Westinghouse
Electric Corporation

Energy Systems

Box 355
Pittsburgh Pennsylvania 15230 0355

AW-94-604

March 21, 1994

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: MR. R. W. BORCHARDT

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: PRESENTATION MATERIALS FROM THE MARCH 17, 1994 MEETING ON AP600 PASSIVE CONTAINMENT COOLING SYSTEM DESIGN BASIS ANALYSES

Dear Mr. Borchardt:

The application for withholding is submitted by Westinghouse Electric Corporation ("Westinghouse") pursuant to the provisions of paragraph (b)(1) of Section 2.790 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10CFR Section 2.790, Affidavit AW-94-604 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-94-604 and should be addressed to the undersigned.

Very truly yours,

N. J. Liparulo, Manager
Nuclear Safety And Regulatory Activities

/nja

cc: Kevin Bohrer NRC 12H5

1588A

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Brian A. McIntyre, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Corporation ("Westinghouse") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Brian A. McIntyre, Manager
Advanced Plant Safety & Licensing

Sworn to and subscribed
before me this 23 day
of March, 1994

Rose Marie Payne

Notary Public

Notarial Seal
Rose Marie Payne, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Nov. 4, 1996
Member, Pennsylvania Association of Notaries

(1) I am Manager, Advanced Plant Safety and Licensing, in the Advanced Technology Business Area, of the Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Energy Systems Business Unit.

(2) I am making this Affidavit in conformance with the provisions of 10CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by the Westinghouse Energy Systems Business Unit in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) Enclosed is Letter NTD-NRC-94-4083, March 21, 1994, being transmitted by Westinghouse Electric Corporation (W) letter and Application for Withholding Proprietary Information from Public Disclosure, N. J. Liparulo (W), to Mr. R. W. Borchardt, Office of NRR. The proprietary information as submitted for use by Westinghouse Electric Corporation is in response to questions concerning the AP600 plant and the associated design certification application and is expected to be applicable in other licensee submittals in response to certain NRC requirements for justification of licensing advanced nuclear power plant designs.

This information is part of that which will enable Westinghouse to:

(a) Demonstrate the design and safety of the AP600 Passive Safety Systems.

(b) Establish applicable verification testing methods.

(c) Design Advanced Nuclear Power Plants that meet NRC requirements.

(d) Establish technical and licensing approaches for the AP600 that will ultimately result in a certified design.

(e) Assist customers in obtaining NRC approval for future plants.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting NRC requirements for advanced plant licenses.

(b) Westinghouse can sell support and defense of the technology to its customers in the licensing process.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar advanced nuclear power designs and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for developing analytical methods and receiving NRC approval for those methods.

Further the deponent sayeth not.

Attachment 2 to Westinghouse Letter NTD-NRC-94-4083

Special NRC/Westinghouse Meeting

NRC Draft Safety Evaluation Report Information Needs For Design Basis Analysis

March 17, 1994

Agenda

Proposed Goals of DSER Info Exchange

DSER Information Exchange Schedule Draft

AP600 Design Basis Analysis Codes & Methods

AP600 WGOTHIC Model Sensitivities

PCCS Large Scale Test WGOTHIC Sensitivities

Content of June 30, 1994 Westinghouse Letter Report to NRC

Agreement on schedule for DBA DSER information

Proposed Goals of DSER Info Exchange

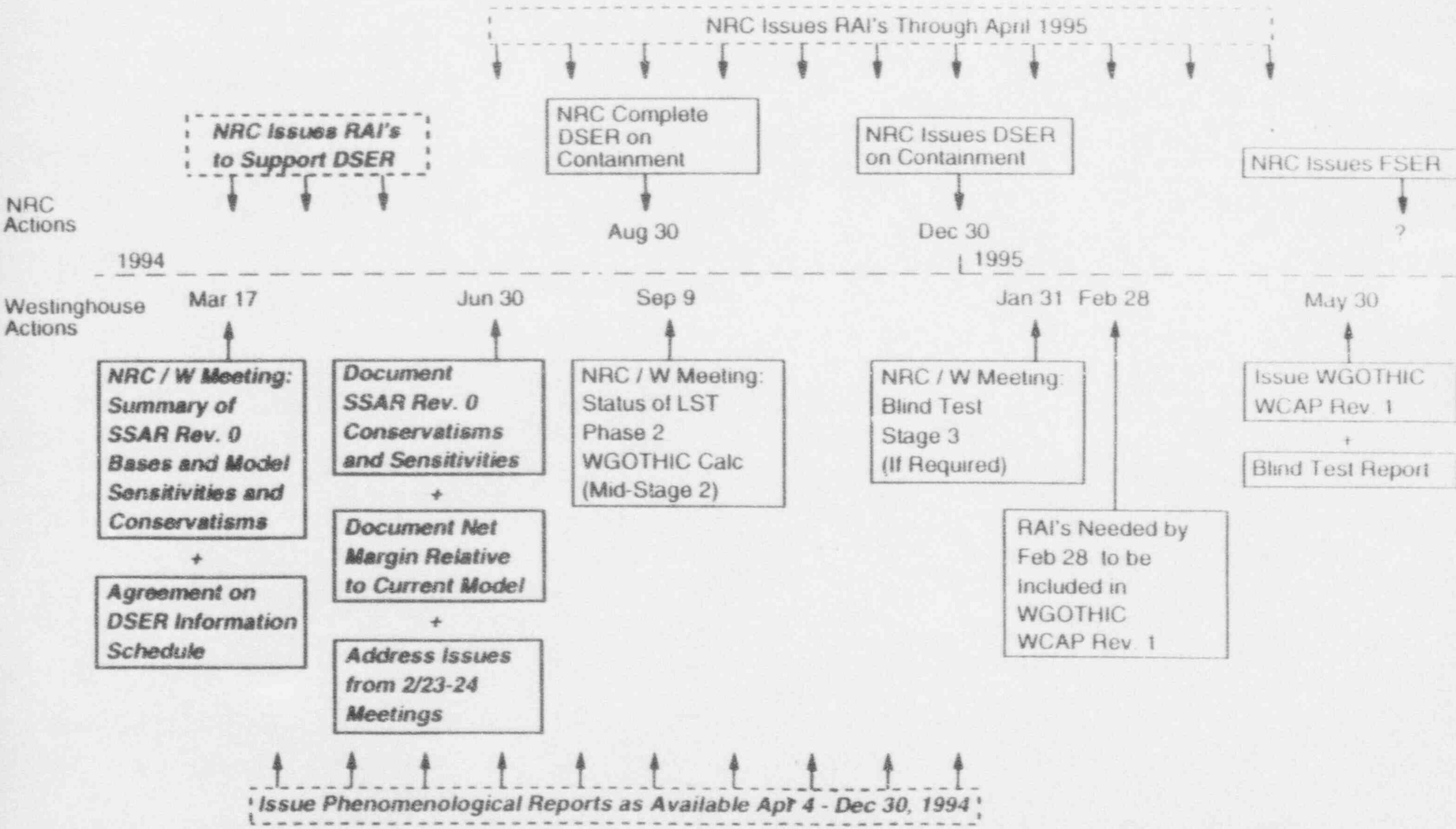
Show SSAR Rev. 0 containment response is conservative
- LOCA M&E
- SLB M&E (PCCS has little impact <600 seconds)
- Containment response B.C.'s and I.C.'s
- Heat & Mass transfer correlations are conservative
- Show effect of overmixing non-condensibles

Show sensitivities in containment response models to support NRC decision making
- Identify which issues are less important effects for DBA
- Show no "cliffs" in models
- Show WGOTHIC behaves as expected and reasonably

Provide other information that supports NRC DSER needs
- Discuss NRC schedule to identify those needs

Show that subsequent model changes do not adversely impact conclusion that SSAR Rev. 0 containment DBA is conservative
- Improvements lead to increased understanding of PCCS performance under postulated conditions

Proposed NRC / Westinghouse Information Exchange Schedule to Support NRC Safety Evaluation Report Needs.



Planned Information Exchange Process

Westinghouse to address NRC DSER needs:

Meet with NRC to address concerns raised on Feb 23-24

- March 17 - SSAR conservatisms and sensitivities
- TBD - Phenomena questions

Provide letter report by June 30 to document presentations of March 17 and "TBD"

Westinghouse to provide updated information as soon as it is available:

Phenomenological reports as they are completed - April 4 through December 31, 1994

Meet with NRC in September 1994 to discuss Status of LST Phase 2 WGOTHIC calculations (Mid Stage 2)

Meet with NRC about January 1995 to discuss Blind Test results (Stage 3) -- optional --

RAI responses within 90 days of receipt

WGOTHIC WCAP Rev. 1 - May 1995

WGOTHIC Blind Test Report - May 1995

AP600 Design Basis Analysis
Codes, Methods, & Conservatisms

General Model Description

Short Term M&E Releases

Subcompartment Pressurization

Long Term LOCA M&E Releases

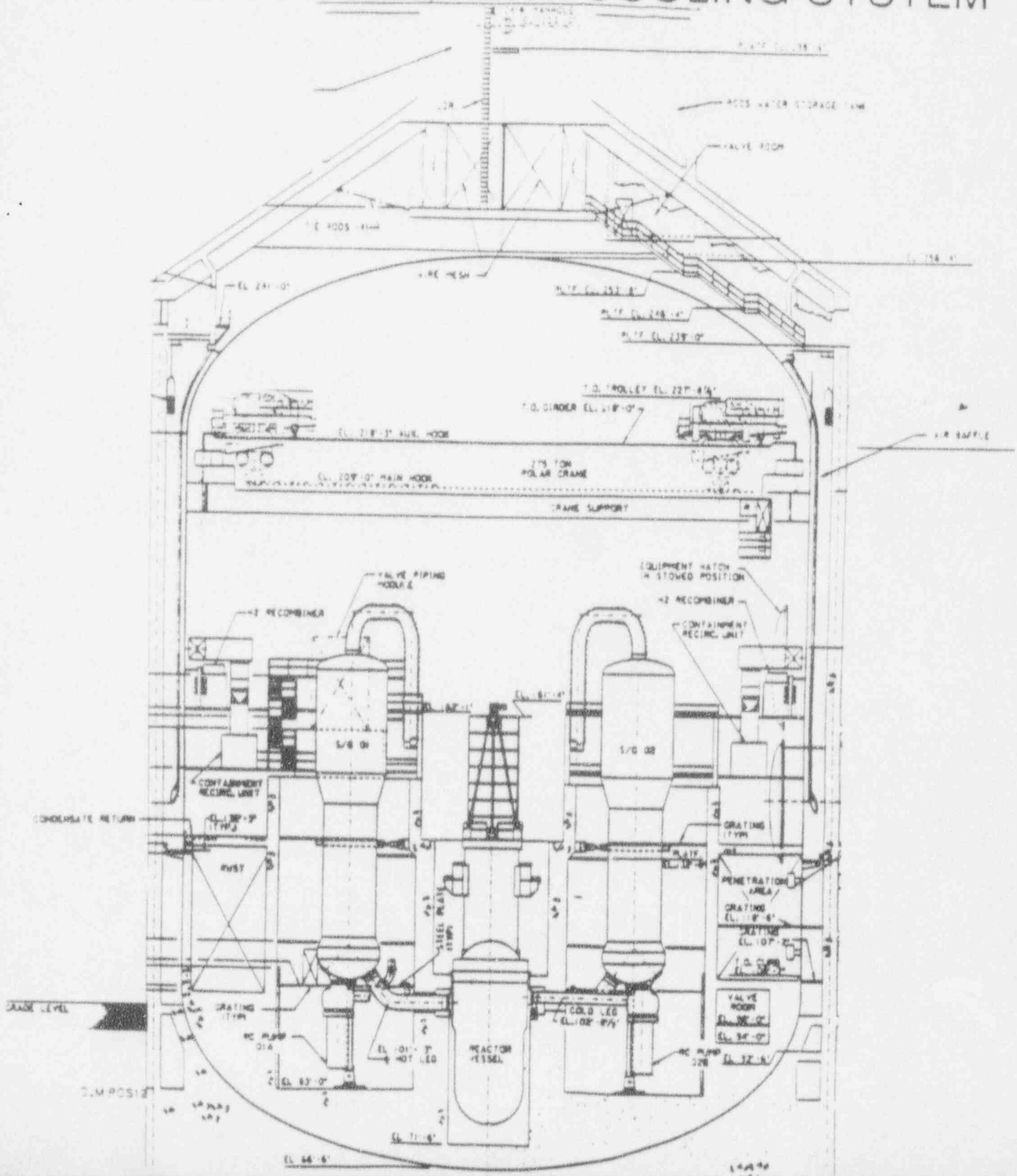
Steamline Break M&E Releases

Containment Pressure & Temperature Response Calculation

- LOCA
- Steamline Break

AP600

PASSIVE CONTAINMENT COOLING SYSTEM



(a, c)

FIGURE 1 WGOTHIC REPRESENTATION OF CONTAINMENT SHELL
(SSAR Model - Half Symmetry)

WGOTHIC CORRELATIONS USED IN WCAP-13246, REV. 0

1.0 Convective Heat Transfer

1.1 External

McAdams turbulent free convection :

$$Nu_{x,free} = 0.13 (Gr_x Pr)^{1/3}$$

and Colburn turbulent forced convection:

$$Nu_{d,forc} = 0.023 Re_d^{4/5} Pr^{1/3}$$

1.2 Internal

McAdams turbulent free convection :

$$Nu_{x,free} = 0.13 (Gr_x Pr)^{1/3}$$

and Colburn turbulent forced convection:

$$Nu_{d,forc} = 0.023 Re_d^{4/5} Pr^{1/3}$$

WGOTHIC CORRELATIONS USED IN WCAP-13246, REV. 0 (cont.)

1.3 User had to choose between free and forced convection

2.0 Mass Transfer - Using heat and mass transfer analogy

The analogy based on McAdams turbulent free convection is:

$$Sh = 0.13(Gr_x Sc)^{1/3}$$

and analogy based on Colburn turbulent forced convection is :

$$Sh = 0.023 Re_d^{4/5} Sc^{1/3}$$

3.0 Liquid Film Heat Transfer

The Chun and Seban correlation for wavy laminar films:

$$Nu = 0.822 Re^{-.22}$$

$$Nu = \frac{h}{k}\left(\frac{\nu^2}{g\sin\theta}\right)^{1/3} \quad and \quad Re = 4\frac{\Gamma}{\mu}$$

4.0 Liquid Film Enthalpy Transport - This model was not in Rev.0 of WCAP-13246. In the LST WGOTHIC model (in Rev. 0 of WCAP-13246) the subcooling of the applied liquid film was simulated.

5.0 Entrance Effect - This model was not included in Rev. 0 of WCAP

II. SELECT MODELS For WCAP-13246, Rev 1

1.0 Convective Heat Transfer

1.1 EXTERNAL

The McAdams[1] turbulent free convection heat transfer correlation:

$$Nu_{x,free} = 0.13(Gr_x Pr)^{1/3} \qquad (1)$$

and the Colburn[2] turbulent forced convection heat transfer correlation:

$$Nu_{d,forc} = 0.023 Re_d^{4/5} Pr^{1/3} \qquad (2)$$

are used for the external convective heat transfer to or from the surfaces.

1.2 INTERNAL

The McAdams turbulent free convection heat transfer correlation:

$$Nu_{x,free} = 0.13(Gr_x Pr)^{1/3} \qquad (3)$$

and the smooth flat plate[3] turbulent forced convection heat transfer correlation:

$$Nu_{x,forc} = 0.0296 Re_x^{4/5} Pr^{1/3} \qquad (4)^*$$

are used for the internal convective heat transfer to or from the surfaces.

1.3 COMBINED FREE AND FORCED

The correlations for combined free and forced convection heat transfer from Churchill[4] are, for turbulent opposed free and forced convection:

$$Nu = (Nu_{free}^3 + Nu_{forc}^3)^{1/3} \qquad (5)^*$$

and for assisting free and forced convection, h_c is the larger of the following three expressions:

$$abs(Nu_{free}^3 - N_{forc}^3)^{1/3} \quad ; \quad 0.75 Nu_{free} \quad ; \quad 0.75 Nu_{forc} \qquad (6)^*$$

The lower limit in the latter equation, which prevents the value of Nu_c from going to zero when Nu_{free} and Nu_{forc} are equal, comes from Eckert and Diaguila[5].

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* Models which differ from those used for the SSAR analyses.

 FC WCAP 13246, Rev. 1

2.0 Mass Transfer

The mass transfer correlation is derived from the heat transfer correlation using the heat and mass transfer analogy:

$$Sh = Nu\left(\frac{Sc}{Pr}\right)^{1/3} \tag{7}$$

The resulting mass transfer coefficient, h_m, from the Sherwood number definition:

$$Sh = \frac{h_m L}{D_v} \tag{8}$$

is multiplied by a correction factor, θ^*, to account for the effect of mass transfer. (The mass transfer correction is discussed in Part 2).

3.0 Liquid Film Heat Transfer

The Chun and Seban[8] correlation for wavy laminar films was selected for use in the WGOTHIC code. The dimensionless correlation for the film Nusselt number is:

$$Nu = 0.822\, Re^{-.22} \tag{9}$$

where

$$Nu = \frac{h}{k}\left(\frac{\nu^2}{g\sin(\theta)}\right)^{1/3} \quad and \quad Re = \frac{4\Gamma}{\mu} \tag{10}$$

4.0 Liquid Film Enthalpy Transport

The liquid film enthalpy transport model solves the transient energy equation at a point at the center of the liquid film for each clime:

$$\rho c_p \left(\frac{\partial T}{\partial t} + w \frac{\partial T}{\partial z} \right) = k \frac{\partial^2 T}{\partial x^2} \qquad (11)^*$$

where x is normal to the surface and z is parallel to the surface. The energy equation is coupled to the wall and the liquid film surface by the equations:

$$k_{wall} \frac{\partial T_{wall}}{\partial x} \bigg]_{wall} = k_{film} \frac{\partial T_{film}}{\partial x} \bigg]_{wall} \quad and \quad k_{film} \frac{\partial T_{film}}{\partial x} \bigg]_{surf} = \dot{q}''_{rad} + \dot{q}''_{conv} + \dot{q}''_{mass} \qquad (12)^*$$

5.0 Entrance Effect

The average value of h(x) between x_1 and x_2 is:

$$\frac{\bar{h}_{x_1,x_2}}{h_\infty} = 1 + F_1 \frac{d\,(x_2^3 - x_1^3)}{L^3 (x_2 - x_1)} \qquad (13)^*$$

The multipliers F_1 are the coefficients recommended by Boelter, Young and Iverson[7] to account for the entrance effect:

$$\frac{h_m}{h_\infty} = 1 + F_1 \frac{d}{L} \qquad (14)^*$$

SHORT TERM MASS & ENERGY

Methodology

- o Leak-Before-Break (LBB) approach utilized
- o Eliminates consideration of dynamic effects for all breaks greater than/equal to 4 inches
- o 3 inch DEG break size is analyzed for RCS hot and cold legs
- o Mass releases calculated using modified Zaloudek correlation (WCAP-8264) for critical mass flux
- o Conservative enthalpies applied to mass releases to determine energy release rates
- o Releases held constant at initial full power steady state conditions for duration of event

RESULTS

- o Releases used in subcompartment analysis

SUBCOMPARTMENT ANALYSIS

Methodology

- o TMD code (WCAP-8077) used to calculate the subcompartment wall differential pressures
- o Uses short term mass & energy releases described previously
- o 3 inch DEG rupture of RCS hot or cold leg
- o 10% margin applied to the releases
- o Break postulated in a steam generator compartment
- o No break postulated for reactor cavity (all piping qualified to LBB)
- o Design can accomodates 40% margin to account for uncertainty between as-built configuration and the configuration modeled

RESULTS

- Peak differential pressure (including 40% margin) is 1.51 psi for the cold leg break, and 1.47 psi for the hot leg break

- Structures are designed to accomodate these results

SUBCOMPARTMENT PRESSURIZATION CONCLUSIONS

Conservative calculation of subcompartment mass and energy releases

TMD approved model and methods used for conservative subcompartment delta P calculation

40% margin retained per SRP guidance for plant at construction permit stage

SSAR Rev. 0 demonstrates sufficient margin to subcompartment acceptance limits.

LONG TERM MASS & ENERGY

Methodology

- o SATAN-VI code (WCAP-10325) used to calculate blowdown releases
- o Refill period conservatively neglected
- o Post-blowdown phase considers the following energy sources for the long term transient
  - Decay heat
  - Core stored energy
  - RCS fluid and metal energy
  - SG fluid and metal energy
  - Accumulators, CMTs, and IRWST

- Analysis uses conservative assumptions to maximize containment response
  - Maximum expected operating temperature
  - Allowance in initial temperature and pressure for instrument error and deadband
  - Margin in volume plus allowance for thermal expansion
  - 100% full power operation
  - Allowance for calorimetric error
  - Alowance in core stored energy for effect of fuel densification
  - Margin in core stored energy
  - Margin in SG mass inventory

o No single failure assumed in the mass and energy release calculations, since there are no active systems involved. The mass and energy releases have been conservatively maximized.

o No additional energy due to metal-water reaction due to low fuel temperatures

o Decay heat calculated using 1979 ANS standard plus 2 sigma

RESULTS

o Releases used in containment integrity analysis (LOCA)

LONG TERM M&E CONCLUSION

Long term mass and energy releases contain significant conservatisms to maximize containment pressure and temperature response.

Steam Line Break Mass and Energy Release to Containment Analysis Methodology Summary

Methodology Basis:

- SRP Section 6.2.1.4 (NUREG-0800)
- WCAP 8822, "Mass and Energy Releases Following a Steam Line Rupture"

Code Used:

Modified Version of LOFTRAN. Core Makeup Tank (CMT) and Passive Residual Heat Removal Model (PRHR) were added

Cases Analyzed:

Power Levels - 102%, 70%, 30% & HZP

Breaks - Full Double Ended Ruptures

- Spectrum of Small Double Ended Ruptures

- Split Ruptures (Largest split rupture which will not generate a low steam pressure steam line isolation signal.)

Break Model:

- Break is assumed to be between the steam generator and the MSIV

- Dry Steam Blowdown

- Moody Critical Flow Model

Super heating of Steam as tube bundle is uncovered was assumed.

Safety Features Assumed For Mitigation:

- Reactor Trip
  Most Reactive RCCA is assumed to stick

- CMT's
  2 CMT's assumed operable. CMT data which would result in minimum CMT boration capability is assumed (i.e. max temperature, min boron concentration, max line resistances, etc.). CMT injection line resistance assumes a failure of one train of isolation valves to open.

- PRHR
  Only 1 PRHR assumed operable. Assumptions for minimum heat removal capability assumed (max line resistance, max IRWST temperature, min heat transfer coefficients, etc.)

Safety Features Assumed For Mitigation:

- Main Steam Isolation Valves (MSIV)*
- Main Feedwater Isolation Valves (MFWIV)*
- Startup Feedwater Isolation Valves (SFWIV)*

* Max closure time assumed. No credit assumed for valve as it is closing, closure is assumed to be a step.

Single Failures Postulated:

- Main Steam Isolation Valve Failure
- Main Feedwater Isolation Valve Failure

Secondary Side Inventory:

- SG level assumed at maximum programmed value plus uncertainties. 10% uncertainty added to initial mass.

- Unisolatable steam in steam lines included in the model and is assumed to blowdown.

- Prior to feed line isolation, maximum main feedwater flow considering a depressurizing steam generator is assumed.

- Following feedwater isolation, unisolatable fluid in feed lines which may flash and enter the steam generator is accounted for in the model.

- Maximum startup feedwater capacity assumed.

Decay Heat Model: 1979 ANS + 2 sigma

Latent Energy Sources:

- RCS Metal Mass Considered
- Intact Steam Generator Inventory (Reverse heat transfer)

Core Kinetics:

- End of Cycle (i.e. maximum reactivity feedback)

Conclusion:

- AP600 SSAR steam line break M&E release analysis was performed with methodology consistent with requirements of SRP 6.2.1.4 and WCAP 8822.

- The SSAR steam line break analysis includes the same level of conservatism as calculations performed for other operating plants.

CONTAINMENT INTEGRITY

Methodology

- o WGOTHIC code (WCAP-13246) used for calculating LOCA and MSLB containment response

- o Containment design basis remains the full double-ended guillotine rupture of a reactor coolant pipe or secondary side pipe

- o Postulated single failure is a failure of one of the valves controlling the cooling water flow; results in reduced cooling flow for PCS operation

- o Conservative initial conditions were chosen to maximize containment pressure/temperature

- o Assumptions used in creating the plant deck:

  - both wet and dry portions of the containment shell were modeled in the WGOTHIC analysis

  - 40% coverage on the top of the dome to 70% coverage on the side walls

  - Conduction from dry to wet sections were not considered, although calcs show this to be a benefit

- Representative external cooling water flowrates, which includes the effects of the single failure, were used for the wet sections

- External cooling water is not initiated until 11 minutes into the transient

- Air leakage flowpaths are included to simulate the effects of air leaking through the baffle

o For the LOCA event, two RCS pipe ruptures are analyzed (DEG breaks of either the hot leg or cold leg)

o For the MSLB event, a representative pipe break spectrum is analyzed, consisting of various power levels, break sizes, and failure assumptions

o Passive internal containment heat sinks include both concrete and metallic structures

CONTAINMENT INTEGRITY

Methodology (continued)

- o Forced convection was chosen on the inner and outer containment sections based on

  - Velocities along wall were in range showing forced convection dominates

  - LST indications that results are conservative with respect to tests

- o Noding was based on the LST model. Noding in the vertical direction and radial direction used in the LST was retained in the AP600 (above the operating deck).

  This noding has been shown to overmix non-condensibles in containment based on LST. The effect of overmixing will be presented in the June 30 letter report.

RESULTS

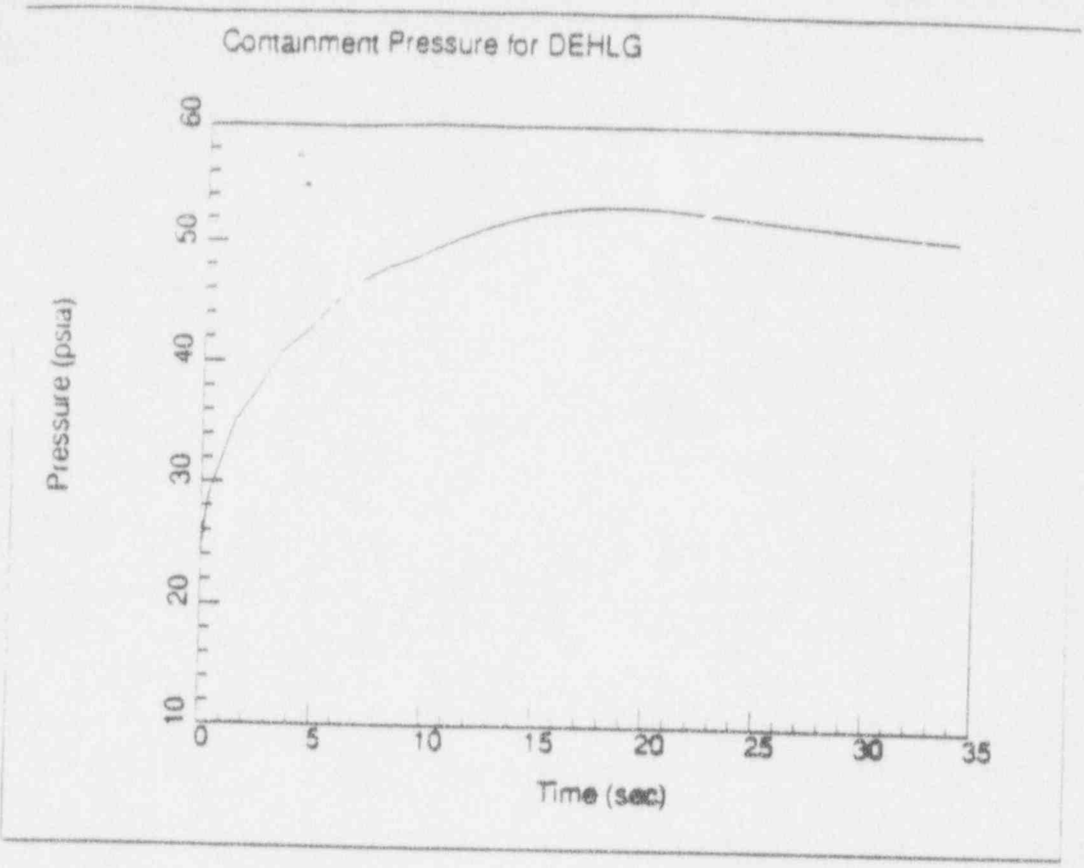
- For the LOCA events, the DEHLG gives the highest blowdown peak pressure of 38.6 psig, while the DECLG gives the highest post-blowdown peak pressure of 39.5 psig (Design pressure is 45 psig)

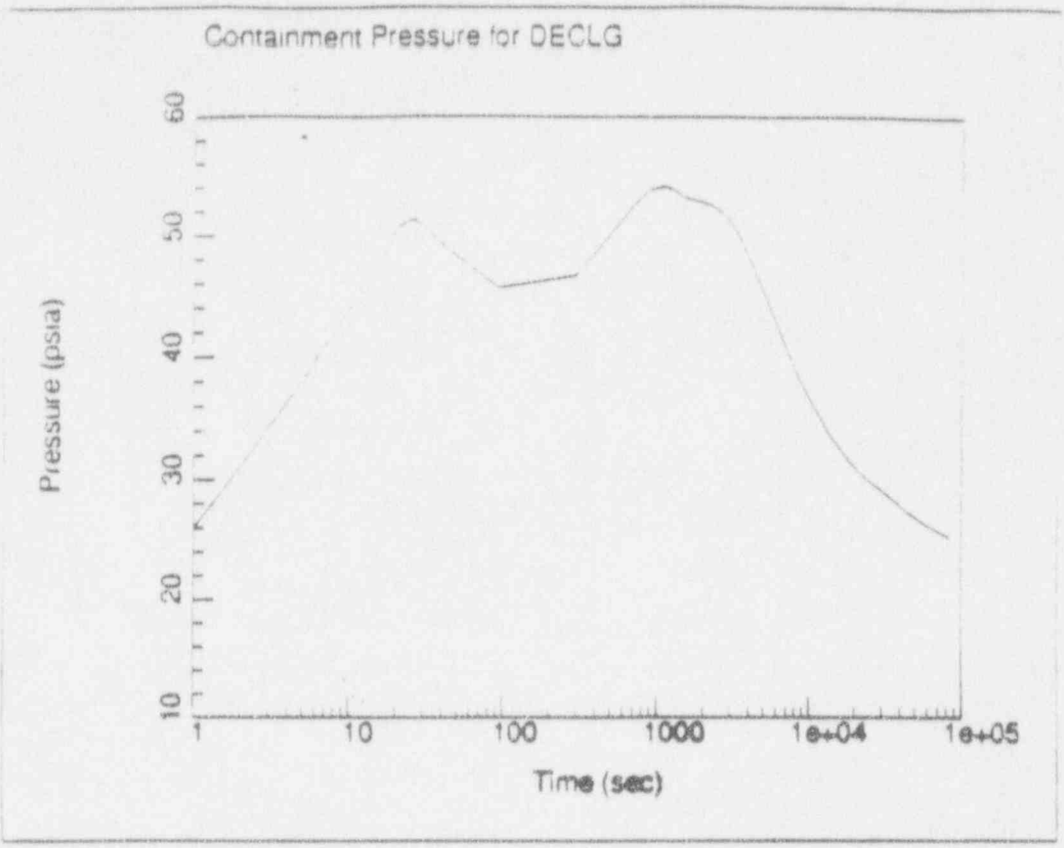
- Pressure at the end of 24 hours is 10.4 psig

- The DEHLG case peak temperature is 353 °F (localized effect), while the DECLG peak temperature is 283 °F

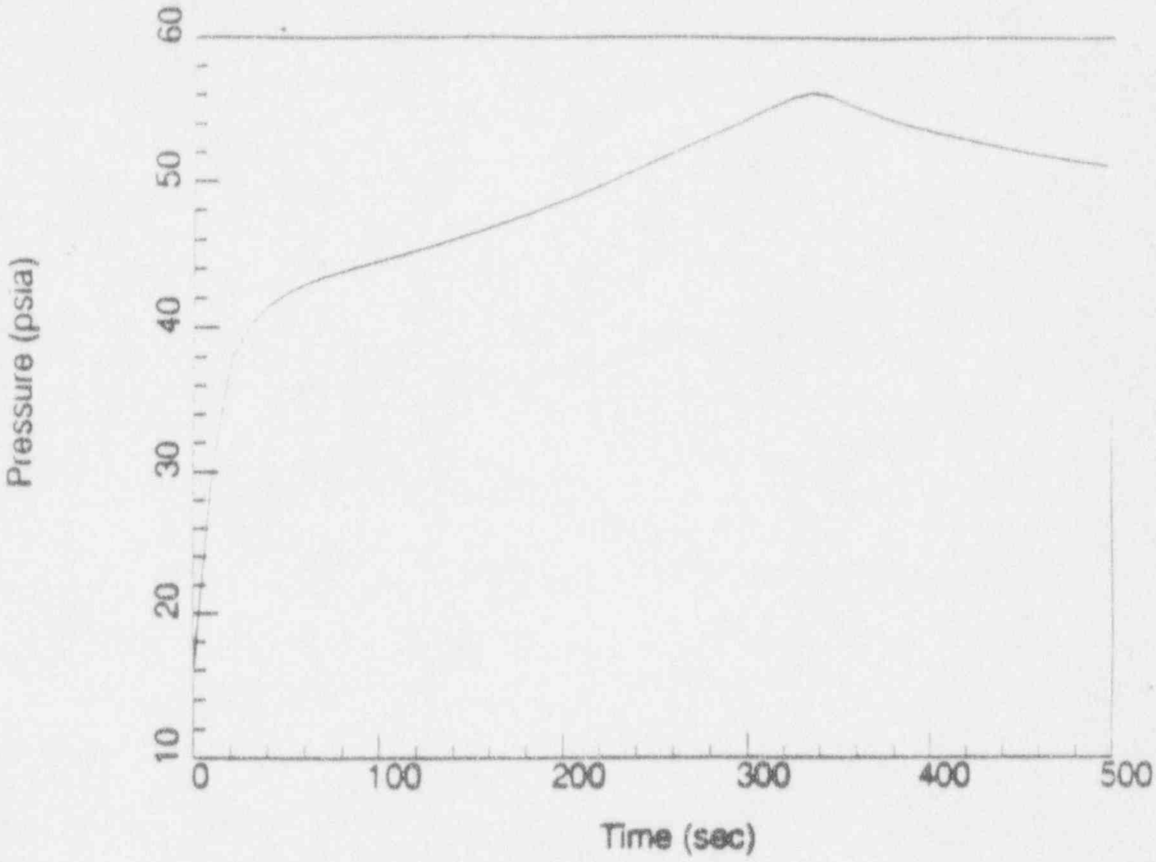
- For the MSLB events, the 1.388 ft^2, Full DER, 30% power, MSIV failure case gives the highest containment peak pressure of 41.4 psig

- The 1.388 ft^2, Full DER, 102% power, MSIV failure case gives a containment temperature of 320.2 °F


Containment Pressure for DEHLG
Pressure (psia)
Time (sec)
10
20
30
40
50
60
0
5
10
15
20
25
30
35


Containment Pressure for DECLG
Pressure (psia)
10
20
30
40
50
60
1
10
100
1000
1e+04
1e+05
Time (sec)

Containment Pressure, 1.388 ft2 DER SLB, 102% Power



CONTAINMENT INTEGRITY ANALYSIS CONCLUSIONS

The SSAR Rev. 0 Containment Pressure and Temperature calculations include margins sufficient to demonstrate that AP600 meets containment integrity acceptance criteria using:

- conservative mass and energy releases
- conservative containment response calc
- inherent conservatism in containment models based on LST comparisons

AP600 WGOTHIC Model Sensitivities

Following study:

- Uses SSAR Rev. 0 AP600 model as base case.

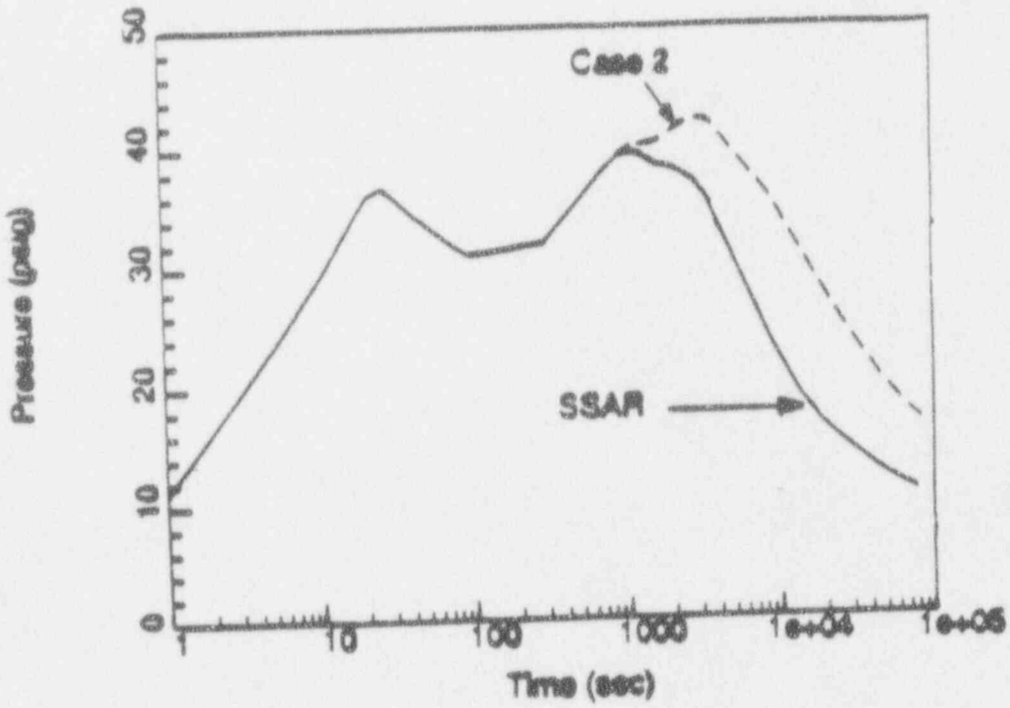
- Varies single parameters over a range sufficient to demonstrate WGOTHIC behaves appropriately and there are no "cliffs" for relevant parameters.

Parameters covered are:

- Wetted fraction coverage
- PCCS water flow rate
- Wetting initiation time
- Inlet air blockage
- Outlet air blockage
- Internal heat sink exposed area
- Chimney height
- Mass and energy, mass flow rate
- Air baffle loss coefficient
- Air baffle bypass leakage

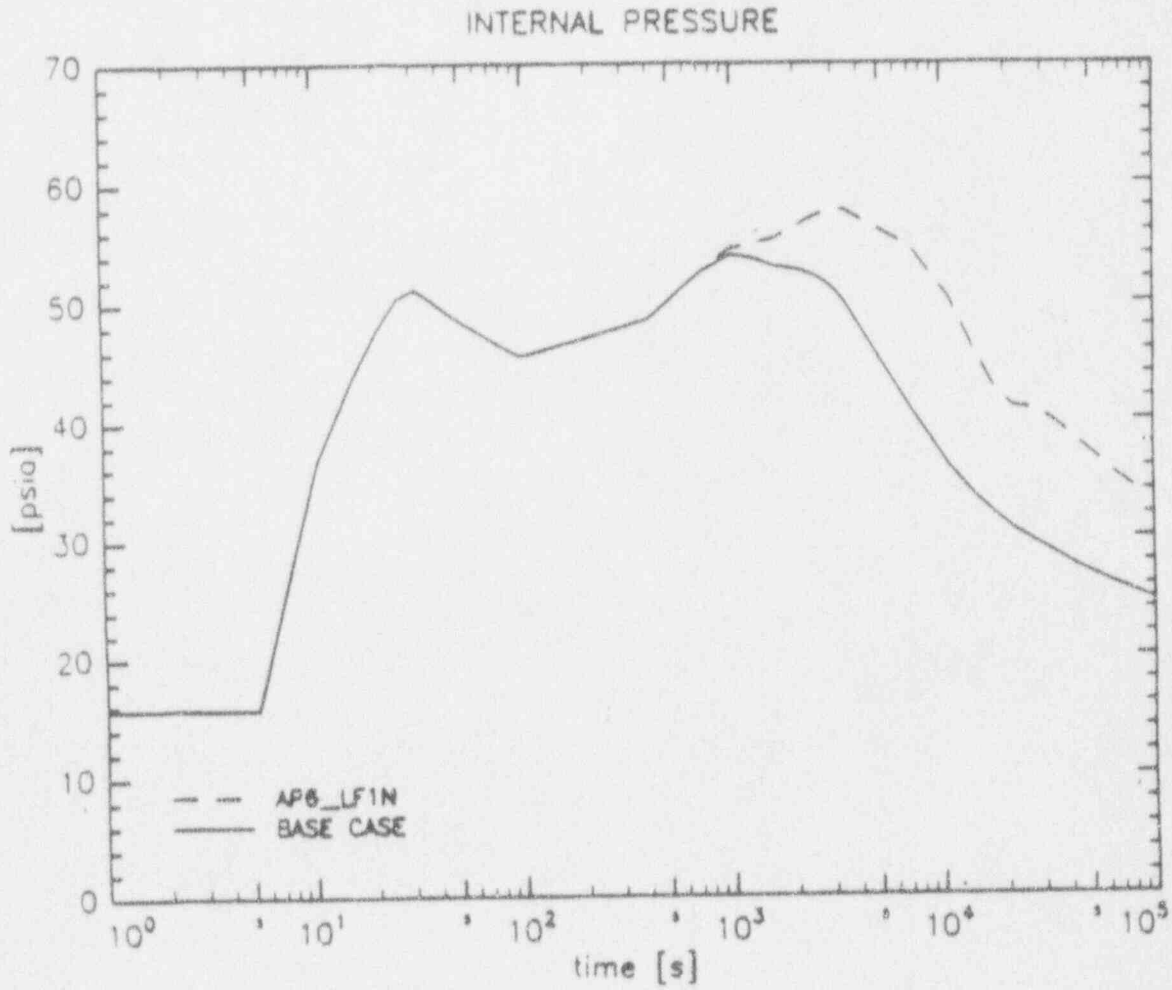
WETTED FRACTION COVERAGE SENSITIVITY

	WETTED FRACTION	PEAK PRESSURE (psig)	DELTA PRESSURE (psig)
SSAR	40% DOME 70% SIDEWALLS	39.5	
CASE 2	20% DOME 40% SIDEWALLS	42.2	2.7



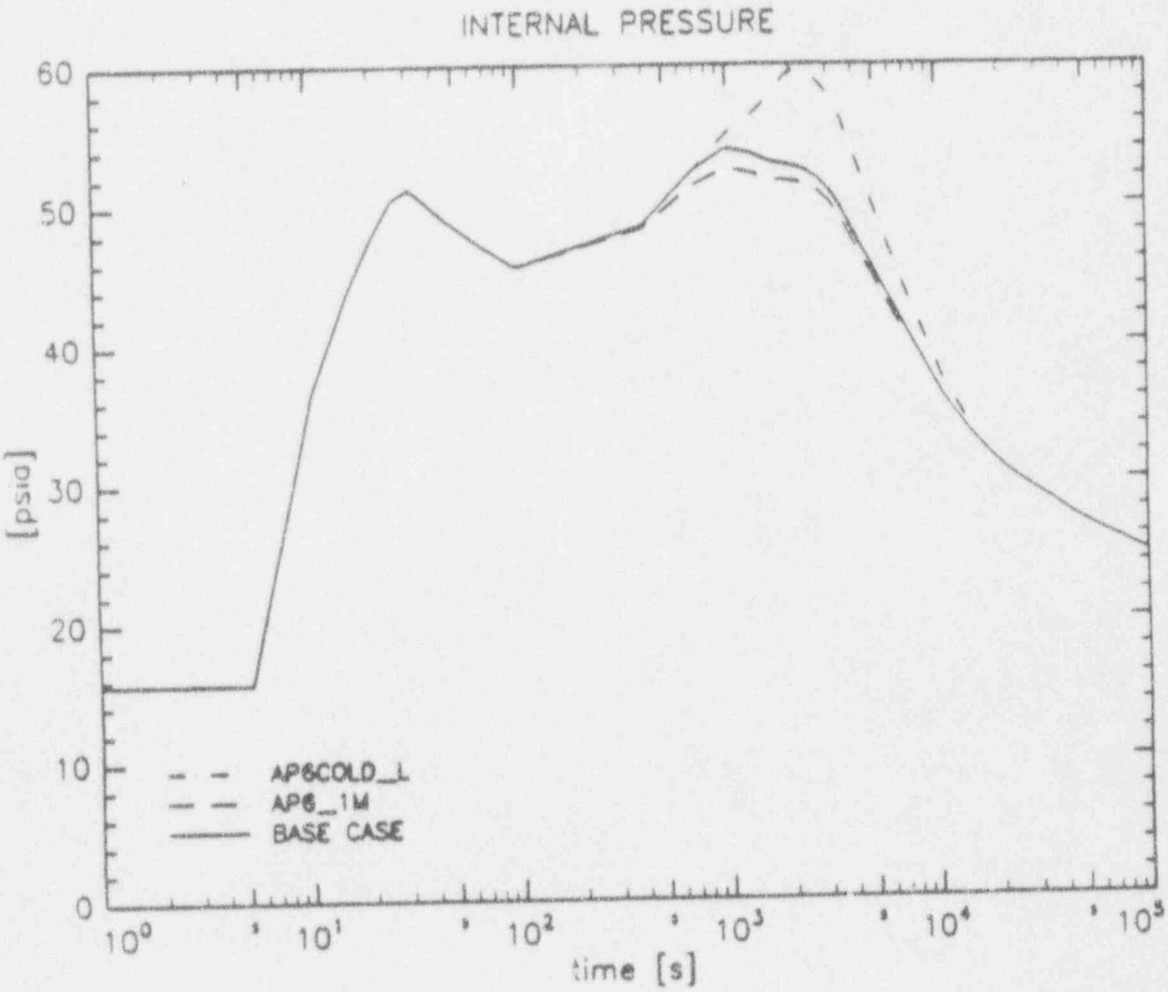
PCCS WATER FLOW RATE

	FLOWRATE (%)	PEAK PRESSURE (psia)	DELTA PRESSURE (psia)
SSAR	100	54.03	
HALF (LF1N)	50	57.76	3.73



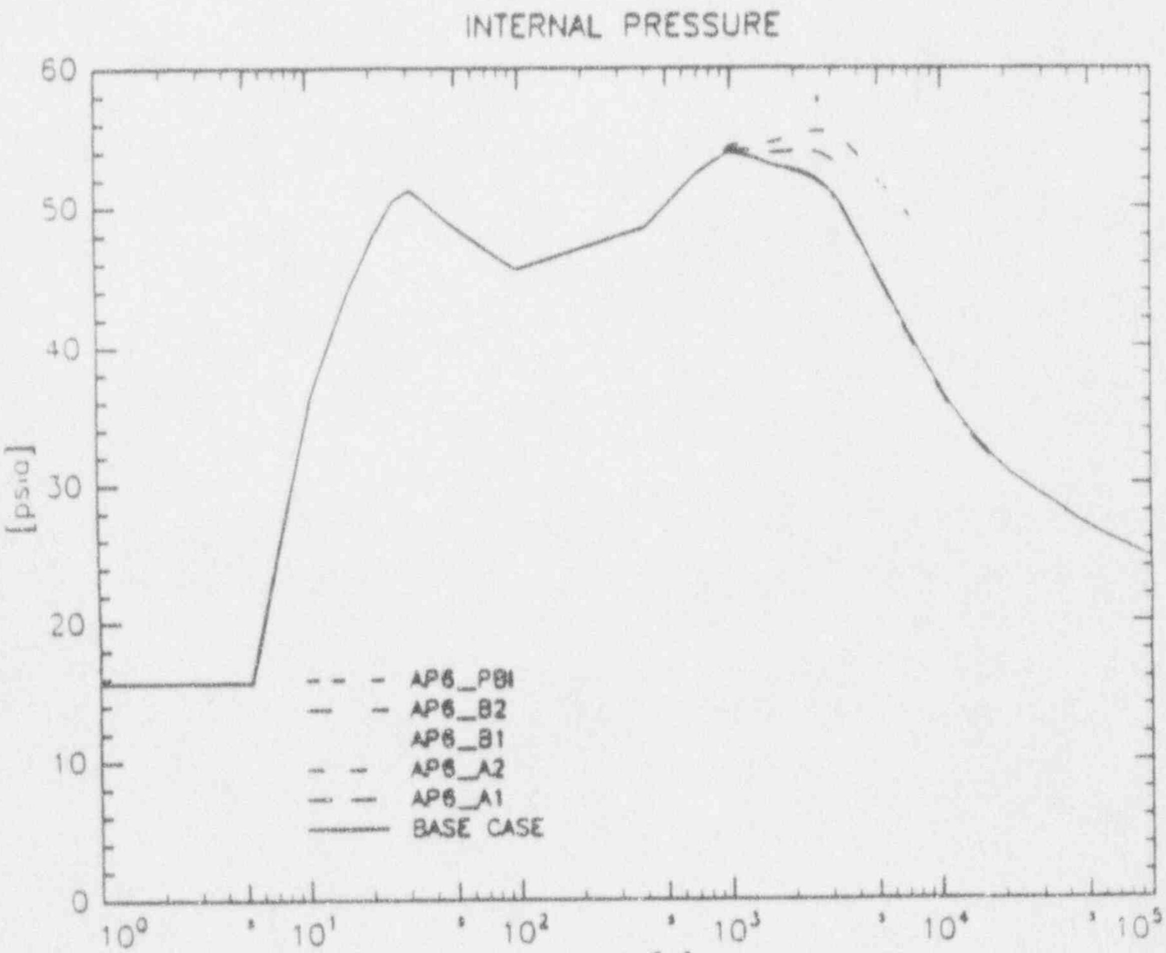
WETTING INITIATION TIME

	STARTUP TIME (min)	PEAK PRESSURE (psia)	DELTA PRESSURE (psia)
RAPID (1M)	1	52.62	-1.41
SSAR	11	54.03	
SLOW (COLD_L)	31	59.74	5.71



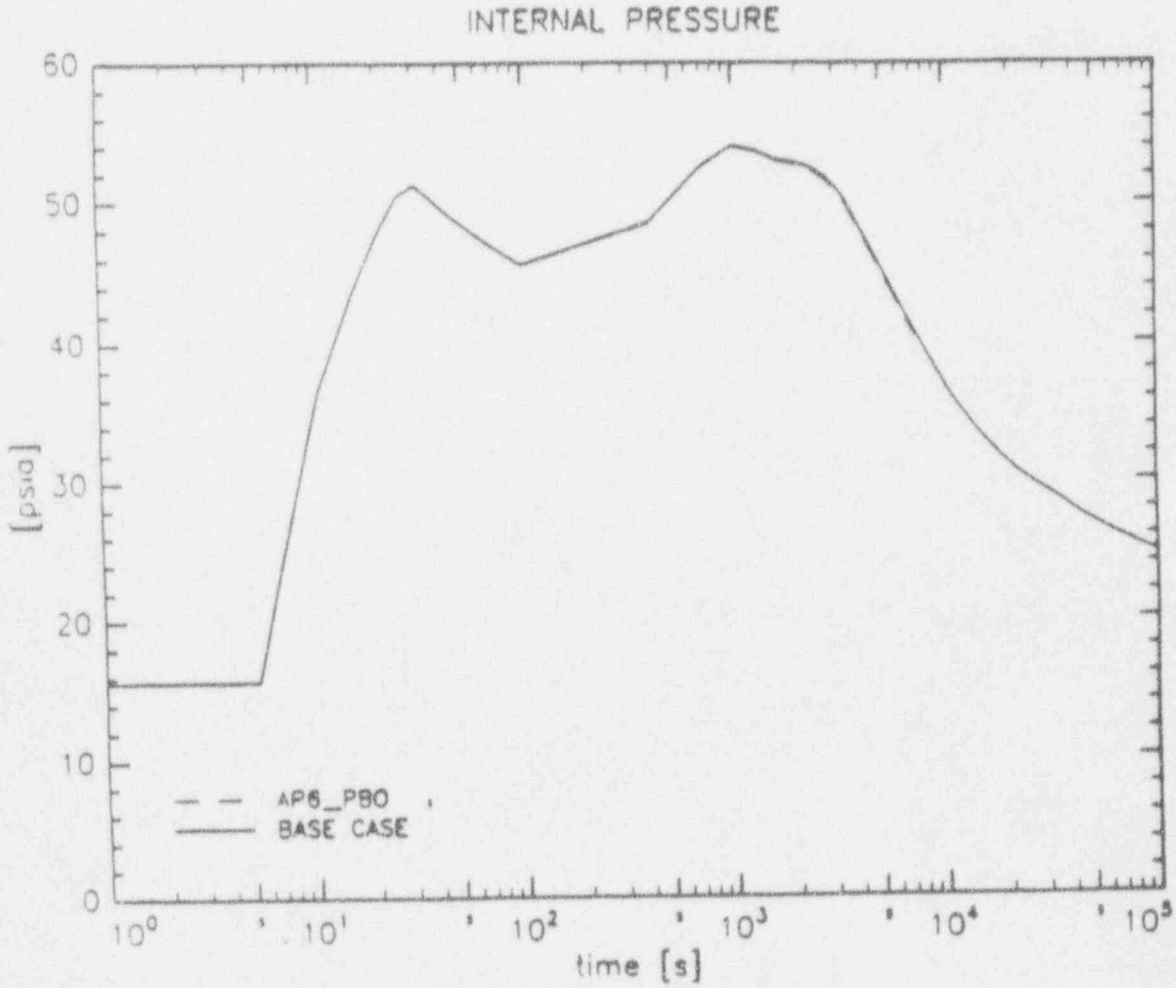
INLET AIR BAFFLE BLOCKAGE
(4 inlets total)

	# INLETS 50% BLOCK	# INLETS 100% BLOCK	PEAK PRESSURE (psia)	DELTA PRESSURE (psia)
SSAR	0	0	54.03	
CASE A1	0	1	54.19	0.16
CASE A2	0	2	55.48	1.45
CASE B1	1	0	53.99	-0.04
CASE B2	2	0	53.99	-0.04
CASE PBI	4	0	54.00	-0.03



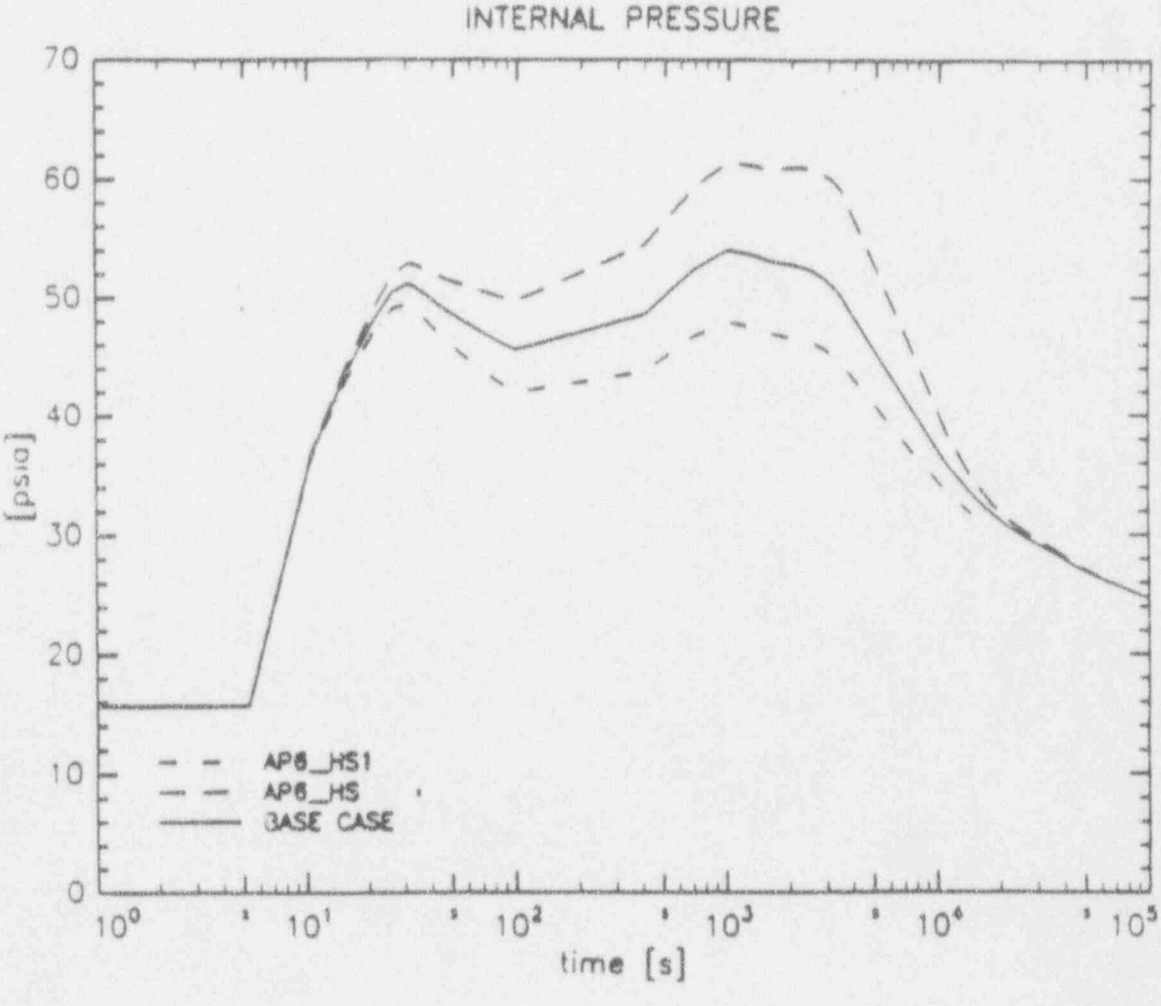
OUTLET AIR BAFFLE BLOCKAGE

	OUTLET BLOCKAGE	PEAK PRESSURE (psia)	DELTA PRESSURE (psia)
SSAR	0%	54.03	
CASE PBO	50%	53.99	-0.04



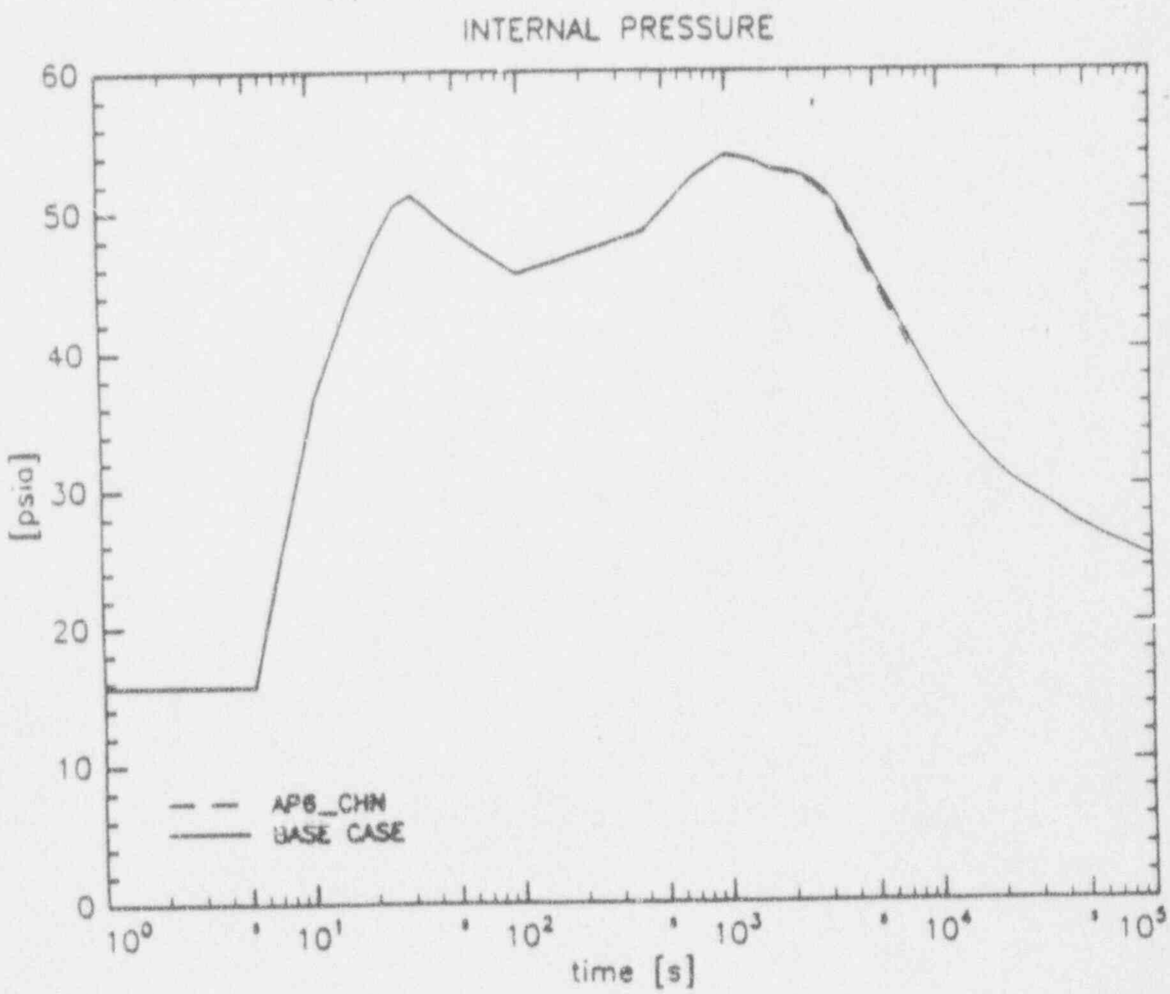
INTERNAL
HEAT SINK - % EXPOSED AREA

	EXPOSED AREA (%)	PEAK PRESSURE (psia)	DELTA PRESSURE (psia)
SSAR	100	54.03	
CASE HS	50	61.37	7.34
CASE HS1	150	49.53	-4.50



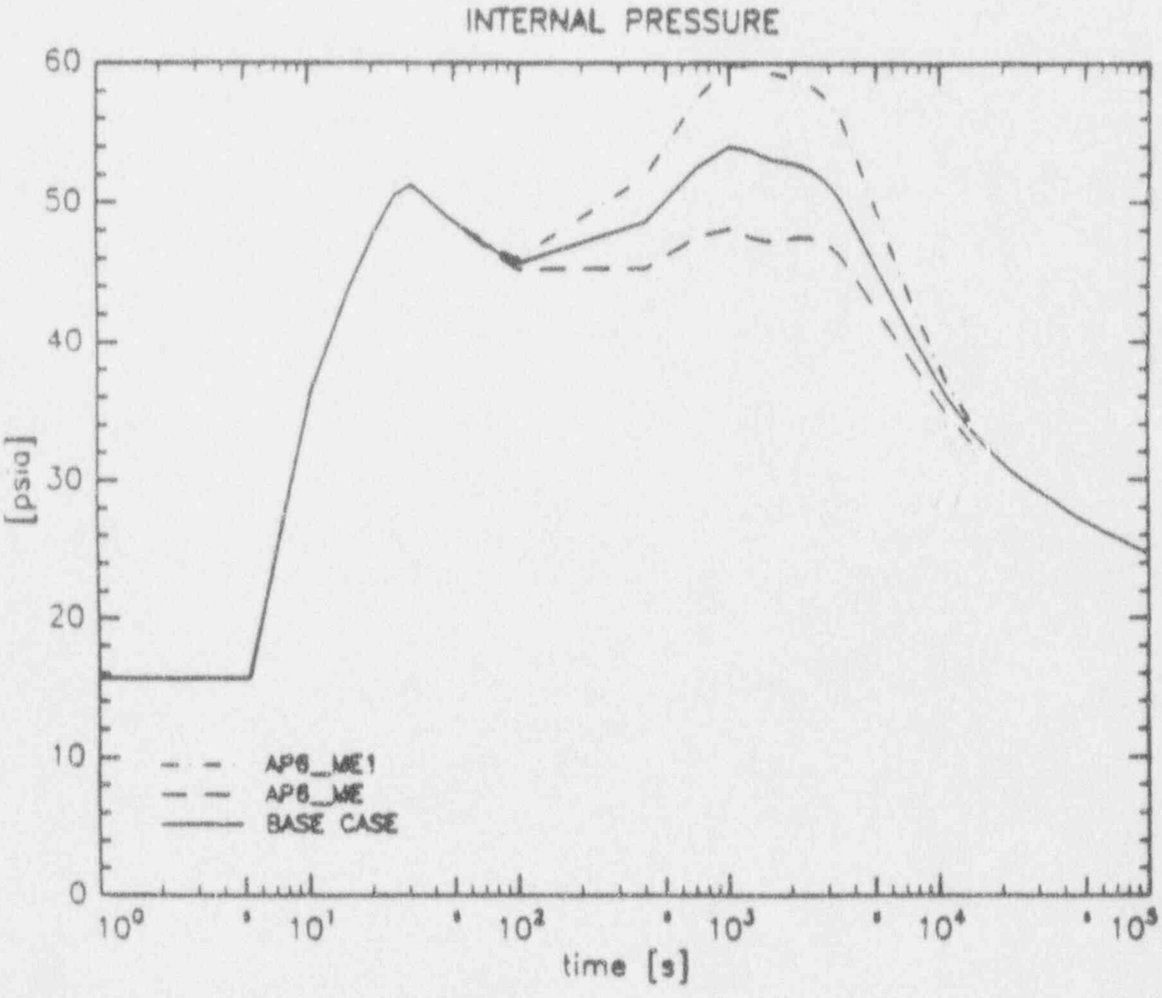
CHIMNEY HEIGHT

	HEIGHT (%)	PEAK PRESSURE (psia)	DELTA PRESSURE (psia)
SSAR	100	54.03	
CASE CHN	200	53.98	-0.05



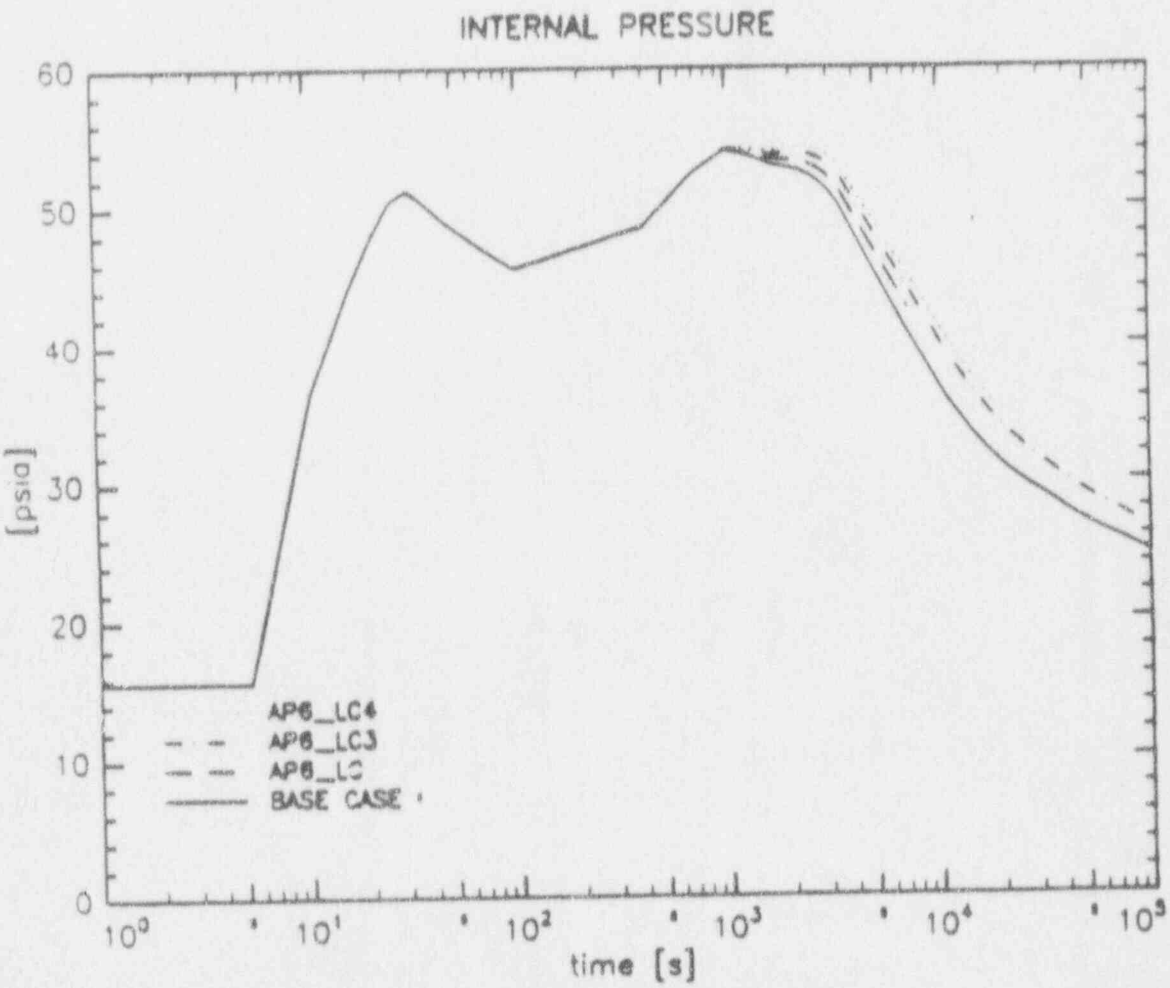
MASS & ENERGY RELEASE

	POST-BLOWDOWN MASS FLOW (%)	PEAK PRESSURE (psia)	DELTA PRESSURE (psia)
SSAR	100	54.03	
CASE ME	75	51.27	-2.76
CASE ME1	125	59.89	5.86



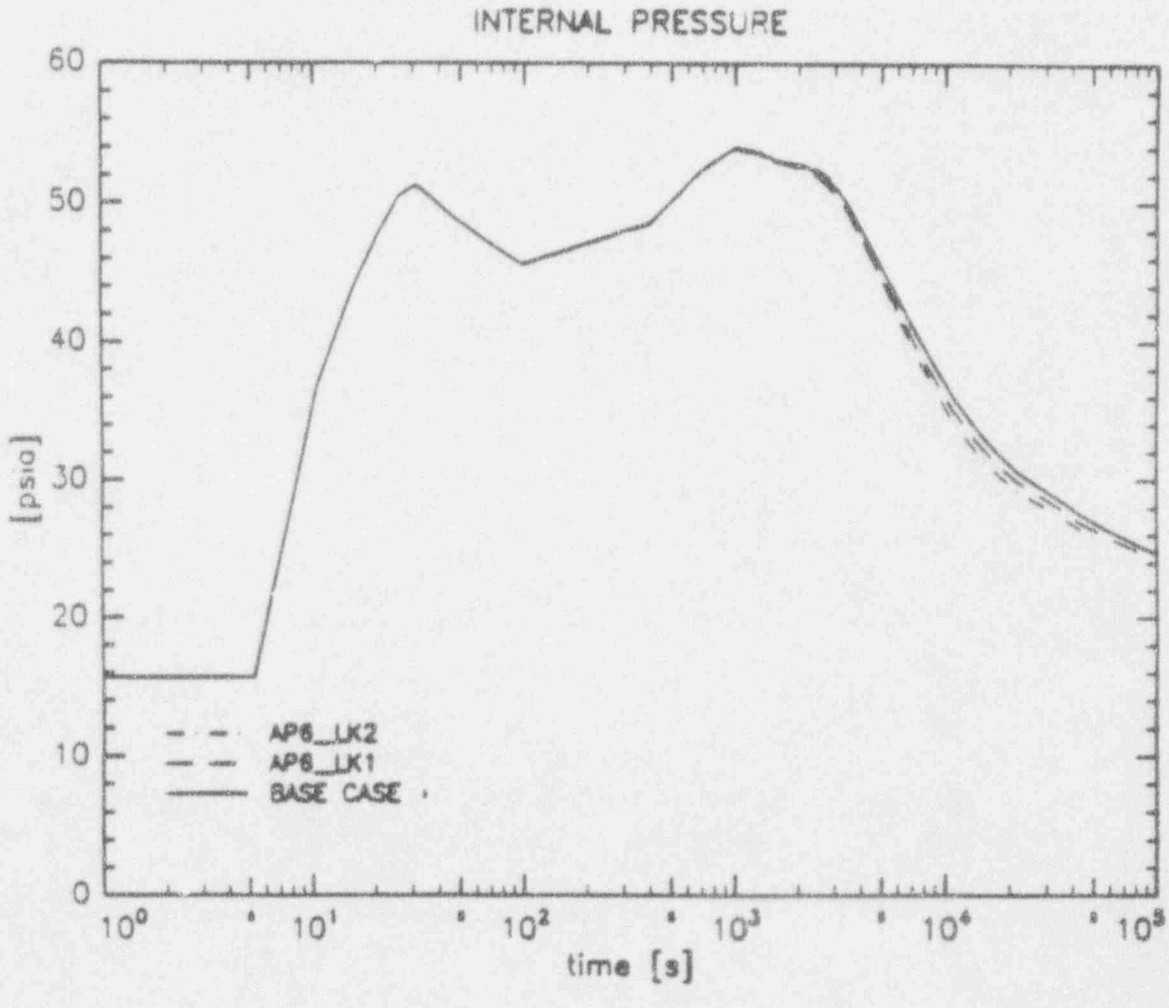
AIR BAFFLE LOSS COEFFICIENT

	PRESSURE LOSS COEFFICIENT (%)	PEAK PRESSURE (psia)	DELTA PRESSURE (psia)
SSAR	100	54.03	
CASE LC	200	54.11	0.08
CASE LC3	300	54.17	0.14
CASE LC4	400	54.25	0.22



AIR BAFFLE BYPASS LEAKAGE

	LEAKAGE AREA (%)	PEAK PRESSURE (psia)	DELTA PRESSURE (psia)
SSAR	100	54.03	
CASE LK1	1000	53.96	-0.07
CASE LK2	10000	53.91	-0.12



AP600 WGOTHIC MODEL SENSITIVITIES
CONCLUSIONS

Sensitivity calculations with WGOTHIC show that there are no "cliffs" in models.

Behavior of code for AP600 produces reasonable and consistent results for a range of parameters for DBA PCCS performance.

External flow resistances and/or moderate changes to external annulus are self correcting

External flow parameters thus have a weak impact on internal containment pressure

PCCS Large Scale Test WGOTHIC Sensitivities

Role of LST in WGOTHIC validation

LST sensitivities

Conclusions

Role of LST in WGOTHIC Validation

Referring to steps outlined at Feb 23-24, 1994 meeting with NRC, the LST is used in the following ways:

WGOTHIC modelling:

Examines the code capability to model flow fields and their influence on heat and mass transfer through the containment vessel.

Proves the ability of the code to model overall system interactions, listed as follows:

- steam delivery and buoyant plume
- mixed convection driven flow field
- non-condensibles effects on H&MT
- influence of short and long term heat sinks
- effects of dead-ended and open compartments
- condensation on inner surface
- conduction through vessel
- sensible and evaporation heat removal
- radiative heat removal
- annulus air flow rate determination

Thus, the LST is used to demonstrate that the code can appropriately model the heat removal mechanisms of the AP600 containment

Role of LST in WGOTHIC Validation (cont.)

WGOTHIC uses the following as input boundary conditions:

- steam flow rate (e.g. mass and energy releases)
- environment temperature outside the shield building
- PCCS water total flow rate
- PCCS water coverage fraction
    - LST measured at hot conditions
    - Water Distribution Tests

LST SENSITIVITIES PRESENTED IN WCAP-13246, REV. 0

- Base Case (LST Baseline Test with no internals)

  - External wetting (67%)
    Both wet and dry portions of the containment shell were modeled
    Conduction from dry to wet sections was not considered

  - Internal forced convection heat transfer above operating deck
    Internal free convection heat transfer below operating deck

  - External forced convection heat transfer (fan on)

  - Simulate subcooling of the applied external water
    by using the Uchida correlation to model condensation inside the vessel and by specifying the outer surface temperature of the vessel to be equal to the measured outer surface wall temperature. The inner surface temperature is forced to be equal to the measured inner surface temperature by multiplying the Uchida correlation (calculated by GOTHIC) by a constant. Heat is not transferred to the annulus in the subcooled region. At the point where subcooling ends and evaporation begins, determined from the measured test results, the WGOTHIC mechanistic correlations are used to model the internal and external heat transfer.

LST SENSITIVITIES PRESENTED IN WCAP-13246, REV. 0

Sensitivities to the Base Case

- Use internal free convection heat transfer above and below operating deck

- Do not simulate subcooling effect

- Decrease external forced convection heat and mass transfer each by 15% by increasing D_h by a factor of 2:

$$h_c \sim \frac{1}{D_h^{0.2}} \qquad h_m \sim \frac{1}{D_h^{0.2}}$$

(a,b)

Figure 39 Measured and Predicted Vessel Surface Temperatures with Forced Convection Correlation for Internal Heat Transfer, Test R11L

Base Case

(a,b)

Figure 40 Measured and Predicted Vessel Surface Temperatures with Free Convection Correlation for Internal Heat Transfer, Test R11L

(a,b)

Figure 30 Measured and Predicted Vessel Inner Surface Temperatures Without Modeling Subcooling for LST R11L

Measured Pressure = 42.79 psia
Predicted Pressure = 57.77 psia

(a,b)

Figure 42 Wet Axial Wall Temperatures and Vessel Pressures for Enhanced External Heat Transfer

LST SENSITIVITY RESULTS

- Internal convective heat transfer
  - Both free and forced convection over predict vessel pressure. Forced convection gives more accurate predictions.
- Simulation of subcooling
  - By modelling subcooling effect, vessel pressure and dome wall temperatures are more similar to the measured results. WGOTHIC heat and mass transfer can be validated while accounting for subcooling.
- External forced convection heat and mass transfer
  - Decreasing both the external heat and mass transfer by 15 % results in a small effect on vessel wall temperatures and less than 2% effect on vessel pressure.

ADDITIONAL SENSITIVITY IN WCAP-13246, REV. 0

- Base Case - SST
    - External wetting (100%)
    - Internal free convection heat transfer
    - External forced convection heat transfer (fan on)
    - Simulate subcooling of the applied external water
- Sensitivities to the base case
    - Do not simulate subcooling effect

(a,b)

Figure 33 Measured and Predicted Vessel Inner Surface Temperatures vs. Vessel Integrated Area for Test 117c-15s

Measured Pressure = 41.81 psia
Predicted Pressure = 58.26 psia

Base Case

(a,b)

Figure 31 Predicted and Measured Vessel Inner Surface Temperatures Without Modeling Subcooling for SST 117c-15a

Measured Pressure = 41.87 psia
Predicted Pressure = 64.1 psia

SUMMARY OF SST SENSITIVITY

Result is consistent with the same sensitivity performed on the LST:

- Simulation of subcooling
  - By modelling subcooling effect, vessel pressure and dome wall temperatures are more similar to the measured results. WGOTHIC heat and mass transfer can be validated while accounting for subcooling.

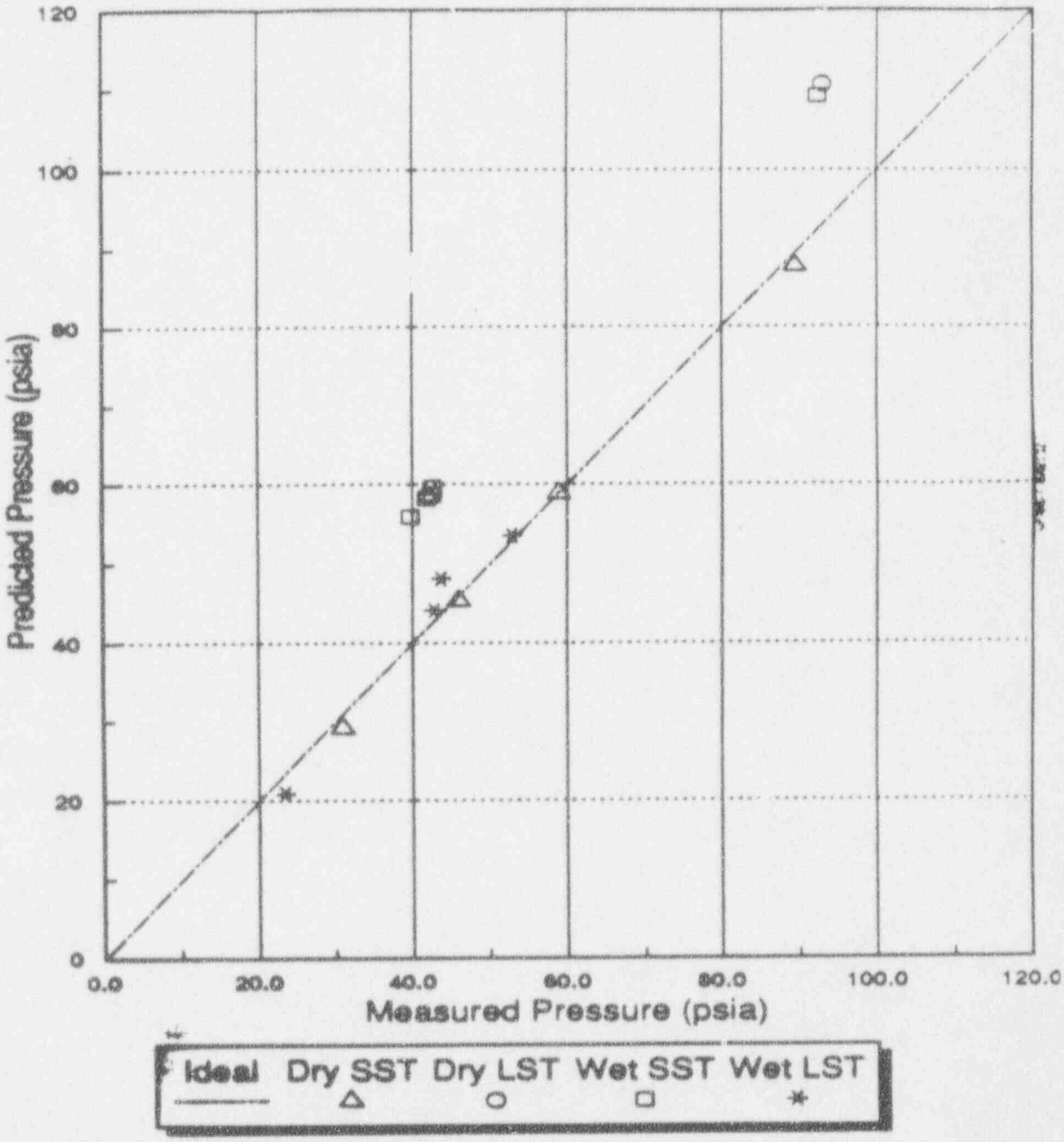


Figure 46 Predicted vs. Measured Vessel Pressures

SUMMARY OF INTEGRAL TESTS IN WCAP-13246, REV. 0

Test	Model Description	Result
Dry SST	- No External Water - Free Internal Heat Transfer - Free External Heat Transfer (No Fan)	Vessel Pressure Predicted Accurately
Dry LST	- No External Water - Free Internal Heat Transfer - Free External Heat Transfer (No Fan)	Vessel Pressure over predicted by ~20%. The mixed convective heat transfer correlation and new mass transfer correlation are expected to improve prediction.
Wet SST	- External Water (subcooling simulated) - Free Internal Heat Transfer - Forced External Heat Transfer (Fan On)	Vessel Pressure over predicted because the vessel is in the mixed convection regime and free was chosen for internal walls.
Wet LST	- External Water (subcooling simulated) - Forced Internal Heat Transfer Above Deck, Free Internal Heat Transfer Below Deck - Forced External Heat Transfer (Fan On)	Vessel Pressure Predicted Accurately

LST Sensitivity Conclusions

The tests themselves vary the most significant parameters and thus provide an indication of sensitivities to real parameters independent of code calculations.

WGOTHIC will be used to calculate LST results and thus it will be verified to appropriately model parametric sensitivity in an integral system.

Sensitivity calculations with WGOTHIC show that there are no "cliffs" in models.

Documentation to be Issued by June 30, 1994

Document results presented in March 17 and "TBD" meetings

Demonstrate effect of phenomenological model changes on net margin relative to SSAR Rev. 0

- based on LST and SSAR cases
- show net effect of phenomena models

Discuss effect of WGOTHIC modelling changes

- subdivided (distributed parameter)
- better representation of dynamic stratification

Discussion leading to defensible conclusion that SSAR Rev. 0 is conservative and that AP600 meets containment integrity acceptance criteria.