MAAP Containment Model

NRC Presentation

June 20,2001

Enclosure 2

Agenda

- Introductory & administrative remarks - NRC
- Desired Outcomes - B. Sepelak
- Plant Benefits - M. Testa/T. Kendall
- Westinghouse remarks - J. DeBlasio
- FAI presentation on technical bases - Dr. R. Henry
- Questions & Answers (non-proprietary)
- FAI presentation - proprietary portion - Dr. R. Henry
- Questions & Answers (proprietary)
- Summary - B. Sepelak/T. Kendall
- Conclusion - NRC

Desired Outcomes

- Provide overview of MAAP containment model technical bases
- Discuss schedule
  - topical (W docket), licensee submittals
  - future NRC meetings
  - ACRS T/H subcommittee meeting
- Open information exchange and feedback

Beaver Valley Benefits

- Change to an atmospheric containment is part of Full Potential Program
  - benefits include enhanced personnel safety
  - program utilizes MAAP containment model
  - atmospheric containment is building block for large power uprate & BELOCA
- Appropriate understanding & allocation of limitations, margin
- Planned atmospheric containment LAR - 3/2002
  - implementation - spring 2003 outage (1R15)

Point Beach Benefits

- Address GL 96-06 steam binding concerns for Containment fan coolers
  - 2-3 engineers continuously involved
  - Appropriate understanding & allocation of limitations, margin
- Address limiting MSLB scenario
  - Failed Feedwater Regulating Valve at 100% power
- Containment response for future thermal up-rate
- LAR Submittal - 02/02 with implementation in 2/03

Benefits of Licensing Approach

- Topical allows for development of a consistent approach
  - topical submittal 1/02
- optimizes use of NRC Resources
  - associated with BV and Point Beach submittals
  - future similar applications
- BV and PB submittals will follow topical bases
  - plant submittals in advance of topical approval
  - enhances review of the topical

A METHODOLOGY FOR REALISTIC EVALUATIONS OF A LARGE DRY CONTAINMENT RESPONSE TO DESIGN BASIS ACCIDENT CONDITIONS

Presented to:

The Nuclear Regulatory Commission

June 20, 2001

Rockville, Maryland

PRESENTATION OUTLINE

- The important considerations of a realistic model.
- How are the mass and energy releases developed and used for design basis evaluations?
- The experimental benchmarks used to test the realistic containment model.
- The representation of uncertainties.
- Conclusions.

THE IMPORTANT CONSIDERATIONS OF A REALISTIC MODEL

- Nodalization.
- Representation of atmospheric motion within the containment subcompartments.
  - Circulation due to blowdown.
  - Forced circulation flows.
  - Natural circulation flows.
  - Countercurrent natural circulation flows.
- Condensing heat transfer.
  - Condensation on cold heat sinks.
  - Containment sprays.
- The influence of water entrainment.

WHAT IS INVOLVED IN A REALISTIC CONTAINMENT MODEL?

- Nodalization:
  a. Should represent the containment geometry.
  b. Needs to represent the displacement of noncondensible gases, i.e. correctly represent the potential for condensation.
  c. Needs to represent the potential for induced circulation, global natural circulation and countercurrent natural circulation.
  d. Needs to represent the behavior of light gases (stratification).

- <u>Conclusion</u>: One node analyses cannot give realistic results – multi-node is required, e.g. 5 to 20 nodes.

WHAT IS INVOLVED IN A REALISTIC CONTAINMENT MODEL? (Continued)

2. Need to represent all the systems which have first order (100%) and second order (10%) influence.

- Conclusion: Need to represent containment geometry, containment heat sinks, fan coolers, sprays, and the containment sump.

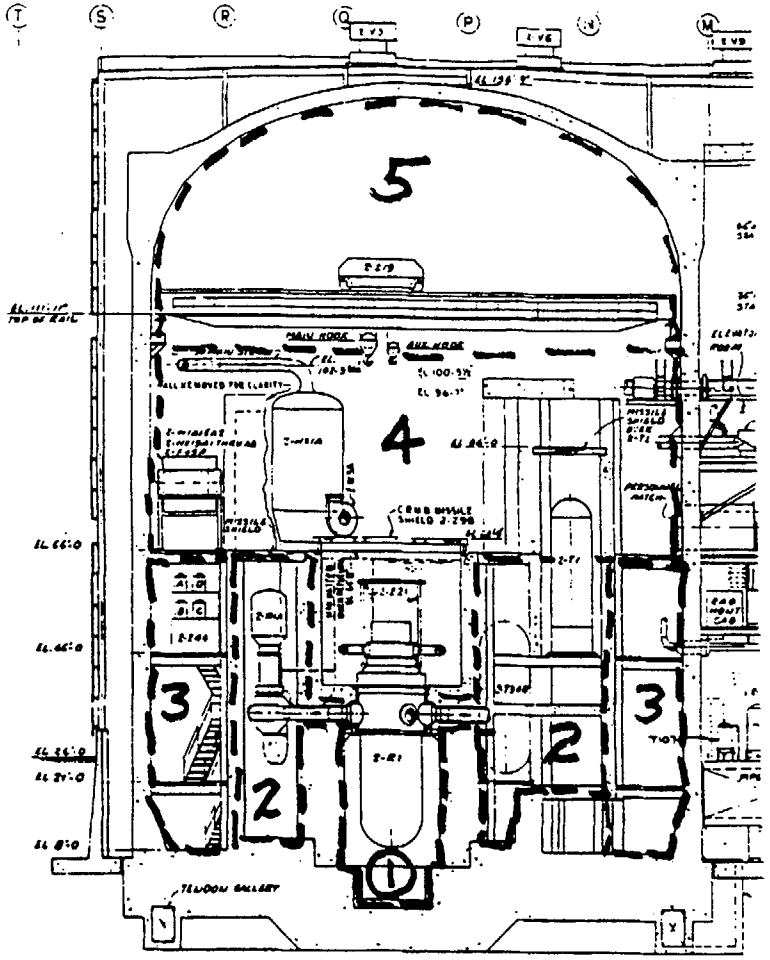
- Need to represent the physical processes which have first order (100%) and second order (10%) effects.

- Conclusion: Need to represent induced circulation, natural circulation/convection, e.g. global and countercurrent.

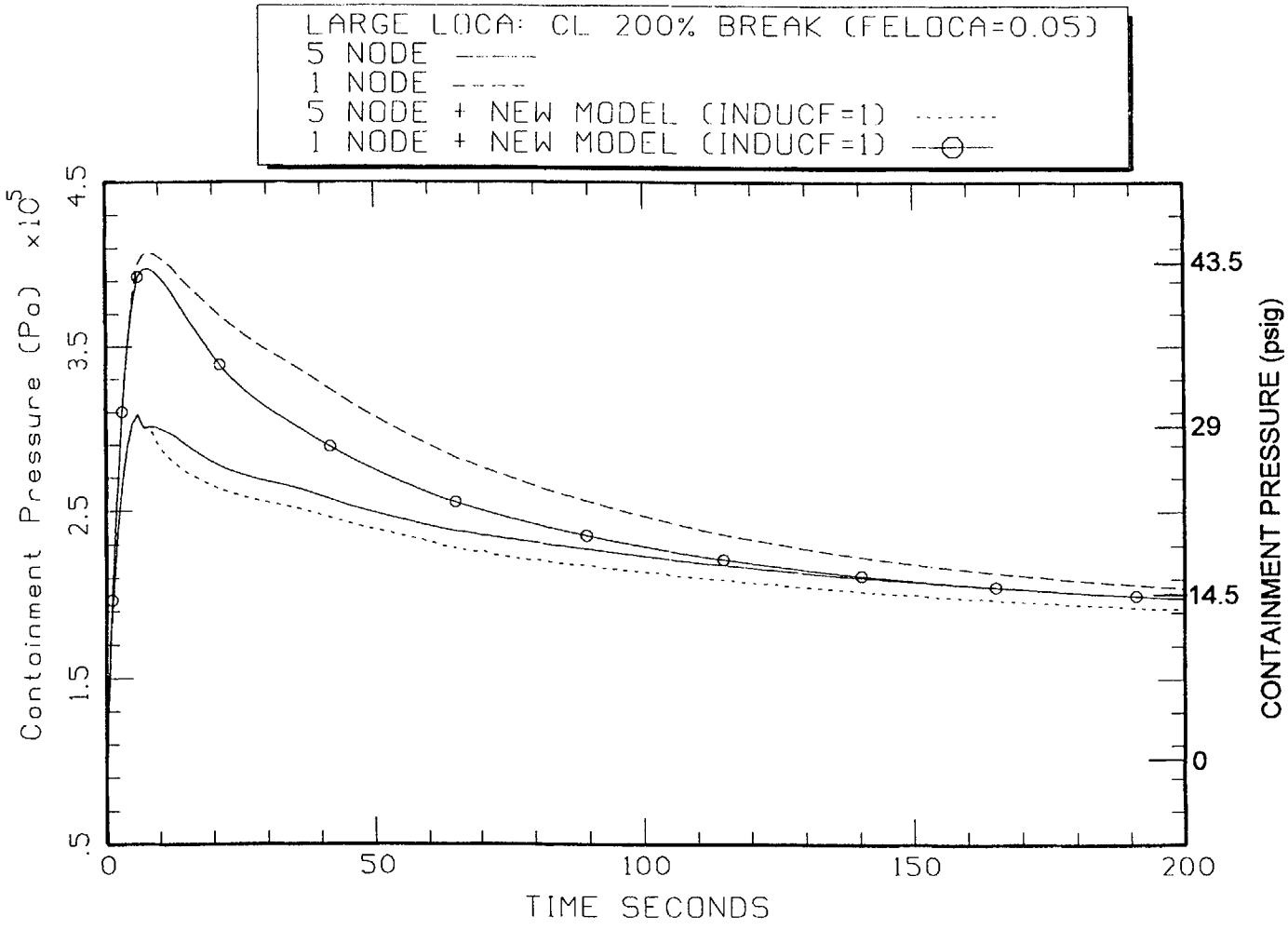
INFLUENCE OF NODALIZATION

- Comparisons with large scale experiments show that several nodes are required.
- Analyses for a reference Westinghouse 2 loop large dry containment shows that analyses with 5 nodes result in a reduction in the peak pressure of at least 15 psi compared to a single node analysis with the same computer code.
- Multi-node is necessary to assess the displacement of air from the break location. This results in increased condensation in the break region which cannot be assessed with a single node model.

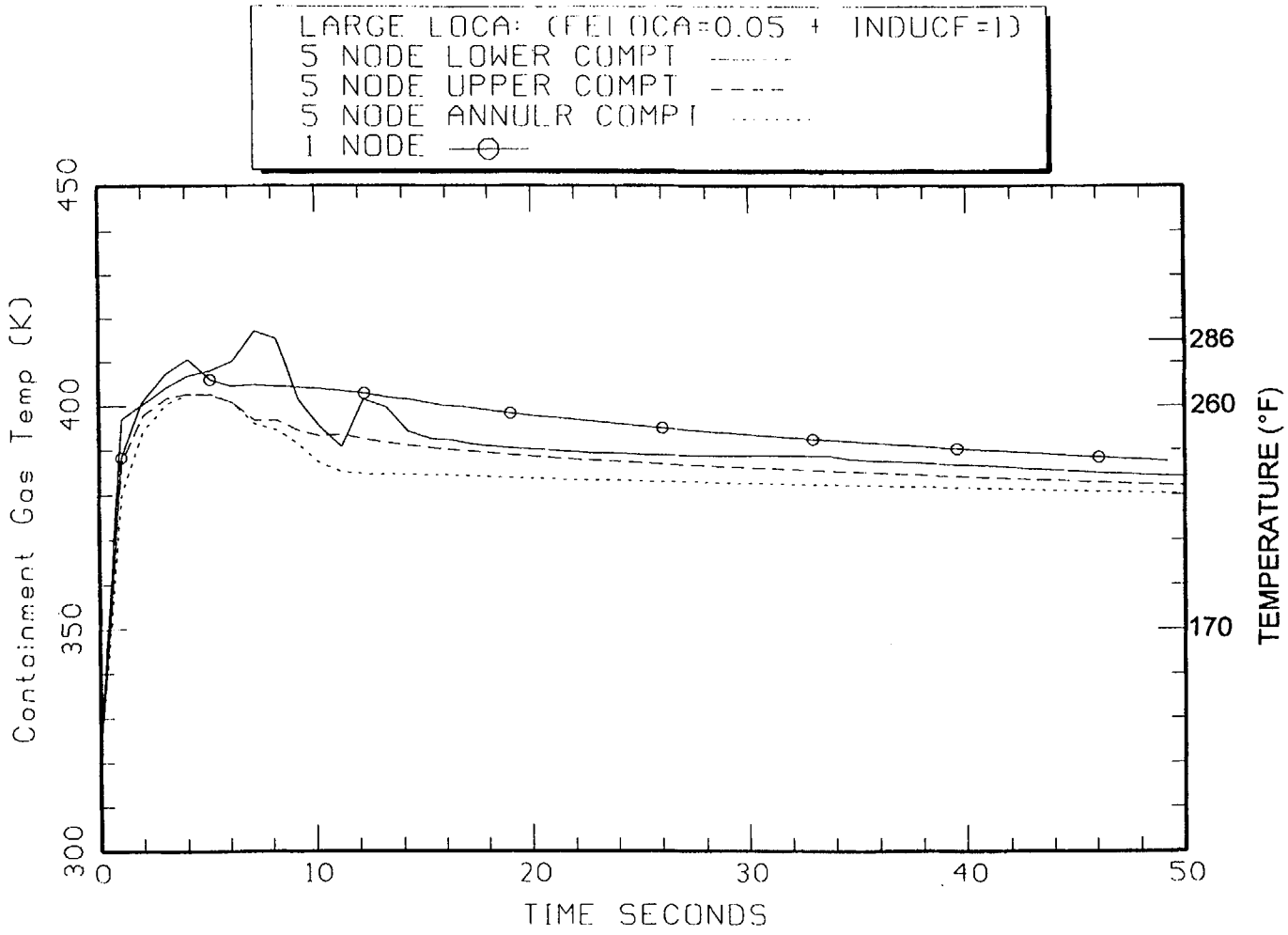
5 NODE CONTAINMENT MODEL



NO SPRAYS OR FAN COOLERS

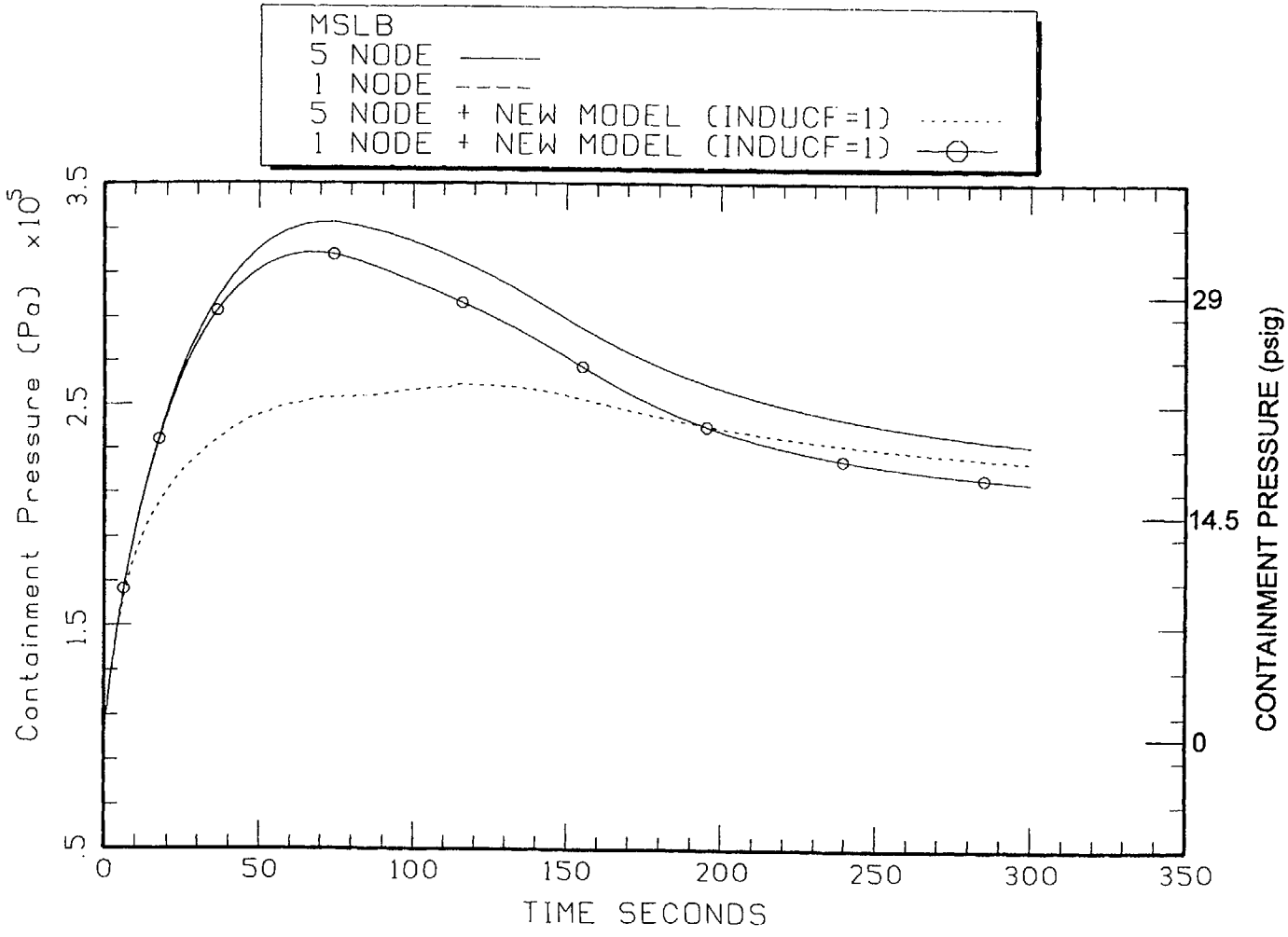


NO SPRAYS OR FAN COOLERS



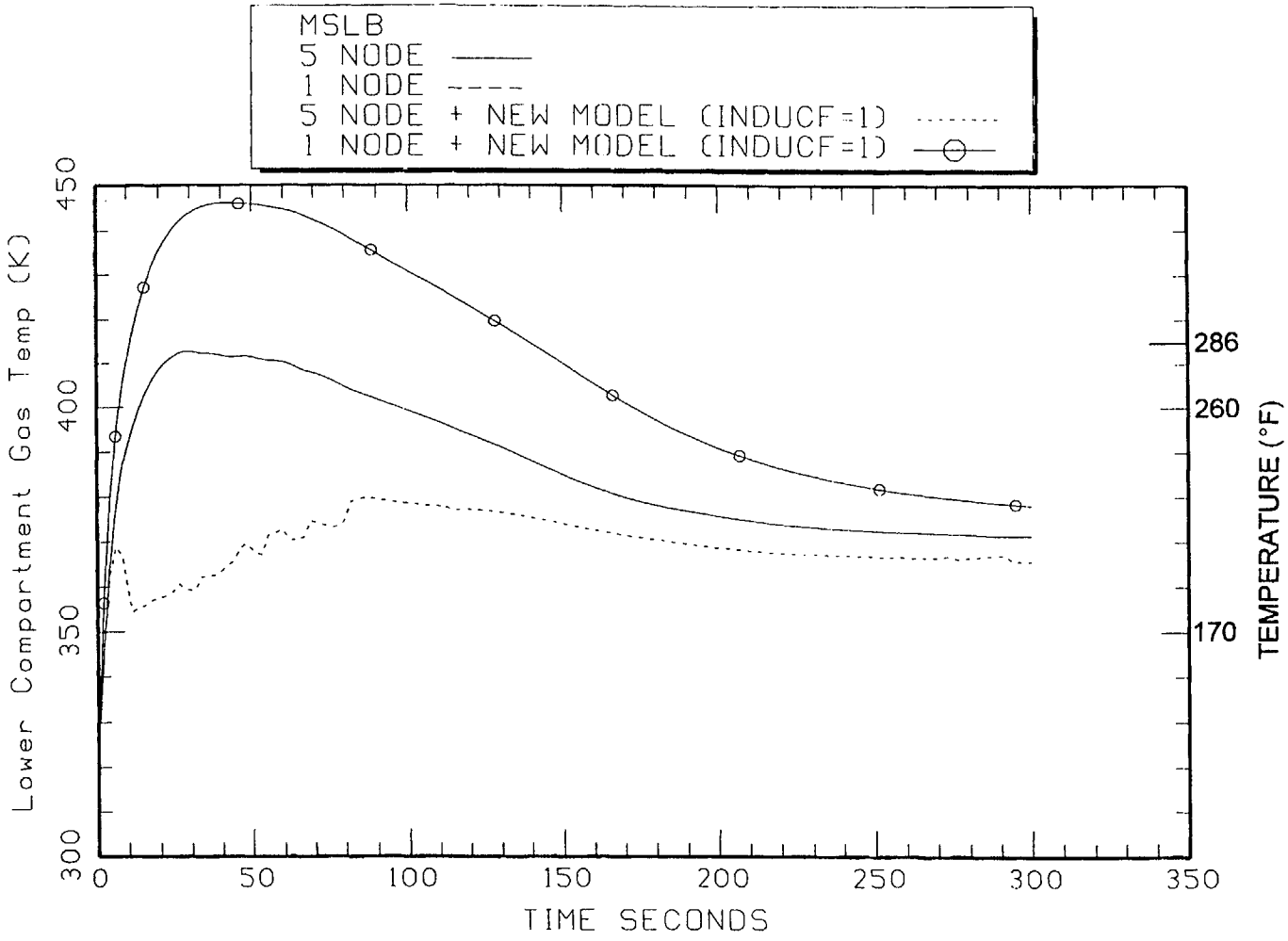
June 20, 2001

NO SPRAYS OR FAN COOLERS

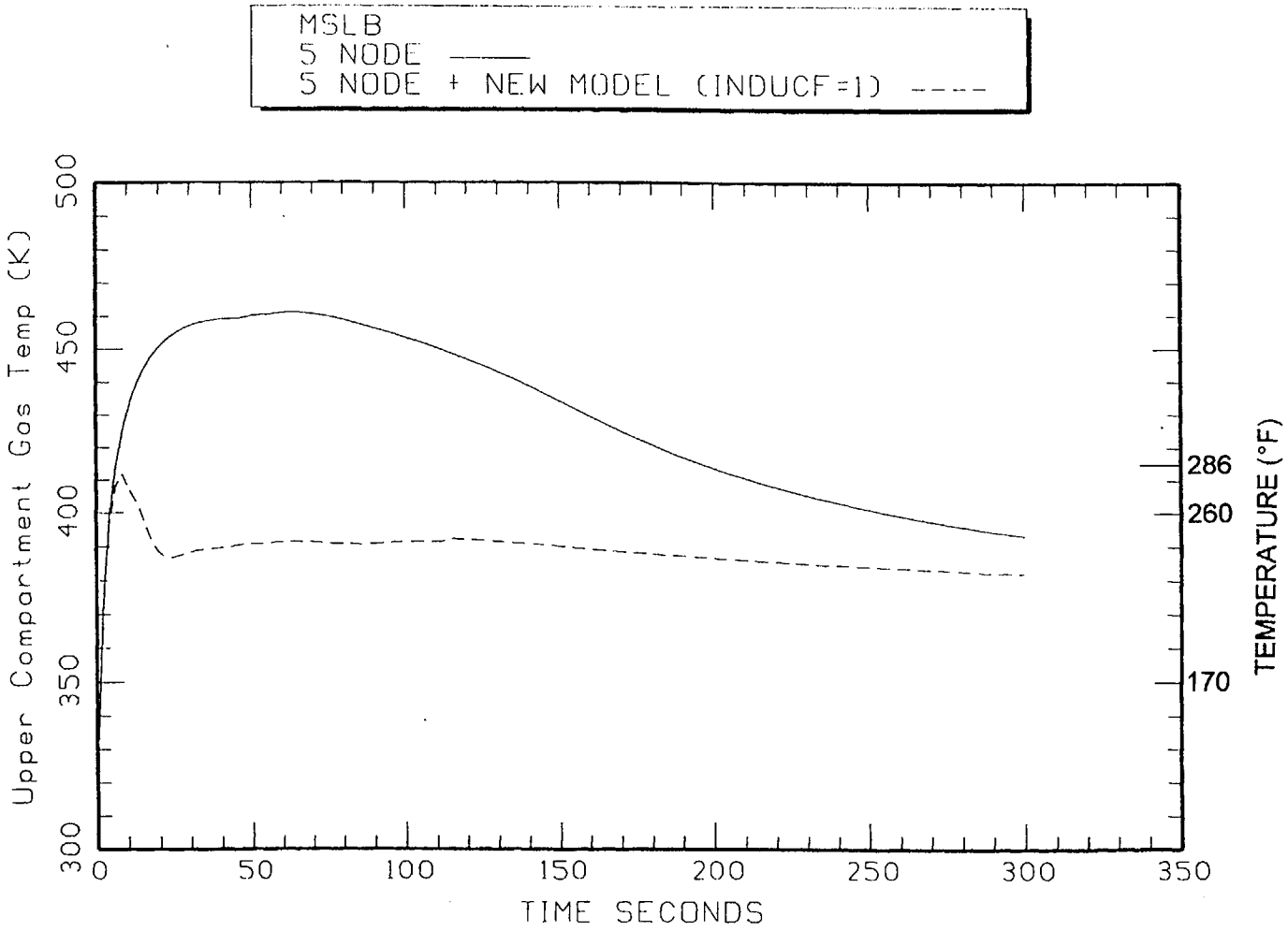


June 20, 2001

NO SPRAYS OR FAN COOLERS



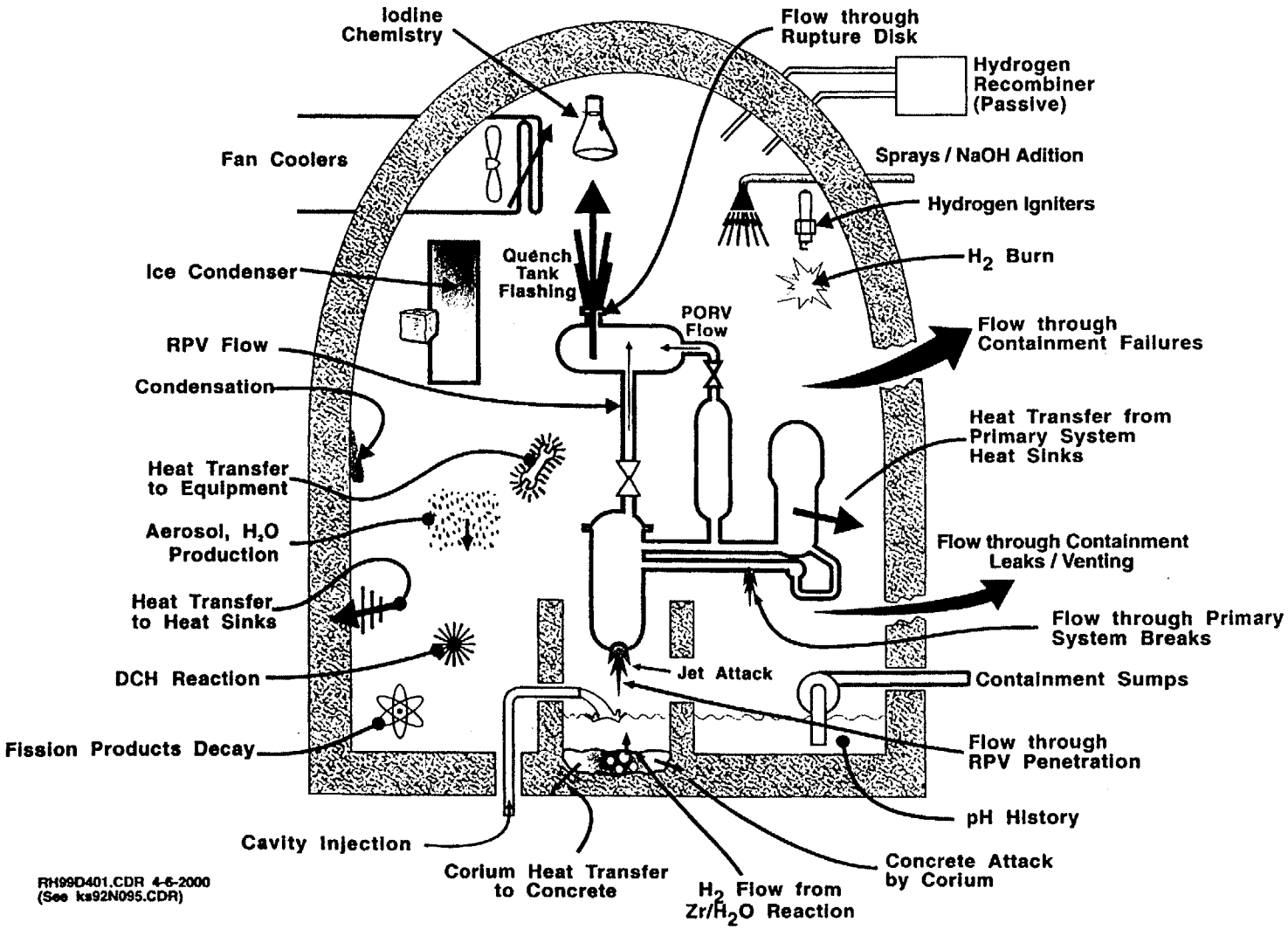
NO SPRAYS OR FAN COOLERS



June 20, 2001

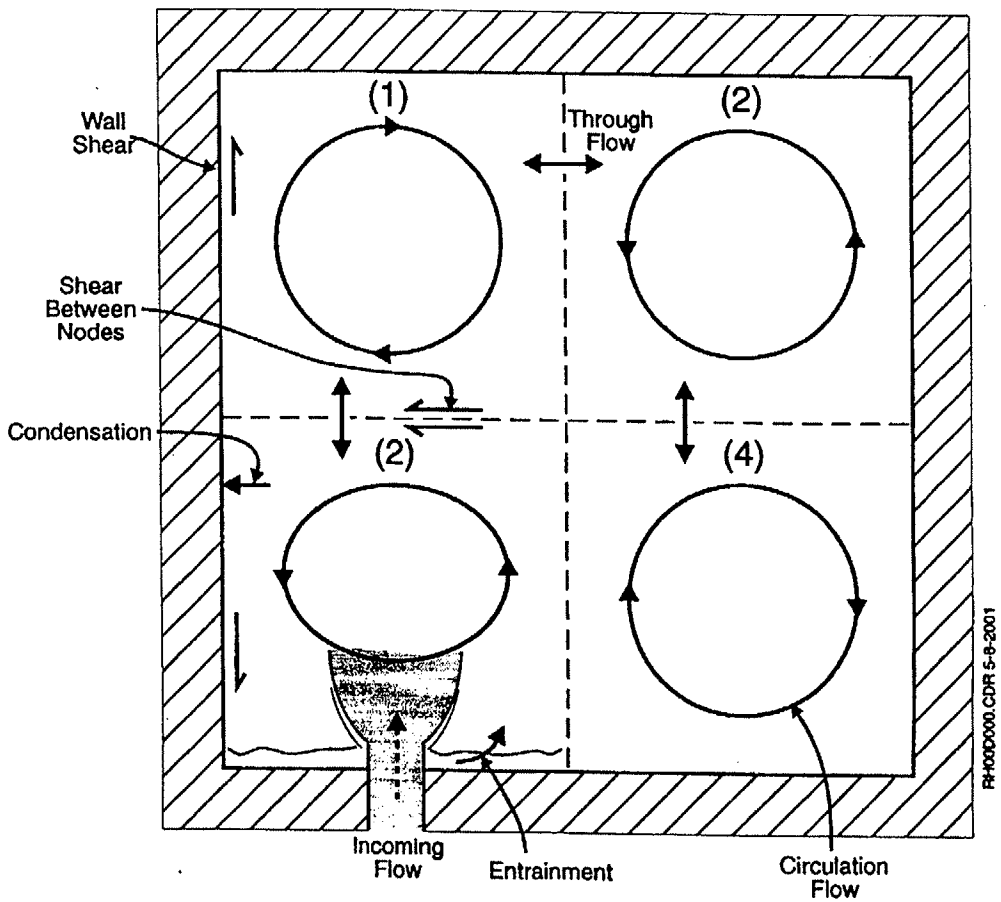
PWR Containment Modeling

(Large Dry and Ice Condensor Configruation)



RH99D401.CDR 4-6-2000
(See ks92N095.CDR)

Schematic of Circulation Flows Evaluated for Each Node (MAAP5 Represents Circulation as a Property of Each Node. The Strength of the Circulation is Determined by a Momentum Balance on Each Node.)



Momentum Balance Solved for Each Node to Determine the Change in the Circulation Velocity

$$I = \int F dt = \int d(m_a U_c)$$

$$\left(M_{in} - M_{out} - F_{fwall} - F_{f,s} - F_D\right)\Delta t = \Delta\left(m_a\ U_c\right) = m_a\ \Delta U_c + U_c \Delta\ m_a$$

$$\Delta U_c = \left[\left(M_{in} - M_{out} - F_{fwall} - F_{f,s} - F_D\right)\Delta t - U_c \Delta\ m_a\right] / m_a$$

I = impulse

M_{in} = incoming momentum $\sum (WU)_{in}$

M_{out} = outgoing momentum $\sum (WU)_{out}$

F_{fwall} = wall friction

$F_{f,s}$ = shear with an adjacent node

F_D = drag on submerged structures

U_c = circulation velocity

m_a = mass of the compartment atmosphere

t = time

Enhancement of the Condensation on Vertical Walls

Use Free Convection to Evaluate the Boundary Layer Thickness

Laminar

$$N_{u,\ell} = \frac{hL}{k} = 0.555\, N_{Ra}^{0.25}$$

Turbulent

$$N_{u,t_1} = 0.13\, N_{Ra}^{1/3}$$

$$N_{u,t_2} = 0.021\, N_{Ra}^{0.4}$$

$$Nu = Max\left(N_{u,\ell}, N_{u,t_1}, N_{u,t_2}\right)$$

$$N_{Ra} = N_{Gr} - N_{PR}$$

$$N_{GR} = g\left[abs\left(T_g - T_{wall}\right)\right]\beta\, L^3/(\nu_g^2)$$

$$N_{PR} = \mu_g\, c_{P,g}/k_g$$

MAAP5

$$N_{u,s} = F_m * N_u$$

$$F_m = 1 + F_{con}\left(\frac{V_R}{V_{R1}}\right)^{0.8}\left(\frac{\rho_{gi}}{\rho_{gas}}\right) NF_{st}$$

$$V_{R_1} = \frac{\nu_{gl}}{\nu_{fl}} \qquad P_1 = 10^5\ Pa$$

$$V_R = \frac{\nu_g}{\nu_f}$$ for the local steam partial pressure

ρ_{gas} gas mixture density in the free stream

ρ_{gi} gas mixture density near the condensing interface

HOW ARE THE MASS AND ENERGY RELEASES DEVELOPED AND USED FOR DESIGN BASIS EVALUATIONS?

- LOCA mass and energy releases for containment integrity.
- LOCA mass and energy releases for NPSH evaluations.
- MSLB mass and energy releases.

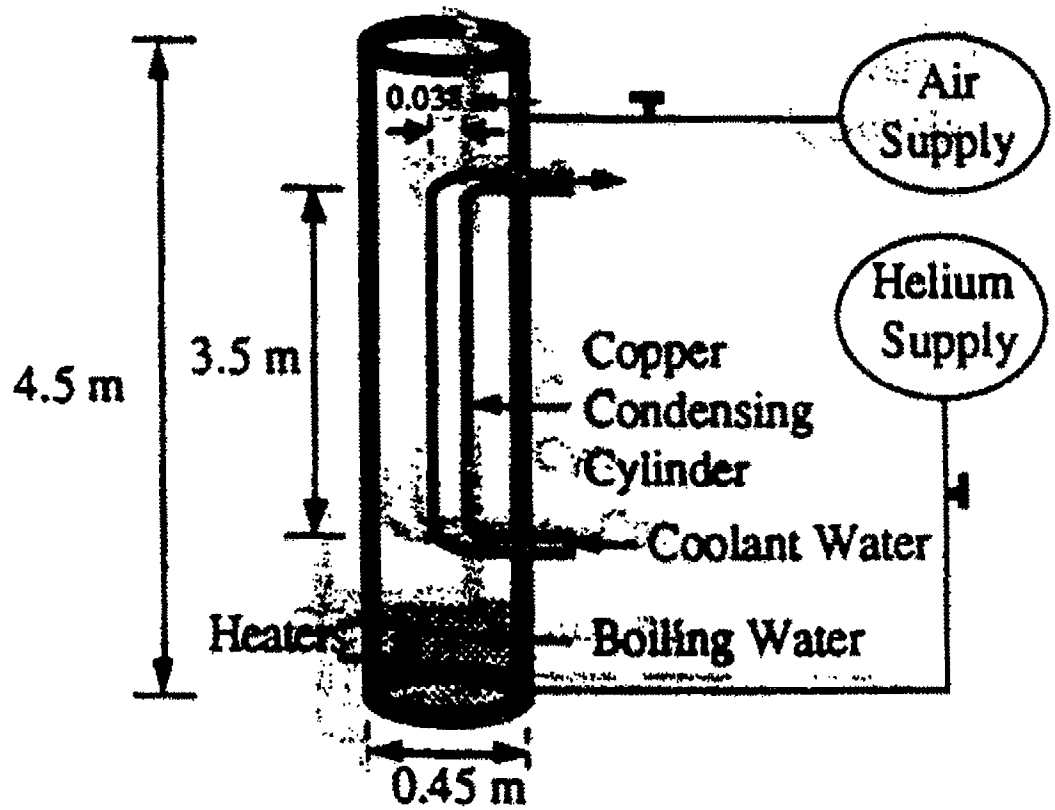
DEVELOPMENT AND INCORPORATION OF DESIGN BASIS MASS AND ENERGY RELEASES WITHIN THE CONTAINMENT

- These design basis analyses will utilize mass and energy releases consistent with the spectrum of design basis accidents to be considered. These include:
  - large break LOCA – containment integrity,
  - large break LOCA – NPSH evaluation, and
  - main steam line break conditions
    - rupture of a main steam line, and
    - split break in a main steam line.
- The design basis mass and energy releases will be developed from primary system models for each plant that have been previously used for design basis calculations.
- The mass and energy releases will be input to the MAAP containment model as a boundary condition. This is exactly the method used for the CVTR and HDR experimental benchmarks.

THE EXPERIMENTAL BENCHMARKS USED TO TEST THE REALISTIC CONTAINMENT MODEL

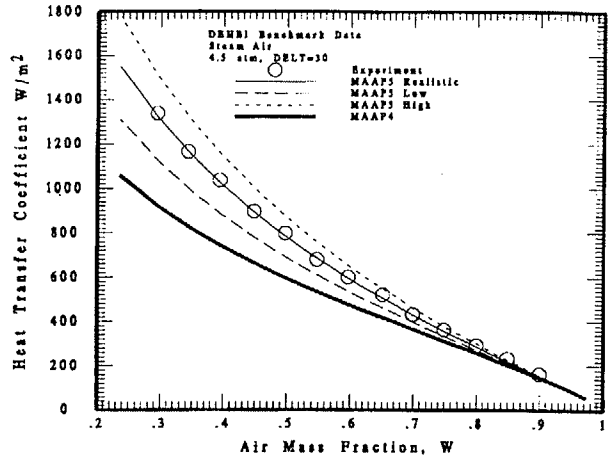
- Separate effects tests.
  - Dehbi condensation experiments.
  - Anderson condensation experiments.
  - Hitachi condensation experiments.
  - Uchida condensation experiments.
  - Tagami condensation experiments.
  - Kulic containment spray tests.
  - Epstein-Kenton countercurrent natural circulation flow tests.
- Large Scale Integral experiments.
  - HDR tests.
  - CVTR tests.
  - CASP tests.
  - These are also a demonstration of using external M&Es.

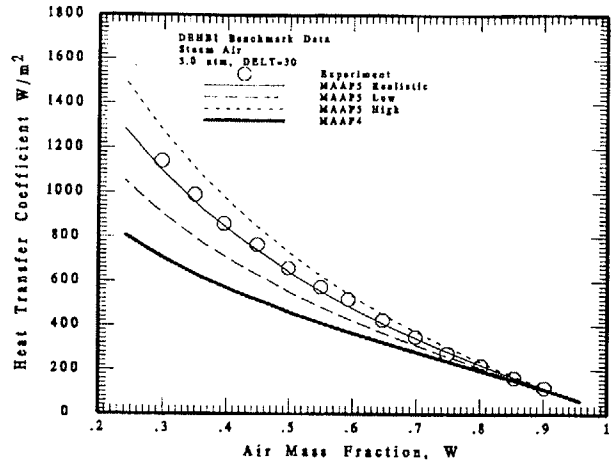
Experimental Apparatus Described by Dehbi et al. (1991)

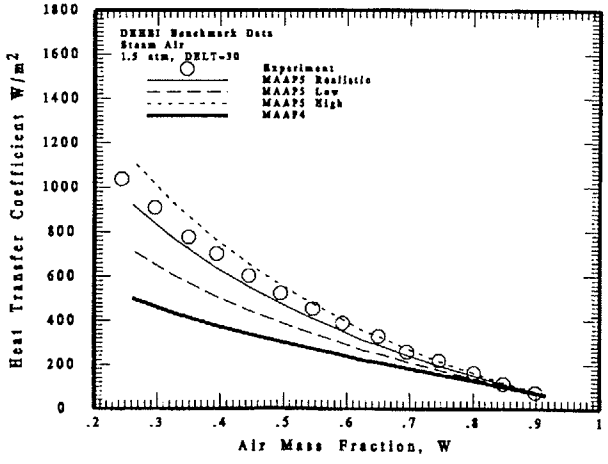


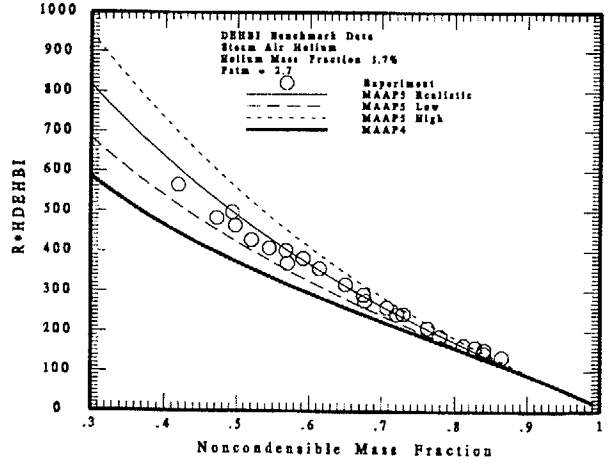
June 20, 2001

Comparison of MAAP4 and MAAP5 With Dehbi's Data

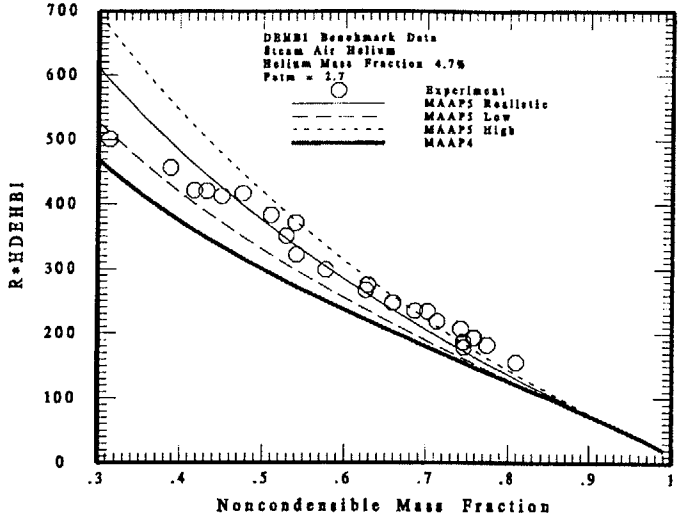


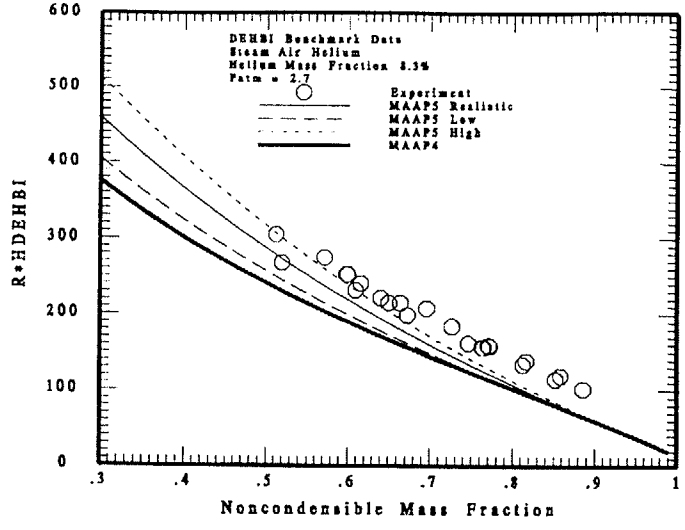






Comparison of MAAP4 and MAAP5 With Dehbi's Data

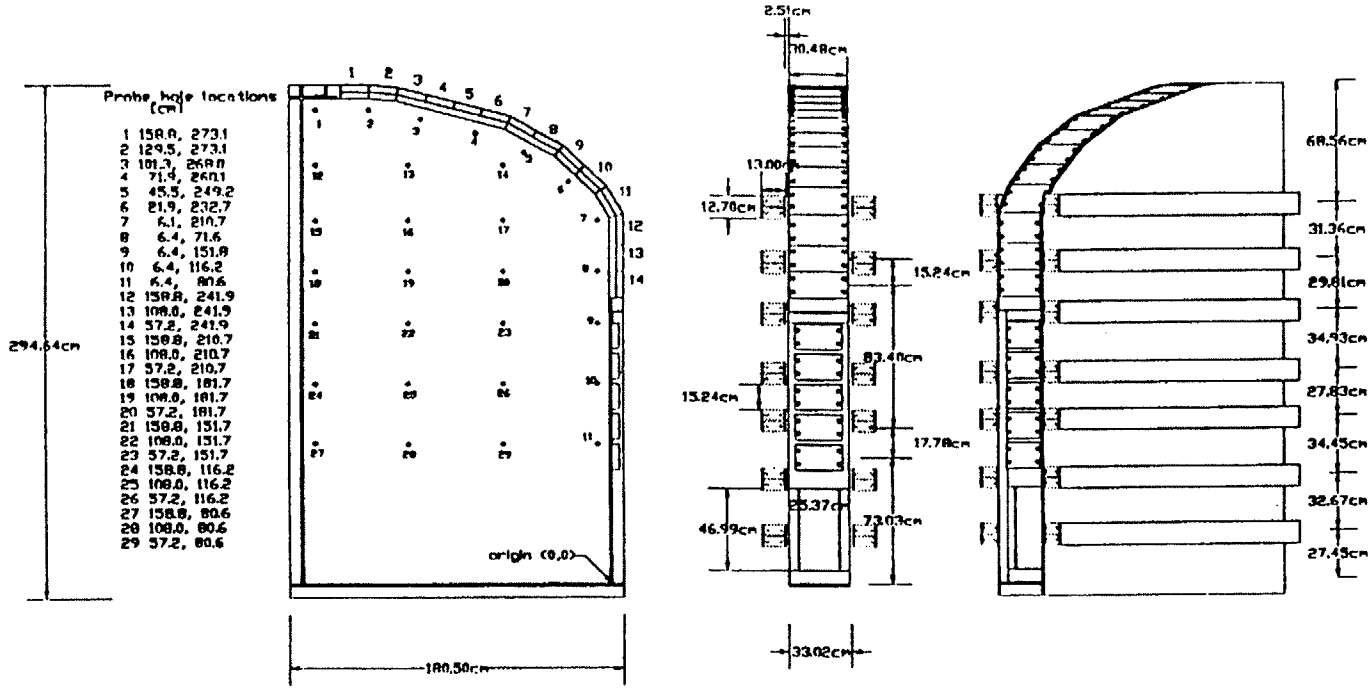




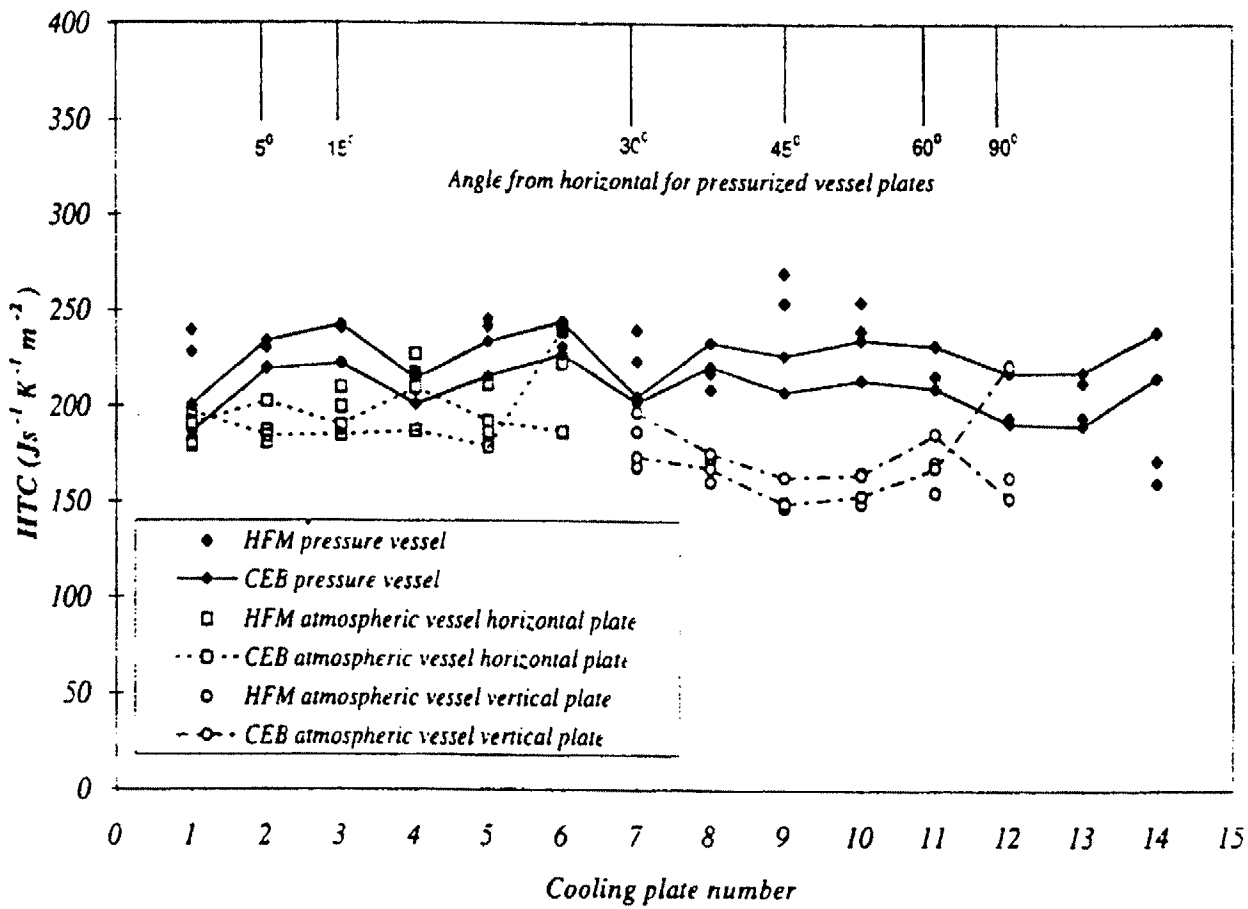
COMPARISON OF ANDERSON'S AND DEHBI'S EXPERIMENTAL RESULTS

Anderson's Experimental Conditions					
T_h (°C)	70	73.7	93.5	106.2	115.7
T_w (°C)	30	33.7	53.5	66.2	75.7
P (bar)	1.0	1.5	2.0	2.5	3.0
W_{nc}	0.78	0.83	0.71	0.61	0.54
W_{nc}/W_N	3.52	5.02	2.42	1.59	1.19
Heat Transfer Coefficients ($W/m^2/K$)					
$h_{T.expt}$	99.9	131.8	275.5	420.3	584.0
$h_{r.Dehbi}$	130.0	115.8	221.8	326.4	428.1

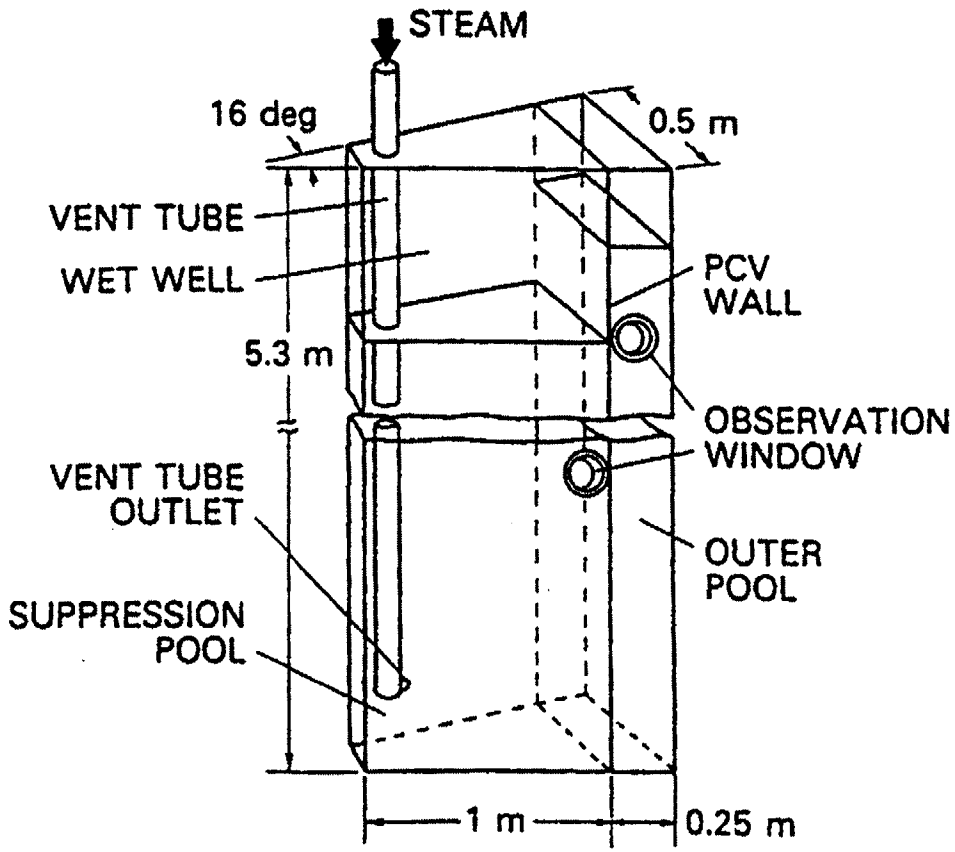
Schematic of the Pressure Test Vessel



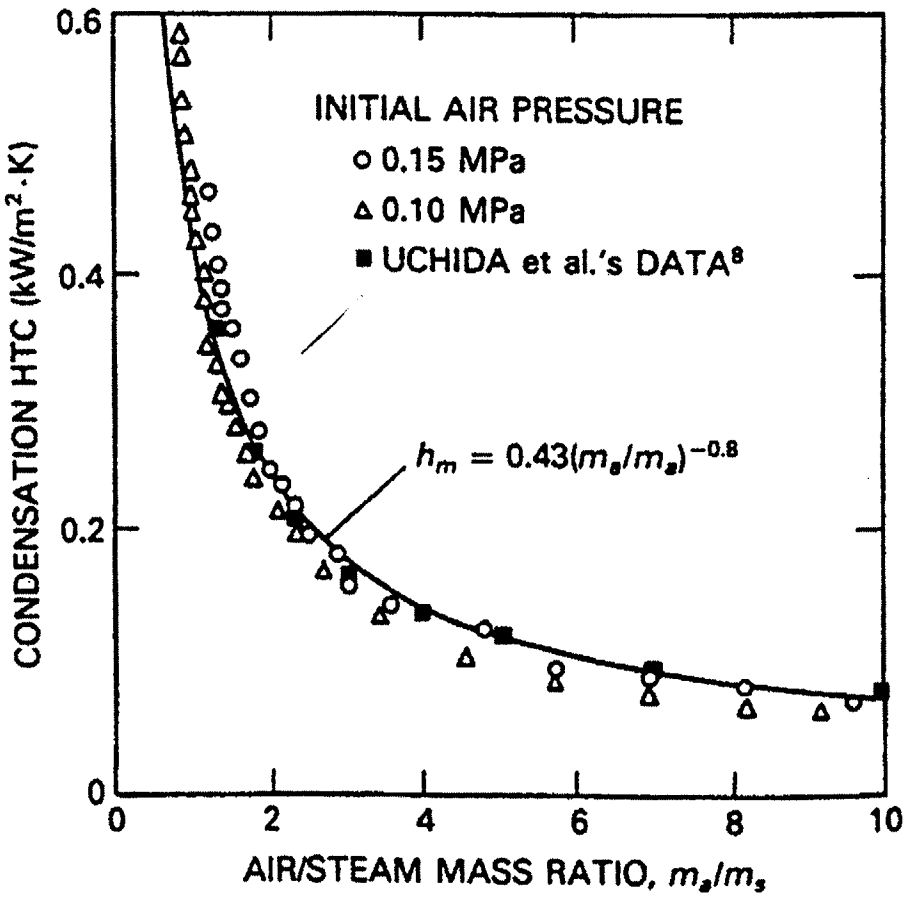
Local Heat Transfer Coefficient Measurement Reproducibility for Both Test Vessel



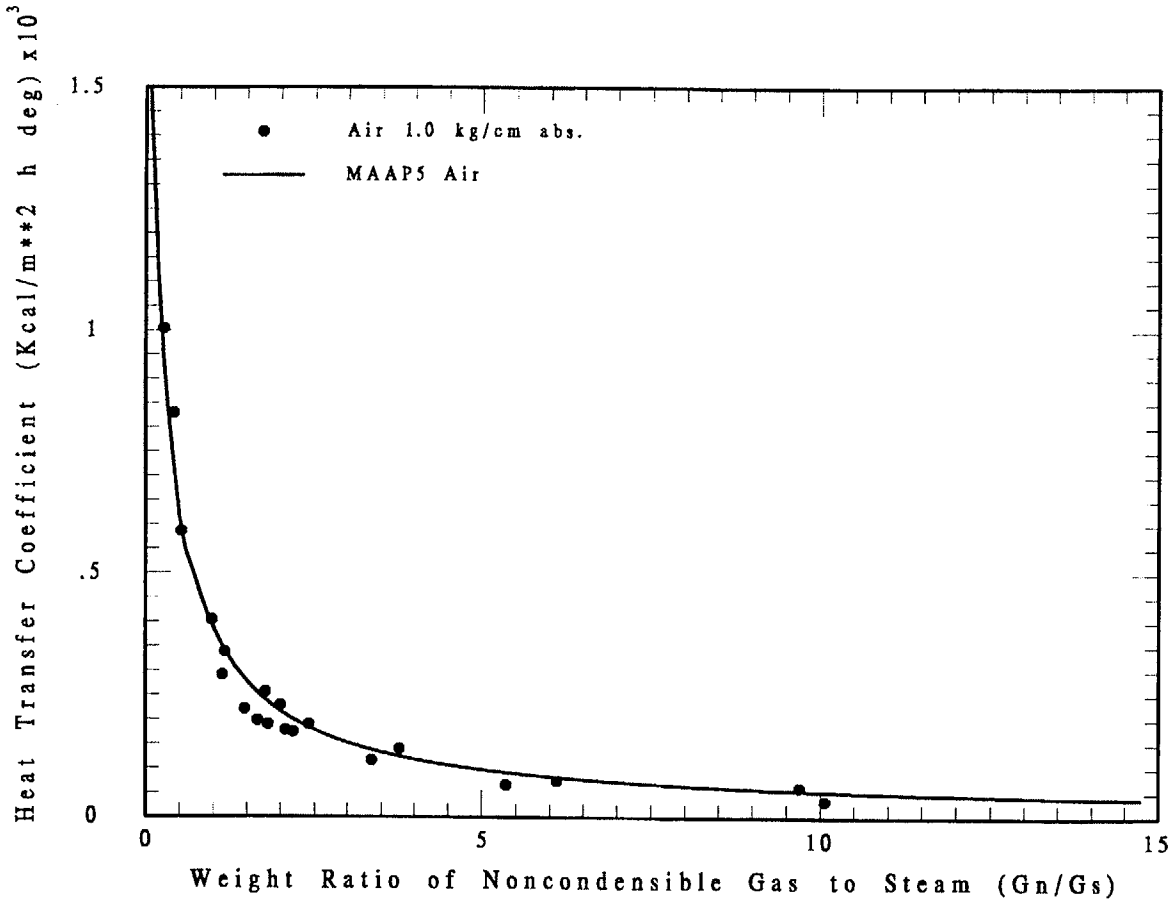
Schematic of the Experimental Apparatus



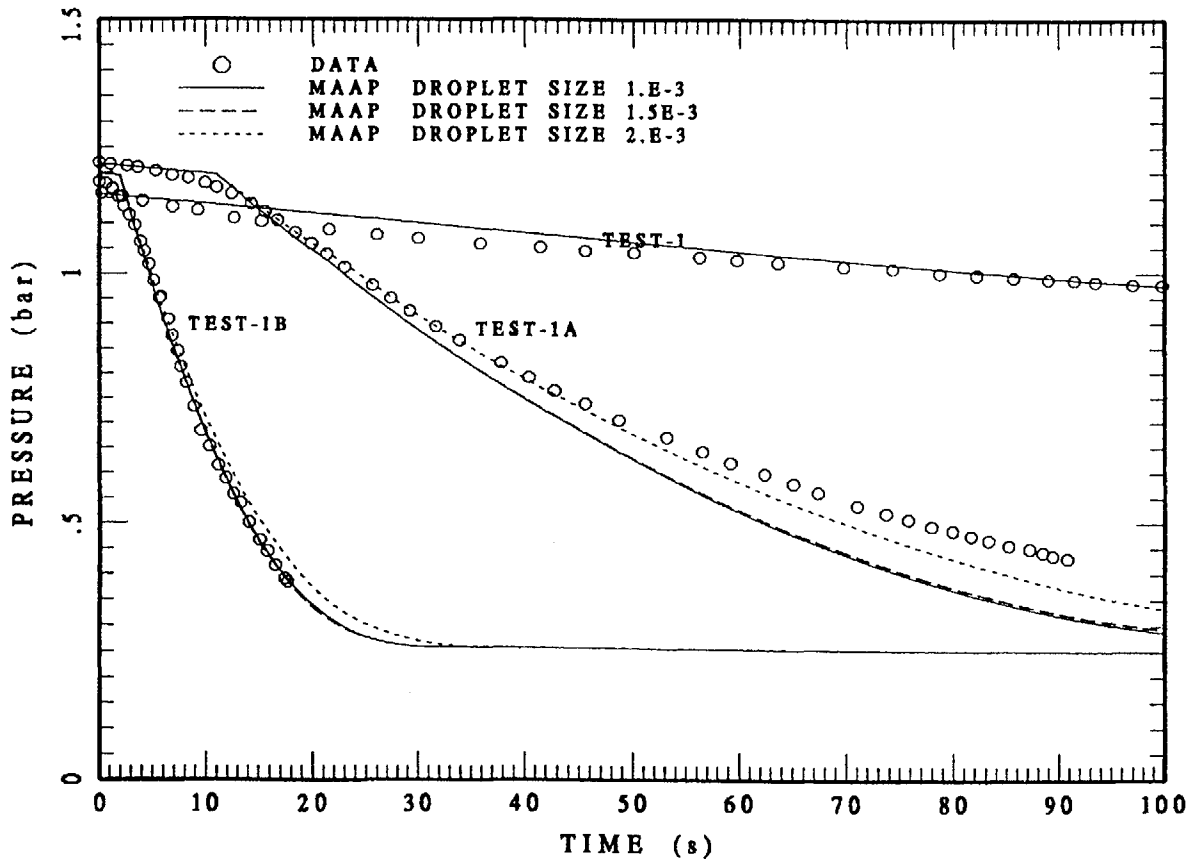
Average Condensation HTC



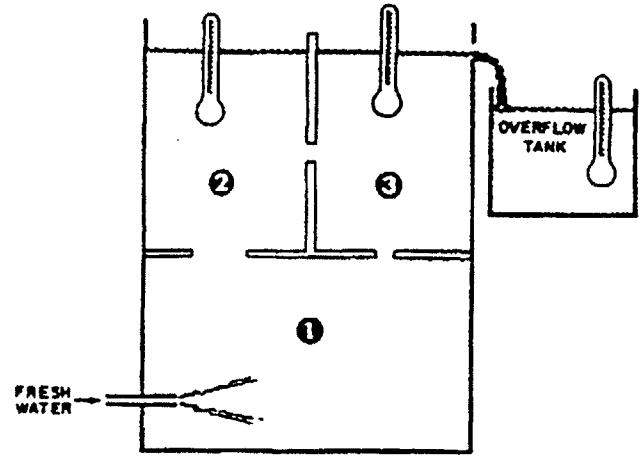
Comparison of the MAAP5 Calculated Overall Heat Transfer Coefficients for Condensation in a Steam-Noncondensible Gas Atmosphere With the Air-Steam Data Reported by Uchida at a Pressure of 1 Bar



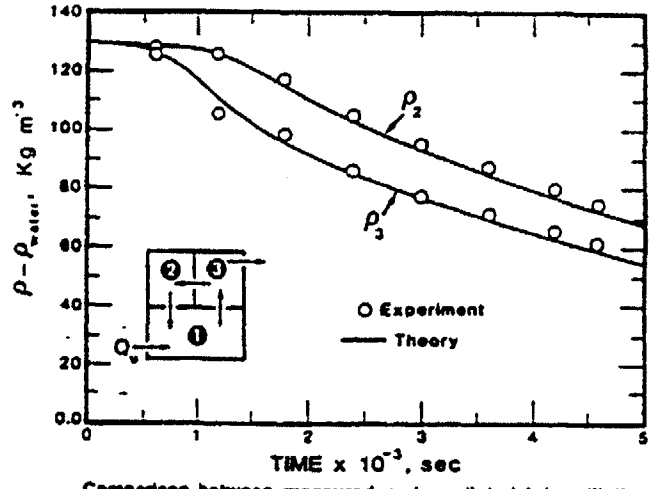
Comparison of the MAAP5Spray Model Prediction in the Experimental Observations Reported by Kulic (1976) For No Spray (Test-1), a Single Spray Nozzle With the Water Temperature at 24°C (Test-1A), and Five Spray Nozzles With a Spray Water Temperature of 24°C (Test-1B)



Epstein-Kenton Countercurrent Natural Circulation Flow Experiments



Three-compartment test configuration; numbers identify compartments

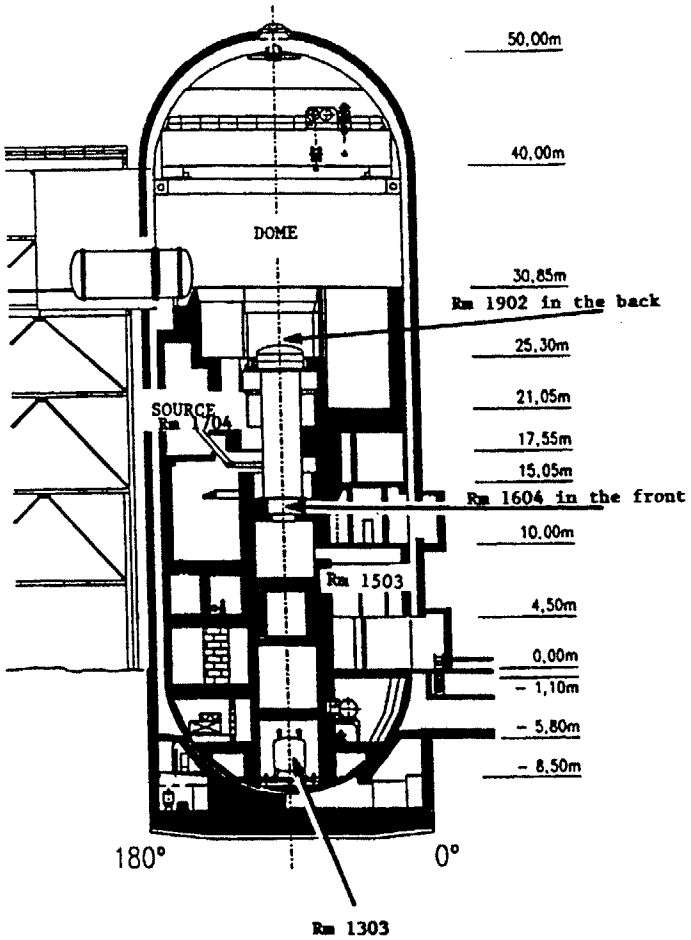


Comparison between measured and predicted brine dilution histories in the three-compartment configuration under conditions where unidirectional flow prevails

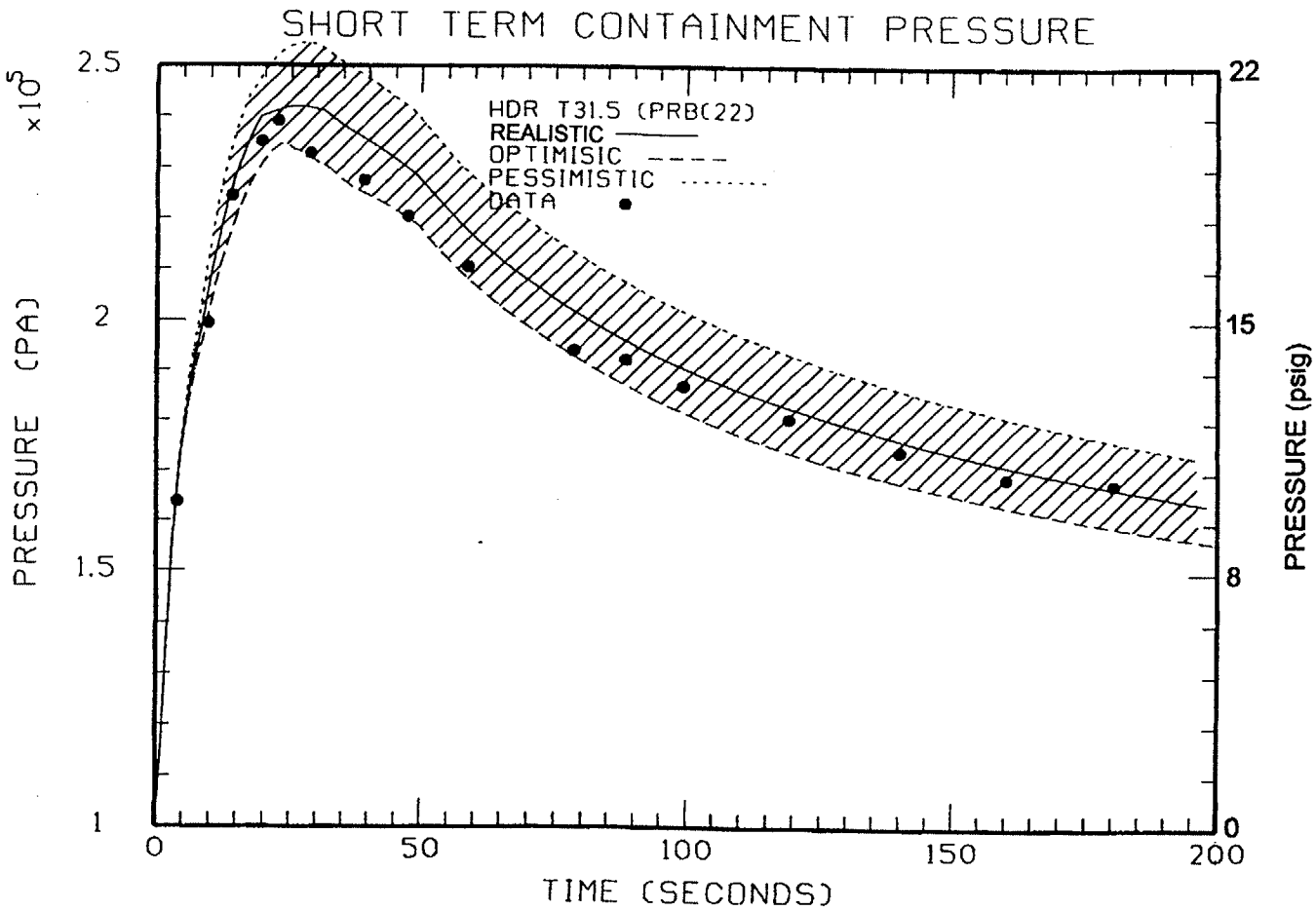
IMPORTANT INTEGRAL BENCHMARKS FOR A LARGE DRY CONTAINMENT

Experiment	Test Results to be Documented	Accident Sequence/Condition Simulated	MAAP5 Comparisons
HDR	HDR Test E11.2 (ISP #29)	Small LOCA with H_2 Release	Yes
	HDR Test T31.5 (ISP #23)	Large LOCA with H_2 Release	Yes
	HDR Test V44 (ISP #16)	Main Steam Line Break	Yes
CVTR	CVTR-3	MSLB	Yes
	CVTR-4	MSLB Plus Containment Spray	Yes
	CVTR-5	MSLB Plus Containment Spray	Yes
Battelle Frankfurt Tests	Test D15 (CASP-1)	Steam & Two-Phase Blowdown into a Sealed PWR Containment	Yes
	Test D16 (CASP-2)	Water Blowdown Into a Scaled PWR Containment	Ongoing
S&L Tests	All Tests	Containment Response for a Large LOCA Including Accumulated Water	Ongoing

HDR FACILITY WITH KEY LOCATIONS FOR T31.5

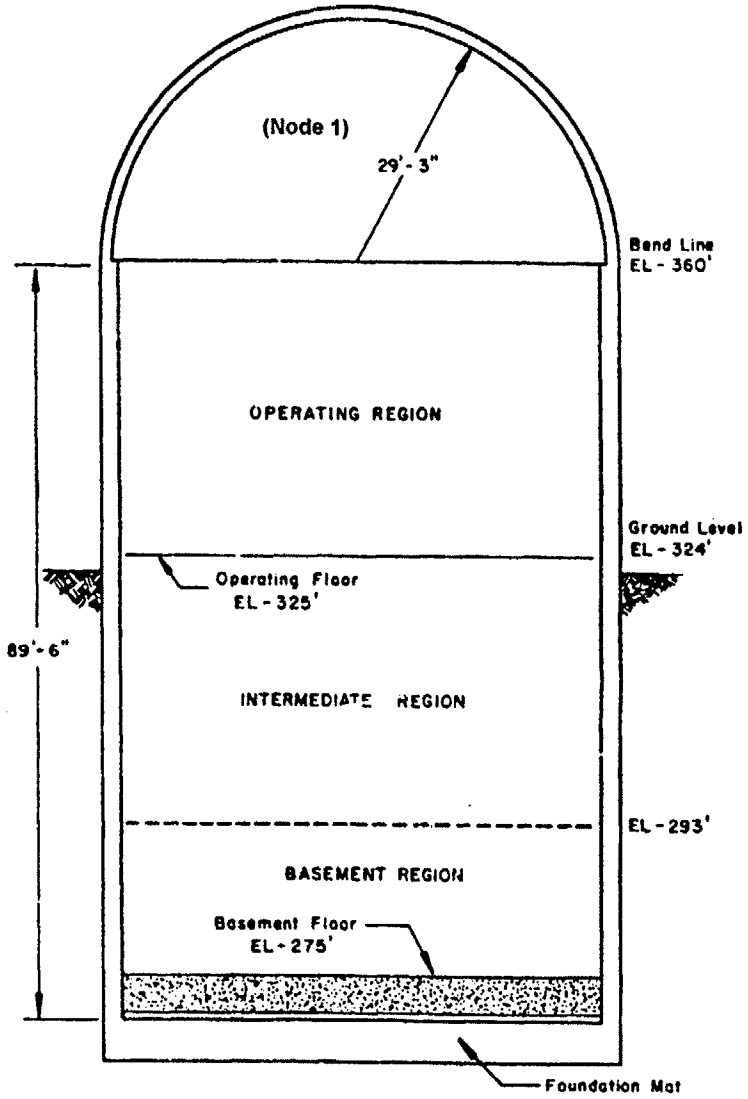


NO SPRAYS OR FAN COOLERS

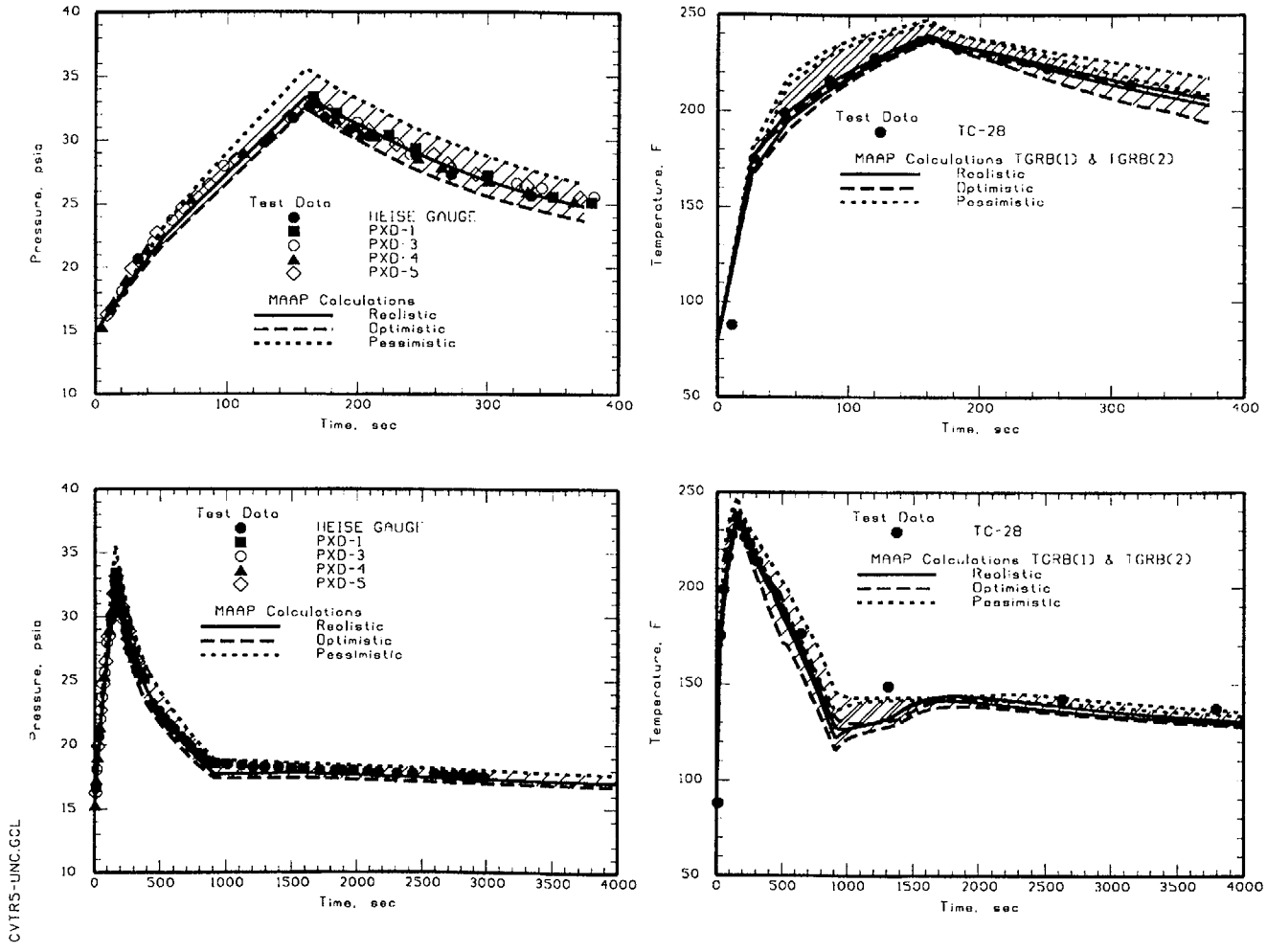


CVTR Containment Building

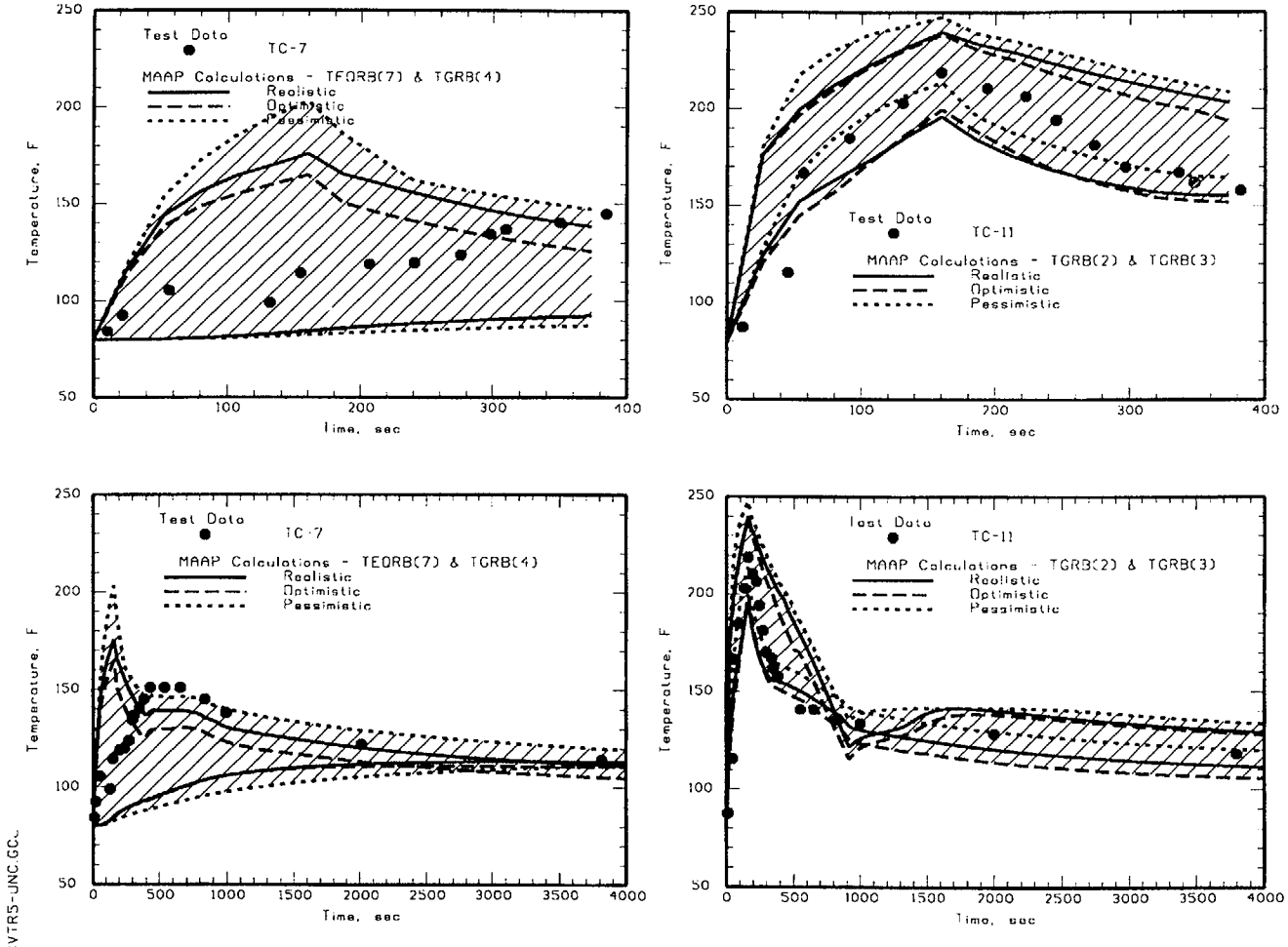
June 20, 2001



CVTR Containment Response, Test 5

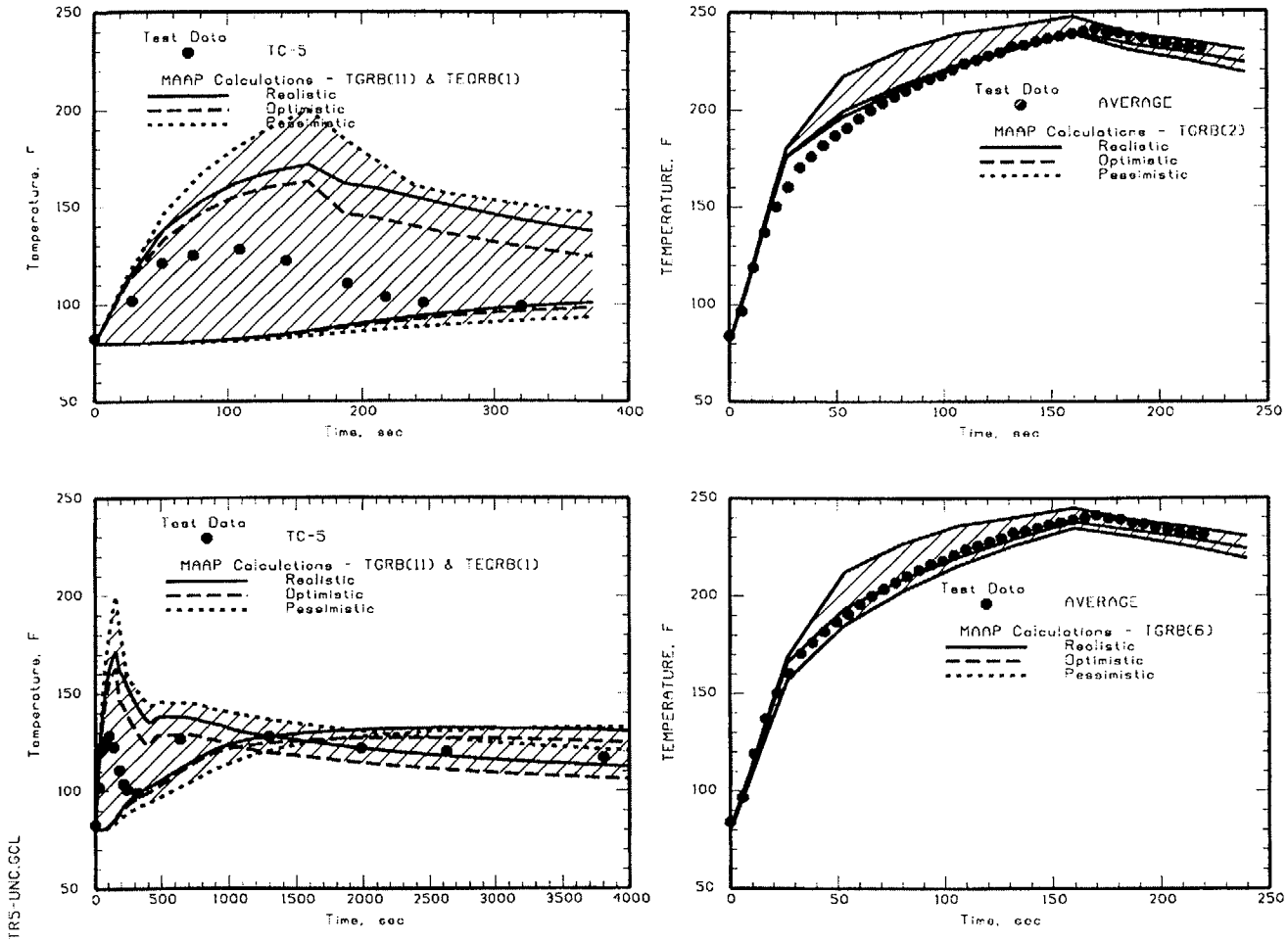


CVTR Containment Response, Test 5



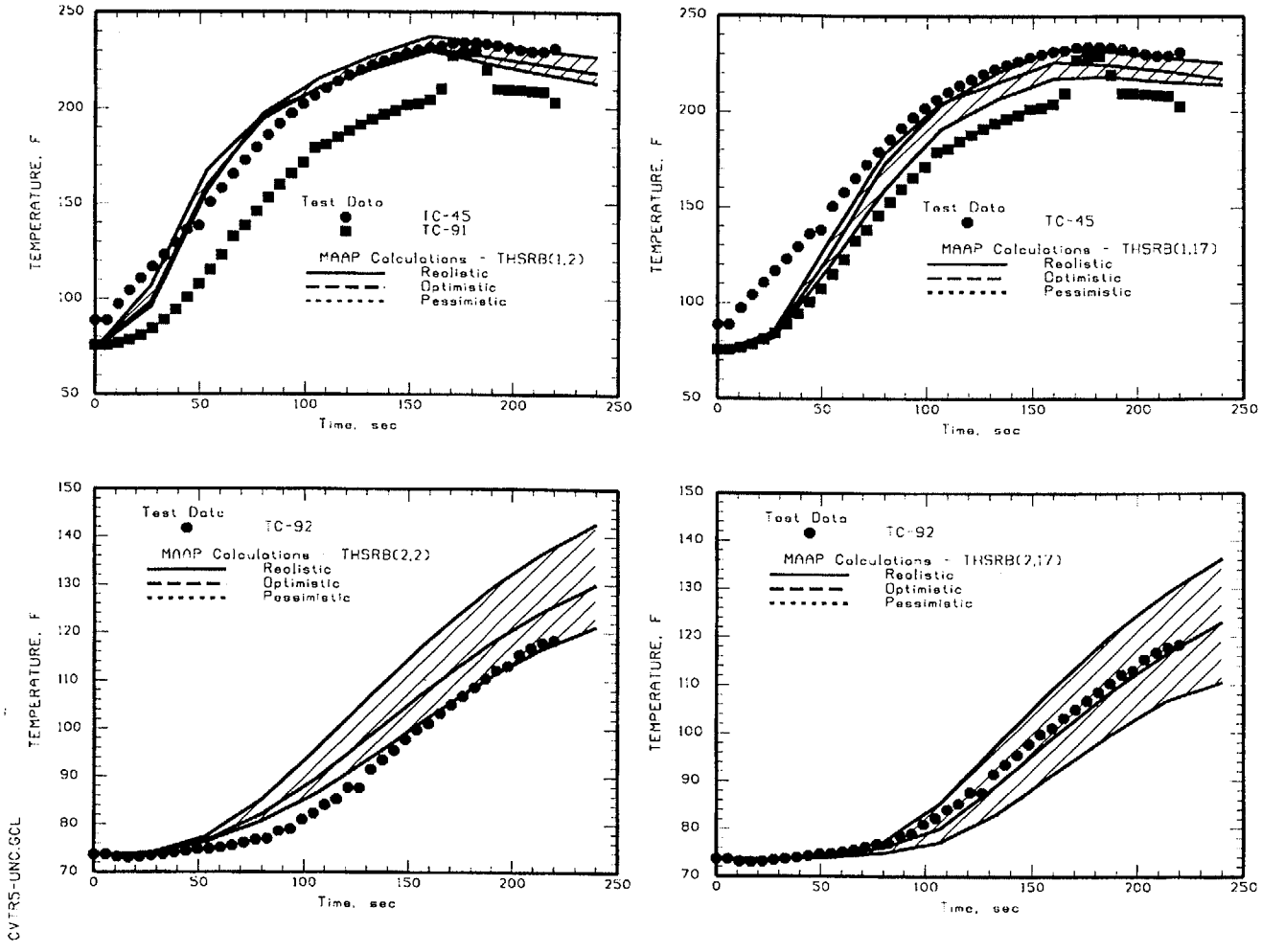
CVTR5-UNC.GC.

CVTR Containment Response, Test 5



CVTRS-UNC.GCL

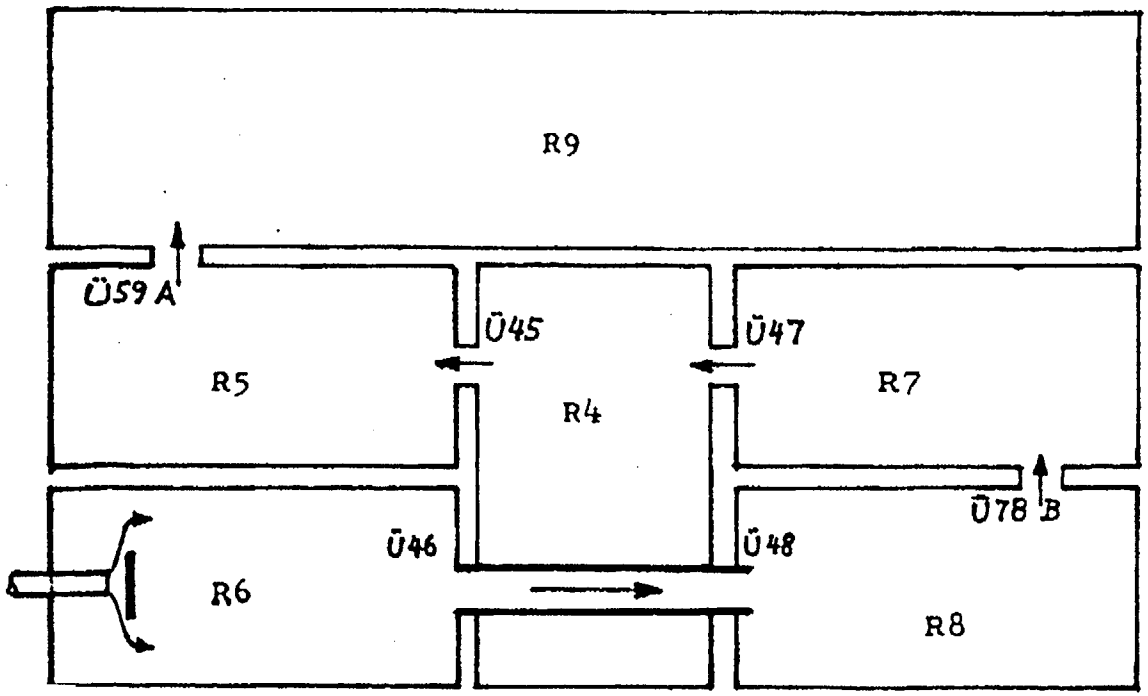
CVTR Containment Response, Test 5



Battelle Frankfurt Tests

For the present experiment D15 the compartments of the containment are connected such as to form a "chain of compartments":
R6 →R8→R7→R4→R5→R9.

Arrangement of compartments:



June 20, 2001

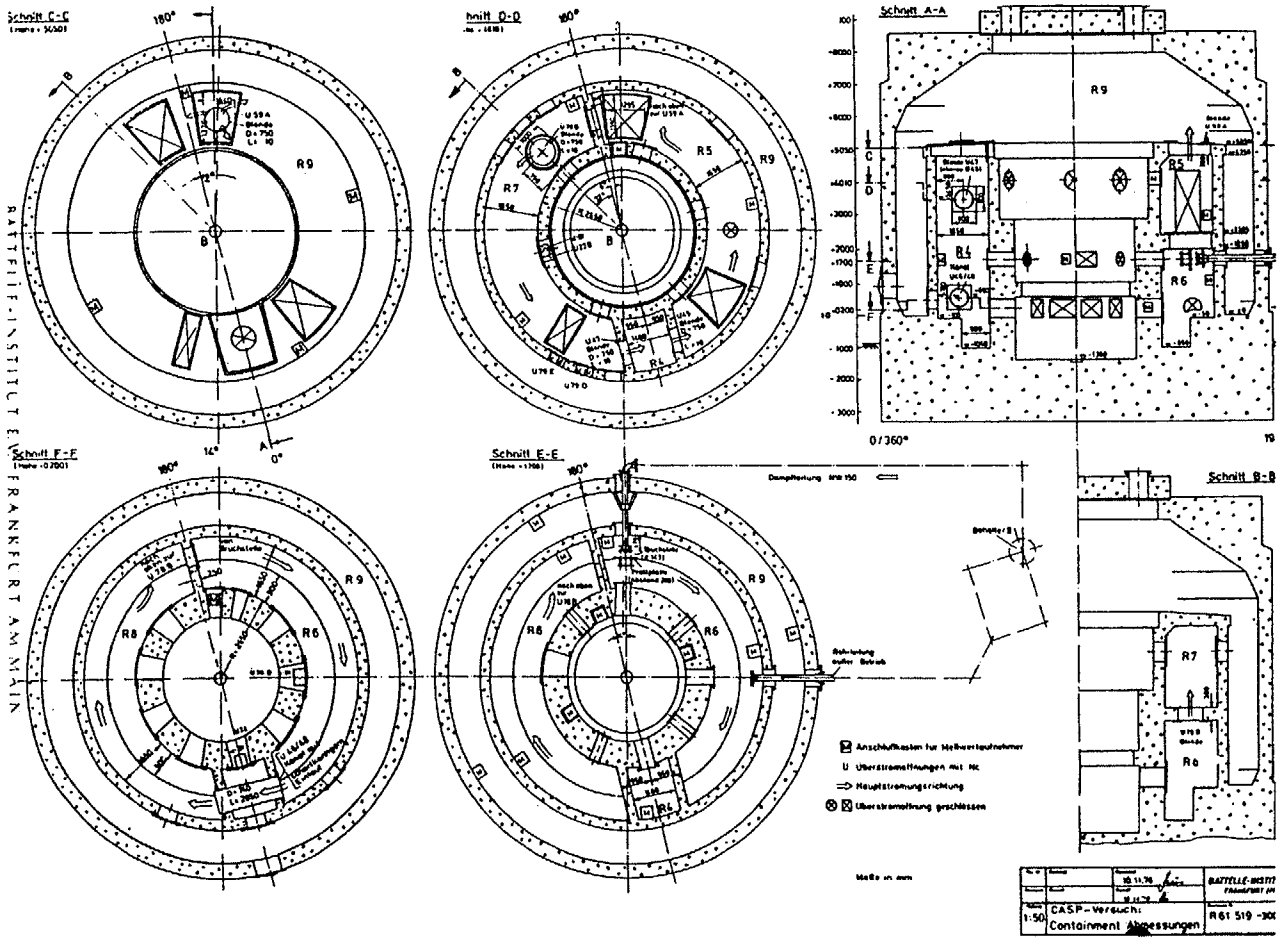
Input for Battelle Frankfurt Test D15

	Designation	Compartment Volume (m^3)	Concrete Surface Area (m^2)	Metal* Surface Area (m^2)	Vent Dia. (m)	Vent Area (m^2)
Break compartment	R6	41.26	90.12	25.7		
1st vent (channel R6/R8)	γ46/γ48	0.8			0.74	0.430
2nd compartment	R8	40.53	92.0	18.3		
2nd vent (orifice)	γ78B				0.75	0.442
3rd compartment	R7	40.4	76.6	16.0		
3rd cent (orifice)	γ47				0.75	0.442
4th compartment	R4	12.2	38.6	16.4		
4th vent (orifice)	γ45				0.75	0.442
5th compartment	R5	41.05	76.1	27.4		
5th vent (orifice)	γ59A				0.75	0.442
6th compartment	R9 etc.	450	645.8	87.5		

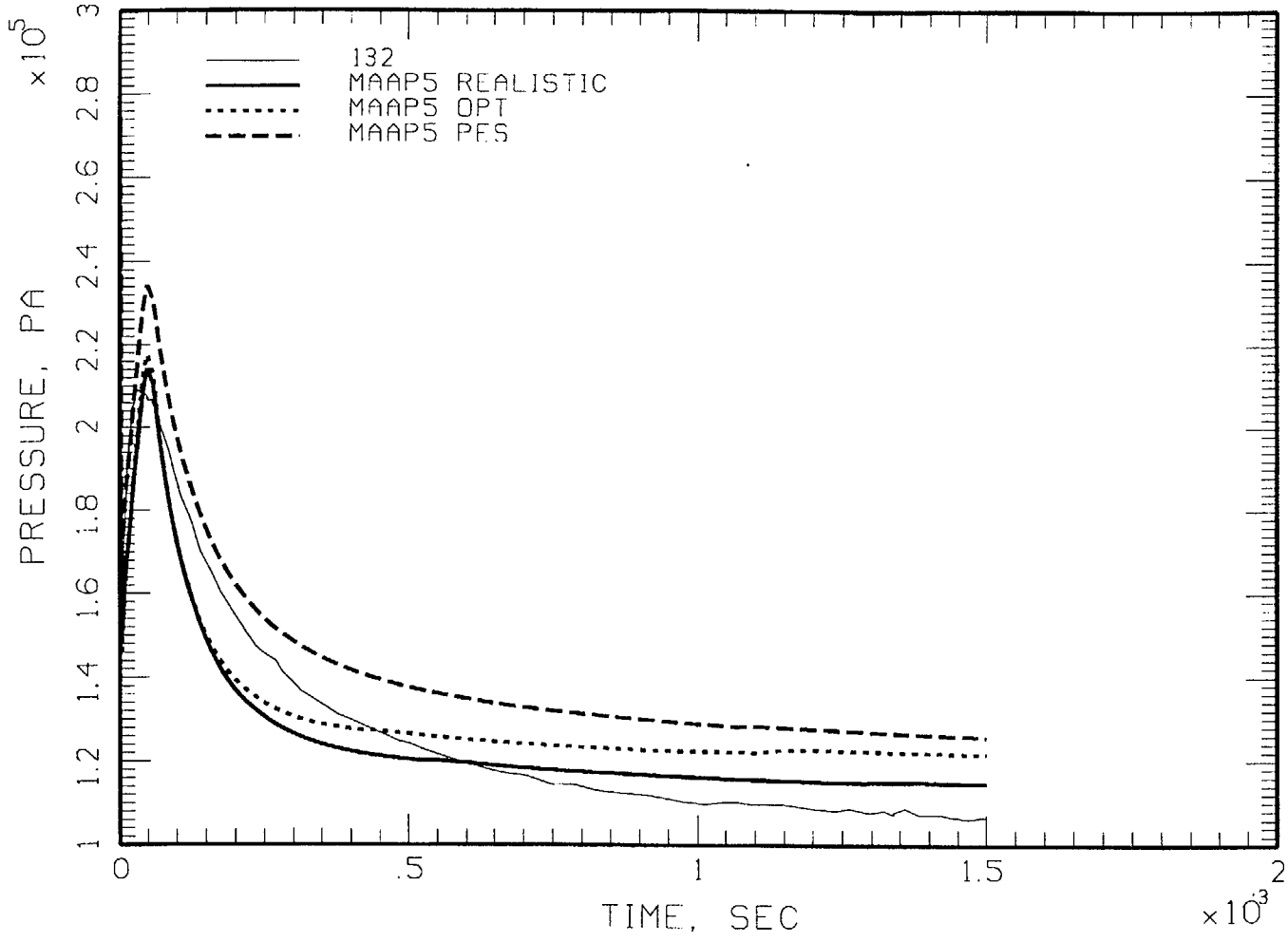
*Detailed list of the surface areas of metal components on the next pages. The surface areas include internals in the individual compartments, such as pipes, cover plates, etc.

June 20, 2001

Test Building Configuration for Battelle Frankfurt Experiment D-15



Comparison of MAAP5 and Battelle Frankfurt Experiment D-15



THE REPRESENTATION OF UNCERTAINTIES

- Realistic uncertainty boundaries for individual phenomena are developed using separate effects tests.
- These uncertainty boundaries are tested with large scale, integral experiments.

PROPRIETARY

THE 5SSTAR PROCESS TO QUALIFY ANALYTICAL MODELS (COMPUTER CODES)

PROPRIETARY

5SSTAR

(5 Step Structured Treatment for Analytical Representation)

PROPRIETARY

Comparison of the 5SSTAR Process and the Six Basic Principles Defined in DG-1096 "Transient and Accident Analysis Methods"

Conclusion With Respect to the Uncertainty Evaluations

CONCLUSIONS

- The passive heat sinks in a large dry containment are very effective in condensing steam and reducing the containment pressure. These can only be properly represented using a realistic model with sufficient nodalization (5-20 nodes).
- The MAAP5 models for condensation and structural heat sinks and that due to containment sprays have been benchmarked against the applicable separate effects tests. This includes tests with steam and air as well as gas mixtures of air-helium-steam.
- The MAAP5 large dry containment model has been compared to the relevant large scale containment experiments. Furthermore, these experiments include those conditions typical of both large break LOCA accidents as well as as MSLBs.
- The 5SSTAR process provides a structured approach for understanding and separating ALL relevant experiments as well as to quantify and characterize the uncertainties. This also simplifies the process of keeping the analysis current.
- The composite of the extensive benchmarking with applicable experiments and the comparison with large scale results, as well as the inclusion of realistic uncertainty boundaries for the physical models provides the necessary technical basis for assessing the response of large dry containment building to design basis events.