAINMENT VESSEL RESPONSE TO INTERNAL DESIGN PRESSURE OF 45 PSIG - MEMBRANE STRESSES (SPHI = MERIDIONAL, STHT = CIRCUMFERENTIAL)

SUBJECT	OFFICE	REVISION	REFERENCE NO
TASK #1992-2, AP600, WESTINGHOUSE	CBI NOE-A		902657
	MADE BY: RSR; VERIFIED BY: TJA	MADE BY; VERIFIED BY	2B-15 SHT __ OF __
	DATE: 5/15/92; DATE: 5/20/92	DATE; DATE	

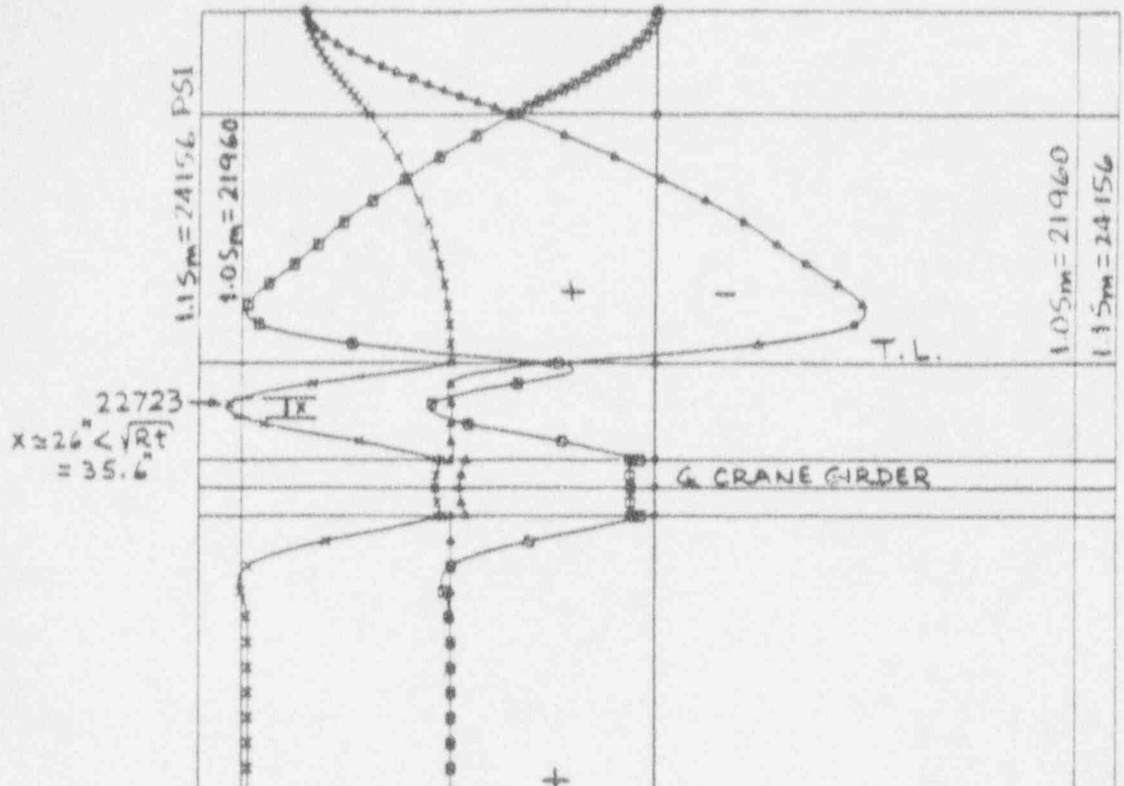

FIGURE 20

MEMBRANE PRINC. STRESS DIF. ALONG MERIDIAN -- □:S1-S2, Δ:S1-S3, X:S2-S3
902657 AP600 WESTINGHOUSE. PR: INTERNAL PRESSURE OF 45 PSI 9/19/91
MAXIMA 21718. 18644. 22723. PSI

SUBJECT	OFFICE	REVISION		REFERENCE NO
ASME LEVEL C PRESSURE	CBI NOE-A			902657
TASK #1, CBI PHASE 3 STUDY	MADE BY RSD / VERIFIED BY TJA	MADE BY	VERIFIED BY	SHT 1-36 OF
AP600, WESTINGHOUSE	DATE 9/30/91 / DATE 10/15/91	DATE	DATE	

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BUCKLING STRESS EVALUATION

AT THE BOTTOM T. L. (EL. 104'-1 1/2)

THE LOAD COMBINATION, 'D + L - SSE' RESULTS INTO MERIDIONAL COMPRESSION AND TANGENTIAL SHEAR. (SET 1: σ_φ = -2.7 KSI AND $\tau_{\varphi\theta}$ = 0.4 KSI; SET 2: σ_φ = -1.7 KSI AND $\tau_{\varphi\theta}$ = 1.1 KSI)

BUCKLING EVALUATION IS PERFORMED USING ASME III CODE CASE N-284 (PROPOSED REVISION). ALLOWABLES: $\sigma_{\varphi a}$ = -5.5 KSI AND $\tau_{\varphi\theta a}$ = 6.0 KSI.

MAXIMUM VALUE OF THE INTERACTION EQUATION FOR COMBINED 'AXIAL COMPRESSION + SHEAR' IS 0.5 (SET 1 CONTROLS), THE ALLOWABLE VALUE IS 1.0.

IN THE KNUCKLE

THE LOAD COMBINATION, 'P_d + T_a' = 'P_d' RESULTS INTO MERIDIONAL TENSION AND CIRCUMFERENTIAL COMPRESSION. (DUE TO P_d[a]: σ_φ = 11.0 KSI AND σ_θ = -10.5 KSI; DUE TO T_a[b]: σ_φ = 0.0 AND σ_θ = -0.1 KSI, NOTE THAT STRESSES DUE TO T_a ARE VERY SMALL)

BUCKLING EVALUATION IS PERFORMED BY BOSOR5 ANALYSIS USING INTERNAL PRESSURE ONLY AND A FACOR OF SAFETY FROM ASME III CODE CASE N-284.

THEORETICAL BUCKLING INTERNAL PRESSURE IS 174 PSIG. USING A FACTOR OF SAFTY OF 2.0, THE ALLOWABLE DESIGN PRESSURE IS 87 PSIG. ACTUAL DESIGN PRESSURE IS 45 PSIG.

[a]DESIGN PRESSURE OF 45 PSIG (INTERNAL).

[b]ACCIDENT THERMAL (SHELL BELOW EL. 132'-3, 70°F AND SHELL ABOVE EL. 132'-3 AND STIFFENERS, -40°F, AND CRANE GIRDER AT 50°F).

STRESS COMPONENTS AND STRESS INTENSITY EVALUATION AT THE BASE (EL. 100'-0)

P_d DESIGN PRESSURE OF 45 PSIG (INTERNAL)

T_a ACCIDENT THERMAL (SHELL BELOW EL. 100'-0, 70°F AND SHELL ABOVE EL. 100'-0, 280°F)

NOTE: STRESSES DUE TO D, L, AND SSE ARE NOT REPORTED HERE AS THEY ARE NOT EXPECTED TO BE CRITICAL FOR BUCKLING IN COMPARISON WITH THE STRESSES DUE TO T_a.

LOAD	LOCATION	TYPE	σ_φ	σ_θ	$\tau_{\varphi\theta}$	σ_I	σ_a
P_d	θ = 0° AND 90°	I	-6.2	-1.9	0		
		M	10.8	3.3	0		
		O	27.9	8.4	0		
T_a	θ = 0° AND 90°	I	67.2	-16.8	0		
		M	0.3	-36.9	0		
		O	-66.7	-57.0	0		
P_d	θ = 0° AND 90°	M	10.8	3.3	0	10.8	33[a]
		I / O	27.9	8.4	0	27.9	80[b]
P_d + T_a	θ = 0° AND 90°	M	11.1	-33.6	0	44.7	80[b,c]
		I / O	61.0	-18.7	0	79.7	80[b]

[a] 1.5 TIMES S_{mc} FOR 'P_L' OR '$P_L + P_b$'.

[b] 3.0 TIMES S_{m1} FOR '$P_L + P_b + Q$'.

[c] BUCKLING EVALUATION IS NOT YET COMPLETE.

Table 3.8.2-2

Containment Vessel Pressure Capabilities

Containment Element	Pressure Capability at Ambient Temperature	
	Deterministic Severe Accident Capacity(1)	Minimum Specified Yield(2)
Cylinder	125 psig ①	144 psig ②
Ellipsoidal Head	104 psig ③	146 psig ④ 174 — for buckling F.S. = 1.0
22 foot equipment hatch	117 psig ⑤	196 psig ⑥
16 foot equipment hatch	96 psig ⑦	161 psig ⑧
Personnel airlocks(3)	>163 psig ⑨ Test w F.S. =	>300 psig ⑩ Test S

(1) The buckling capacity of the ellipsoidal head is taken as sixty percent of the critical buckling pressure calculated by the BOSOR-5 non-linear analyses. Evaluations of the other elements are according to ASME Service Level C and include use of Code Case N284.

(2) The estimated maximum pressure capability is based on minimum specified material properties.

(3) The capacities of the personnel airlock are estimated from test results.

① Based on tensile stress $p = \frac{St}{R} = \frac{60000 \times 1.625}{780} = 125$ psi

② Based on von Mises – tensile stress $p = \frac{St}{R}\frac{2}{\sqrt{3}} = 144$ psi

③ Based on buckling $p = \frac{173}{1.67} = 104$ psi $1.67 = \frac{2}{1.2}$

④ Based on tensile stress at crown (von Mises) $p = \frac{2St}{R} = \frac{60000 \times 1.625}{1347} = 146$ Bosor
145 longhand

⑤ N-284 F.S = 1.67

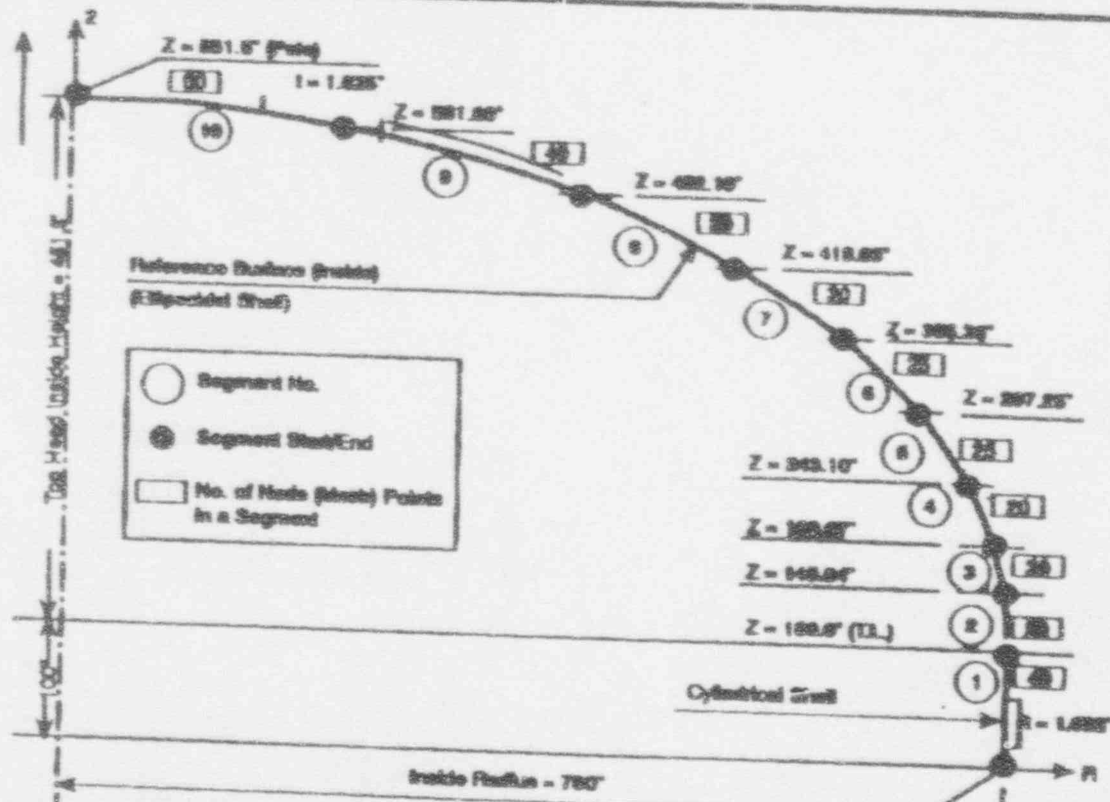
⑥ N-284 F.S. = 1.00

⑦ N-284 F.S = 1.67

⑧ N-284 F.S. = 1.0

⑨ Based on $\frac{S_u}{S_y} = \frac{70000}{38000} = 1.84$ $\frac{300}{1.84} = 163$

BOSOR-5 Model of Containment Vessel Head



Boundary Condition: Axial and Circumferential Displacements and Meridional Rotation = 0 (Fixed), and Radial Displacement Free.

Thickness, t = 1.685"

Material: SA537 Class 2

Material Properties at Ambient Temperature:

Modulus of Elasticity = 29.5E6 PSI, Poisson's Ratio = 3.0,

Yield Strength = 60,000 PSI.

40086.17

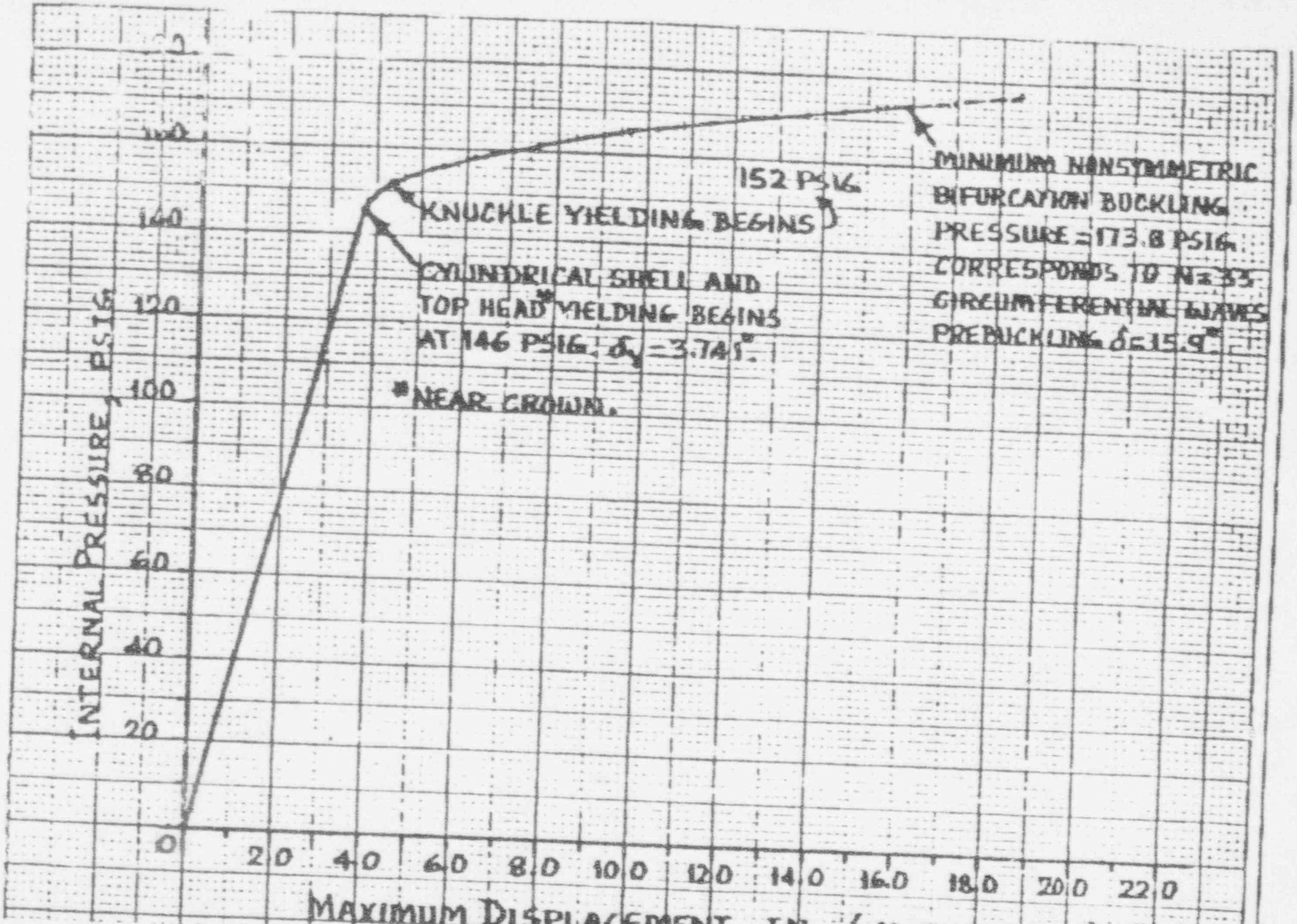


FIG. 3.5: INTERNAL PRESSURE-MAXIMUM DISPLACEMENT CURVE

902657: BUCKLING OF TOP HEAD 12/17/91 3

DEFORMED STRUCTURE

LOAD STEP 42. LOAD = 1.738E+02 PRESTRESS PSIG

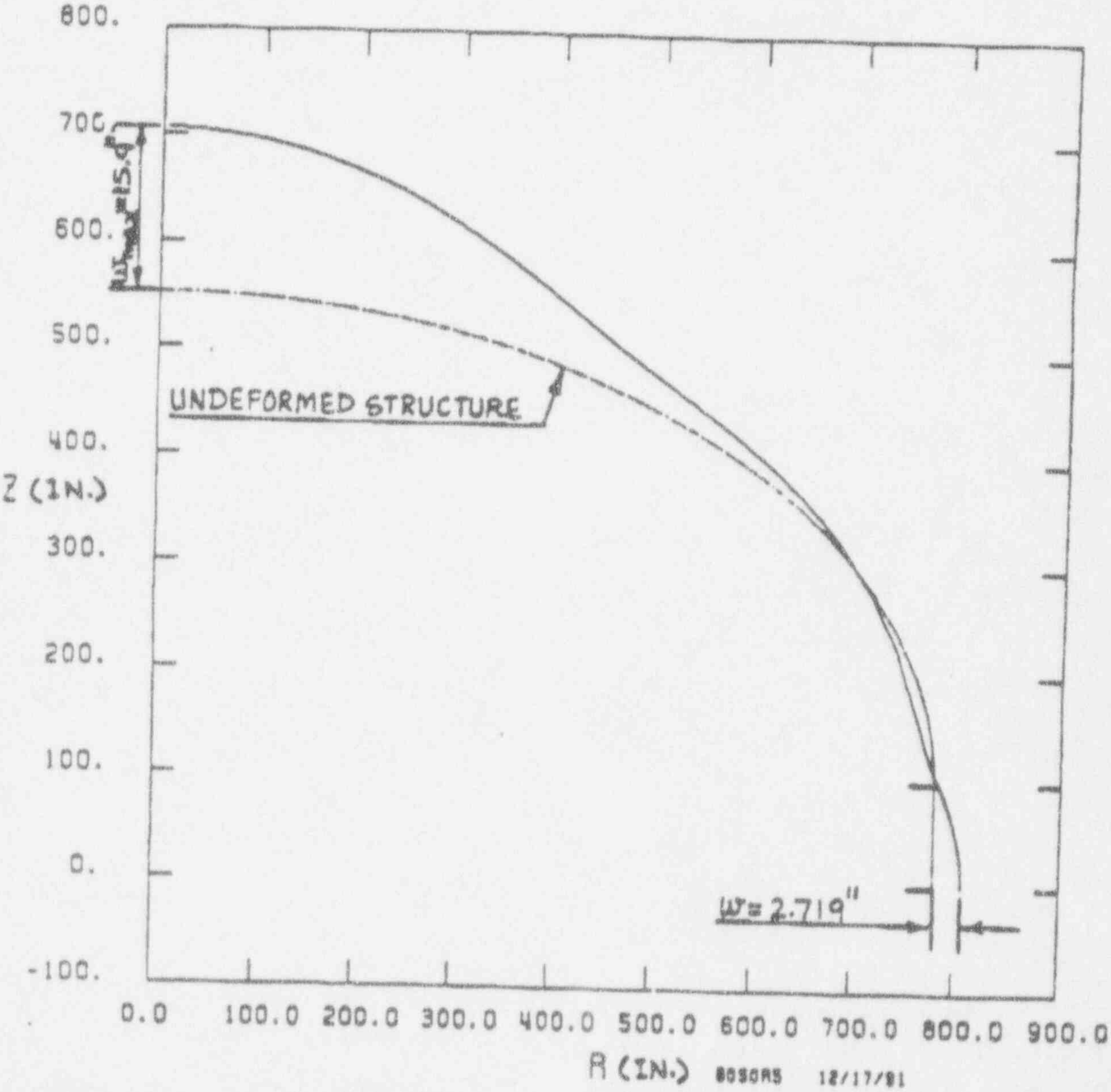


FIG. 3-6: PREBUCKLING DISPLACEMENTS AT $P_{cr_{MIN}}$ = 173.8 PSIG (BOSOR5)

SUBJECT	OFFICE	REVISION		REFERENCE NO.
BUCKLING CAPACITY EVALUATION	CBI NOE-A			902657
TASK #3, CBI PHASE 3 STUDY	MADE BY RSR	VERIFIED BY RA	MADE BY	VERIFIED BY	SHT 3-12 OF
AP600, WESTINGHOUSE	DATE 12/17/91	DATE 2/12/96	DATE	DATE	

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GO 944 AUG 87

STRESS COMPONENTS AND STRESS INTENSITY EVALUATION AT THE TOP T. L. (EL. 218'-8 1/2)

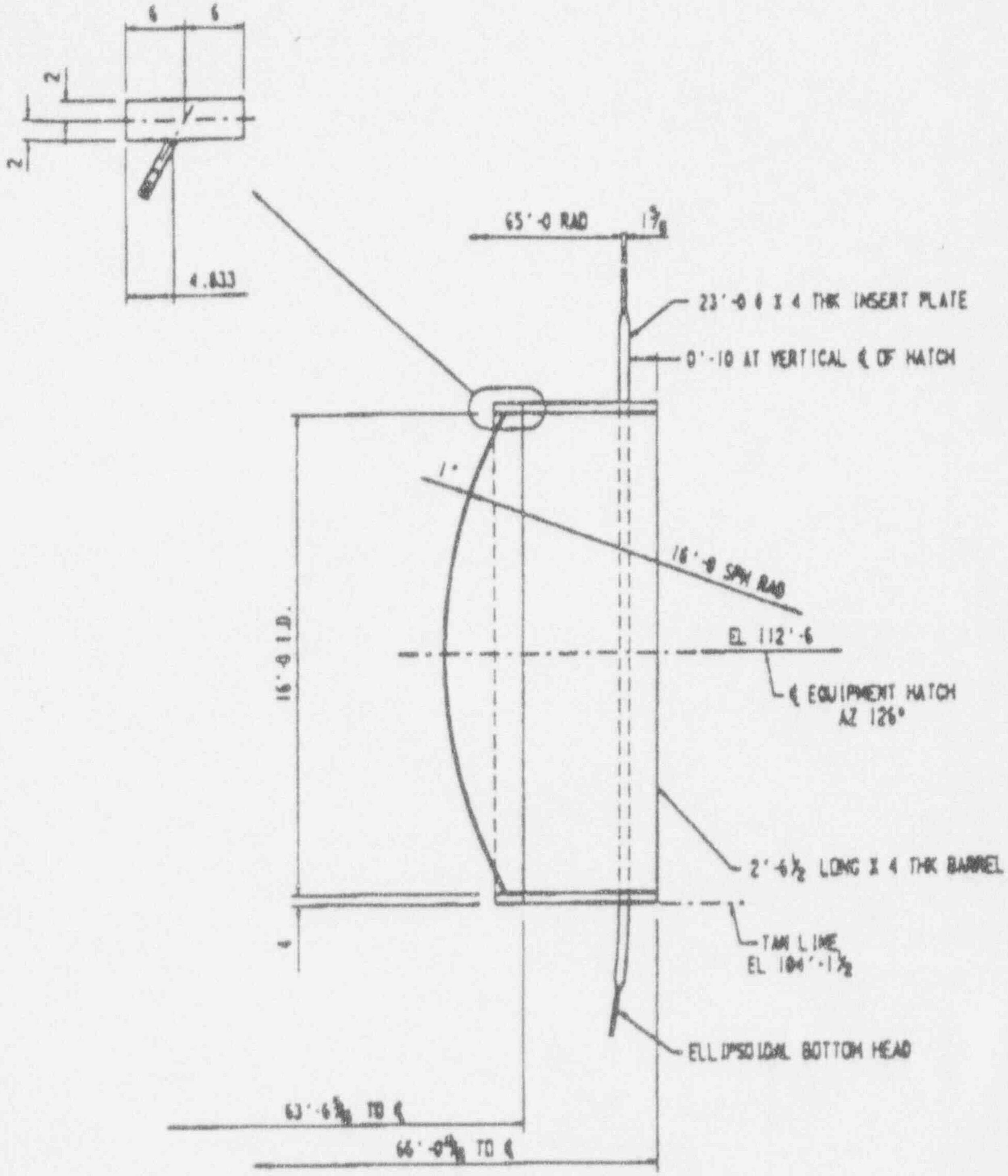
P_d DESIGN PRESSURE OF 45 PSIG (INTERNAL)
T_a ACCIDENT THERMAL (SHELL BELOW EL. 132'-3, 70°F AND SHELL ABOVE EL. 132'-3 AND STIFFENERS, -40°F, AND CRANE GIRDER AT 50°F)

ASSUMPTION: STRESSES DUE TO D, L, AND SSE ARE SMALL.

LOAD	LOCATION	TYPE	σ_φ	σ_θ	$\tau_{\varphi\theta}$	σ_I	σ_a
P_d	θ = 0° AND 90°	I	11.2	5.8	0		
		M	10.8	5.6	0		
		O	10.4	5.5	0		
T_a	θ = 0° AND 90°	I	-0.1	-0.2	0		
		M	0.0	-0.1	0		
		O	0.1	-0.1	0		
P_d	θ = 0° AND 90°	M	10.8	5.6	0	10.8	33[a]
		I / O	11.2	5.8	0	11.2	80[b]
P_d + T_a	θ = 0° AND 90°	M	10.8	5.5	0	10.8	80[b]
		I / O	11.1	5.6	0	11.1	80[b]

[a] 1.5 TIMES S_{mc} FOR 'P_L' OR '$P_L + P_b$'.

[b] 3.0 TIMES S_{m1} FOR '$P_L + P_b + Q$'.



16'-0 I.D. EQUIPMENT HATCH

LOCAL EFFECTS AT MAJOR PENETRATIONS AND ATTACHMENTS

- CRANE GIRDER
- PERSONNEL AIRLOCK
- EQUIPMENT HATCHES
- MAIN STEAM AND FEEDWATER PENETRATIONS
- ROOF CONSTRUCTION SUPPORTS

SEISMIC MODELING

SEVERE ACCIDENT CASE - DETERMINE CAPACITY

- LONGHAND CALCULATIONS BASED ON TENSILE STRESSES REACHING YIELD
- BUCKLING CONSIDERATIONS

PASSIVE CONTAINMENT COOLING SYSTEM

JANUARY 20, 1994
DAN MCDERMOTT

AP600

PASSIVE CONTAINMENT COOLING SYSTEM DESIGN BASIS

- Limit peak containment pressure to less than 45 psig design pressure for design basis events (large LOCA, steamline break)
- Reduce containment pressure to 1/2 peak pressure within 24 hours
- Cooling water supplied for 3 days with no operator action or outside assistance, provisions for simple actions to replenish water supply within 3 days
- As a goal, limit containment pressure to <45 psig for an indefinite time, even if no action is taken to replenish water supply

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PASSIVE CONTAINMENT COOLING SYSTEM DESIGN BASIS

- Automatically actuated
- Once actuated, operation shall not be dependent on electrical power, continuous operation of mechanical components
- Meets single failure criteria for design basis events
- System reliability consistent with plant CMF and SRF criteria

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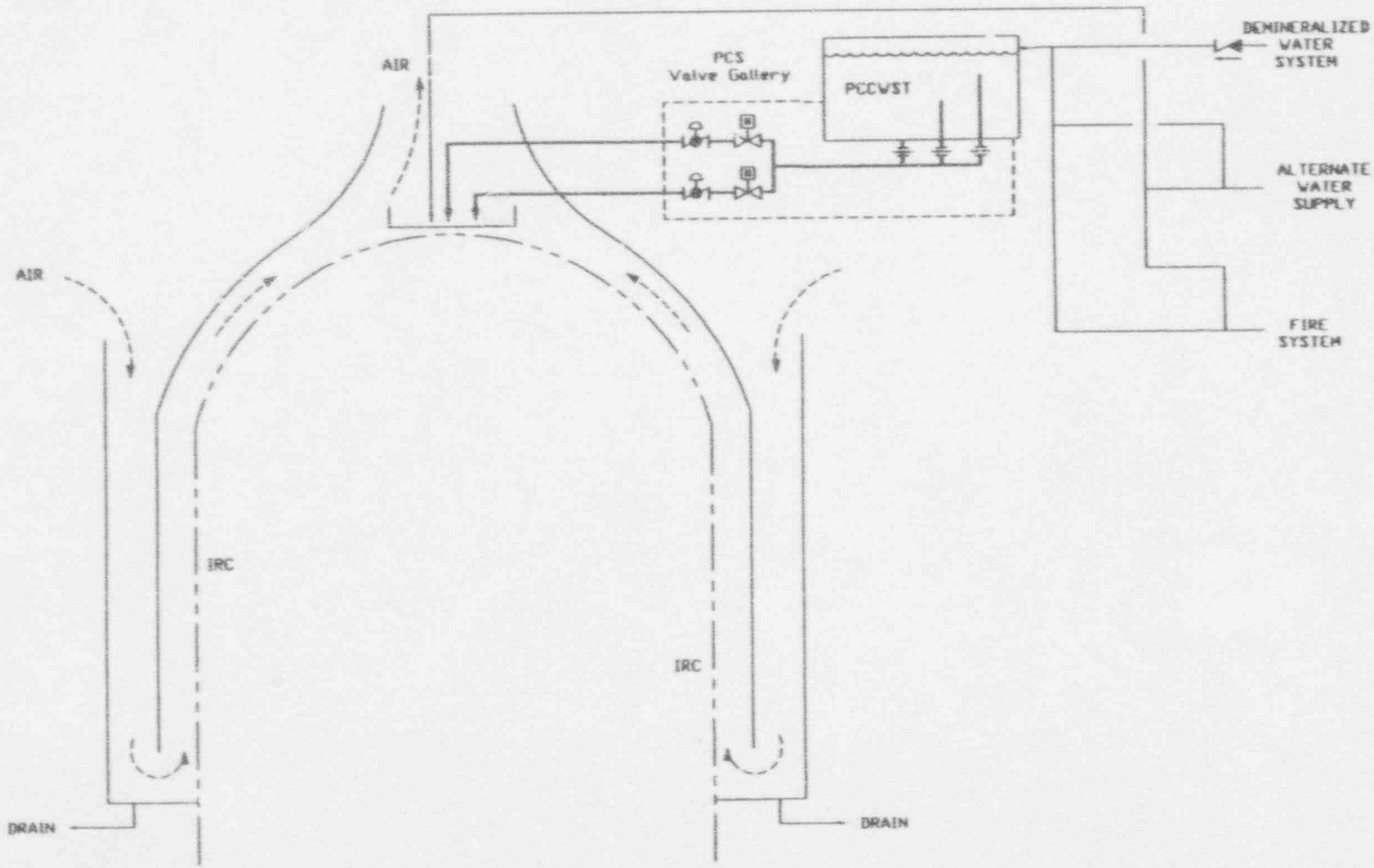
PCS - SIMPLIFIED SKETCH



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PASSIVE CONTAINMENT COOLING SYSTEM
SYSTEM FEATURES

- Containment wetting for evaporative cooling
  - Water storage tank
    - Integrated into the Shield Building
    - 400,000 gallons useable volume
    - Gravity Drain
  - Parallel Fail Open Isolation Valves
    - Leakage Detection
  - Water distribution bucket (30" Diameter)
  - Water distribution features
    - Two Acceptable Configurations
    - Distribution Arms
    - Weir Water Distributers (Coverage 90% to 35%)
  - Annulus Drains
  - Long Term makeup water (Beyond 72 hours)

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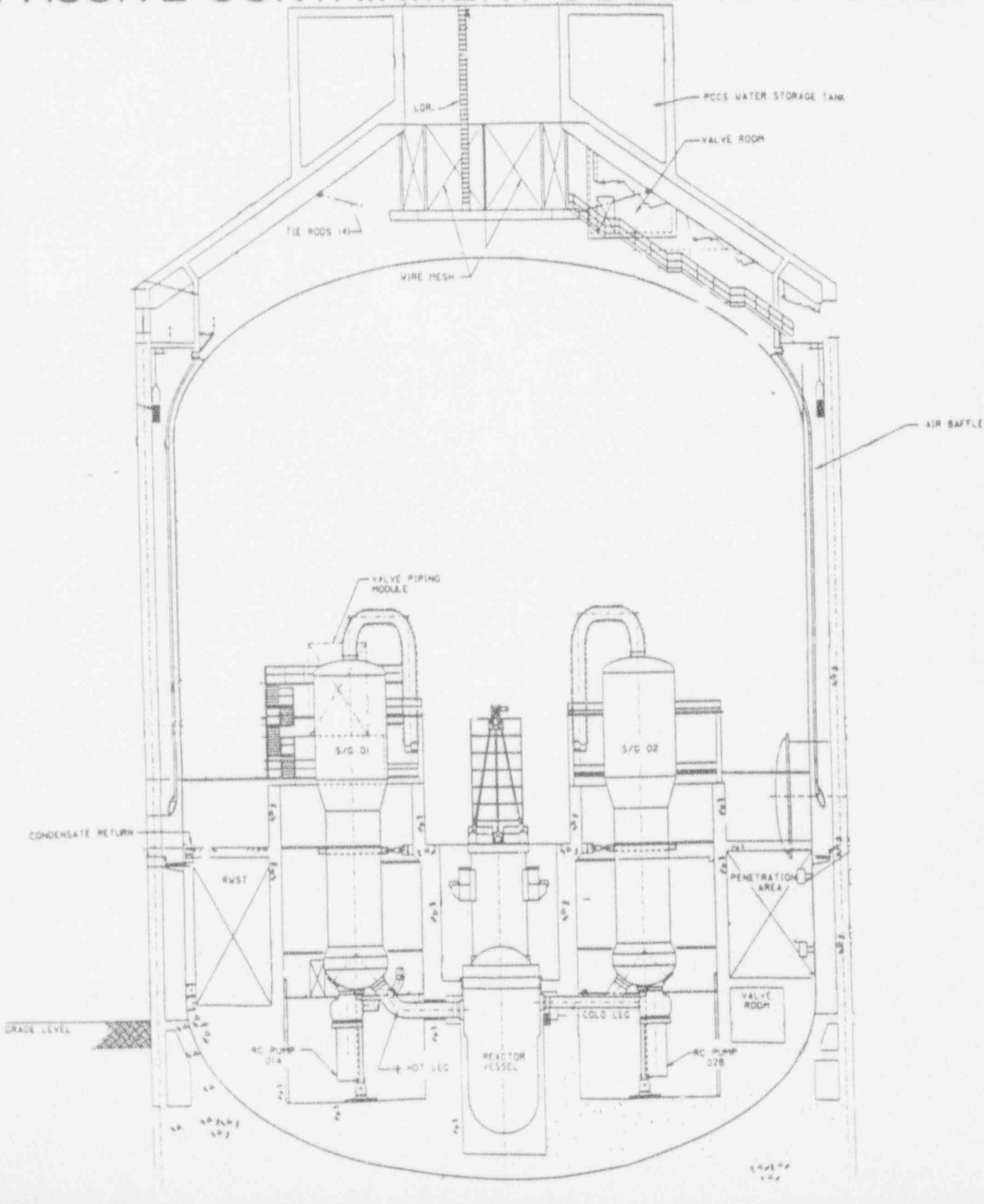
PASSIVE CONTAINMENT COOLING SYSTEM



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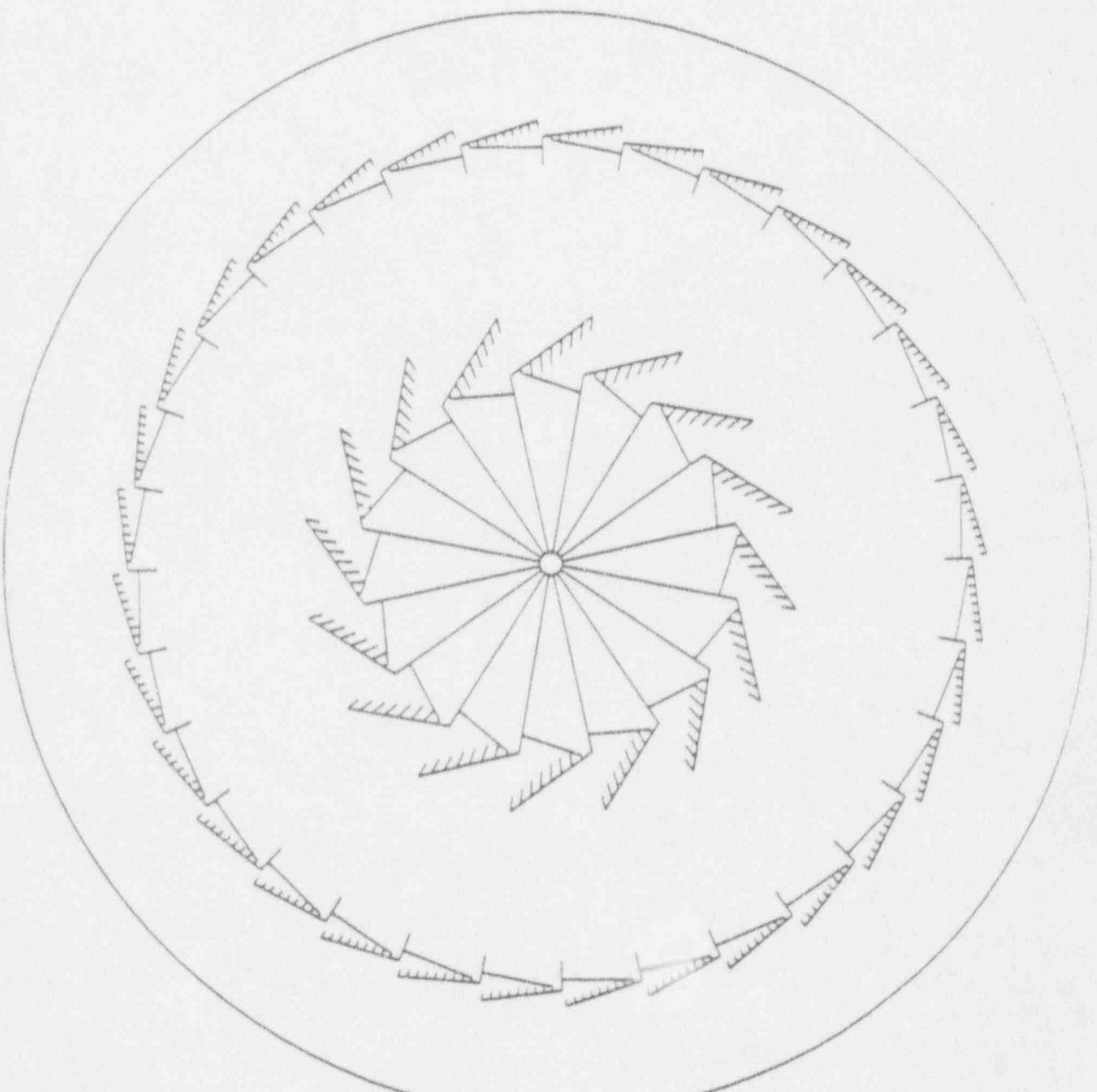
PASSIVE CONTAINMENT COOLING SYSTEM WATER DISTRIBUTION

Containment dome plan view



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CONTAINMENT COOLING SCENARIOS

- Loss of Coolant Accident
- Steam Line Break
- Passive Residual Heat Removal Transients
- Negative Pressure Transients

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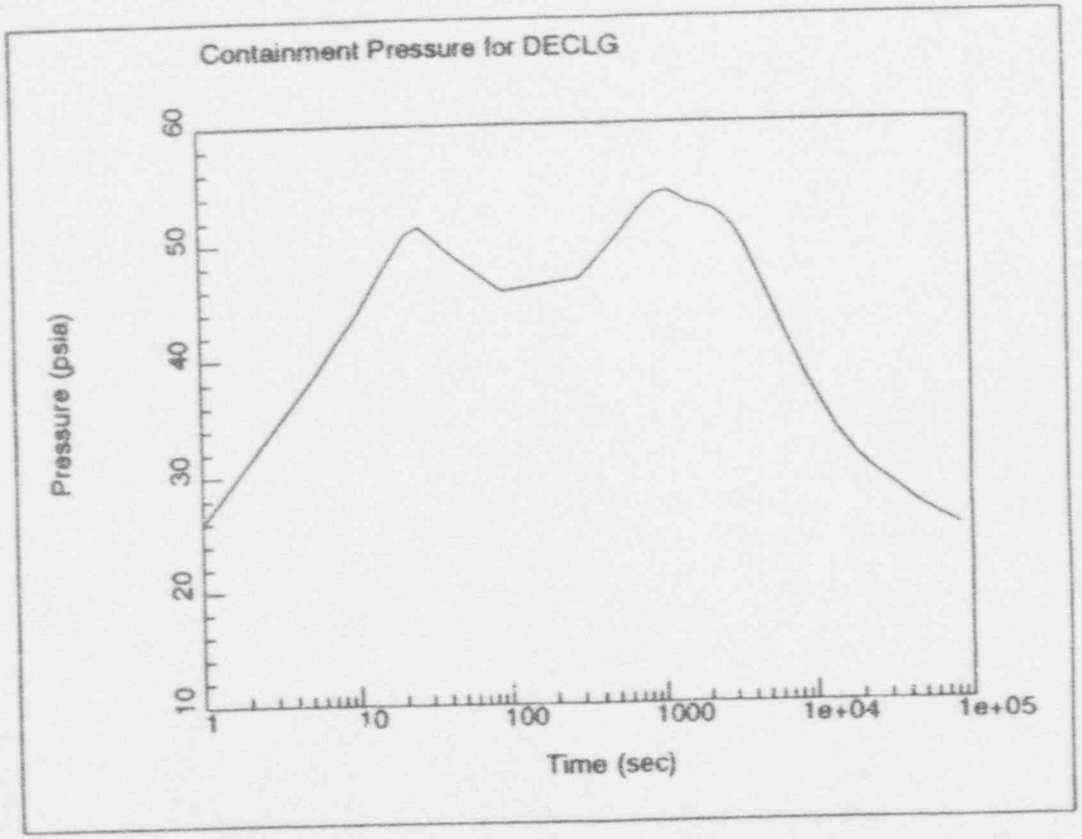
CONTAINMENT COOLING SCENARIOS
LOSS OF COOLANT ACCIDENT



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CONTAINMENT COOLING SCENARIOS

LOSS OF COOLANT ACCIDENT - TEMPERATURE PROFILES

Containment Shell Temperature Profiles for Cold Leg Break

		Dome		Spring Line		Operating Deck[1]	
Time		Wet	Dry	Wet	Dry	Wet	Dry
0.	I						
	O						
100.	I						
	O						
700.	I						
	O						
1300.	I						
	O						
1900.	I						
	O						
3100.	I						
	O						
7600.	I						
	O						
19600.	I						
	O						
31600.	I						
	O						
86400.	I						
	O						

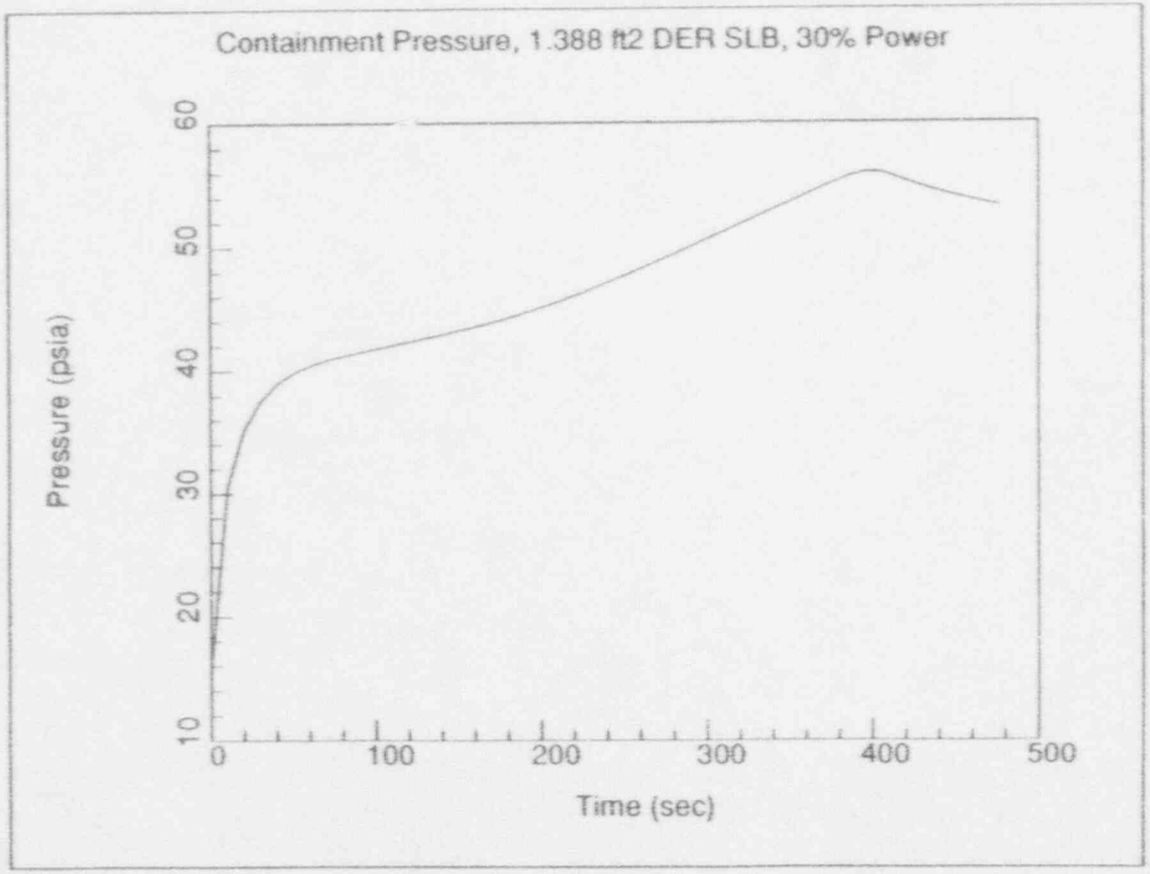
b

Notes: 1 w/phenolic coating inside
I - Inside shell
O - Outside shell

AP600

CONTAINMENT COOLING SCENARIOS

STEAM LINE BREAK



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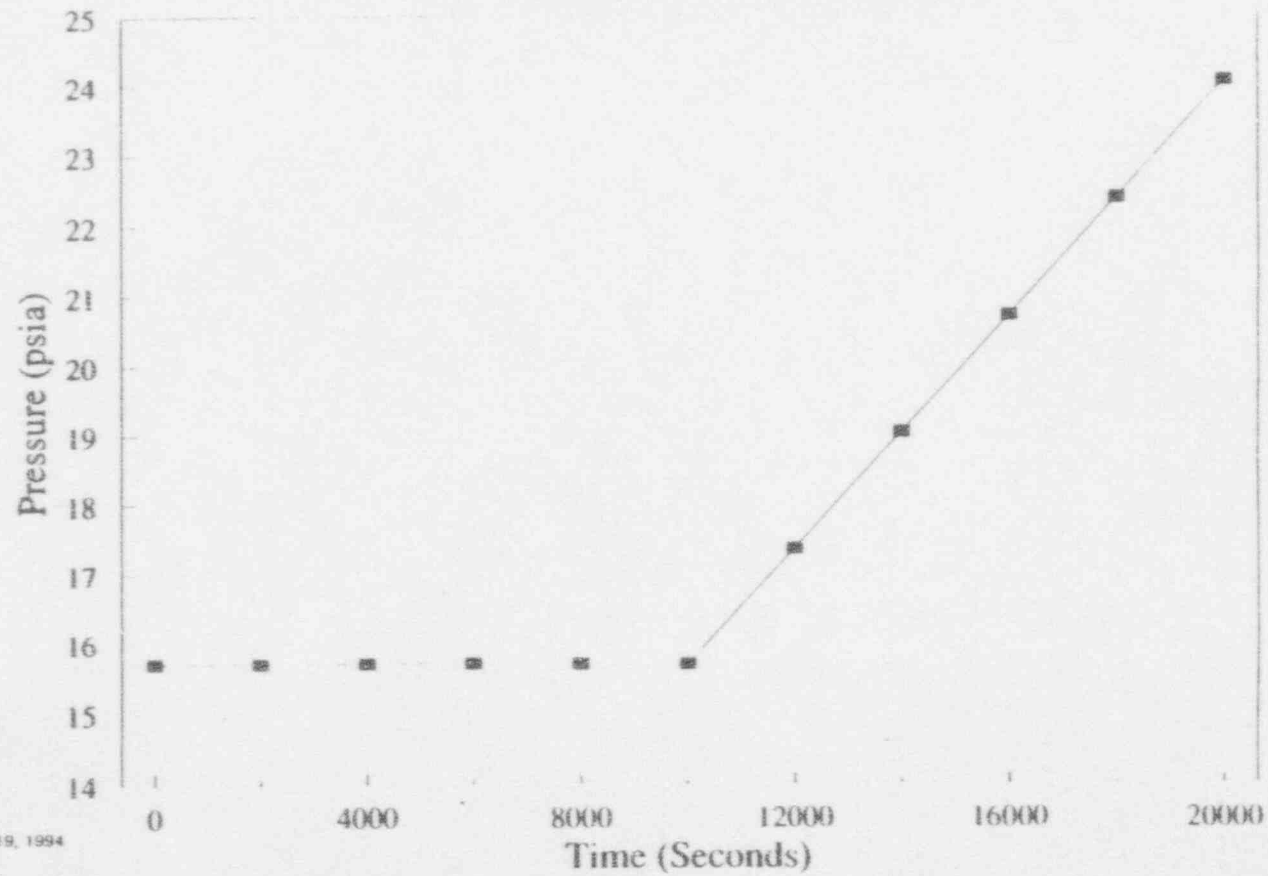
AP600

CONTAINMENT COOLING SCENARIOS
PASSIVE RESIDUAL HEAT REMOVAL TRANSIENTS

PASSIVE RHR OPERATION
Pressure Transient versus Time



DJM PCS12094 AP6 January 19, 1994

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CONTAINMENT COOLING SCENARIOS
NEGATIVE PRESSURE TRANSIENTS

- Events Considered
  - PCS actuation
  - IRWST Pumpout
  - Failed Fan Cooler Control
  - Purge System Maloperation
  - Loss of all AC @ Limiting Environmental Conditions

- Environmental Conditions (-40 F/45 mph wind)
- Results (hand calculations) <3.0 psid @ 30 minutes
- Event Termination

CONTAINMENT COOLING SCENARIOS

CONTAINMENT TESTING PROGRAMS

CONTAINMENT WATER DISTRIBUTION TESTS

OBJECTIVES: CHARACTERIZE WATER DISTRIBUTION FOR
- RANGE OF FLOWS
- VARIETY OF DISTRIBUTION MECHANISMS
- WORST CASE SURFACE DEFECTS
- ESTABLISHMENT OF WATER DISTRIBUTION DESIGN

LARGE SCALE CONTAINMENT COOLING SYSTEM TESTS

OBJECTIVES: TO PROVIDE DATA TO VERIFY CONTAINMENT COMPUTER CODES AND MODELS USED TO ASSESS PCS PERFORMANCE OVER
- RANGE OF VESSEL PRESSURES
- RANGE OF WATER DISTRIBUTIONS
- RANGE OF AIR VELOCITIES

WIND TUNNEL TESTS

OBJECTIVES:
- DETERMINE WORST CASE PRESSURE DISTRIBUTION DEVELOPED ACROSS THE AIR BAFFLE
- DEMONSTRATE INTERACTIONS OF WIND AND BUILDINGS WILL NOT CAUSE A DECREASE IN NATURAL CIRCULATION COOLING

INTEGRAL CONTAINMENT COOLING TEST

OBJECTIVE: CONFIRM THE OPERATION AND HEAT REMOVAL CAPABILITY OF THE PASSIVE CONTAINMENT COOLING DURING ACCIDENT CONDITIONS