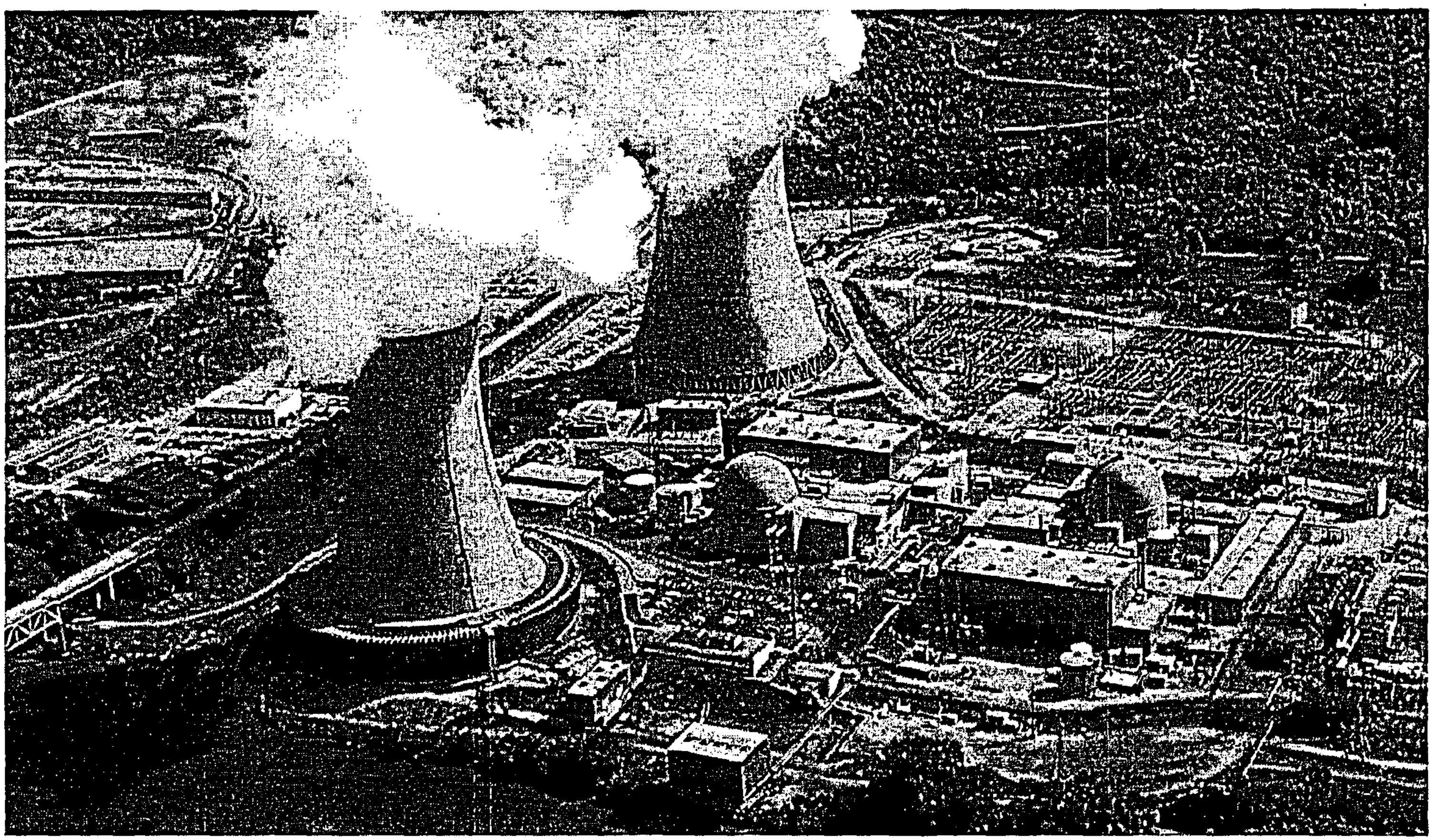
MAAP-DBA Code Meeting
December 10, 2003



FENOC
FirstEnergy Nuclear Operating Company

Agenda

- Introductions
- Objectives
- NRC comments after review of Pre-Application Report
- MAAP-DBA Code Features
  - Single Node Containment Model
  - Multiple Node Containment
  - Generalized Containment Modeling Features
- MAAP-DBA Code Benchmarking
  - GOTHIC Comparisons
  - Separate Effects Experiments
  - Integral Effects Containment Experiments
  - NOTRUMP Comparisons
- Results for Limiting Cases
- Staff Comments
- Conclusions

Objectives

- Provide Update on MAAP-DBA Model
- Discuss MAAP-DBA Code Benchmarking
- Review Results of Limiting Cases
- Obtain Staff Feedback on Pre-Application Report

MAAP-DBA Code Features

Pre-Application and Final LAR Summary

Parameter	Mass/Energy	Containment Model Used	Containment Methods	Precedents	MAAP-DBA Benchmarks	Results To Date and NRC Submittal Schedule
LOCA: Peak Pressure Gas Temperature Cont. Liner Temp	NRC Approved WCAP 10325-P-A	Single Node MAAP-DBA	Std Review Plan Tagami Heat Transfer No Entrainment 10% Airborne Water	NRC Approved: W-312 C-E #1 W-212 In NRC Review: C-E #2	GOTHIC 6.0a HDR – V44 HDR – T31.5 BFMC D-16	Model Description This Pre-Application Report Limiting Pressure Case: <45 psig Both Units This Pre-Application Report Remaining Cases: LAR 2004
MSLB Peak: Peak Pressure Gas Temperature Cont. Liner Temp	NRC Approved WCAP 8822-P-A	Single Node MAAP-DBA	Std Review Plan Uchida Heat Transfer No Entrainment 8% Re vaporization	NRC Approved: W-312 C-E #1 W-412 W-212 In NRC Review: C-E #2	GOTHIC 6.0a CVTR #3 CVTR #4 CVTR #5	Model Description This Pre-Application Report Limiting Pressure Case: <45 psig Both Units This Pre-Application Report Remaining Cases: LAR 2004
LOCA: NPSH	NRC Approved WCAP 10325-P-A	Multi Node MAAP-DBA	Std Review Plan Natural Convection No Entrainment 10% Airborne Water	NRC Approved M&E Current Licensing Methods	N/A	Model Description This Pre-Application Report Plant Analysis: LAR 2004
SBLOCA: Cont. Pressure NPSH Sump Water Inventory	MAAP Generated M/Es	Multi Node MAAP-DBA	Std Review Plan Natural Convection No Entrainment 10% Airborne Water	Cook Station	NOTRUMP NUPEC M-7-1	Benchmarking: This Pre-Application Report Plant Analysis: LAR 2004

Overview

- Plant Specific Application of MAAP-DBA to BVPS is supported by:
  - Previous NRC Acceptance of Methodology for Design Bases Analysis at other plants as well as at BVPS
  - Benchmarking against GOTHIC in BVPS Specific Analysis
  - Benchmarking to Separate Effects Experiments
  - Benchmarking to Integral Effects Containment Experiments
- Peak pressure remains less than current design basis – No rerating required for atmospheric conversion

Single Node Model

- Tagami Heat Transfer Used for Calculating LOCA and Uchida for MSLB:
  - Peak Pressure
  - EQ Temperatures
  - Liner Temperatures
- The same Tagami/Uchida correlations as in current licensing basis (Unit 2 UFSAR) are incorporated in MAAP-DBA.
  - The Tagami maximum heat transfer coefficient is given as

$$h_{max} = 75 \left(\frac{E_p}{V t_p} \right)^{0.6}$$

FENOC
FirstEnergy Nuclear Operating Company

Single Node Model

Where

h_{max}	=	Tagami heat transfer coefficient (Btu/hr-ft^2-^oF)
E_p	=	Integrated energy released to the containment at the time of the first peak pressure (Btu),
V	=	Containment free volume (ft^3), and
t_p	=	Time of the first peak pressure (sec).

- Before the first peak pressure is reached, the heat transfer coefficient is calculated as:

$$h = h_{max} \left(t / t_p \right)$$

where t is the time in seconds after the accident.

Single Node Model

- After the first peak pressure is reached, the following equation is used to calculate the heat transfer coefficient:

$$h = h_{stag} + \left(h_{max} - h_{stag}\right) e^{-0.05(t-t_p)}$$

Where

h_{stag} = The stagnation heat transfer coefficient = 2 + 50 X (Btu/hr-ft^2-^{o}F), and

X = Steam/Air mass ratio.

Single Node Model

- The Uchida heat transfer coefficient is given as

$$h = HP_s / (3.25 P_t) \text{ if } 0.01 \leq (P_s / P_t) \leq 0.19$$

or

$$h = H e^{-3.5\left(1 - \frac{P_s}{P_t}\right)} \text{ if } (P_s / P_t) > 0.19$$

where

h	=	Uchida heat transfer coefficient (Btu/hr-ft^2-^{o}F),
H	=	Heat transfer coefficient for pure steam (200 Btu/hr-ft^2-^{o}F),
P_s	=	Partial pressure of steam, and
P_t	=	Total pressure of containment atmosphere.

Multiple Node Model

- Multi Node Model with Natural Convection Heat Transfer used for Calculating:
  - LBLOCA NPSH and Sump Water Temperature
  - SBLOCA Sump Water Level and Temperature

- Natural convection heat transfer is calculated based on correlation of the form of the average Nusselt number

$$N_u = a(R_a)^n = h_{conv} \frac{L}{k_g}$$

FENOC
FirstEnergy Nuclear Operating Company

Multiple Node Model

where

R_a = Gr Pr

Gr = compositional Grashof number

$$= \frac{\rho_g^2 \, g / \Delta\rho_g / L^3}{\rho_g \, \mu_g^2}$$

$$Pr = \frac{\mu_g \, c_{pg}}{k_g}$$

MAAP-DBA Code Features

- During LOCA blowdown interval 10% of the non-flashed liquid is treated as airborne suspended water and the balance is directed to the sump water pool.
- For MSLB when gas is super heated, revaporization of condensate is allowed. The revaporization fraction is 8%.
- No Credit for Forced Convection Heat Transfer
- No Credit Taken for Entrainment of Water From Pools and Containment Surfaces

MAAP-DBA Code Features

- Generalized Containment Model Addresses the following:
  - Pressure and Temperatures in a Region (1)
  - Heat Transfer to Passive Heats Sinks (1)
  - Heat Removal by Active Systems (1)
  - Flow rates between Containment Building Compartments (2)

(1) Applies to both single and multiple node application

(2) Applies only to multiple node applications

MAAP-DBA Code Benchmarking

- GOTHIC Comparisons
  - Comparisons of Limiting LOCA and MSLB Cases were run
    - LOCA cases for DEHL
    - MSLB cases:
      - Unit 1 - 1.4ft^2 DER @30% power
      - Unit 2 - 1.069ft^2 DER @ 0% power
  - GOTHIC and MAAP-DBA used the same initial conditions (See Table 2-2)
  - Single node containment model with Tagami/Uchida yielded good agreement for peak containment response (See Table 2-3)

GOTHIC –MAAP-DBA Comparisons

Table 2-2 Input Conditions for MAAP-DBA and GOTHIC Comparison

	GOTHIC Version 6.0a	**MAAP-DBA**
Nodes	Single	Single
Entrainment (Pools and Films)	Yes	No
Forced Convection	No	No
LOCA Airborne Water Droplet Fraction	10%	10%
Spray Droplet Diameter	1000 microns	1000 microns
LOCA Airborne Water Droplet Diameter	100 microns	100 microns
Initial Containment Pressure	14.2 psia	14.2 psia
LOCA: Heat Transfer (Short Term)	Tagami	Tagami
MSLB: Heat Transfer	Uchida with 8% revaporization	Uchida with 8% revaporization

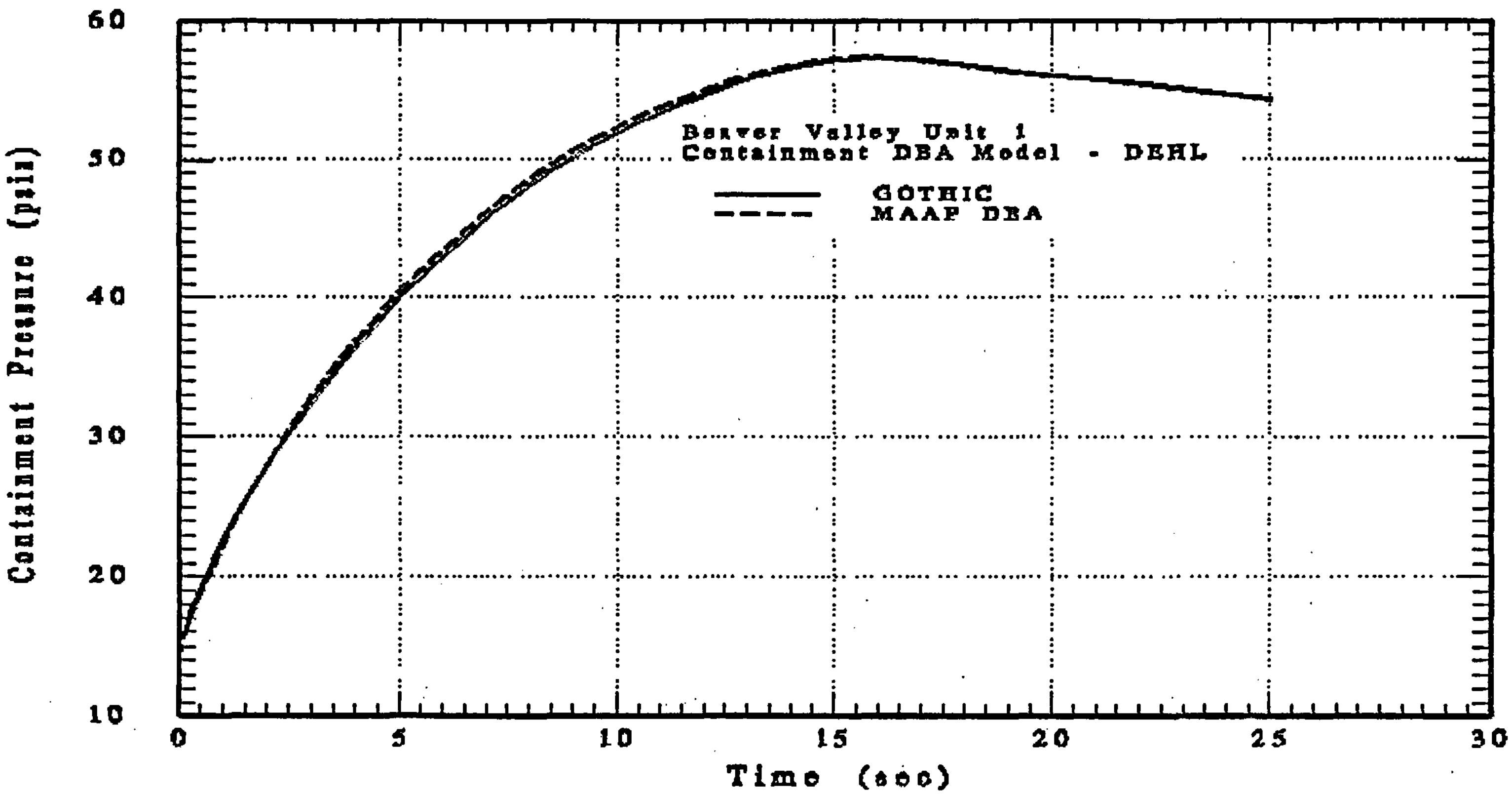
MAAP-DBA Code Comparisons

Table 2-3 Summary of MAAP-DBA and GOTHIC Comparison

Unit	Sequence	Results Comparison							
		LOCA				MSLB			
		Pressure (psia)		Gas Temperature (°F) @Peak Pressure		Pressure (psia)		Gas Temperature (°F) @ Peak Pressure	
		MAAP-DBA	GOTHIC	MAAP-DBA	GOTHIC	MAAP-DBA	GOTHIC	MAAP-DBA	GOTHIC
1	Case 8L	57.57	57.41	267.4	266.3	—	—	—	—
2	Case 3L	58.99	58.29	269.7	268.2	—	—	—	—
1	Case 15M	—	—	—	—	56.8	57.8	342.6	341.3
2	Case 16M	—	—	—	—	51.5	52.9	327.1	329.8

GOTHIC –MAAP-DBA Comparisons

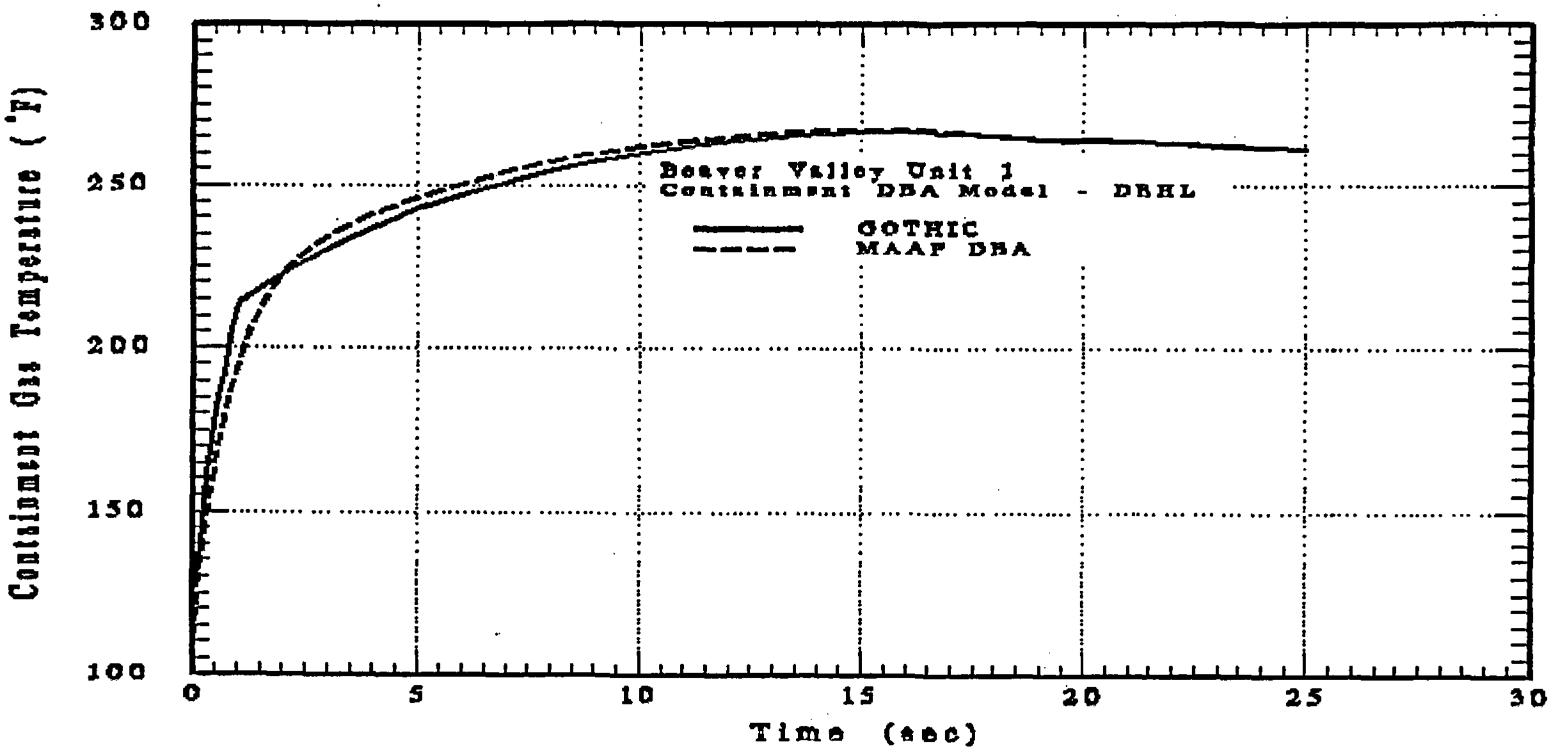
Comparison of Pressure Results from MAAP-DBA and GOTHIC for Large LOCA (BVPS Case 8L)



FENOC
FirstEnergy Nuclear Operating Company

GOTHIC –MAAP-DBA Comparisons

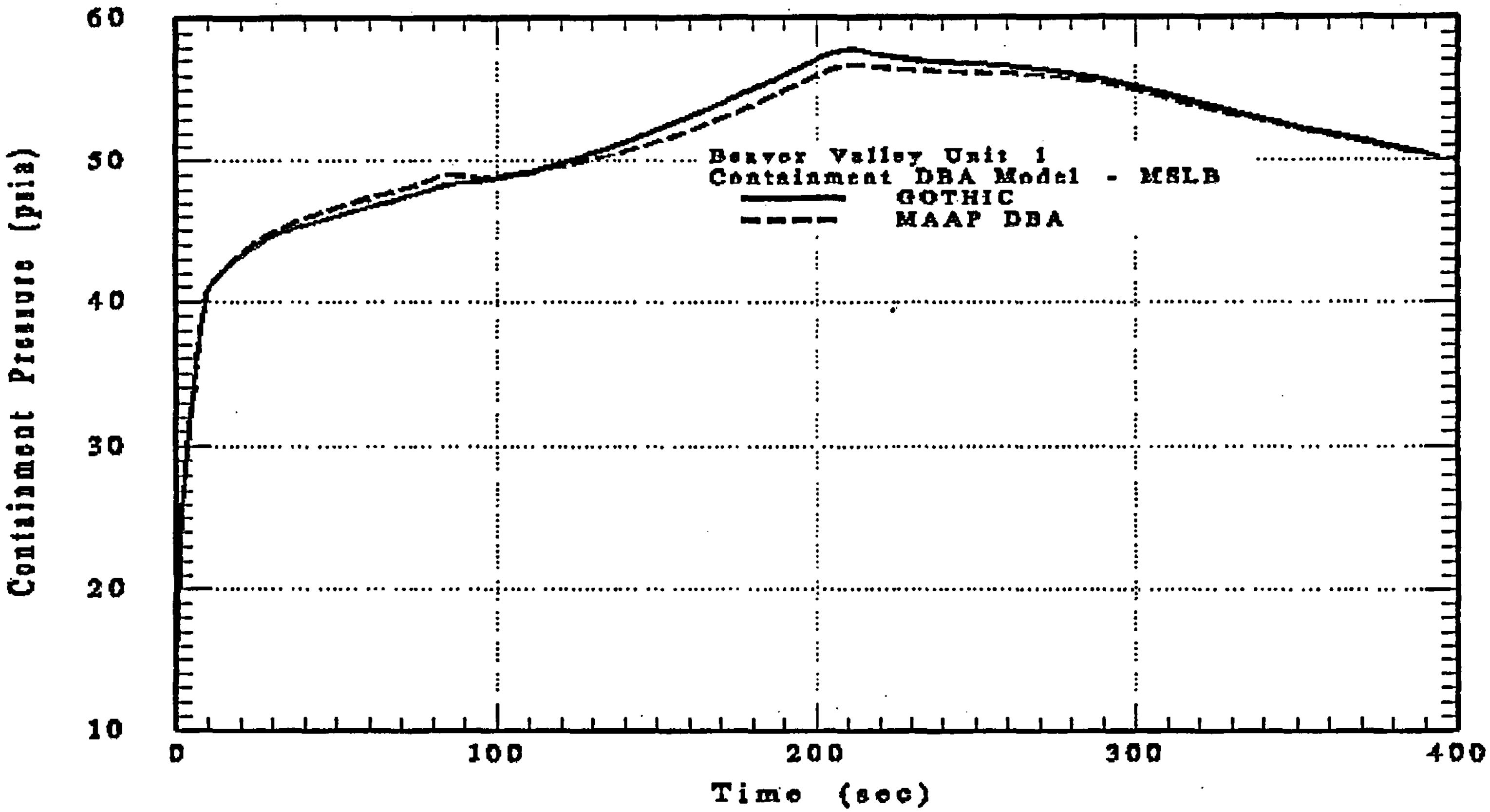
Comparison of Gas Temperature Results from MAAP-DBA and GOTHIC for Large LOCA (BVPS Case 8L)



FENOC
FirstEnergy Nuclear Operating Company

GOTHIC –MAAP-DBA Comparisons

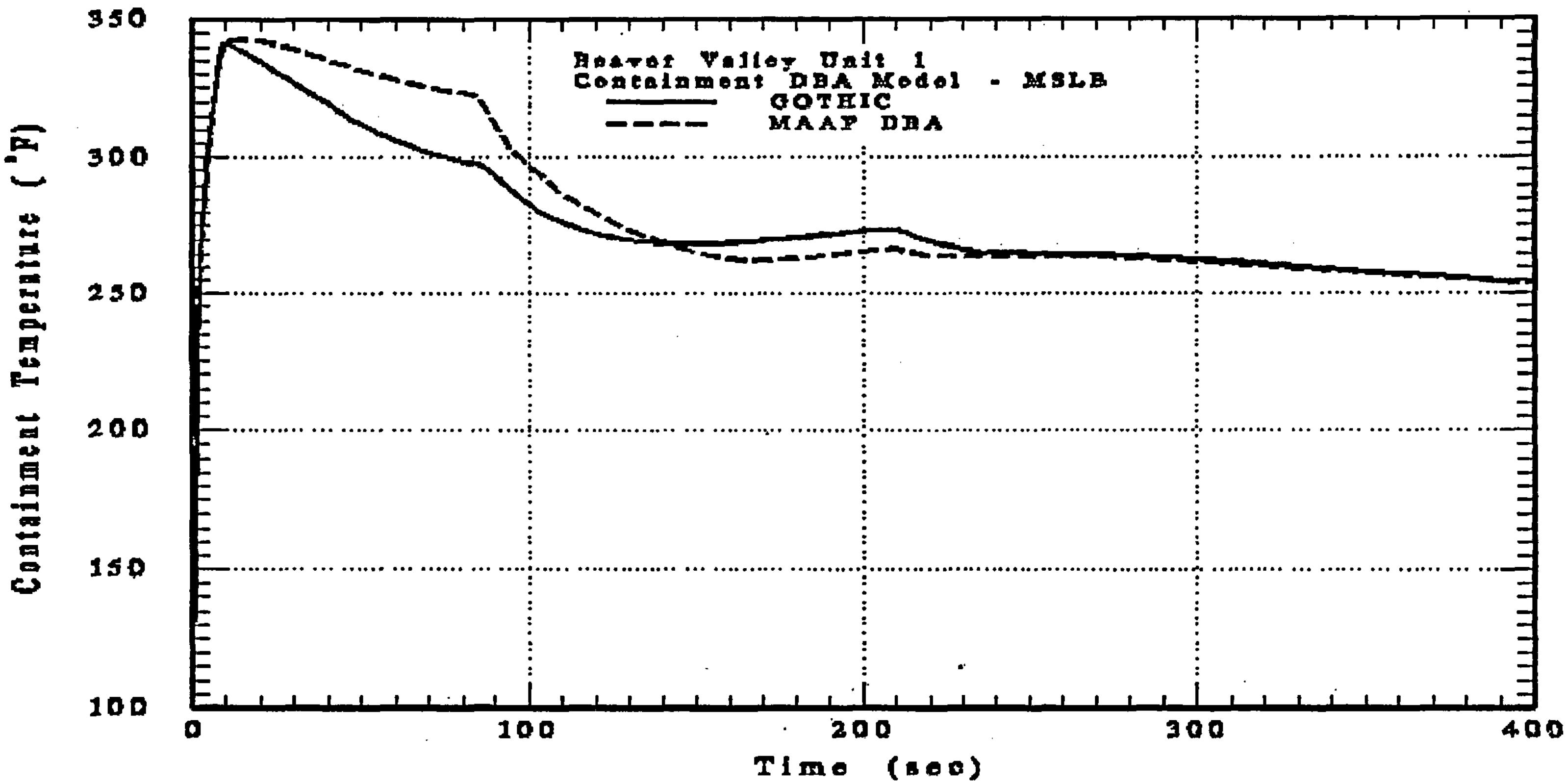
Comparison of Pressure Results from MAAP-DBA and GOTHIC for MSLB (BVPS Case15M)



FENOC
FirstEnergy Nuclear Operating Company

GOTHIC –MAAP-DBA Comparisons

Comparison of Temperature Results from MAAP-DBA and GOHTIC for MSLB
(BVPS Case15M)



FENOC

Separate Effects Experiments

Table 2-4 Separate Effects Tests Used for MAAP-DBA Containment Response Benchmark		
Benchmark	**Test**	**Application**
1.	U. of Wisconsin Flat Plate	Condensation heat transfer (HMTA with forced convection used for multiple node models)
2.	PHEBUS FPT0	Condensation with non-condensables present
3.	Dehbi	Condensation with non-condensables present
4.	JAERI PHS-1	Spray heat removal
5.	Spray Droplet Heat Transfer (Kulic)	Spray droplet heat removal

MAAP-DBA Code Benchmarking

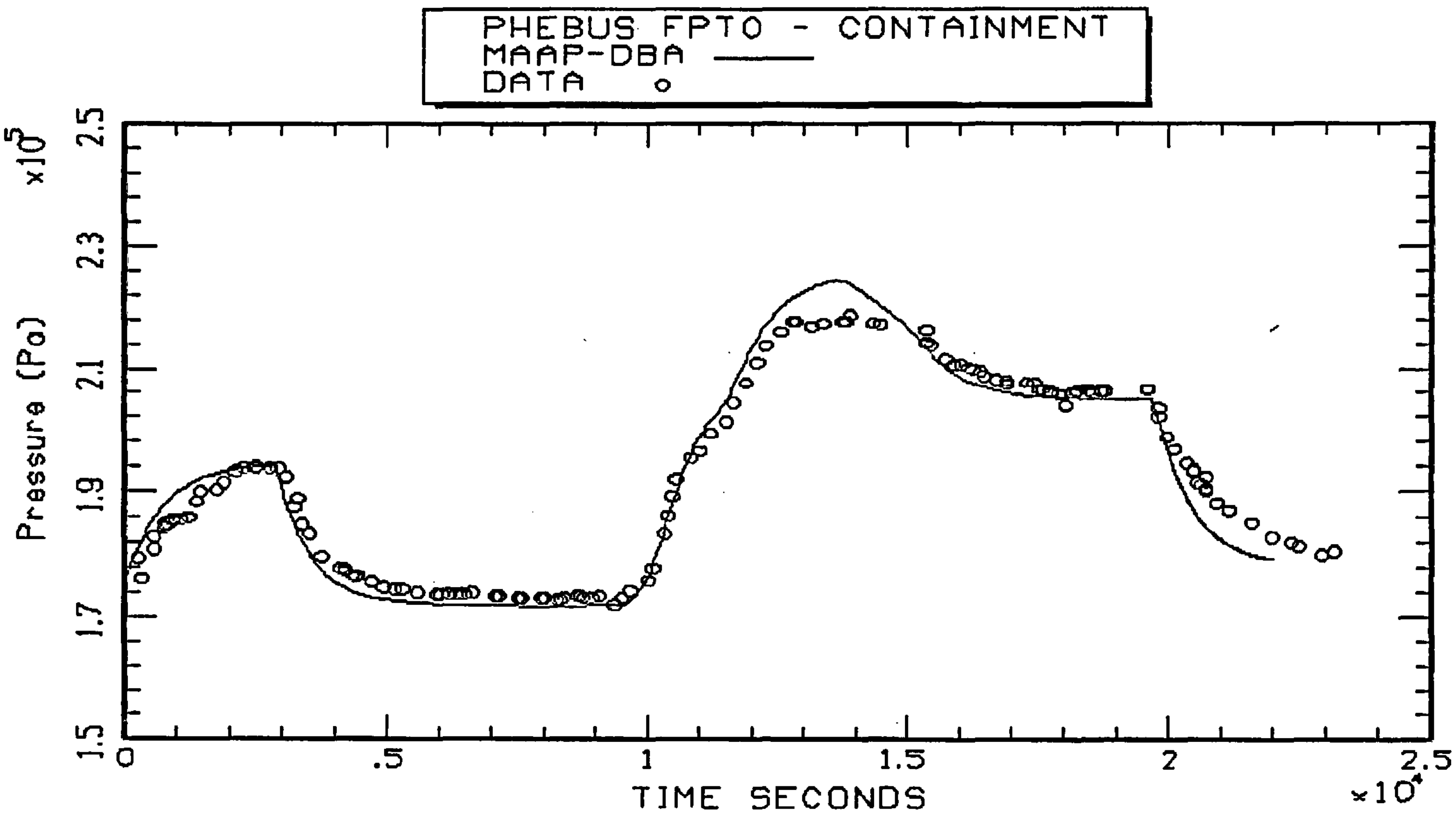
Table 2-5 Comparison of MAAP-DBA Average Condensation Heat Transfer Coefficients for the Wisconsin Square Channel Experiments

Case #	T_{mix}, °C	T_w, °C	m_{air} / m_{steam}	V, m/s	h_{exp}*	$h_{exp\ (max,\ min)}$*	MAAP-DBA*/**
1	70	30	3.58	1	111.1	(122.2, 99.99)	113.9
2	70	30	3.58	3	213.9	(235.3, 192.5)	235.4
3	80	30	1.808	1	163.9	(180.3, 147.5)	165.2
4	80	30	1.808	3	305.6	(336.2, 275.0)	310
5	90	30	0.706	1	255.5	(281.1, 229.95)	256.3
6	95	45	0.31	1	546.	(600.6, 491.4)	402.9

1) *Heat transfer coefficient in $w/m^2/K$.

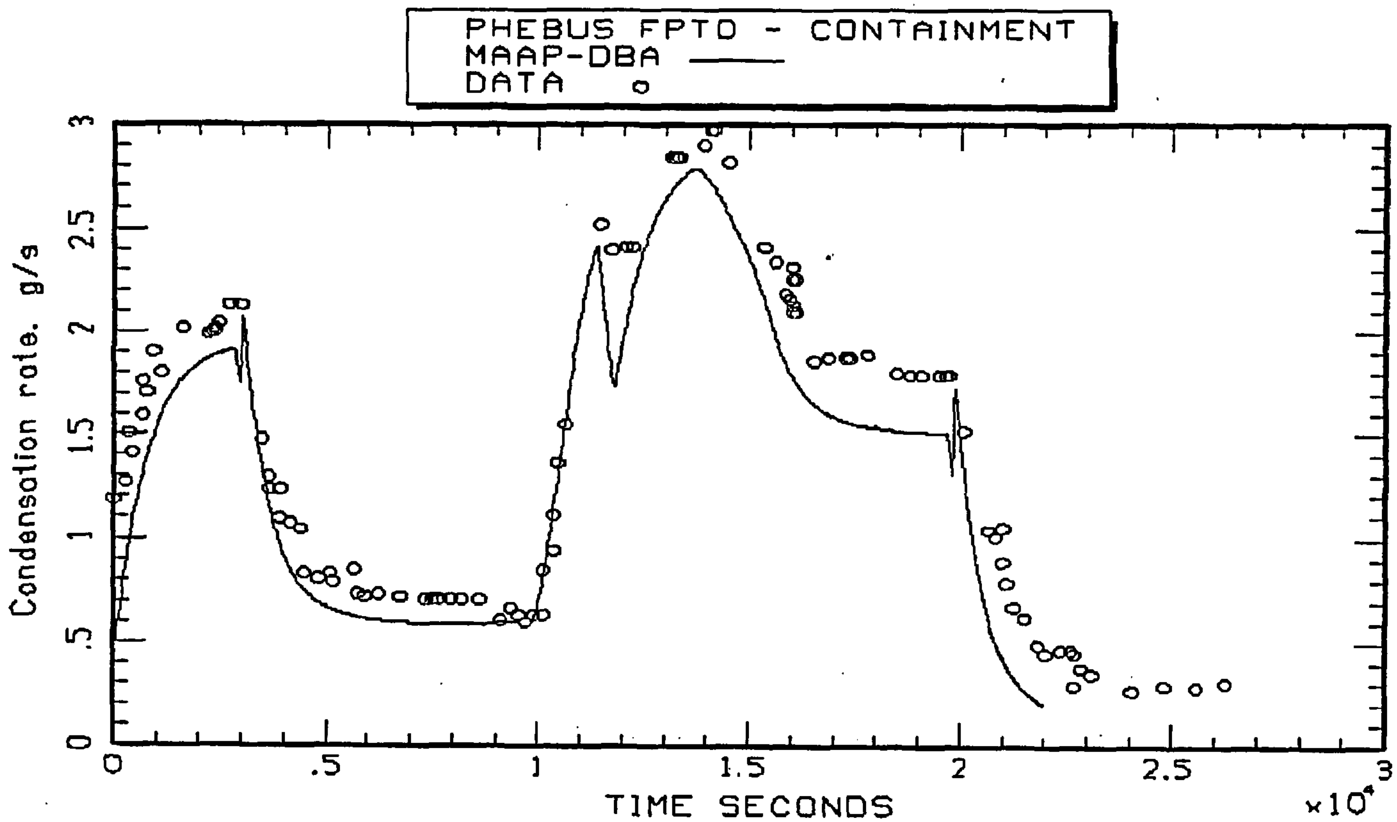
2) **MAAP-DBA uses the maximum of the natural or forced convection values. At 1 m/s, the code is using the natural convection value.

PHEBUS FTP0 Pressure Profile



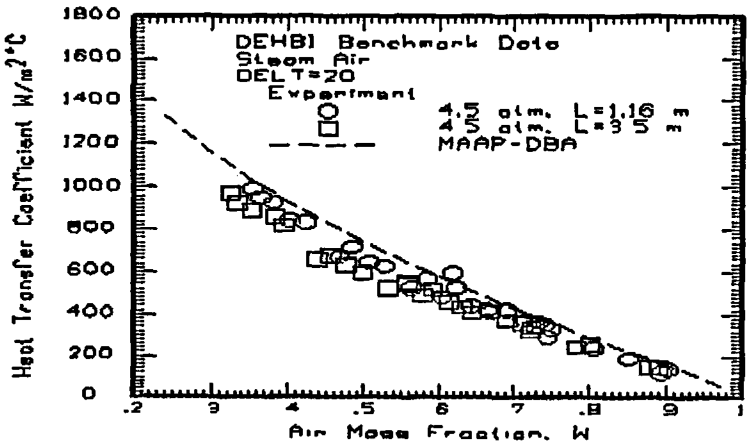
FENOC
FirstEnergy Nuclear Operating Company

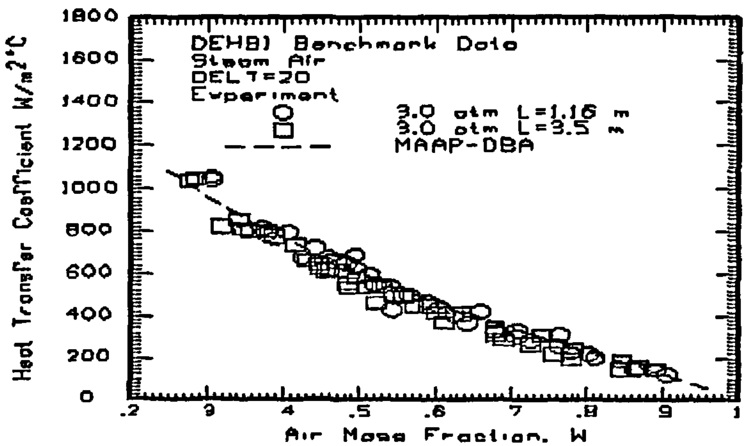
PHEBUS FPT0 Condensation Rate Profile

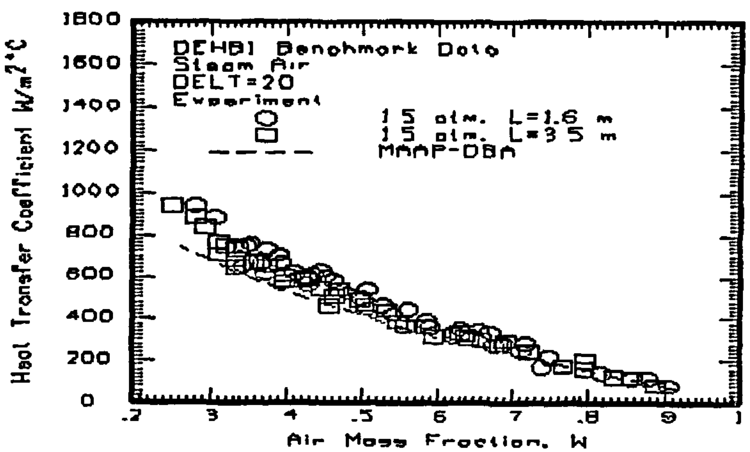


FENOC
FirstEnergy Nuclear Operating Company

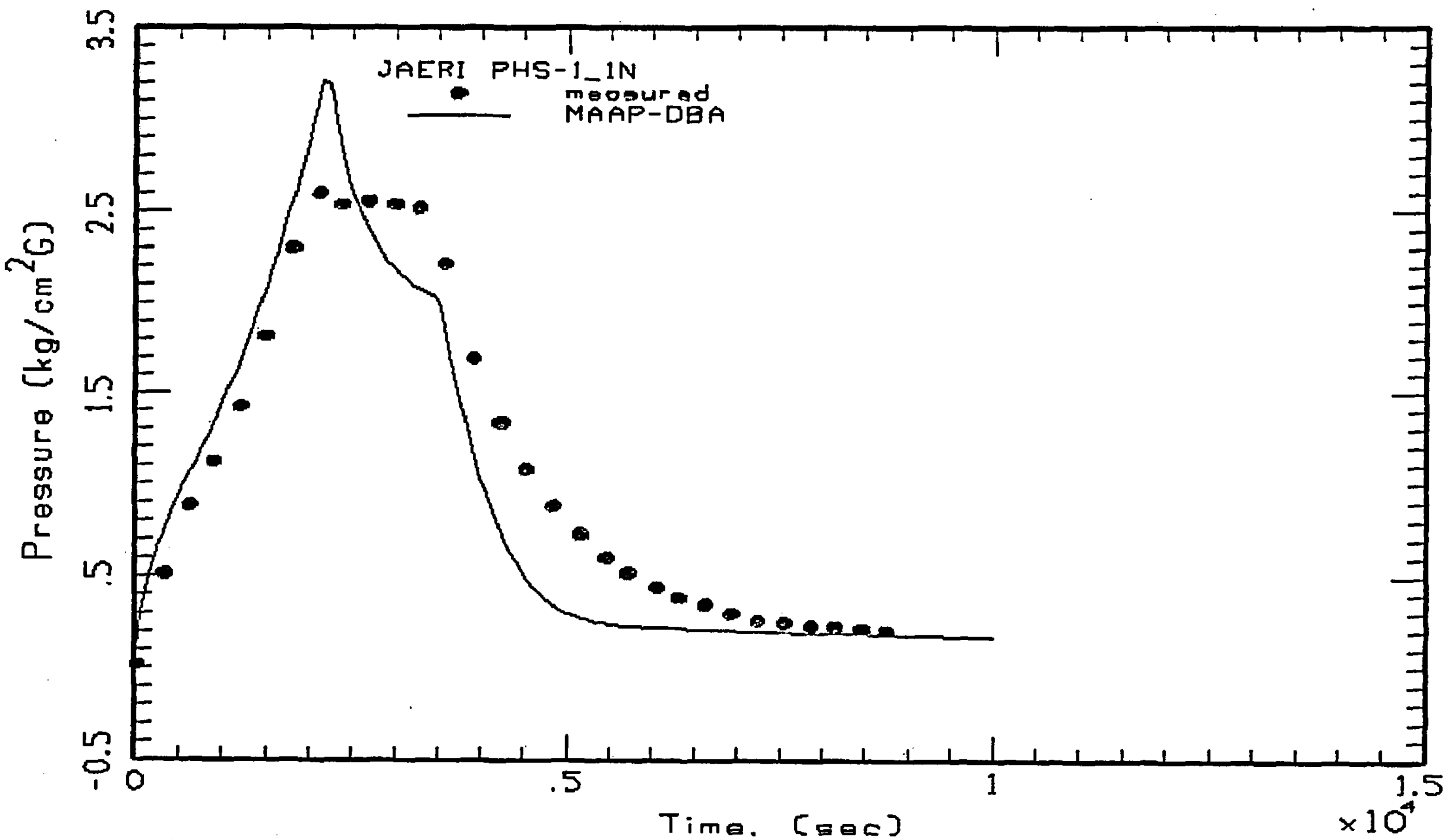
Comparison of the MAAP-DBA Condensation Heat Transfer Model with the Experimentally Determined Steam-Air Condensing Heat Transfer Coefficients





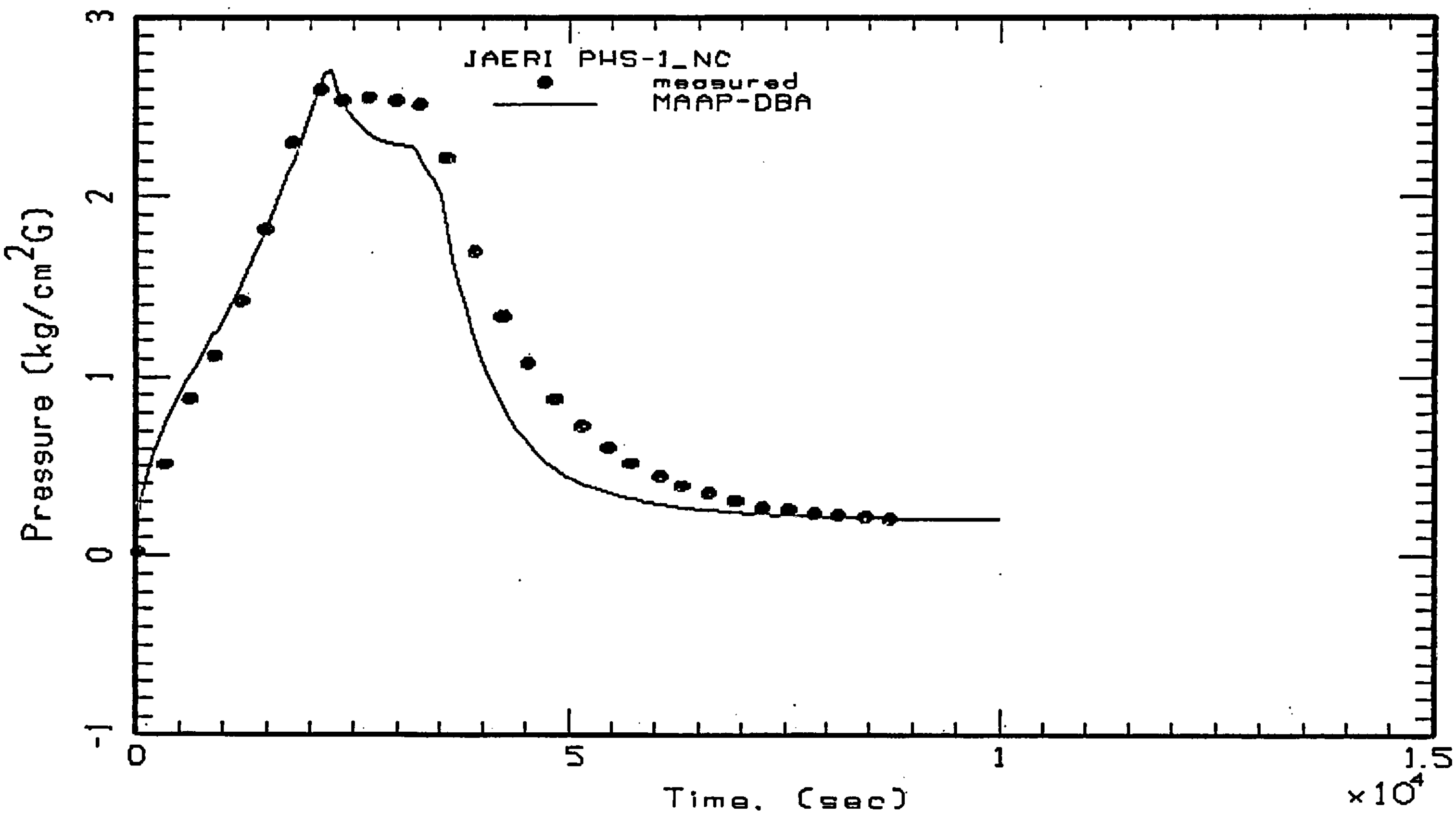


MAAP-DBA Single Node Model Pressure Profile for JAERI Test PHS-1



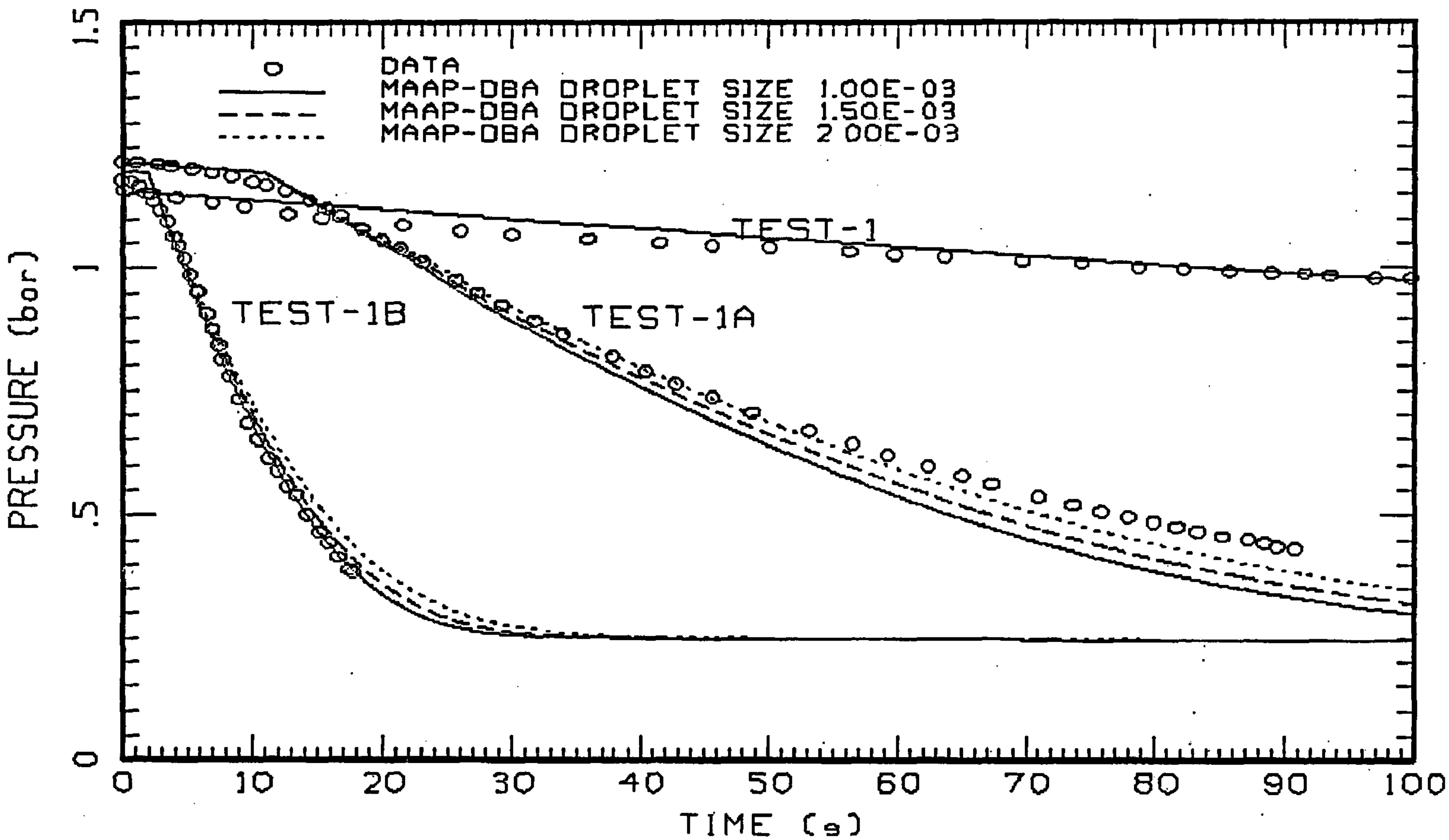
FENOC
FirstEnergy Nuclear Operating Company

MAAP-DBA Multiple Node Model Pressure Profile for JAERI Test PHS-1



FENOC
FirstEnergy Nuclear Operating Company

MAAP-DBA Pressure Profiles for Kulic Spray Tests



FENOC

FirstEnergy Nuclear Operating Company

Integral Effects Experiments

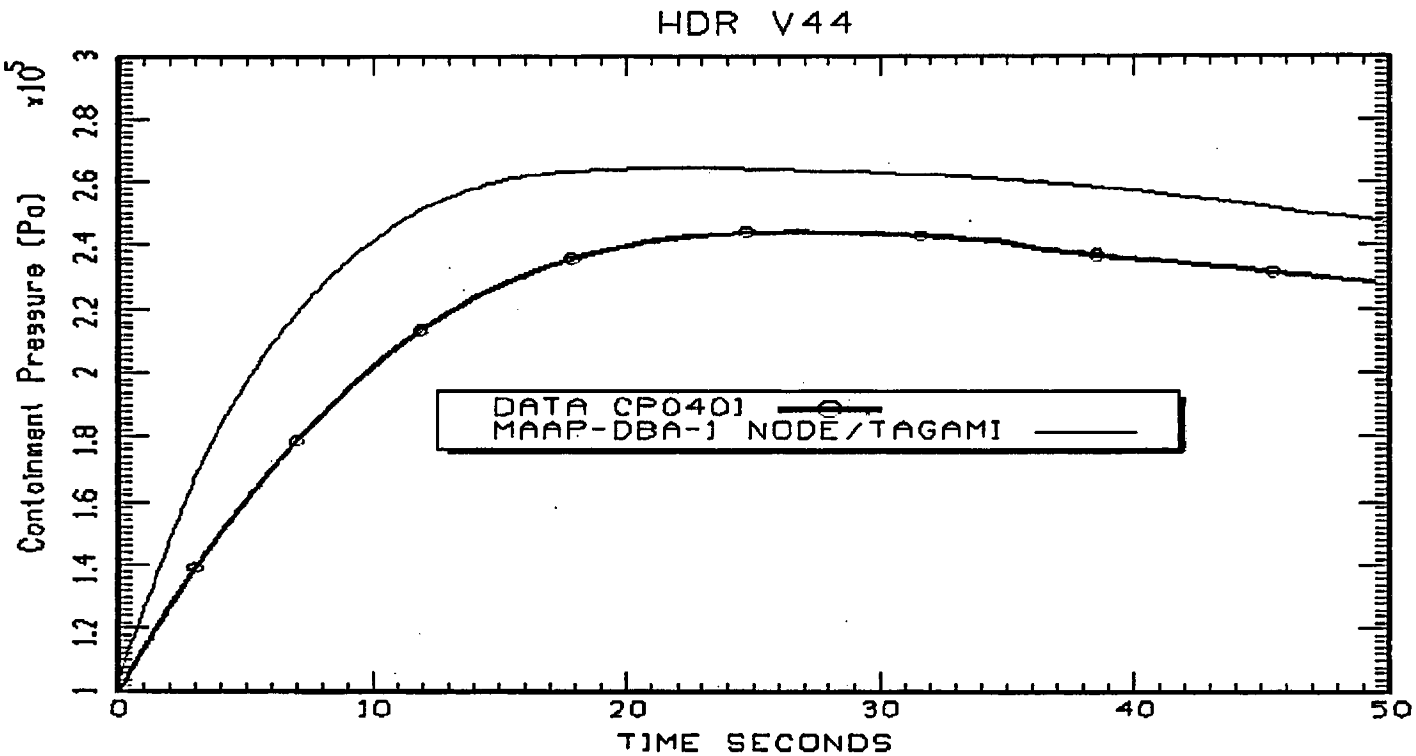
Table 2-6 Integral Effects Tests Used for MAAP-DBA Containment Response Benchmark

Benchmark	Test	Application
1.	HDR-V44	Large loss of coolant accident (LOCA)
2.	HDR-T31.5	Large LOCA
3.	NUPEC M-7-1	Small LOCA
4.	CVTR #3	Main steamline break without containment spray
5.	CVTR #4, #5	Main steamline break with spray actuation
6.	BFMC D-16	Large LOCA

* Benchmark numbers 1, 2, 3, and 6 are International Standard Problems.

Integral Effects Experiments

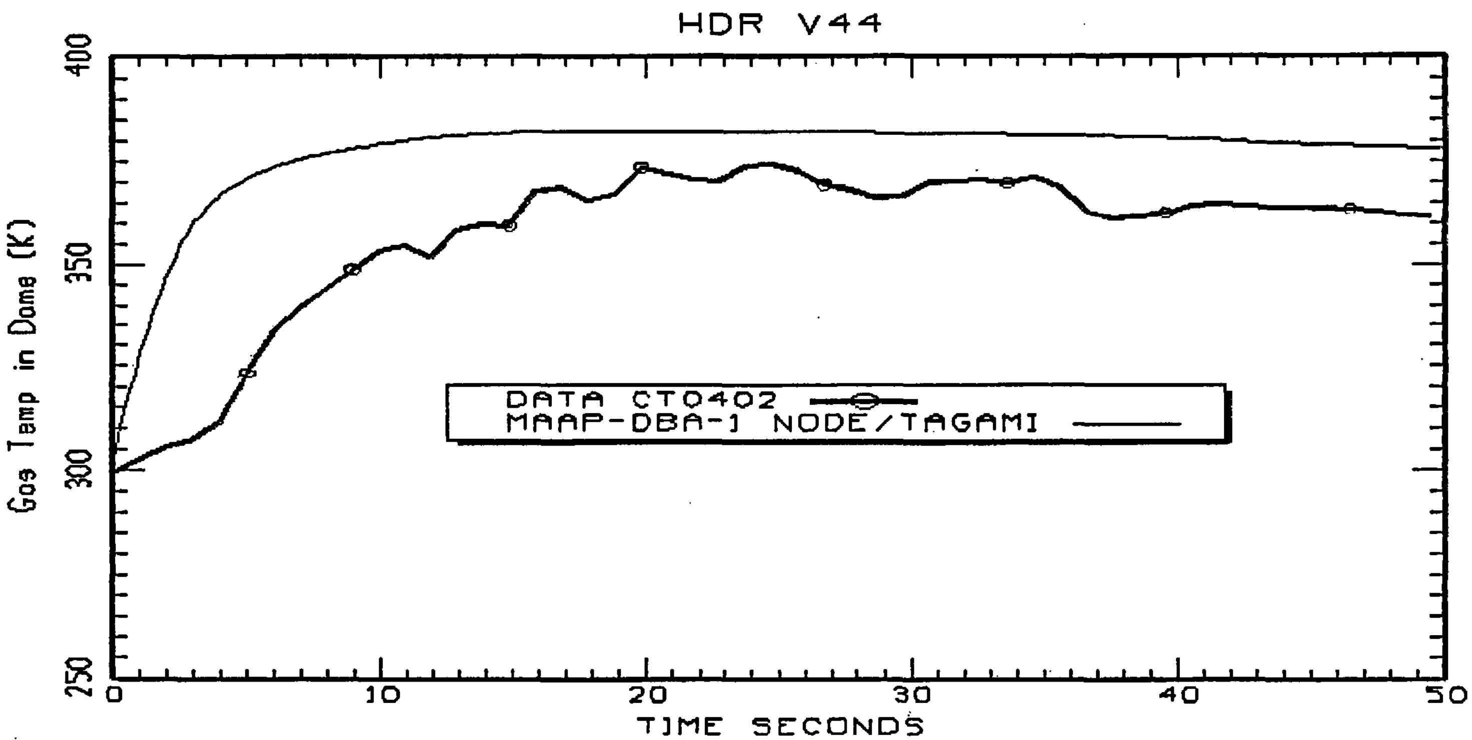
HDR-V44 Pressure Profile



FENOC
FirstEnergy Nuclear Operating Company

Integral Effects Experiments

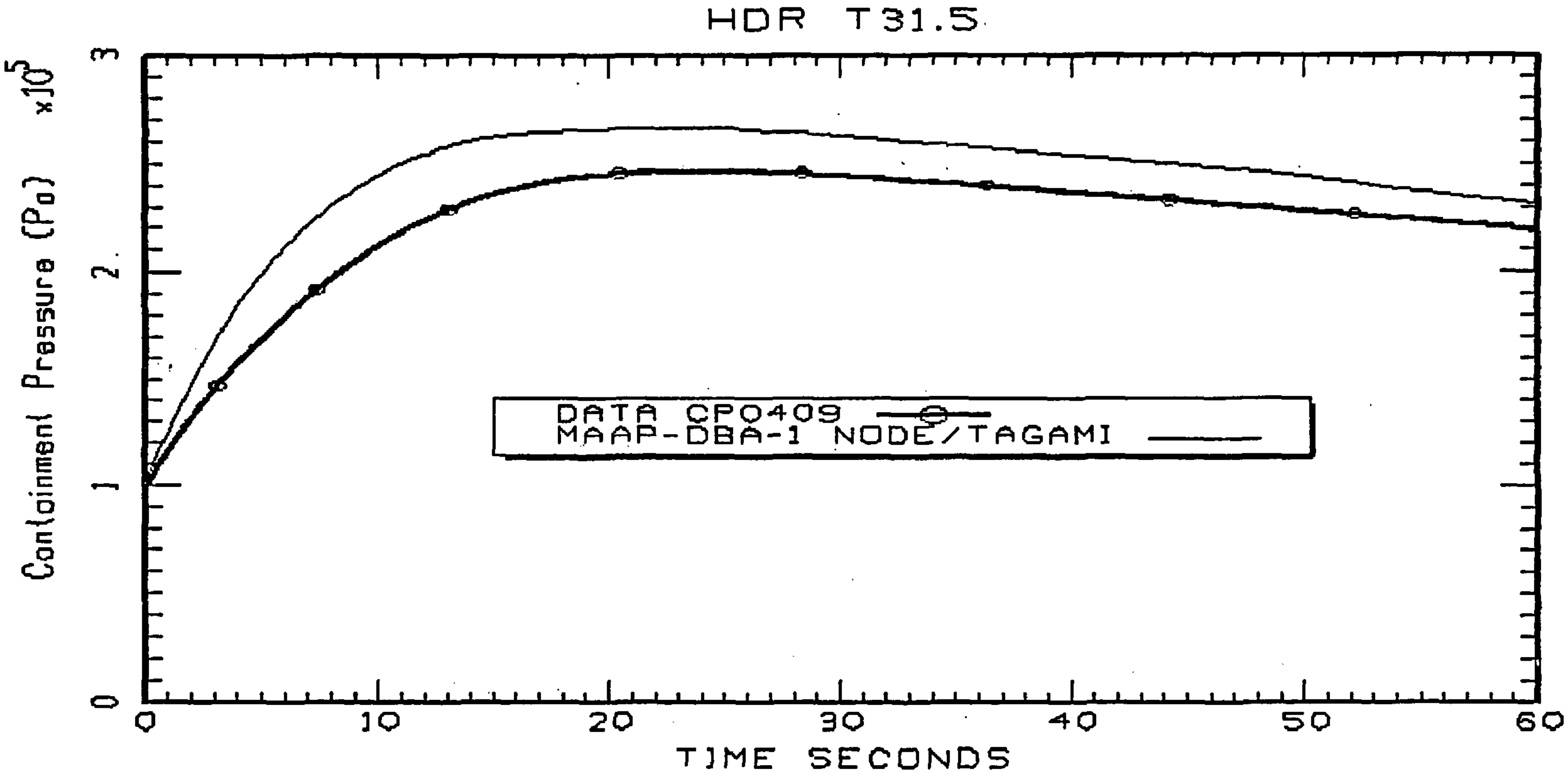
HDR-V44 Gas Temperature Profile



FENOC
FirstEnergy Nuclear Operating Company

Integral Effects Experiments

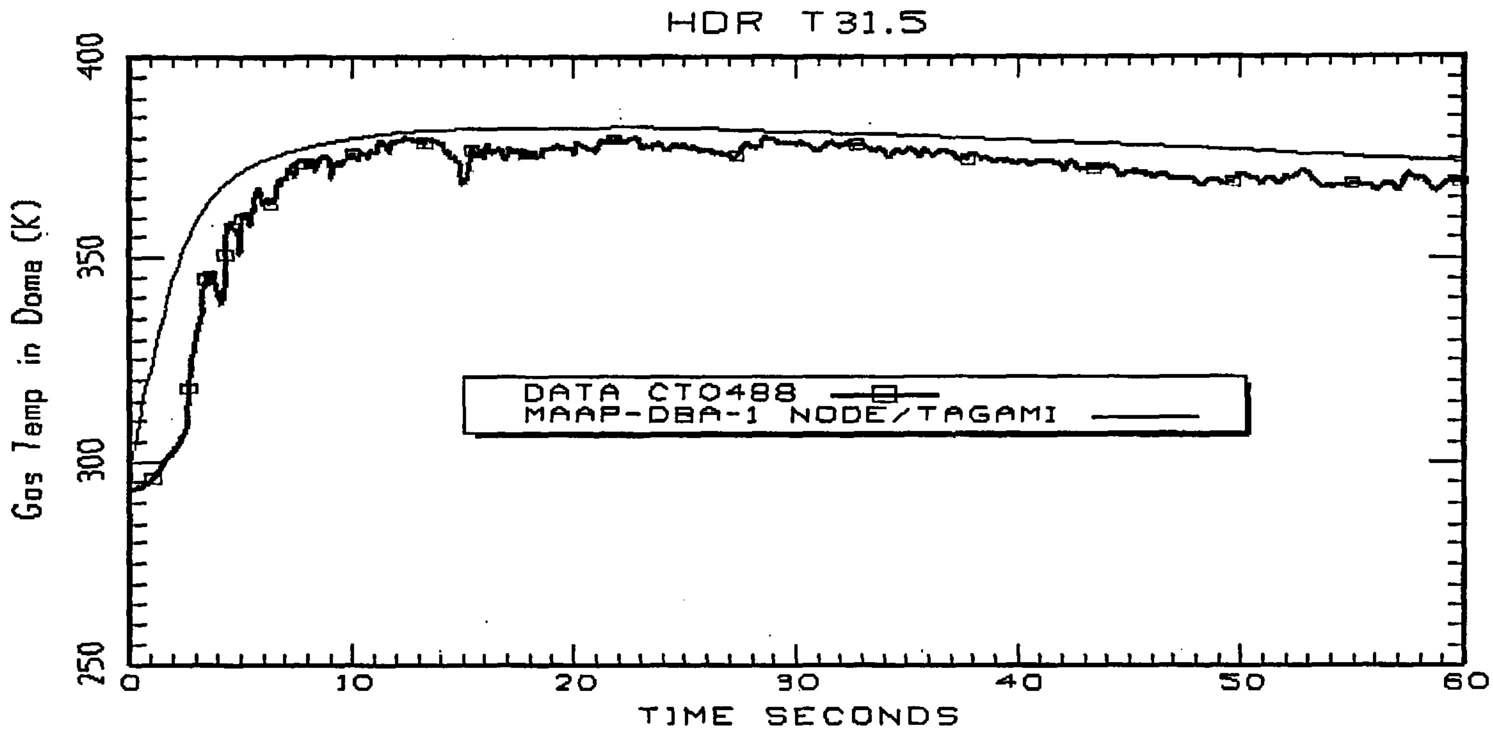
HDR-T31.5 Pressure Profile



FENOC
FirstEnergy Nuclear Operating Company

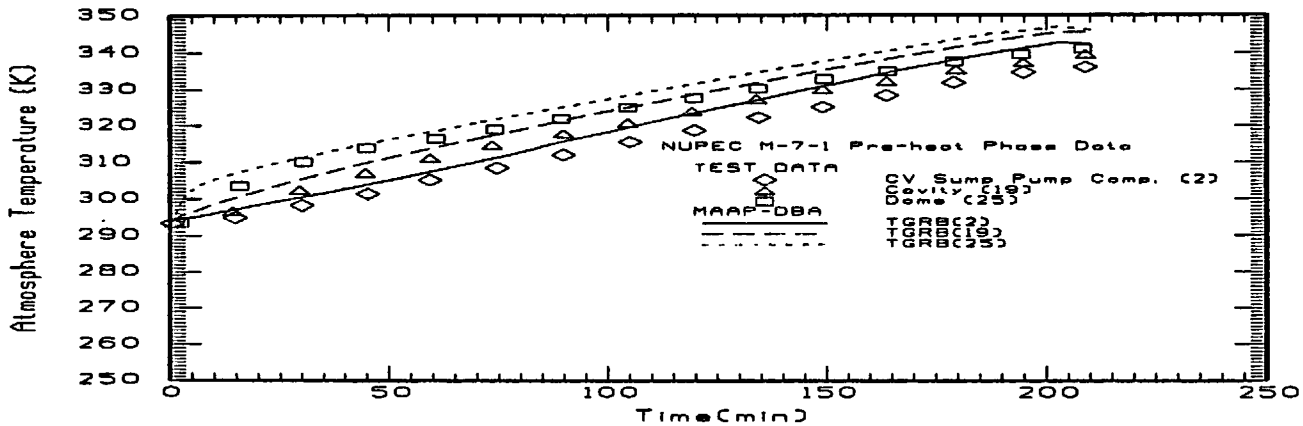
Integral Effects Experiments

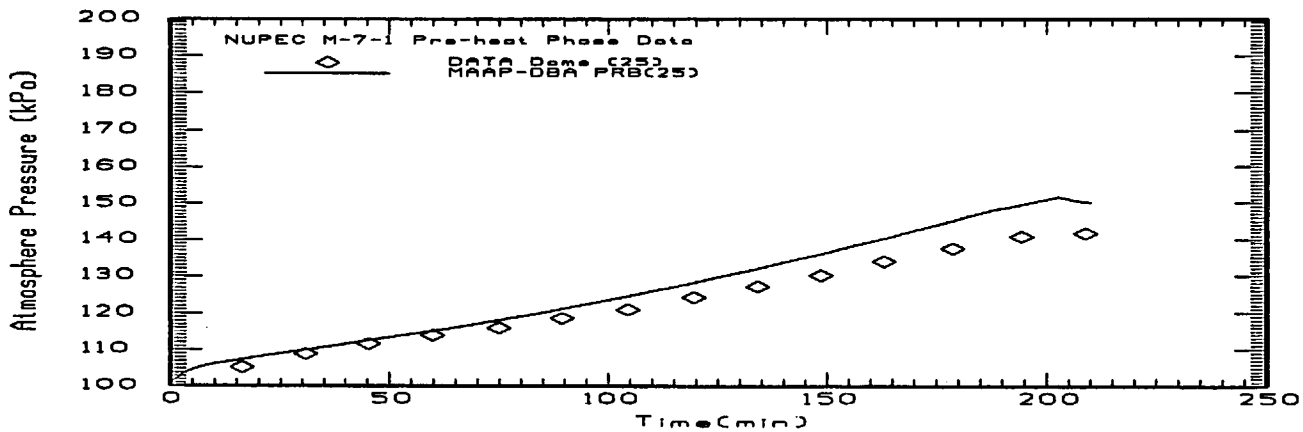
HDR-T31.5 Gas Temperature Profile



Integral Effects Experiments

Comparison of NUPEC M-7-1 Preheat Phase Gas Temperatures and Containment Pressure

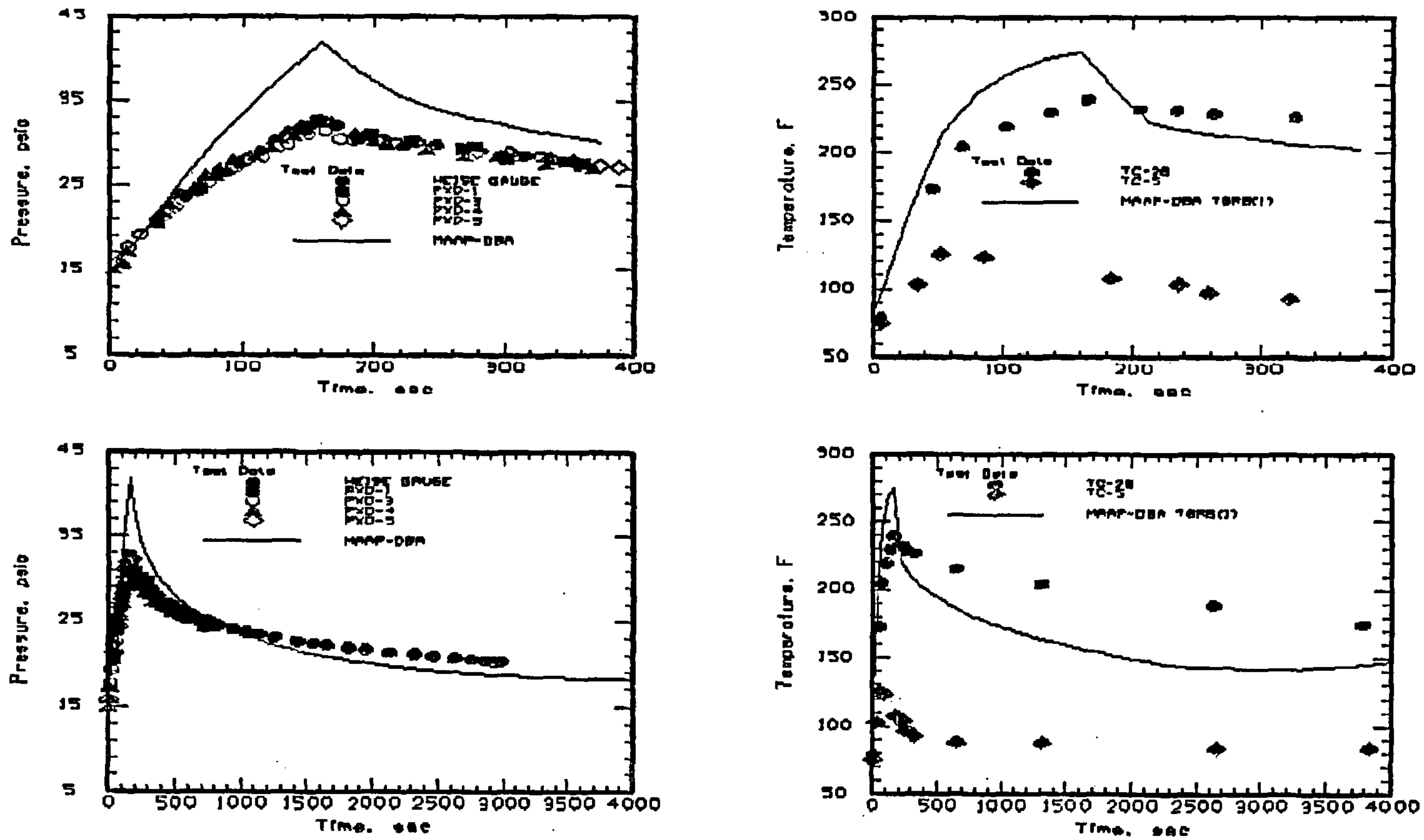




FENOC

Integral Effects Experiments

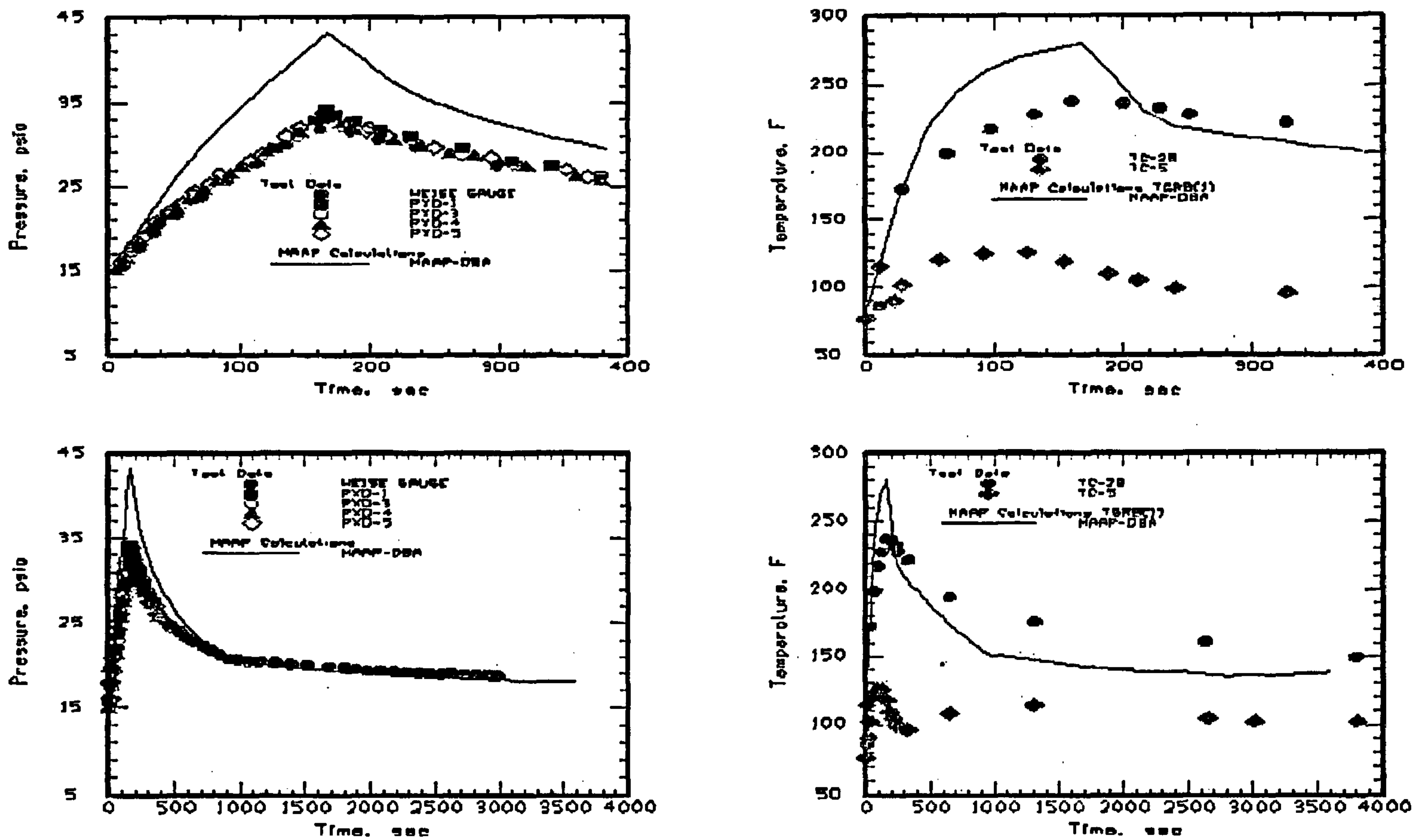
Comparison of CVTR Test 3 Containment Pressure



FENOC
FirstEnergy Nuclear Operating Company

Integral Effects Experiments

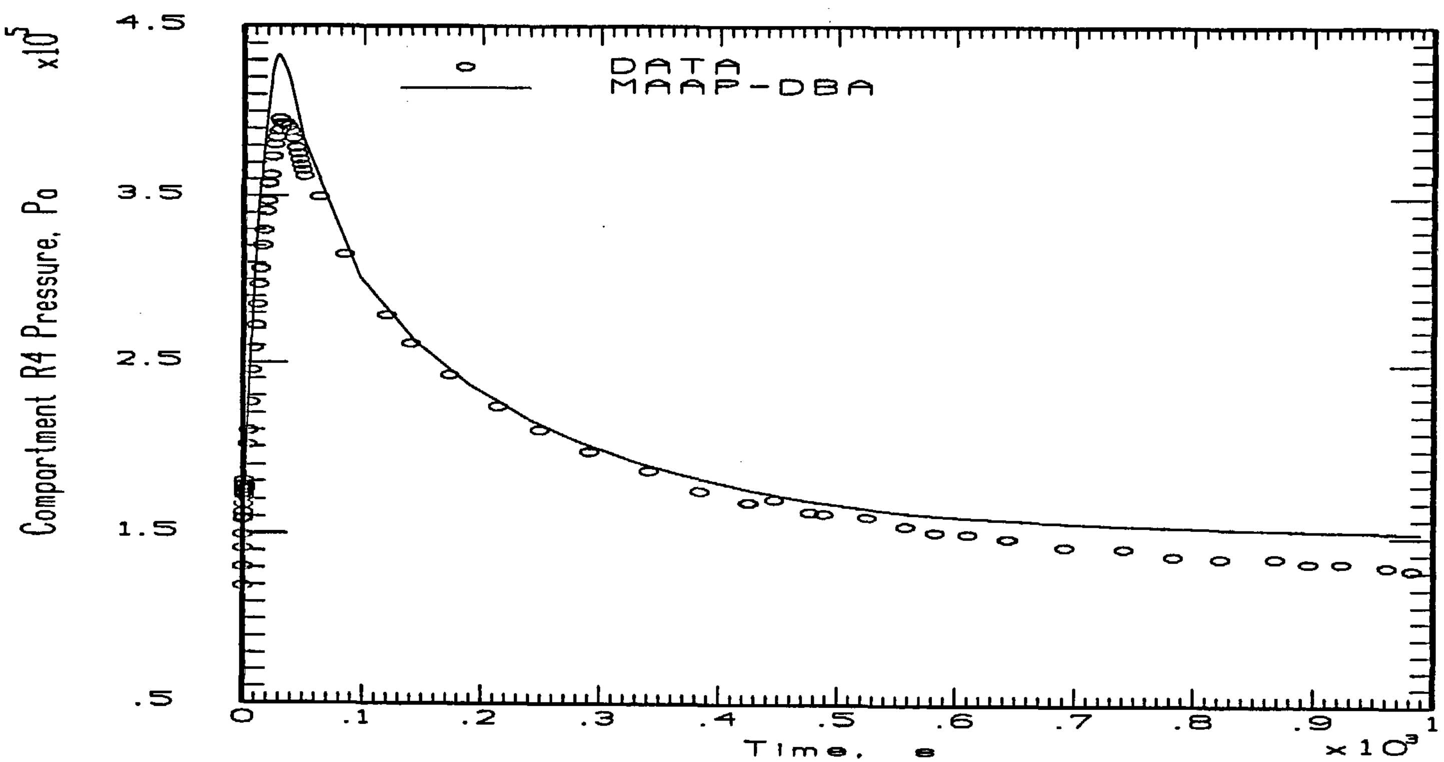
Comparison of CVTR Test 4 Containment Pressure



FENOC
FirstEnergy Nuclear Operating Company

Integral Effects Experiments

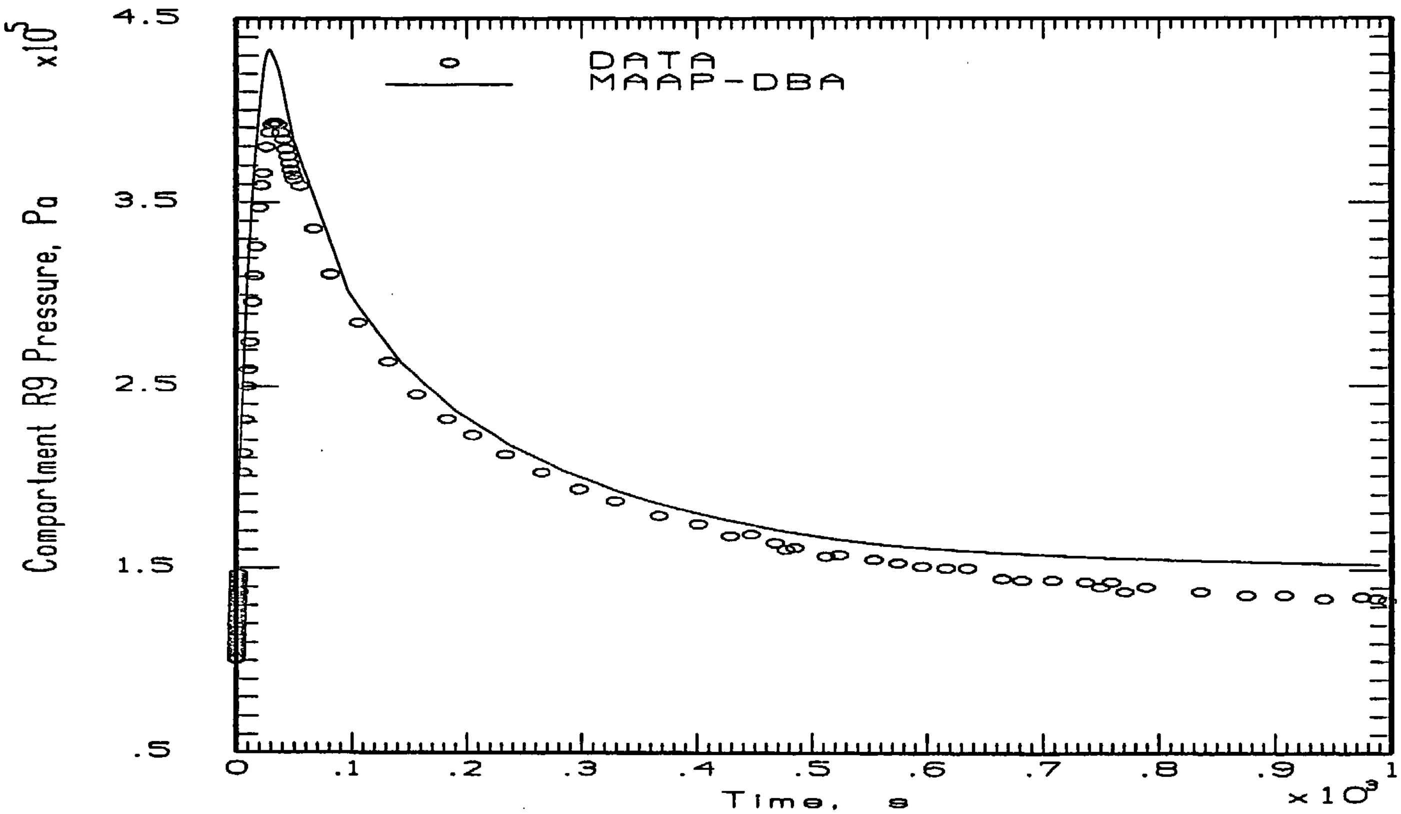
Comparison of BFMC D-16 Pressure History in the Break Compartment



FENOC

Integral Effects Experiments

Comparison of BFMC D-16 Pressure History for Outer Room

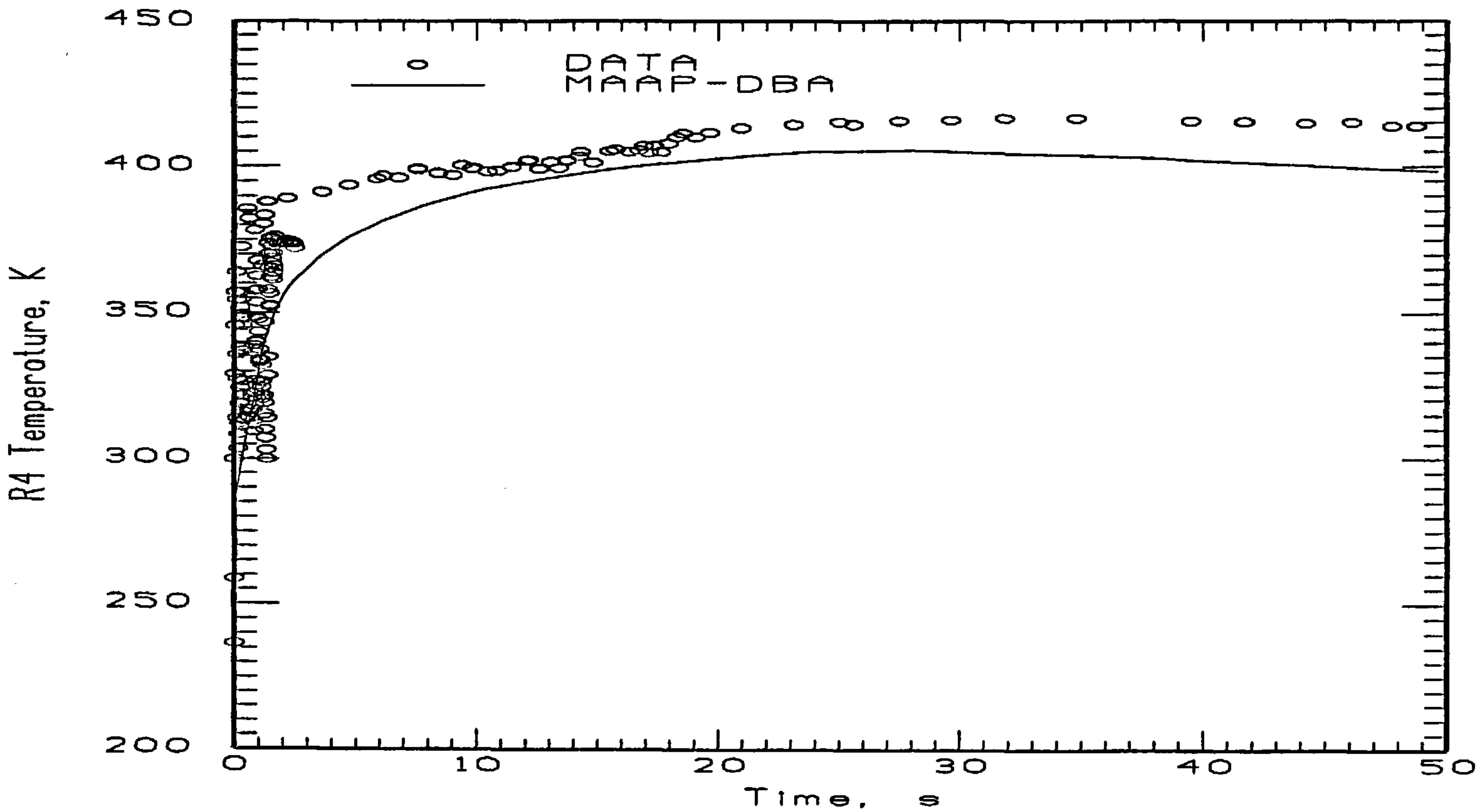


FENOC

FirstEnergy Nuclear Operating Company

Integral Effects Experiments

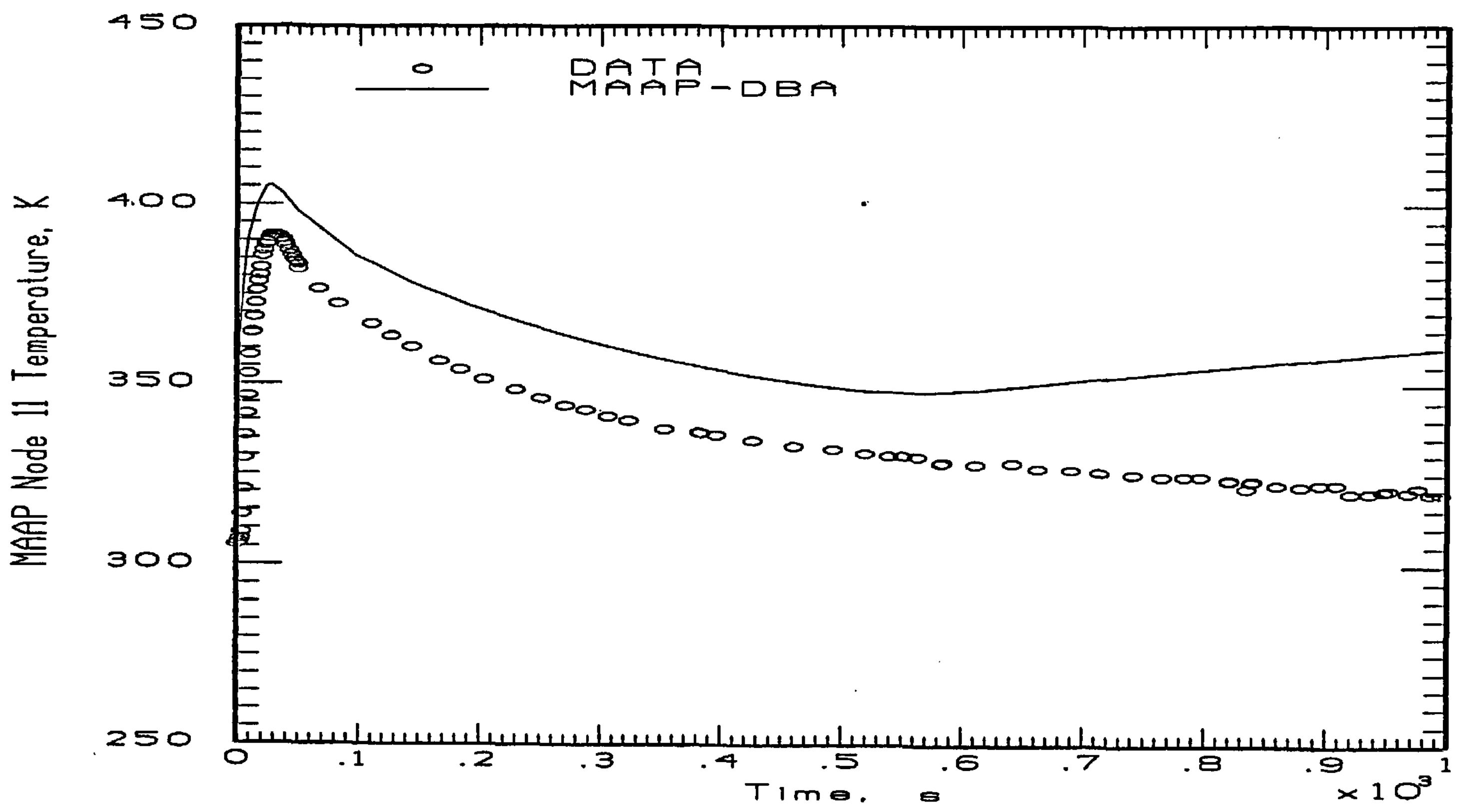
Comparison of BFMC D-16 Temperature History for Break Room



FENOC
FirstEnergy Nuclear Operating Company

Integral Effects Experiments

Comparison of BFMC D-16 Temperature History for Outer Room



FENOC

Integral Effects Experiments

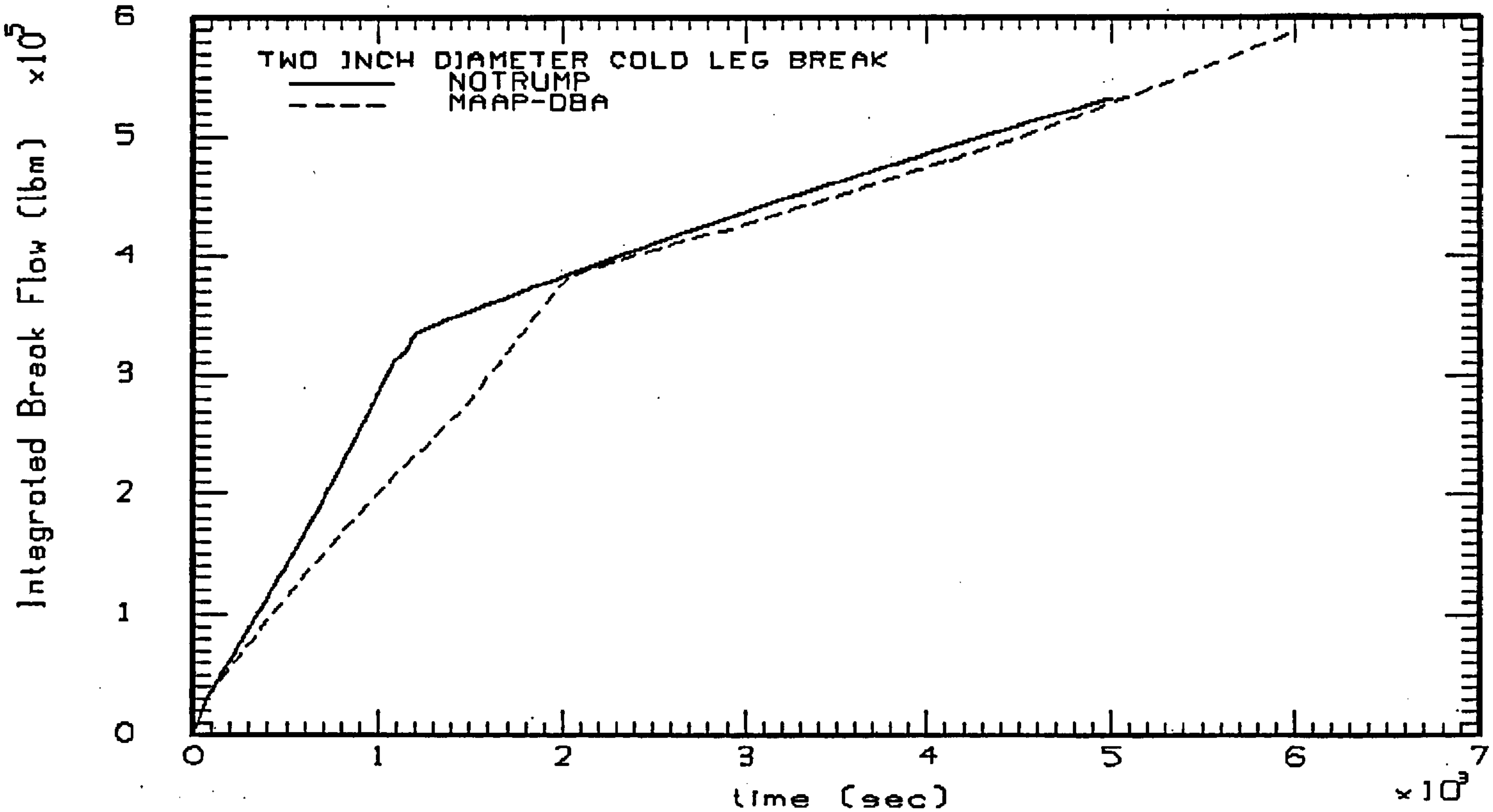
- The single node containment models that applied the Tagami and Uchida heat transfer correlations over-predicted the peak containment pressures observed in this set of Integral Effects Experiments.

MAAP-DBA Code Benchmarking Against NOTRUMP

- NOTRUMP used to benchmark Small Break LOCA Mass and Energy Release histories.
  - A spectrum of break sizes and locations were generated and good agreement was obtained.
  - MAAP was also benchmarked with NOTRUMP in support of AP600 for a spectrum of Hot Leg breaks sizes.
  - MAAP was benchmarked at D.C. Cook for a spectrum of break sizes and accepted for SBLOCA (Sump inventory calcs) by the NRC.

NOTRUMP Comparisons

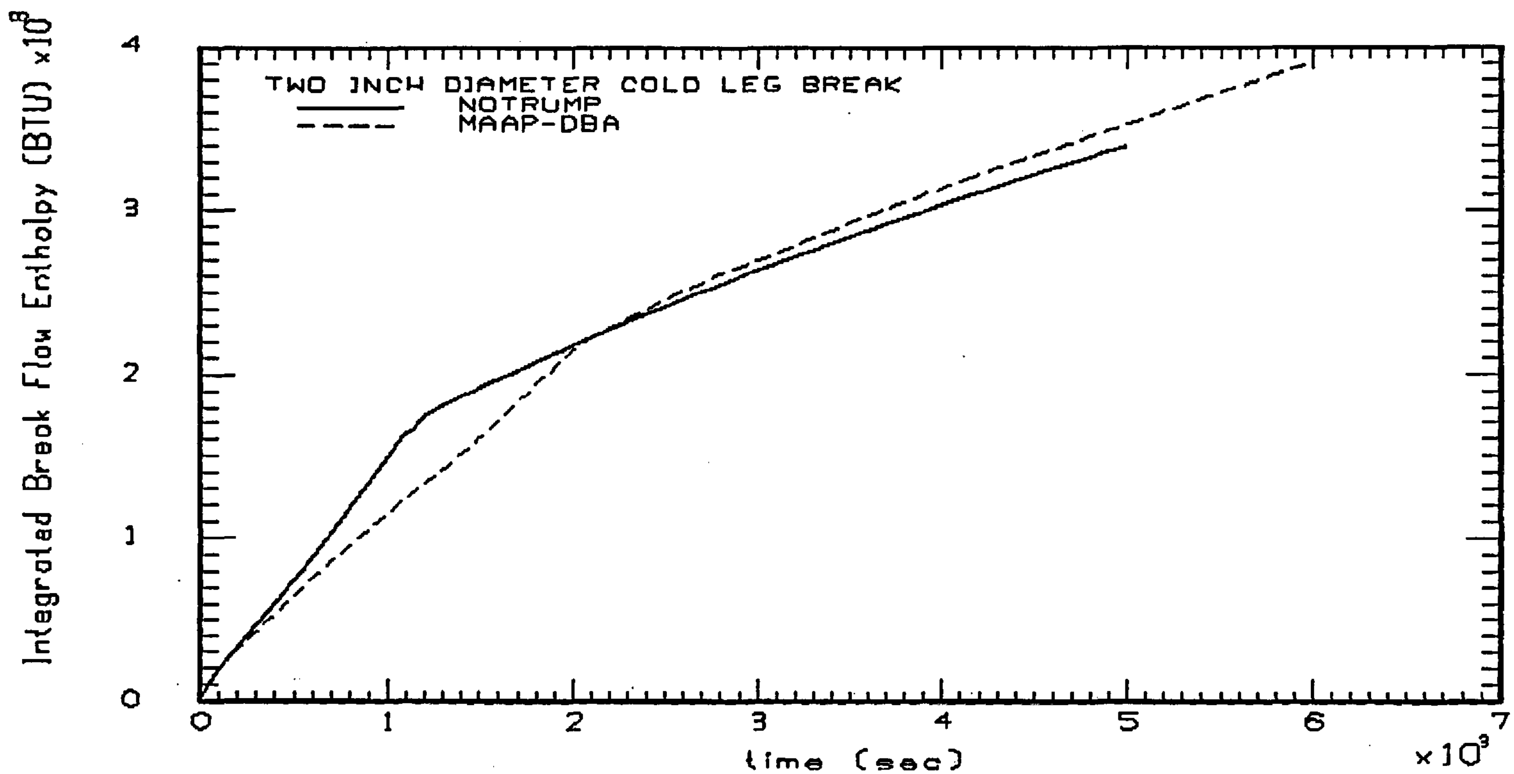
Comparison of 2 Inch Cold Leg Releases For BVPS



FENOC
FirstEnergy Nuclear Operating Company

NOTRUMP Comparisons

Comparison of 2 Inch Cold Leg Releases For BVPS



FENOC

FirstEnergy Nuclear Operating Company

Results for Limiting Cases

- Limiting Large Break LOCA and MSLB cases for both units have been quantified
- Single node MAAP-DBA models used Tagami and Uchida heat transfer correlations to calculate heat transfer to passive heat sinks
- LOCA produced the limiting peak pressure
- Peak pressures using MAAP-DBA are below 45 psig design pressure

Results for Limiting Cases

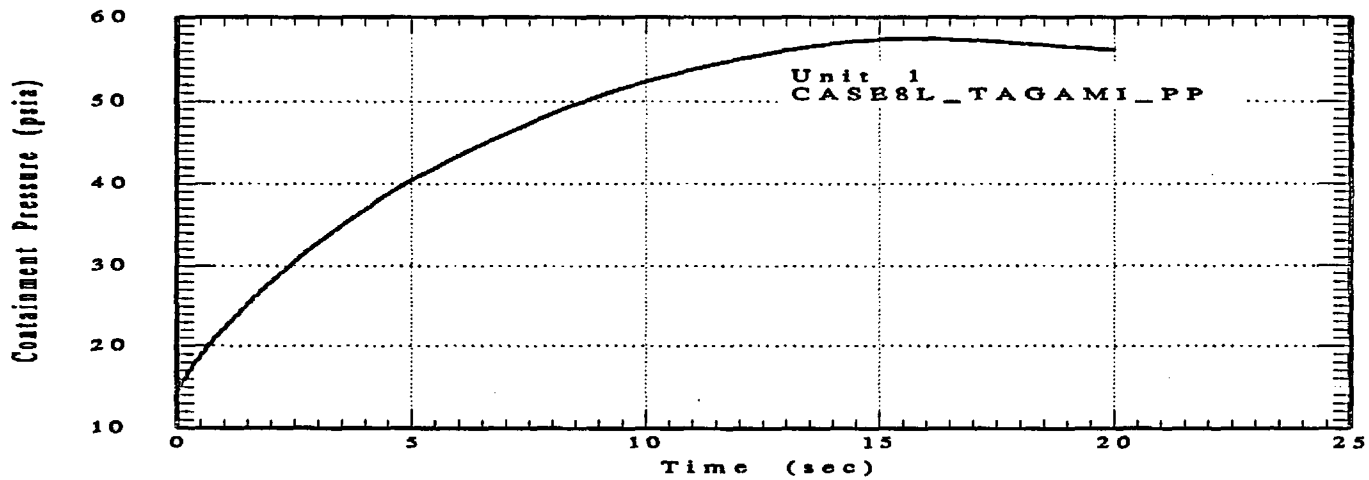
Key Model Assumptions Used by MAAP-DBA for BVPS	
Nodes	Single
Entrainment (Pools and Films)	No
Forced Convection	No
LOCA Airborne Water Droplet Fraction	10%
Spray Droplet Diameter	1000 microns
LOCA Airborne Water Droplet Diameter	100 microns
Re-vaporization	8%
Initial Containment Pressure	14.2 psia
LOCA: Heat Transfers (Short Term)	Tagami
MSLB: Heat Transfers	Uchida

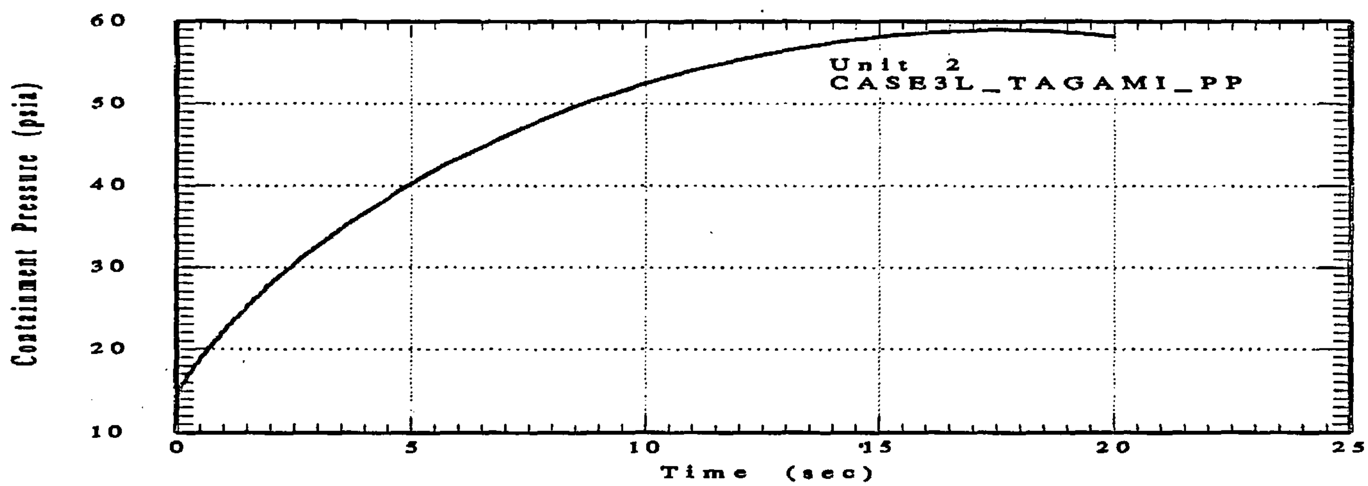
Results for Limiting Cases

Table 3-2 BVPS Containment Response Results

Unit	**Case**	**Accident Type**	**Peak Pressure (psig)**	**Peak Gas Temperature (°F) @ Peak Pressure**
1	Case 8L	LOCA	43.1	267.3
1	Case 15M	MSLB	42.4	342.6
2	Case 3L	LOCA	44.6	269.7
2	Case 16M	MSLB	36.9	327.1

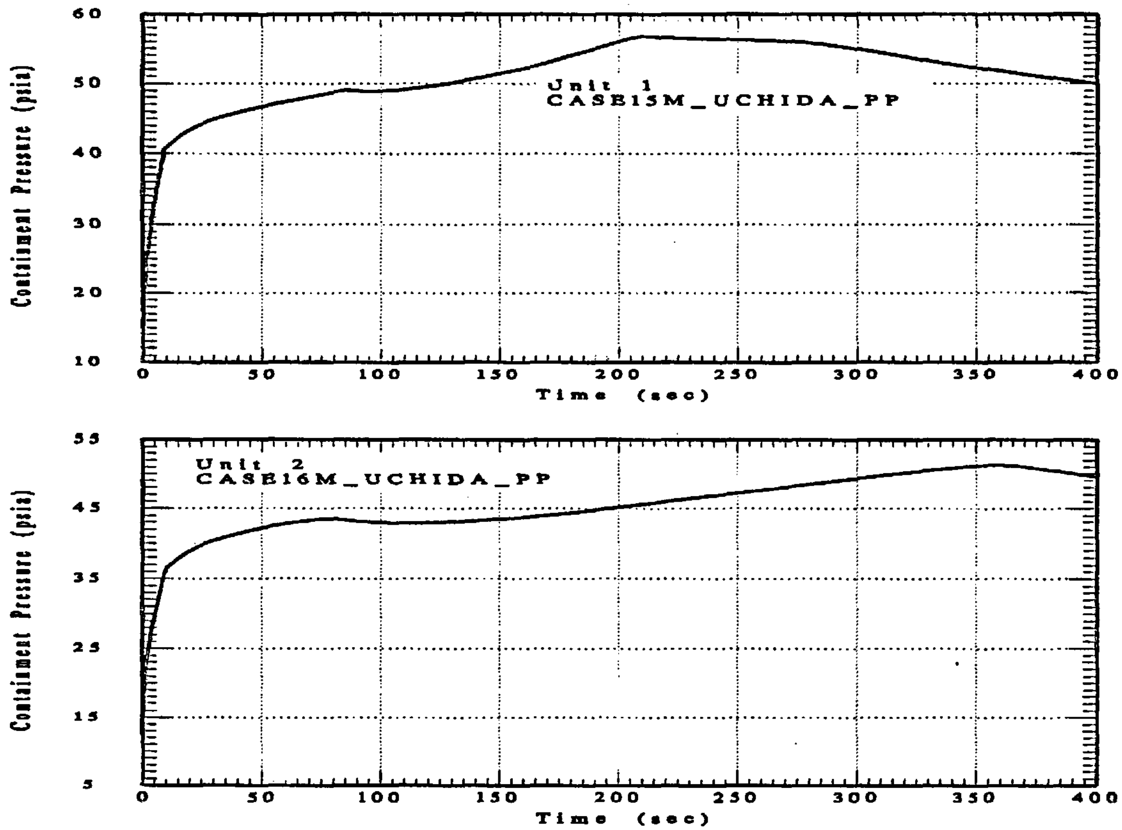
BVPS Large LOCA Pressure Profile (Tagami)





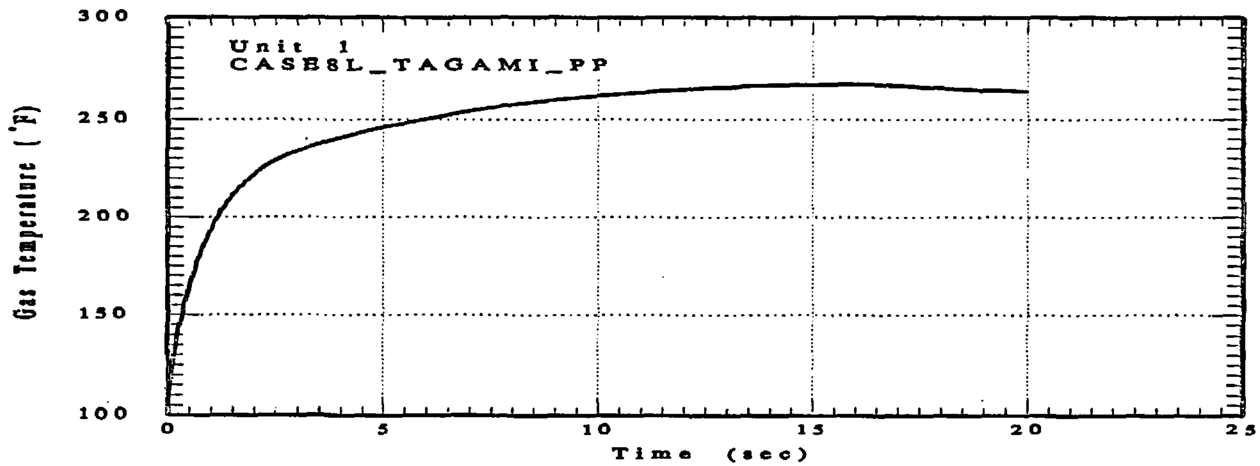
FENOC
FirstEnergy Nuclear Operating Company

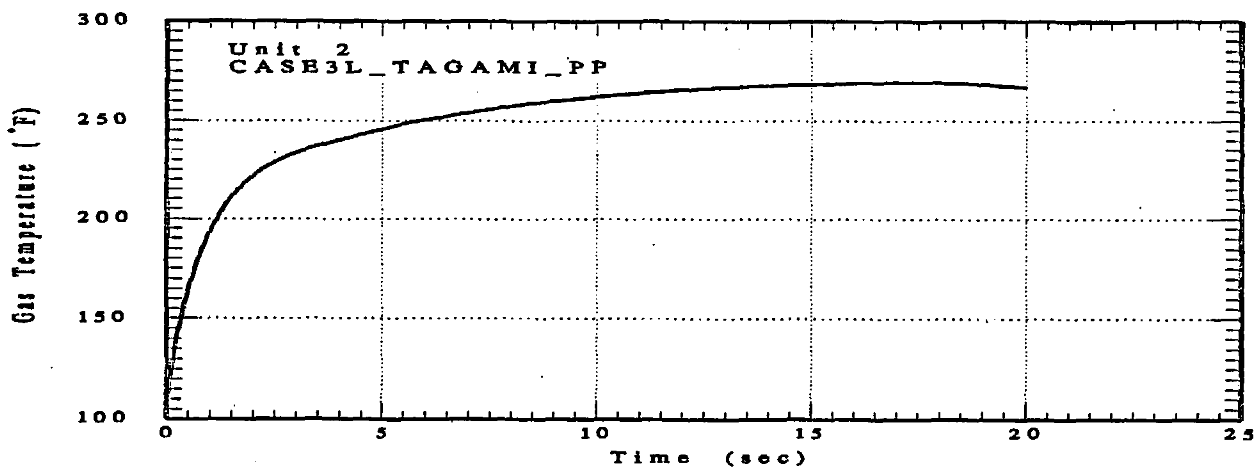
BVPS MSLB Pressure Profile (Uchida)



FENOC
FirstEnergy Nuclear Operating Company

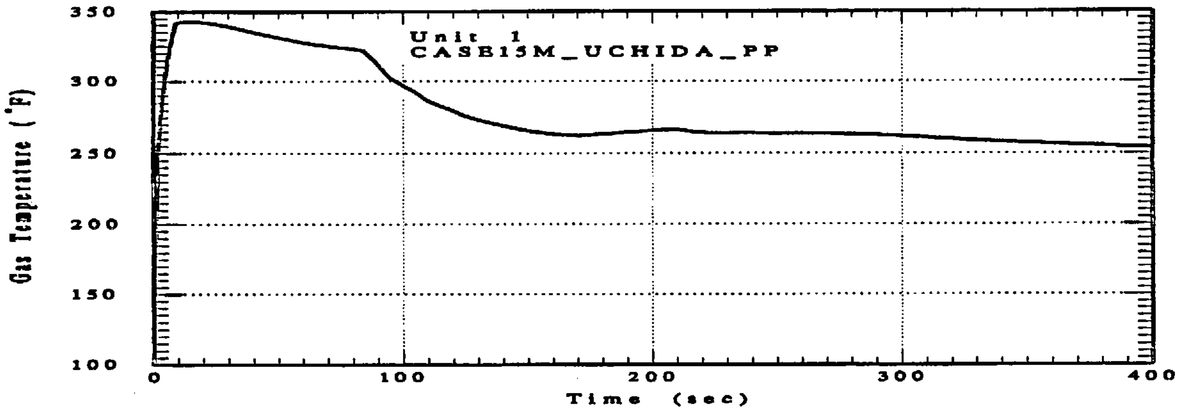
BVPS Large LOCA Gas Temperature Profile

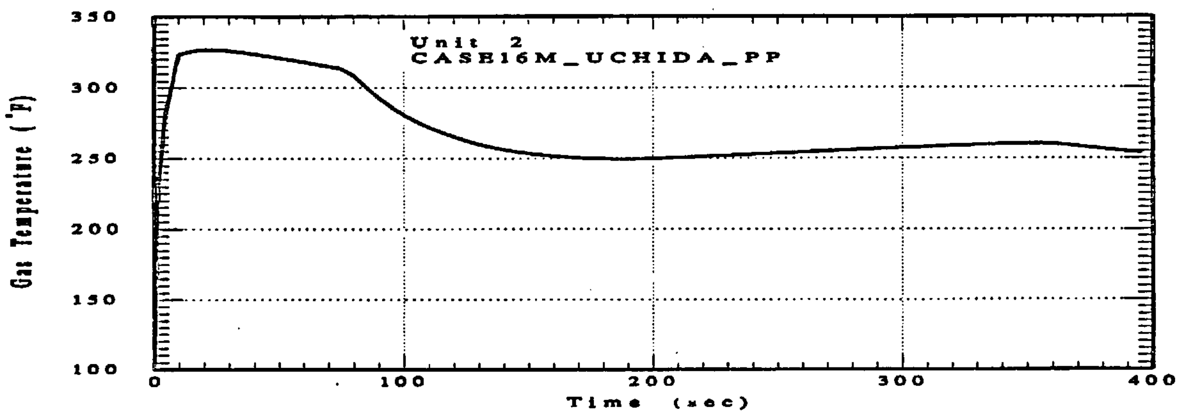




FENOC
FirstEnergy Nuclear Operating Company

BVPS MSLB Gas Temperature Profile





Conclusions

- Plant Specific Application of MAAP-DBA to BVPS is supported by:
  - Previous NRC Acceptance of Methodology for Design Bases Analysis at other plants as well as at BVPS
  - Benchmarking against GOTHIC in BVPS Specific Analysis
  - Benchmarking to Separate Effects Experiments
  - Benchmarking to Integral Effects Containment Experiments
- Peak pressure remains less than current design basis – No rerating required for atmospheric conversion