Attachment 2 to AEP:NRC:0900M

FAUSKE AND ASSOCIATES'
OCTOBER 9, 1997 PRESENTATION

MAAP4 ANALYSES OF THE D.C. COOK CONTAINMENT RESPONSE TO SMALL BREAK LOSS-OF-COOLANT ACCIDENTS

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OUTLINE

- Introduction to the MAAP4 computer code.
- Benchmarking calculations for this effort.
  - Comparison of the containment pressure and ice melt rate with LOTIC-3 for 6″ and 2″ cold leg breaks.
  - Comparison of the RCS break flow with the NOTRUMP model for 6″ and 2″ cold leg breaks.
  - Comparison of RCS break flow with a large break DBA calculation.
  - Comparison of the containment response given DBA mass and energy releases.
  - Comparison with the Westinghouse ice condenser experiments.
- Important input parameters and sensitivity studies for the D.C. Cook nuclear plant evaluations.
- Results for postulated small break LOCAs at the D.C. Cook nuclear plant.

BASIS FOR INVESTIGATING A SPECTRUM OF LOCA CONDITIONS

- A LOCA must be large enough for the containment sprays to be activated and needed over the long term.

- For a large LOCA, the RCS will depressurize, LPI will be initiated and the core will be cooled with cold water leaving the RCS break location. In this case, the containment sprays would only be required early in the accident.

- The sensitivity calculations show that the utilization of containment sprays is the greatest for small LOCA conditions. The utilization of containment sprays is determined by the transient containment pressure including (a) the sprays turning on if the pressure increases to 2.9 psig and turned off at 1.5 psig, and (b) the sprays run continuously once they are activated. Both are evaluated.

INTRODUCTION TO THE MAAP4 COMPUTER CODE

- EPRI owned code and used internationally.
- Developed and maintained under a QA program in compliance with 10CFR50, App. B.
- MAAP4 is structurally organized as a modular code and includes models for:
  - the reactor core response (BWR & PWR),
  - the reactor coolant system response (BWR & PWR),
  - the steam generators (PWR),
  - the containment response (BWR & PWR),
  - the contributions of the emergency safeguard features (BWR & PWR), and
  - the response of adjacent plant building (auxiliary building, etc) where appropriate (BWR & PWR).
- As an integral system model, the focus of MAAP4 is on the total plant response to postulated accident conditions, with particular emphasis on accident management evaluations.
- As an integral system model, the MAAP4 focus is on the best-estimate evaluations for all phenomena evaluated.

MAAP4
Modular Accident Analysis Program

- MAAP4 is a modular computer program written in fortran and is directed at evaluating the integral response of the RCS, containment and ESFs to a broad spectrum of possible accident conditions.

- The MAAP4 code is fast running (variable timestep) and has been developed for:

  - PWR NSSS (B&W, CE, + W) designs
    - large dry containments,
    - subatmospheric containments,
    - ice condenser containments.

  - BWR NSSS (ABB + GE) designs
    - Mark I containments,
    - Mark II containments,
    - Mark III containments.

  - CANDU NSSS designs
    - Ontario Hydro containment designs with the vacuum building,
    - AECL design with a separate containment for each reactor.

  - VVER NSSS designs
    - reactor confinement including the bubble tower.

  - Fugen NSSS design
    - single containment with a suppression pool.

MAAP4
Modular Accident Analysis Program
(Continued)

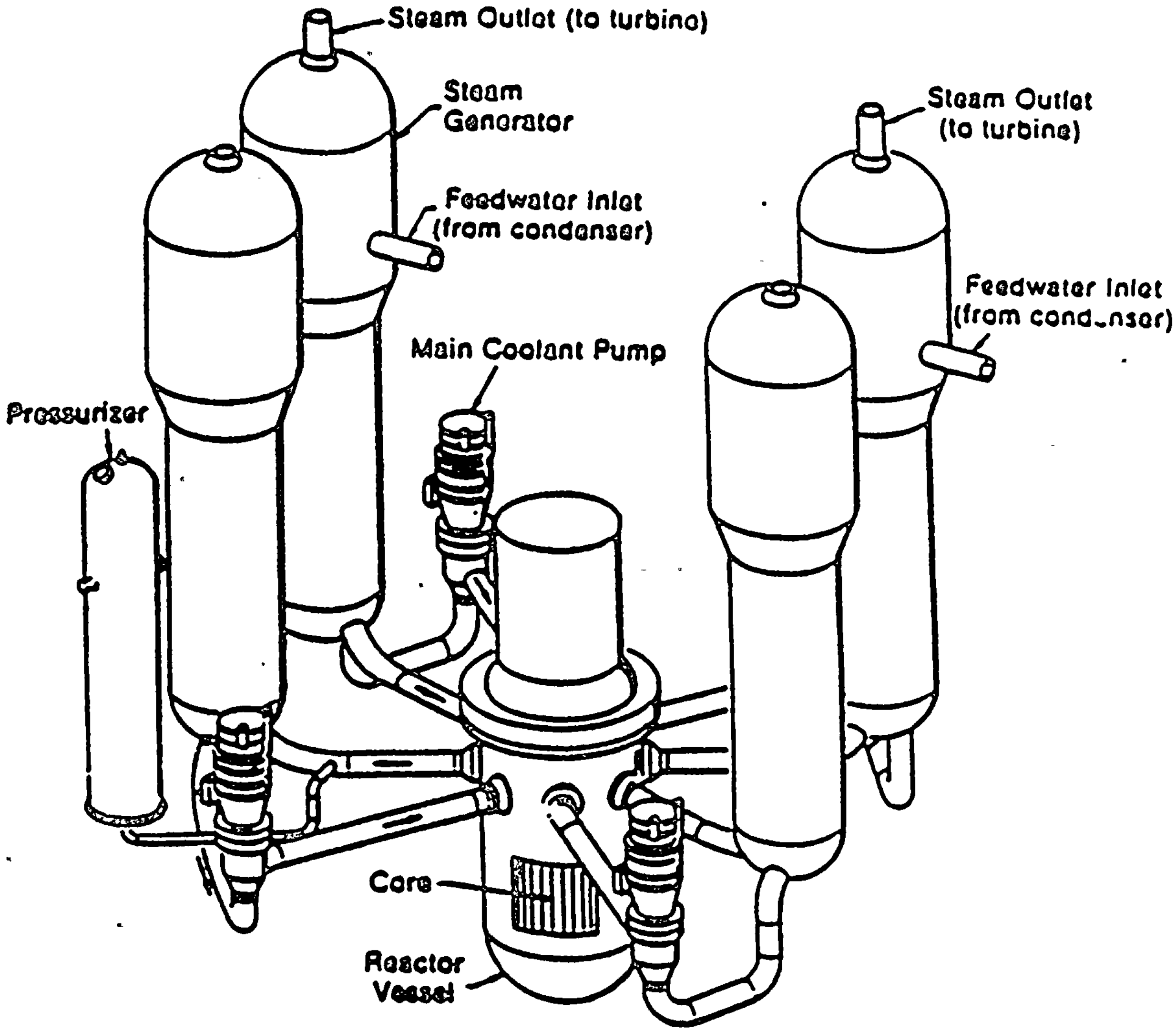
- MAAP4 modeling includes:

  - Response to LOCA or inadequate cooling conditions.

  - Models for core degradation, core melt progression, debris quenching, etc. necessary to evaluate severe accident conditions.

  - A generalized containment model that promotes extensive containment nodalization if desired. This generalized containment is used for all containment types listed above.

- MAAP4 contains a dynamic benchmarking capability that enables the best-estimate models to be benchmarked with available experiments and experience. These benchmarks can be easily repeated as the code evolves.



4 Loop Westinghouse Reactor Coolant System

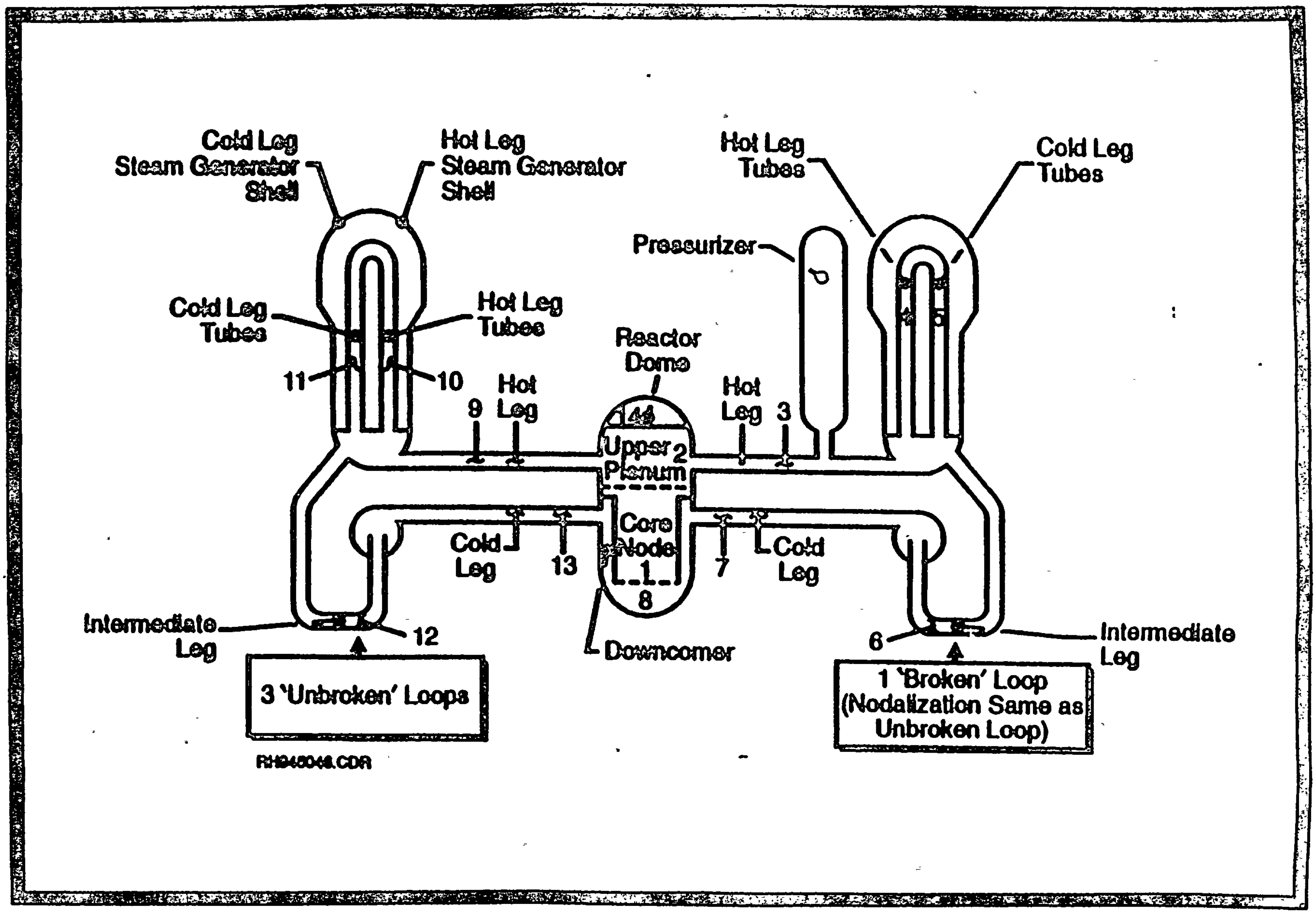


Figure 3-1 PWR primary system nodalization for Westinghouse 4-loop design.

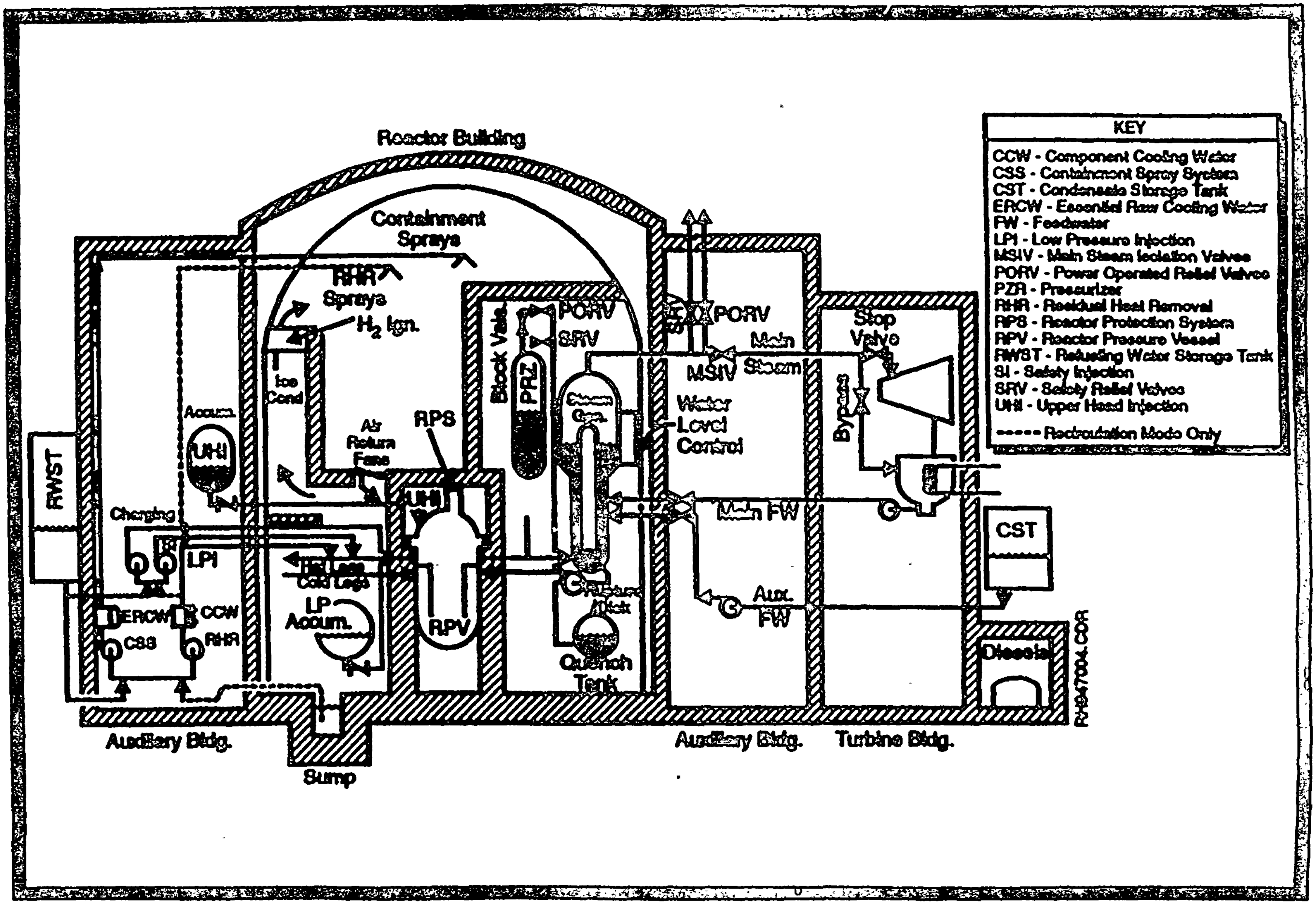


Figure 3-12 Ice condenser PWR safety and other systems (e.g., Sequoyah).

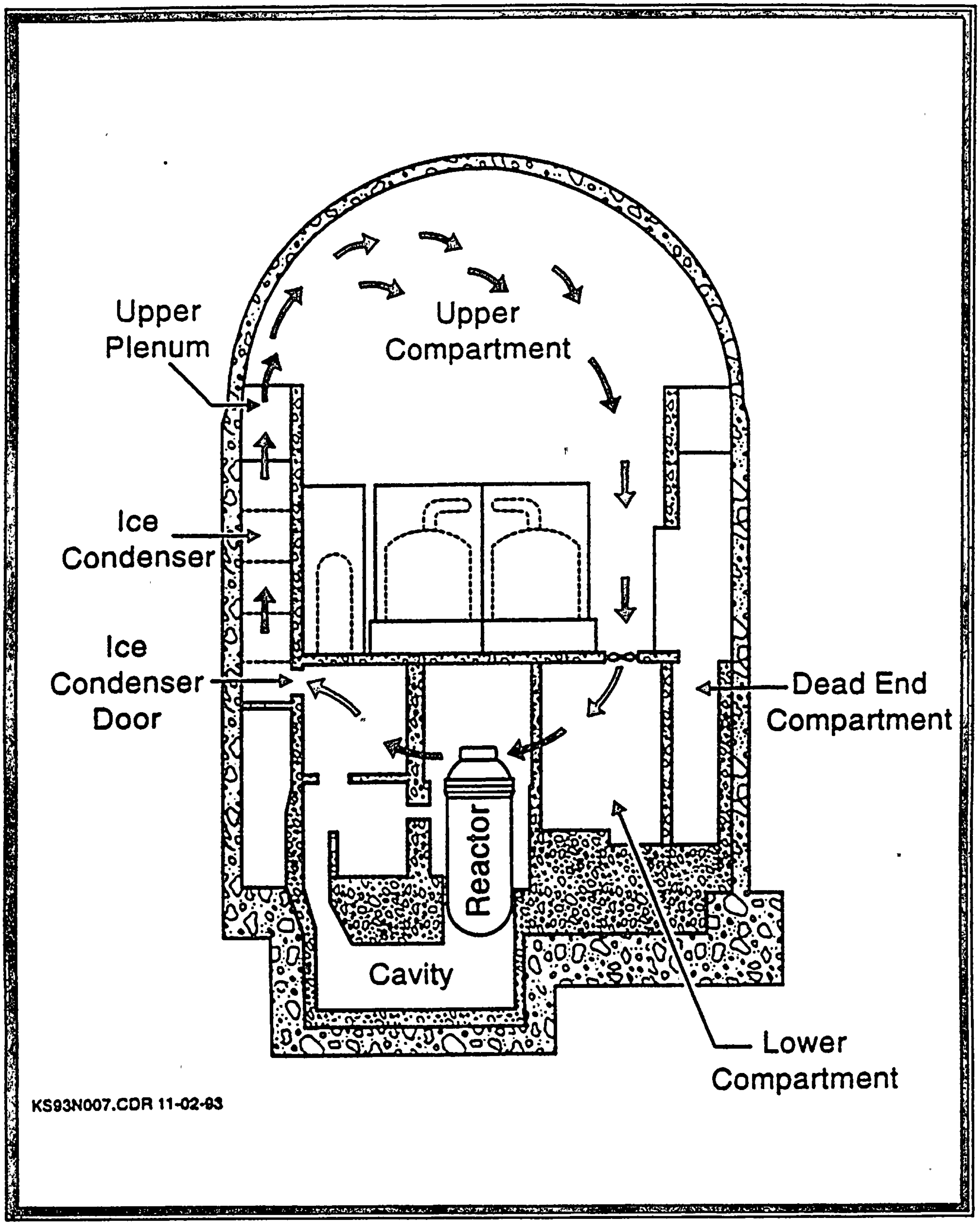
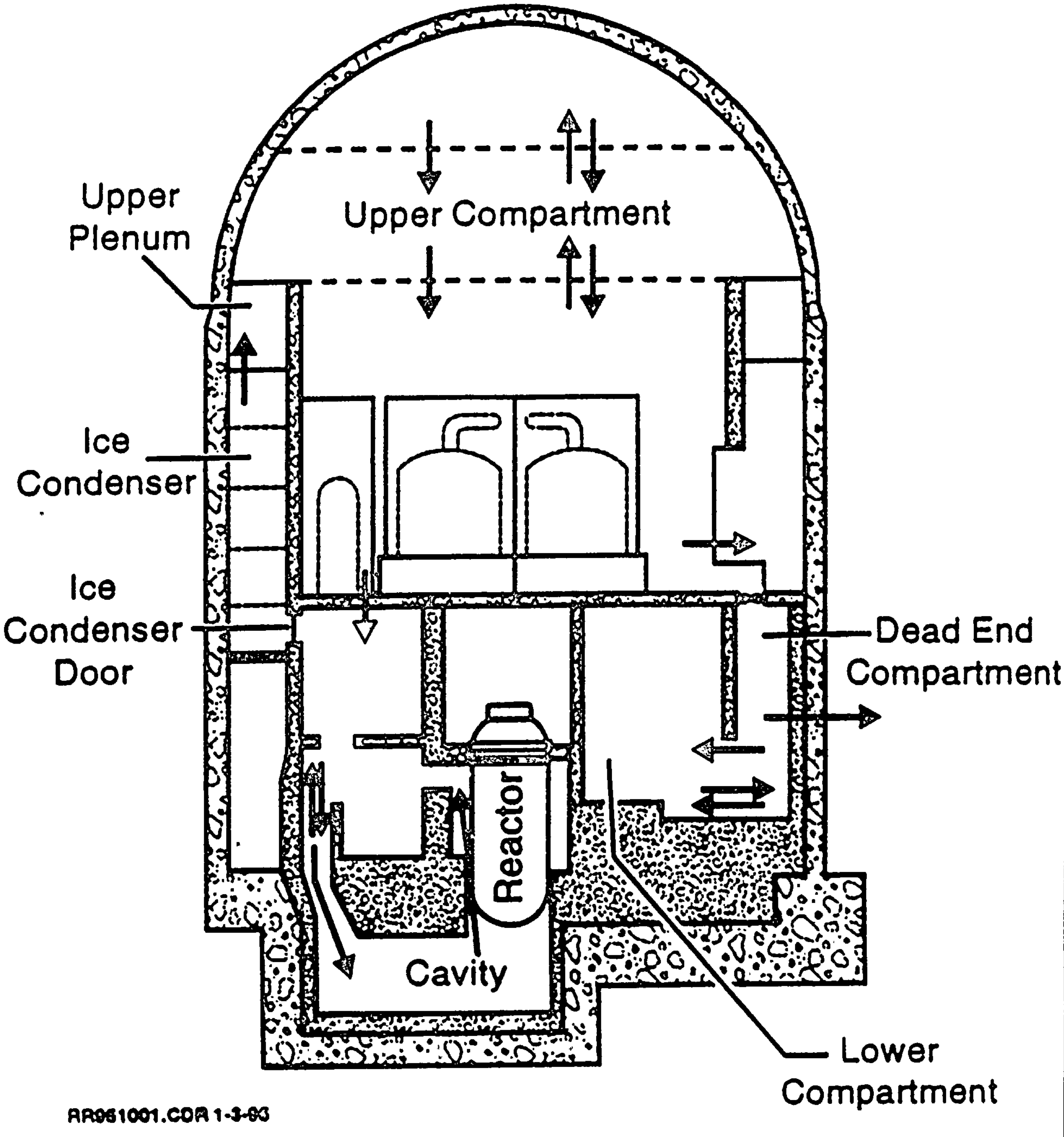
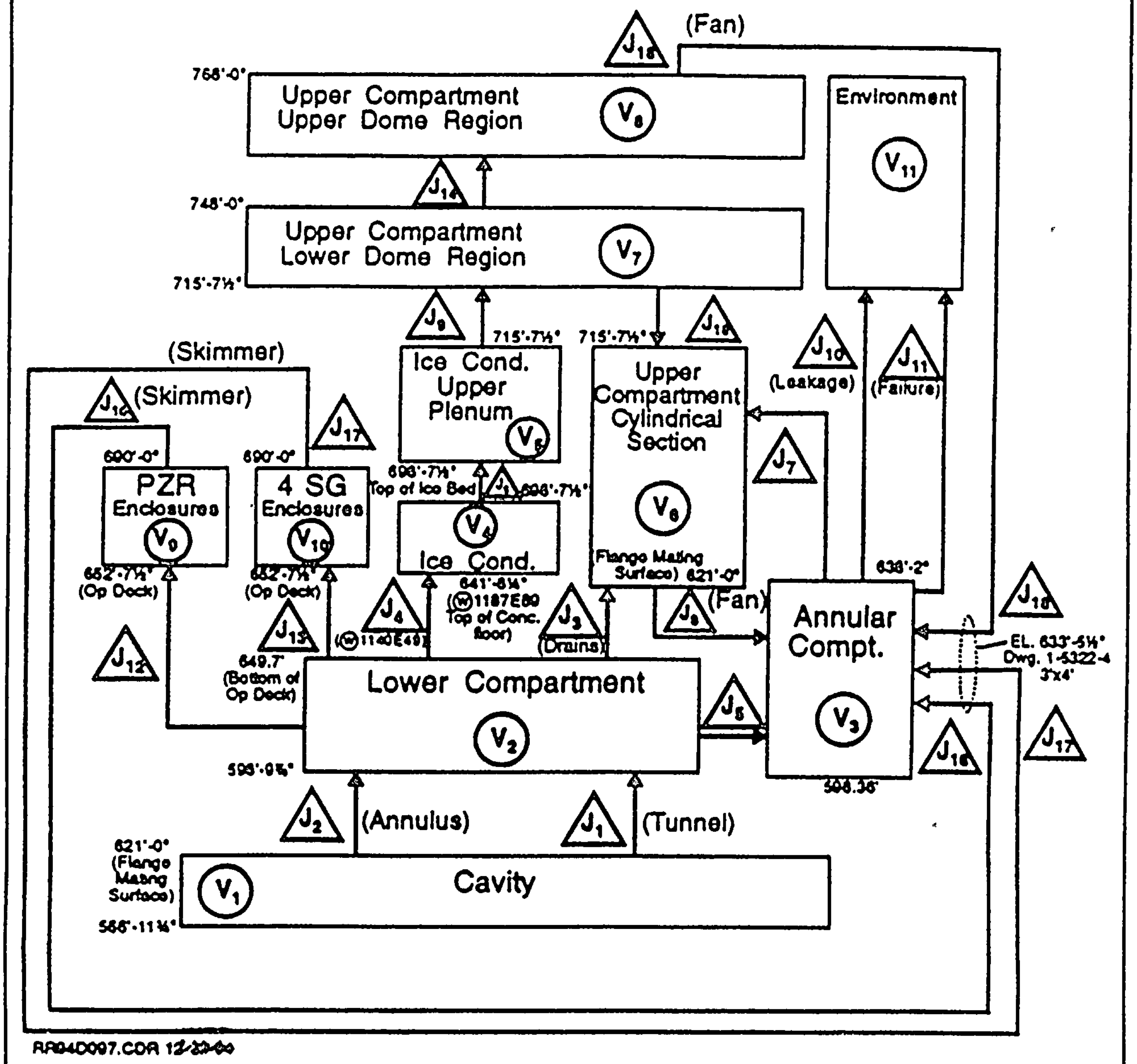


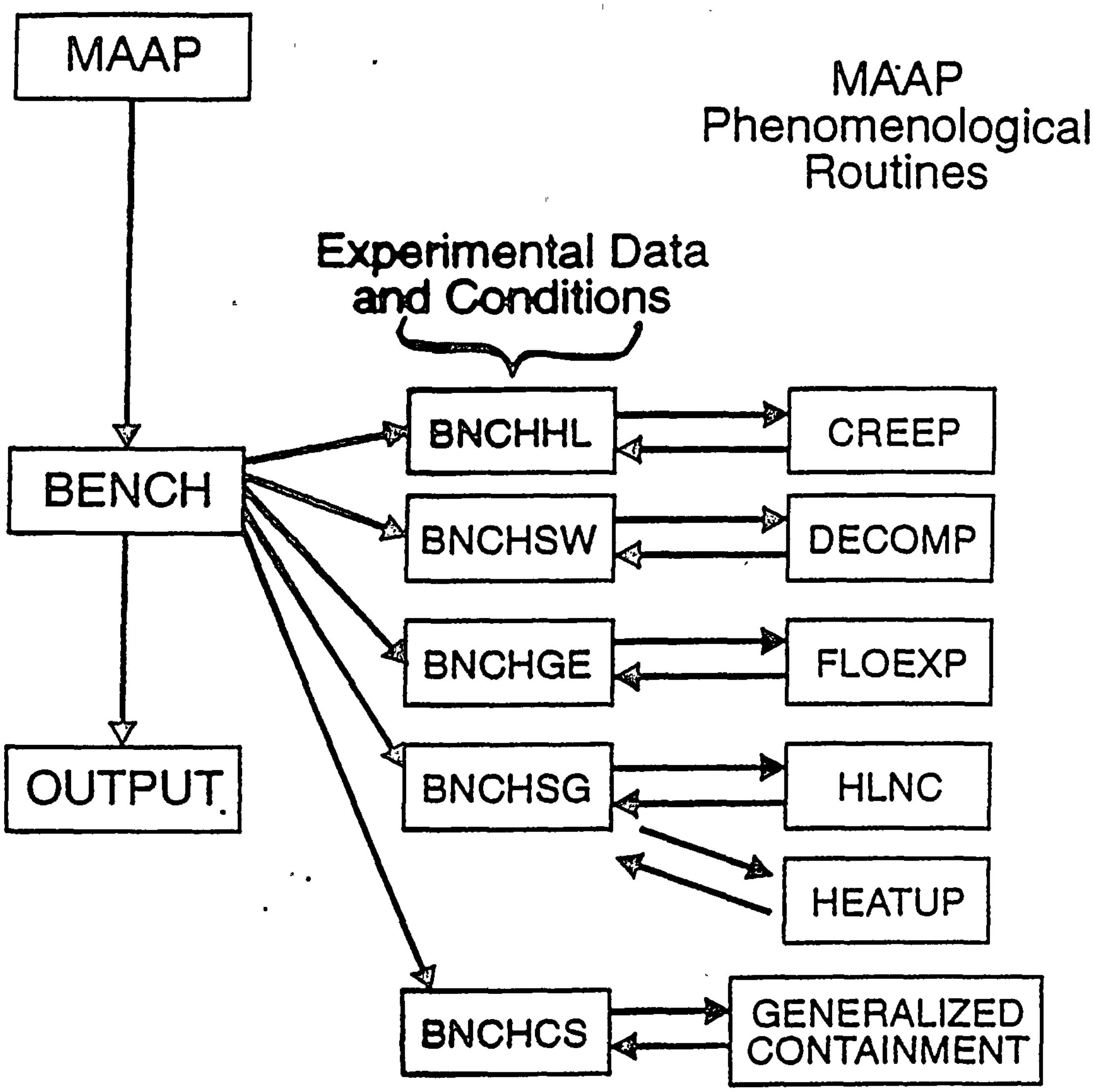
Figure 1 Containment diagram for an ice condenser plant.



D. C. Cook 10 Node Containment Model



D.C. Cook MAAP4 10 Node/18 Junction
Containment Model



Strategy for Incorporating Dynamic Benchmarks Into the MAAP4 Code

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MAJOR BENCHMARKS		
	MAAP4	Current Dynamic Benchmarks
Oyster Creek loss-of-feedwater (BWR)	✔	✔
Crystal River loss-of-feedwater and stuck open PORV (PWR)	✔	✔
Peach Bottom turbine trip tests (BWR)	✔	
Tokai-2 turbine trip (BWR)	✔	
Davis-Besse loss-of-feedwater (PWR)	✔	✔
Brown's Ferry fire (BWR)	✔	
TMI-2 (RCS)	✔ (0-5 hrs.)	✔
TMI-2 containment	✔ (0-5 hrs.)	✔
PHEBUS	✔	✔
LOFT-FP-2	✔	--
HDR	✔	✔
CORA (BWR & PWR)	✔	✔
CSTF	✔	✔
W ice condenser tests		✔
Ice condenser DB calculation		✔
W SG tests	✔	✔
Material creep	✔	✔
ABCOVE aerosol tests	✔	✔
ORNL fission product release tests	✔	✔
DEMONA aerosol tests		
LACE		
ACE experiments	✔	
BETA experiments	✔	

MAAP 4 CONTAINMENT BENCHMARKS REPORTED IN THE OPEN LITERATURE

S. J. Lee, et al., "Benchmark of the HDR E11.2 Containment Hydrogen Mixing Experiment Using the MAAP4 Code," submitted for November, 1997 ANS meeting.

C. Y. Paik, et al., "Validation Exercise for the MAAP4 Containment Model," Fifth International Conference on Simulation Methods in Nuclear Engineering, Montreal, Canada, September 8-11, 1996.

H. Iizuka, et al., "An Analysis of Hydrogen Mixing and Distribution Problem ISP-35 Using MAAP4 Code," PSA'95 Proceedings, November, 1995.

BENCHMARK CALCULATIONS FOR THE D.C. COOK SBLOCA SUMP FILL EVALUATIONS

- Containment pressure and ice melt comparison with LOTIC-3.
  - 6″ cold leg LOCA.
  - 2″ cold leg LOCA.

- The break flow rate spectrum used in the MAAP4 scoping calculations compared with the NOTRUMP model.
  - 6″ cold leg LOCA.
  - 2″ cold leg LOCA.

- The break flow rate for a large break LOCA DBA condition.

- The containment response given DBA mass and energy releases to containment.

- Comparison of the MAAP4 ice condenser model with the Westinghouse experiments.

WHAT IS EXPECTED FROM THE BENCHMARK CALCULATIONS

- Assure consistency between "best estimate" and "design basis" analyses.

- Assure consistency of the MAAP4 ice condenser model with the experimental basis

  - large LOCA,

  - medium LOCA,

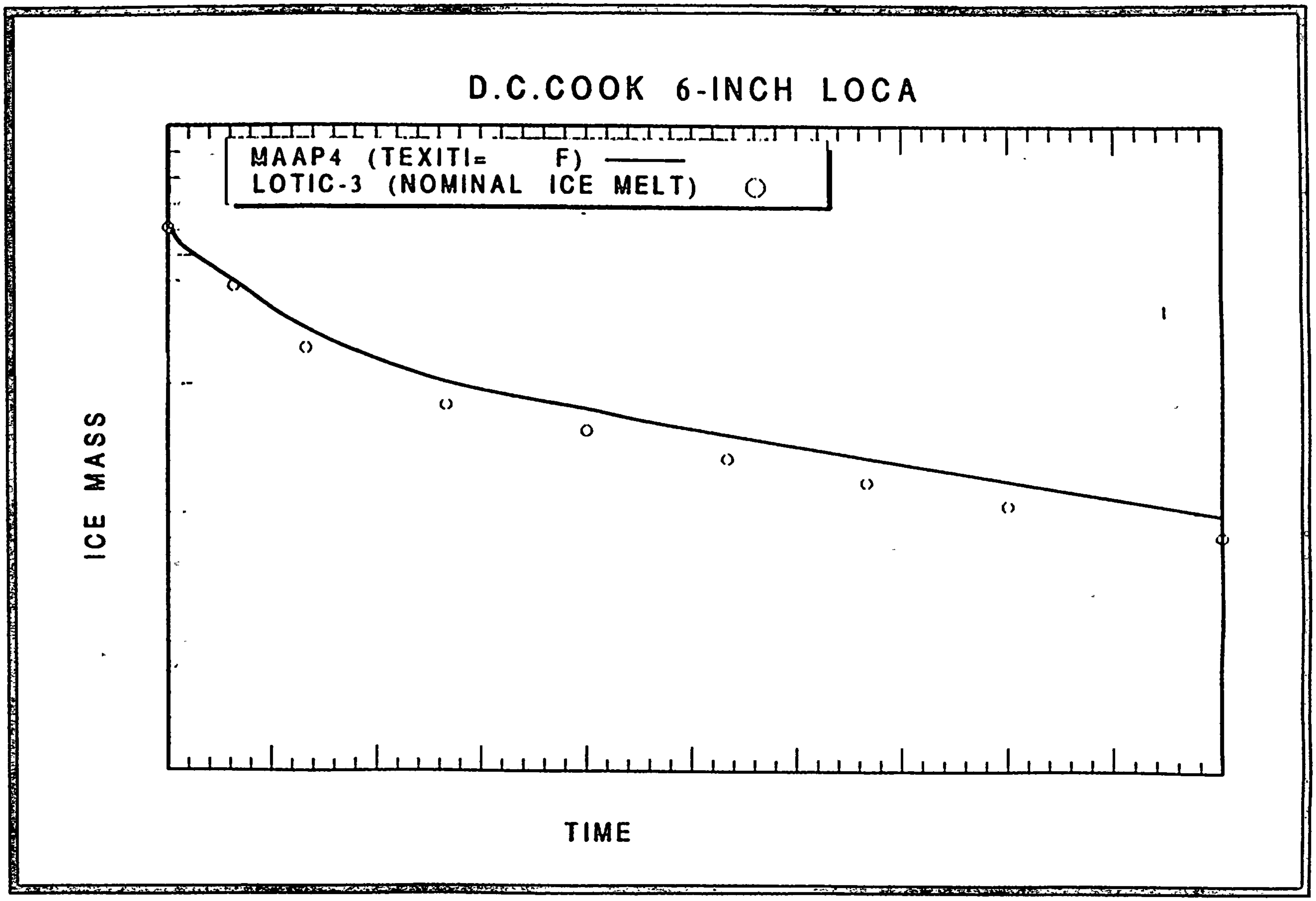
  - small LOCA.

COMPARISON WITH THE LOTIC-3 RESULTS

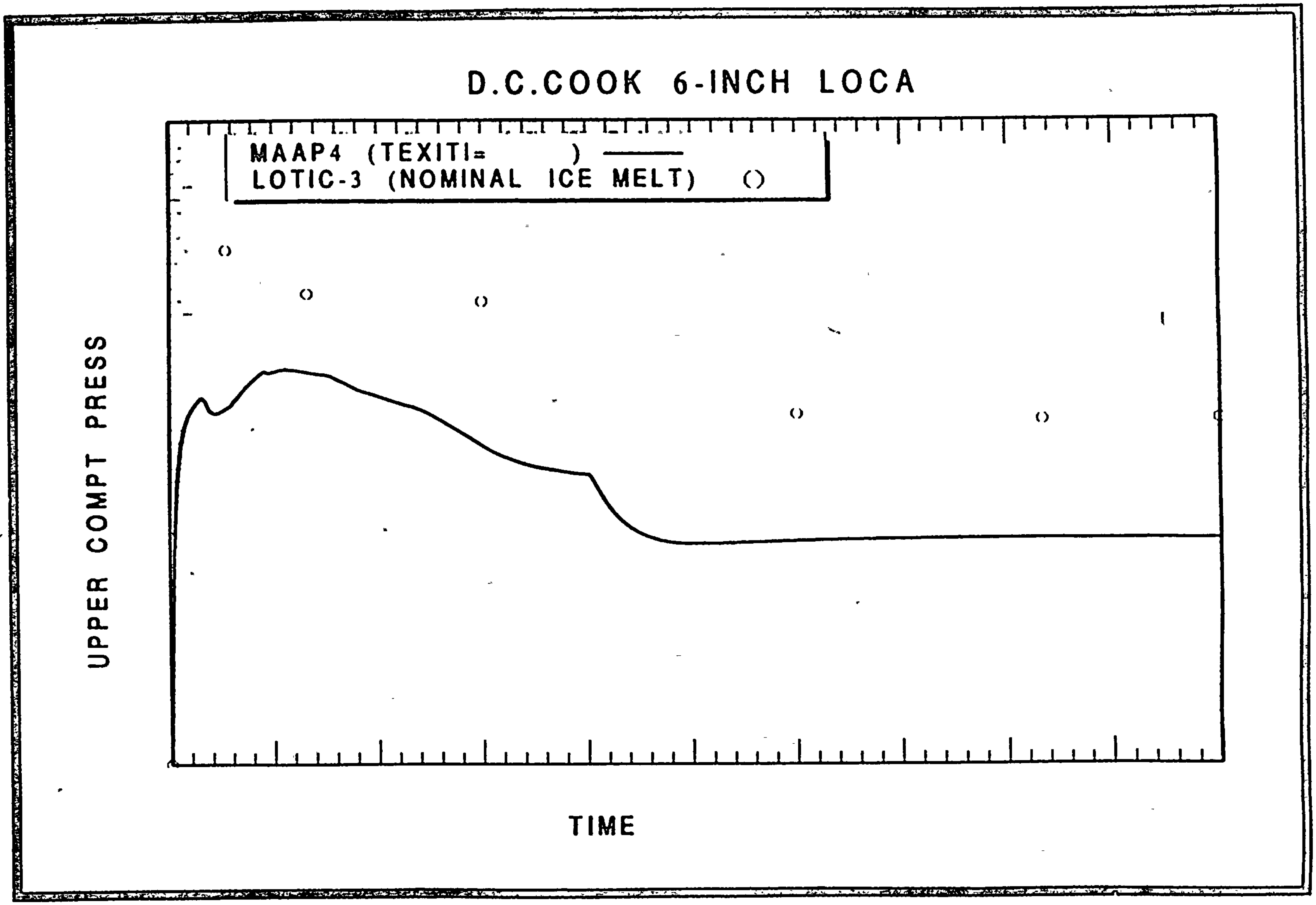
- This comparison is an evaluation of the respective containment models.

- The boundary conditions for both evaluations are the mass and energy releases from a 6″ and a 2″ cold leg LOCA as calculated by NOTRUMP.

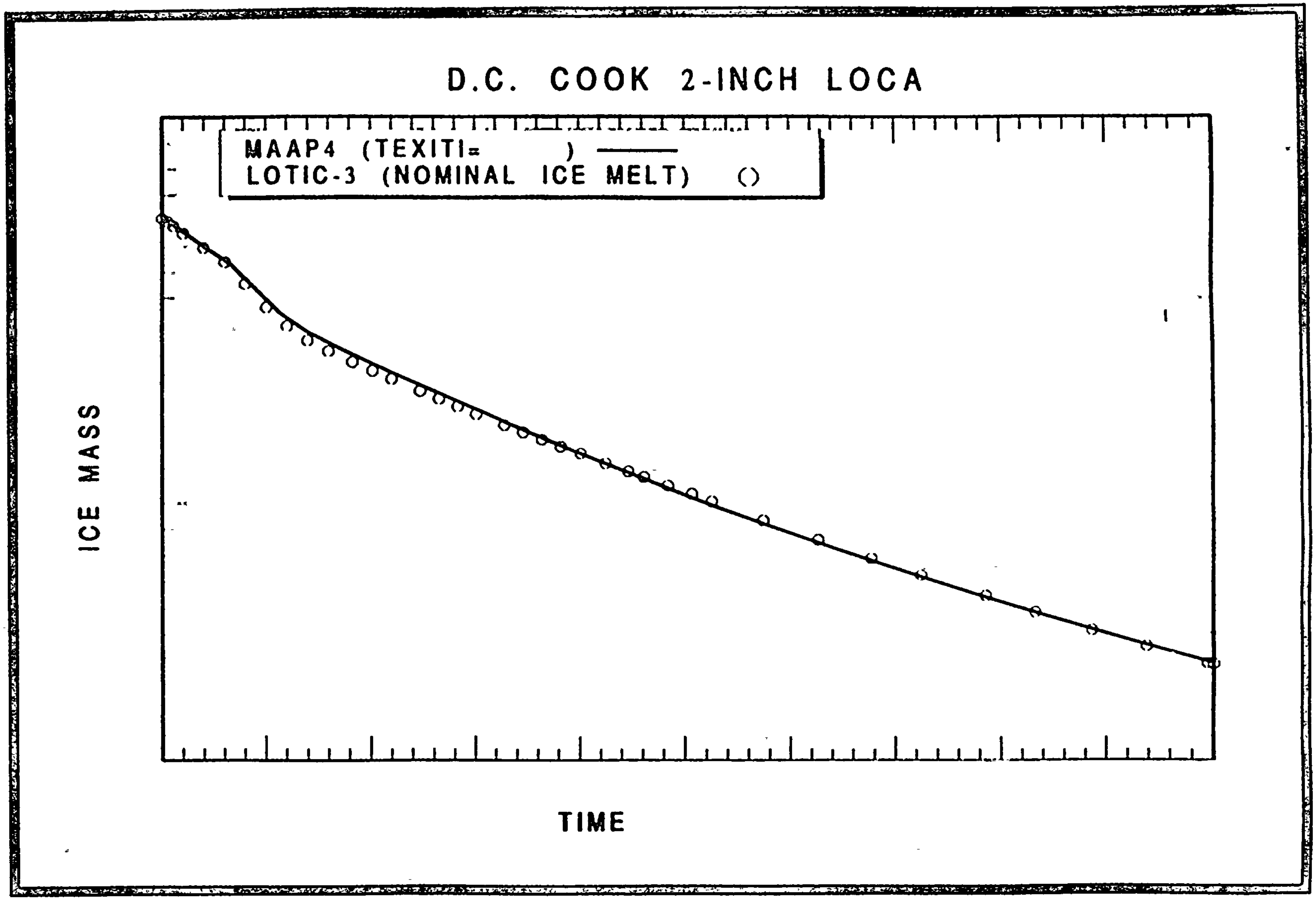
- Given the NOTRUMP mass and energy releases and the specification of the Cook containment, the resulting containment response for the two models can be compared.



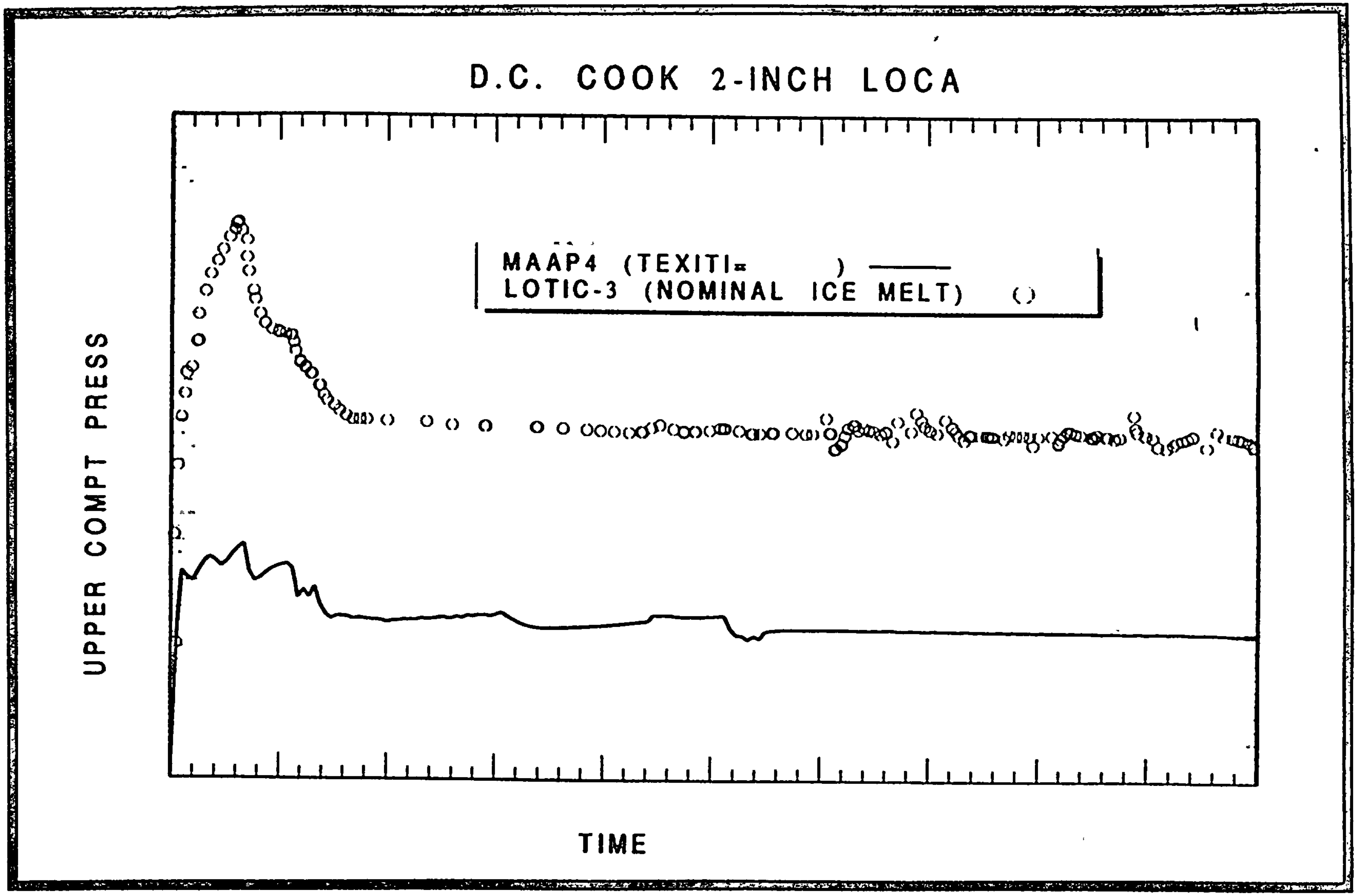
Comparison of the LOTIC-3 and MAAP4 ice depletion rate for a six-inch diameter cold let LOCA (NOTRUMP) for the D.C. Cook Unit 2.



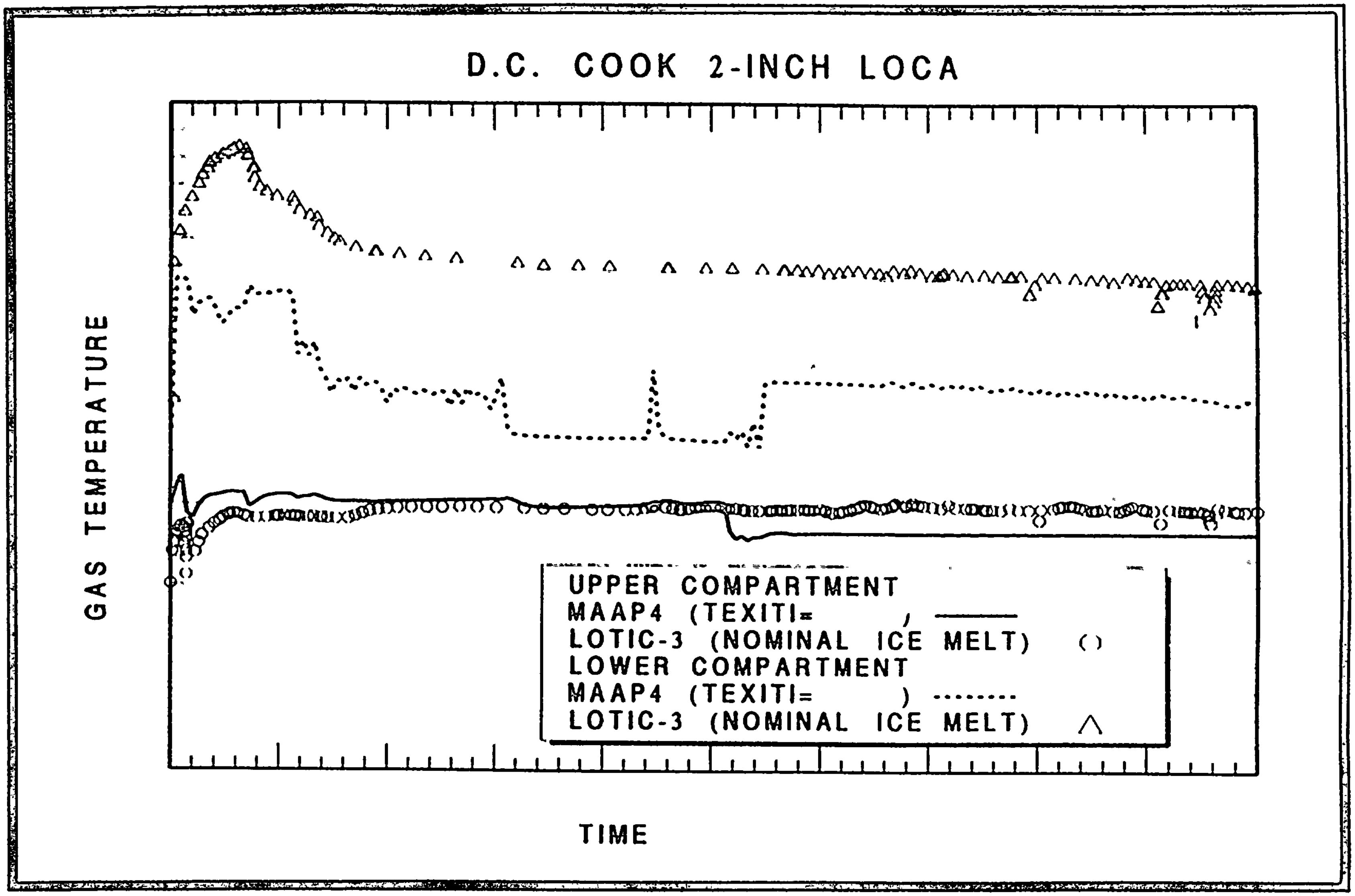
Comparison of the calculated D.C. Cook Unit 2 containment pressure for LOTIC-3 and MAAP4. The RCS blowdown is common to each analysis and is calculated for a six-inch diameter cold leg break using NOTRUMP.



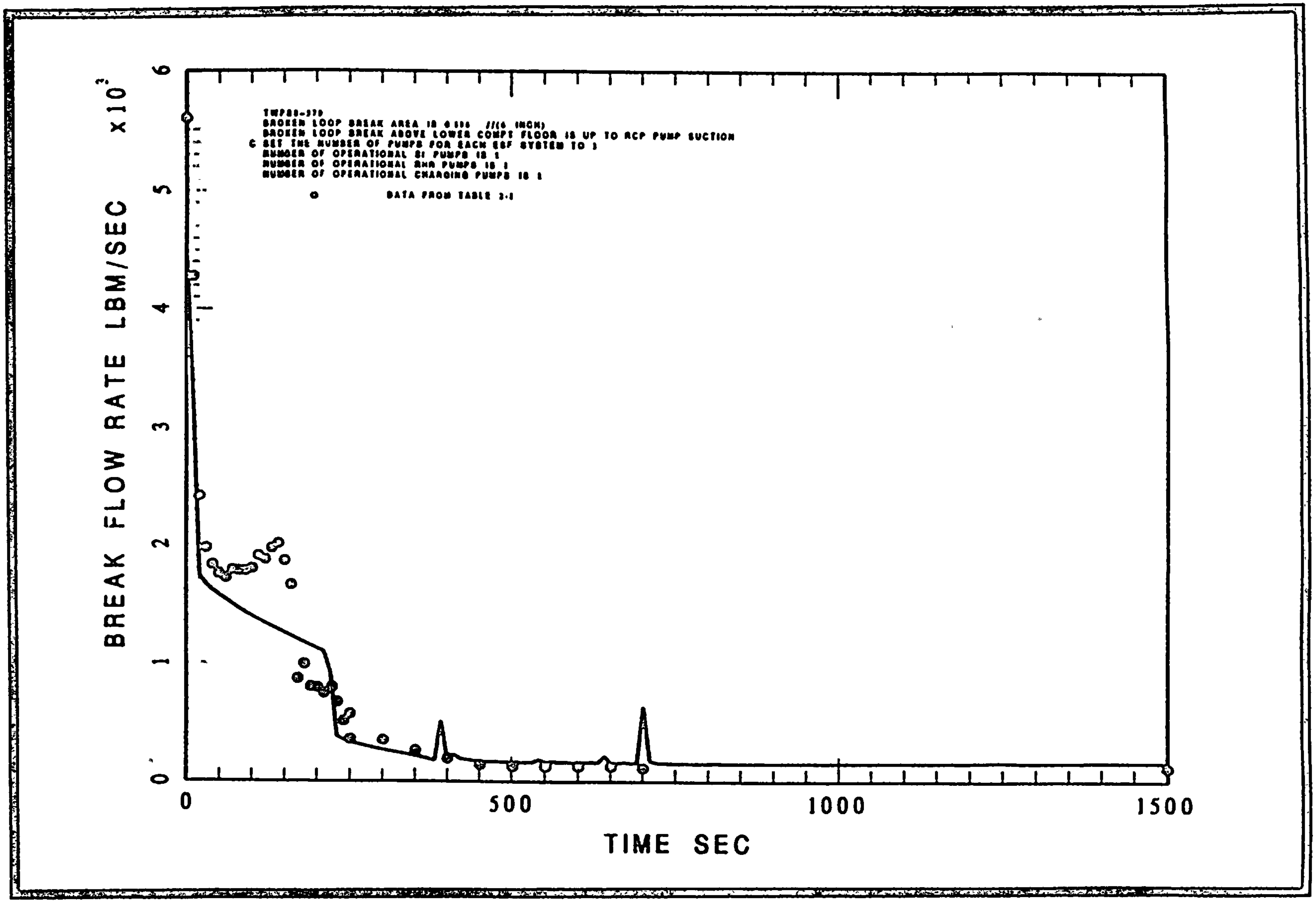
Comparison of the LOTIC-3 ice depletion rate for a two-inch diameter cold leg LOCA with the MAAP4 calculation using the same mass and energy inputs from the NOTRUMP calculation.



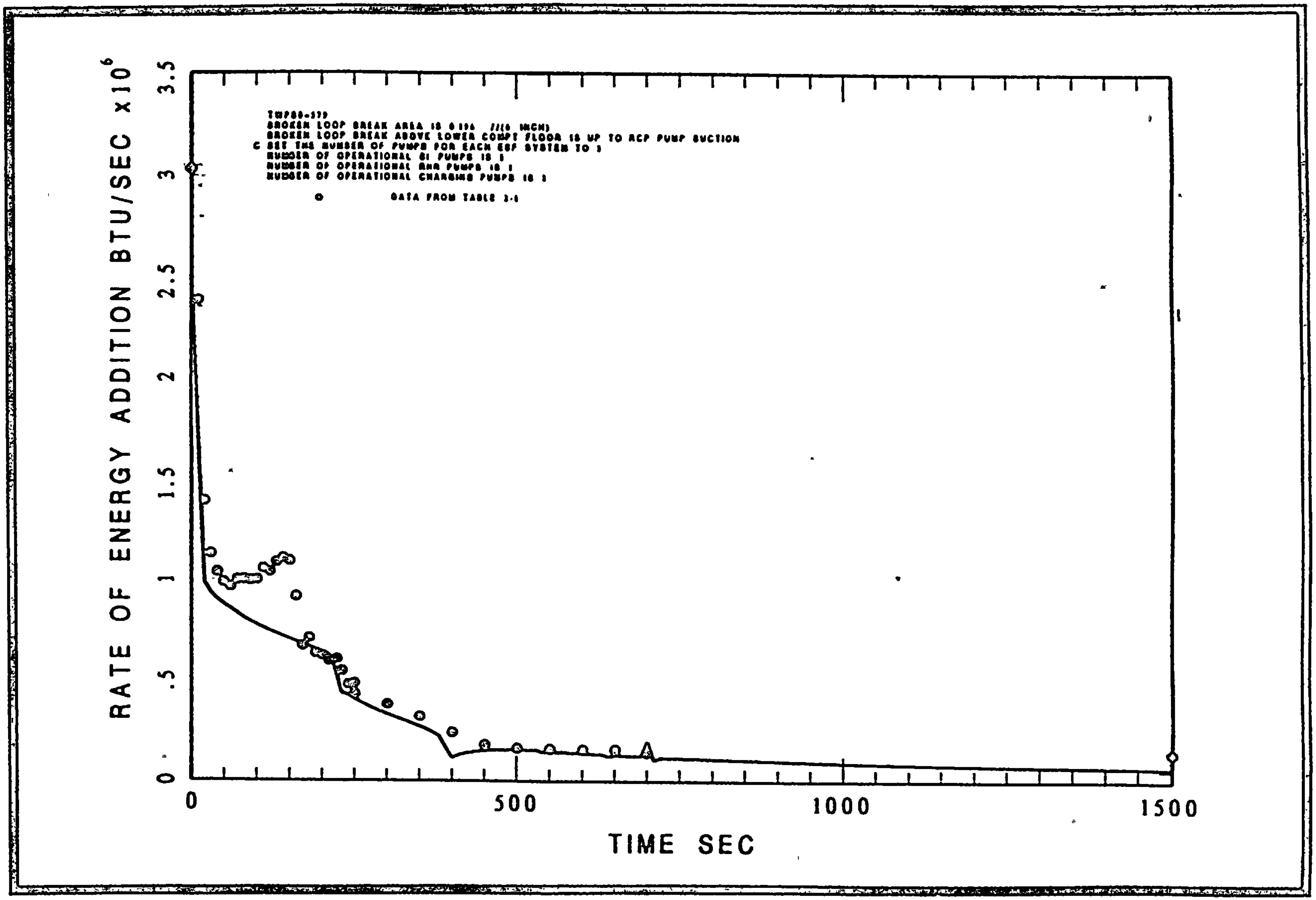
A comparison of the LOTIC-3 containment pressure calculation, biased for maximum containment pressure, with the nominal MAAP4 calculation with the accident initiator being a two-inch diameter cold leg LOCA as represented by NOTRUMP.



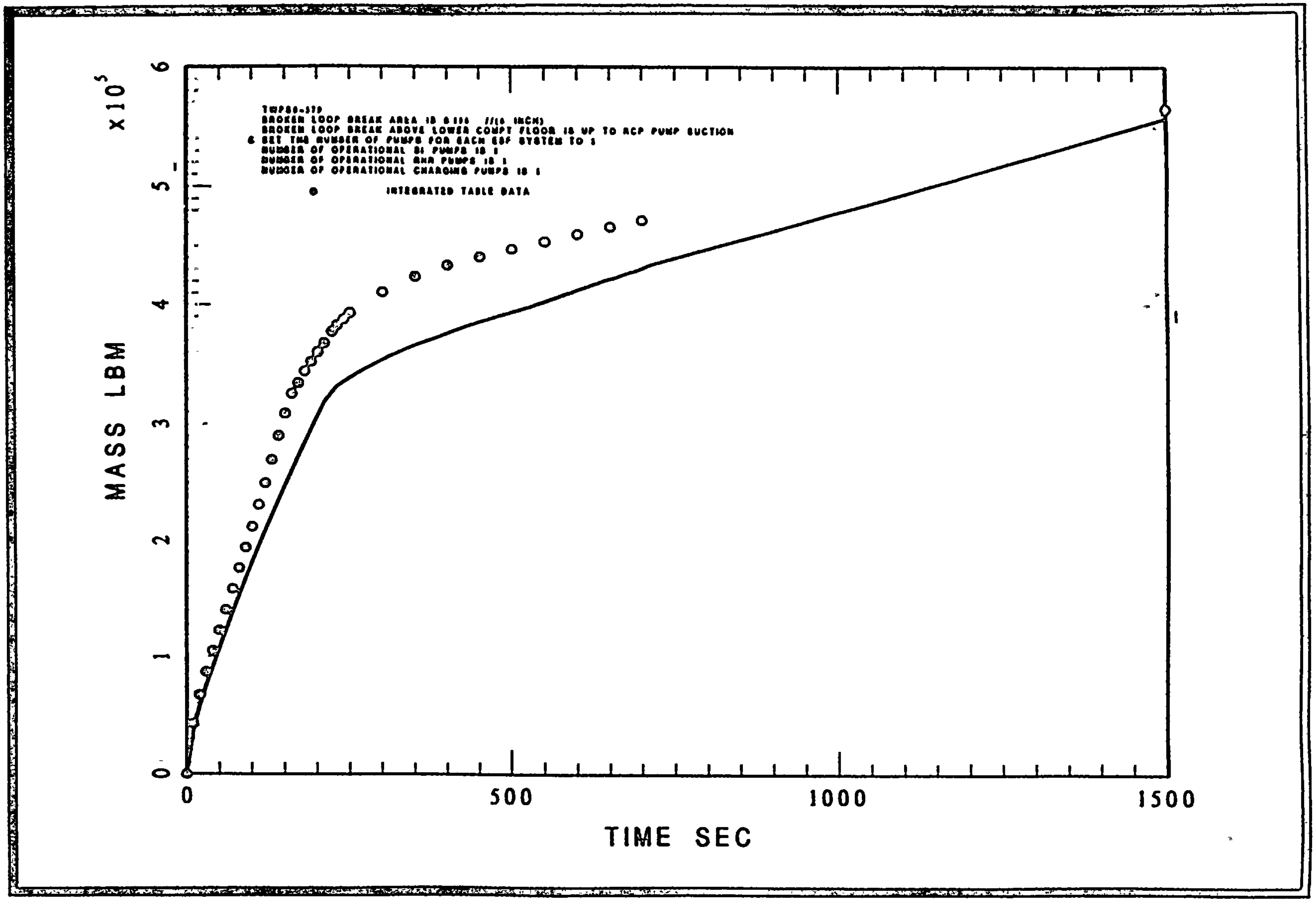
Comparison of the upper and lower containment compartment temperatures for a LOTIC-3 calculation biased for maximum containment pressure and the MAAP4 representation with the accident initiator being a two-inch diameter cold leg LOCA as represented by NOTRUMP.



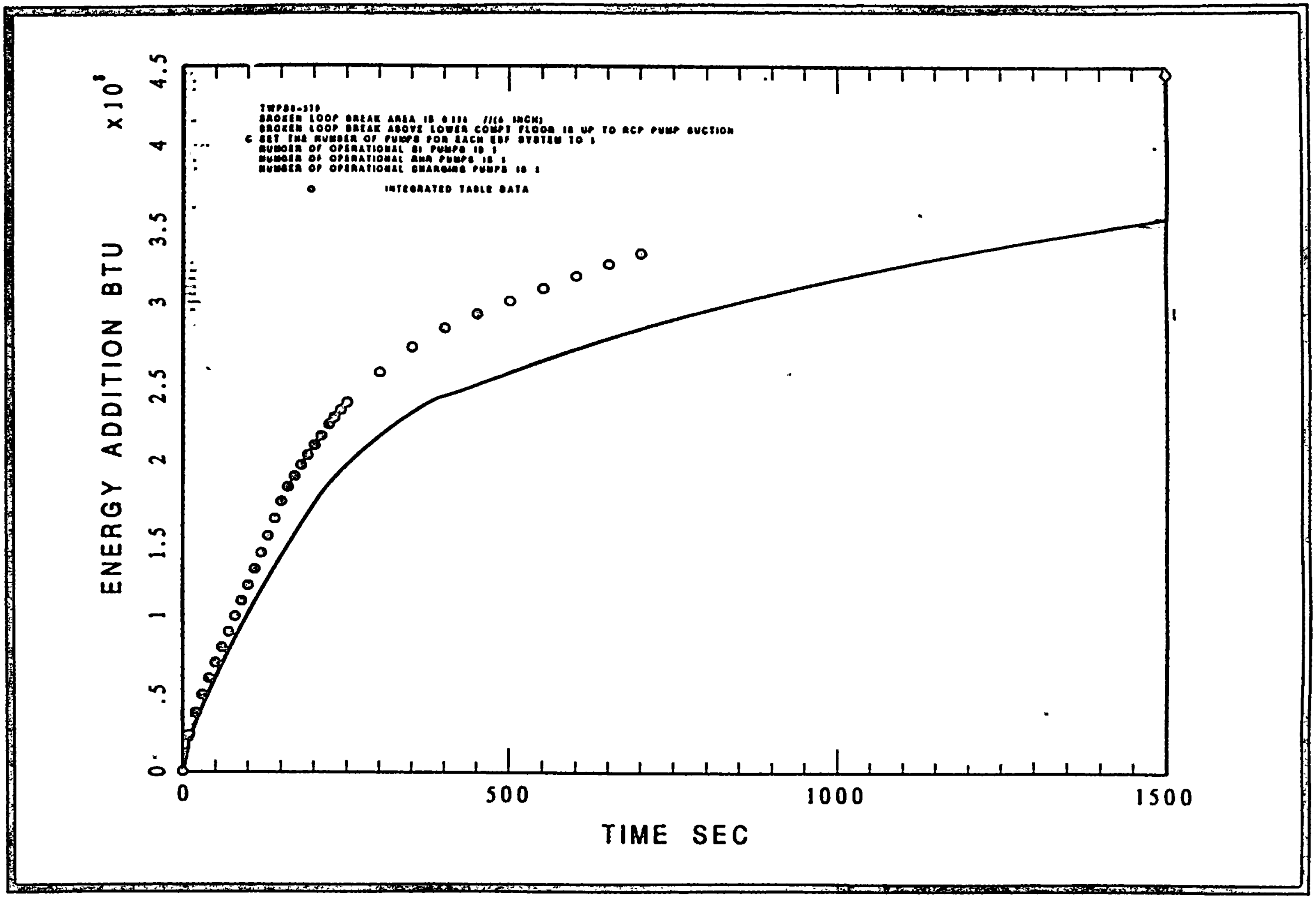
A comparison of the instantaneous mass flow rates for the MAAP4 primary system and NOTRUMP assuming a six-inch cold leg LOCA.



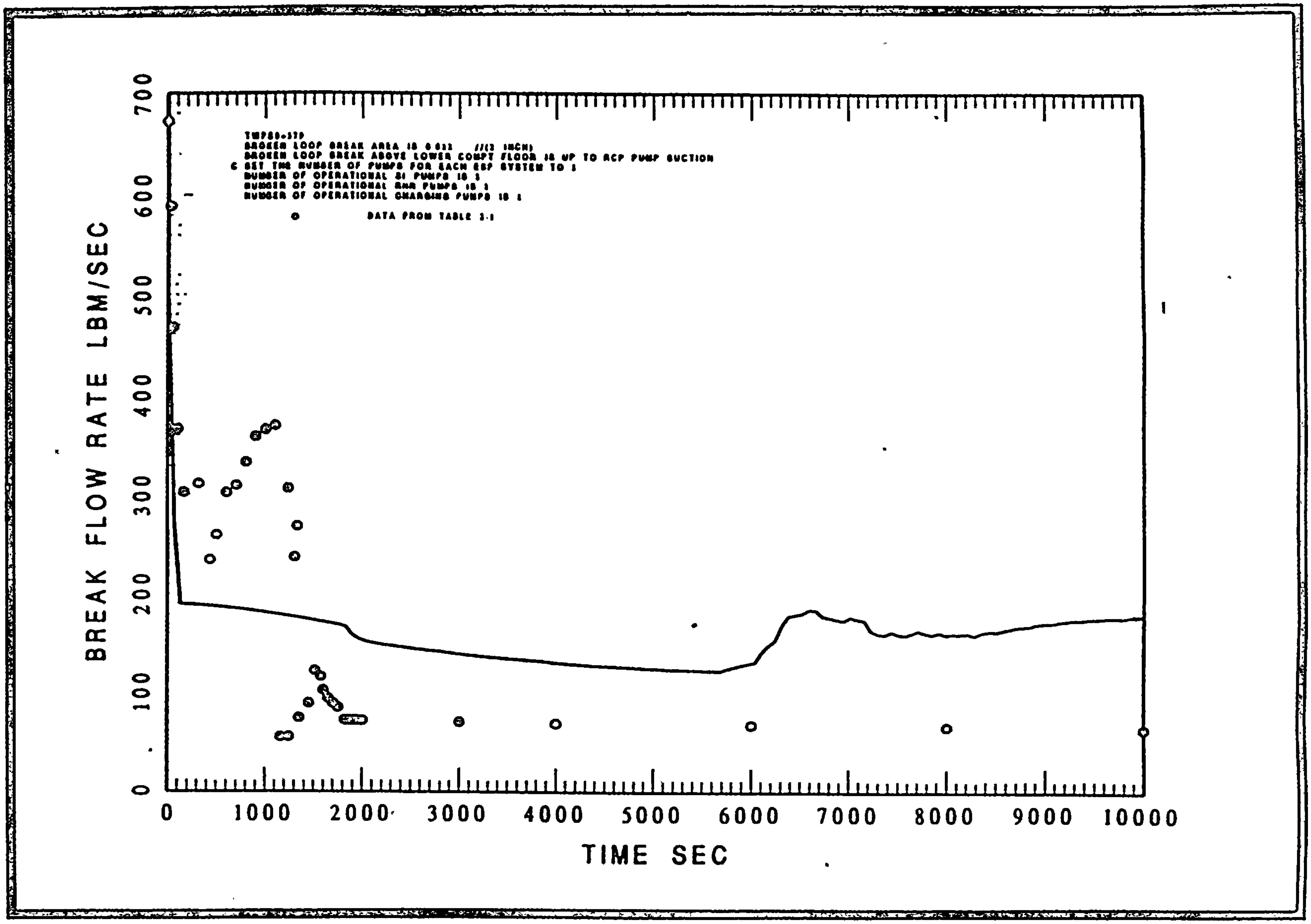
A comparison of the instantaneous energy release to the containment for NOTRUMP and the MAAP4 primary system model assuming a six-inch cold leg LOCA.



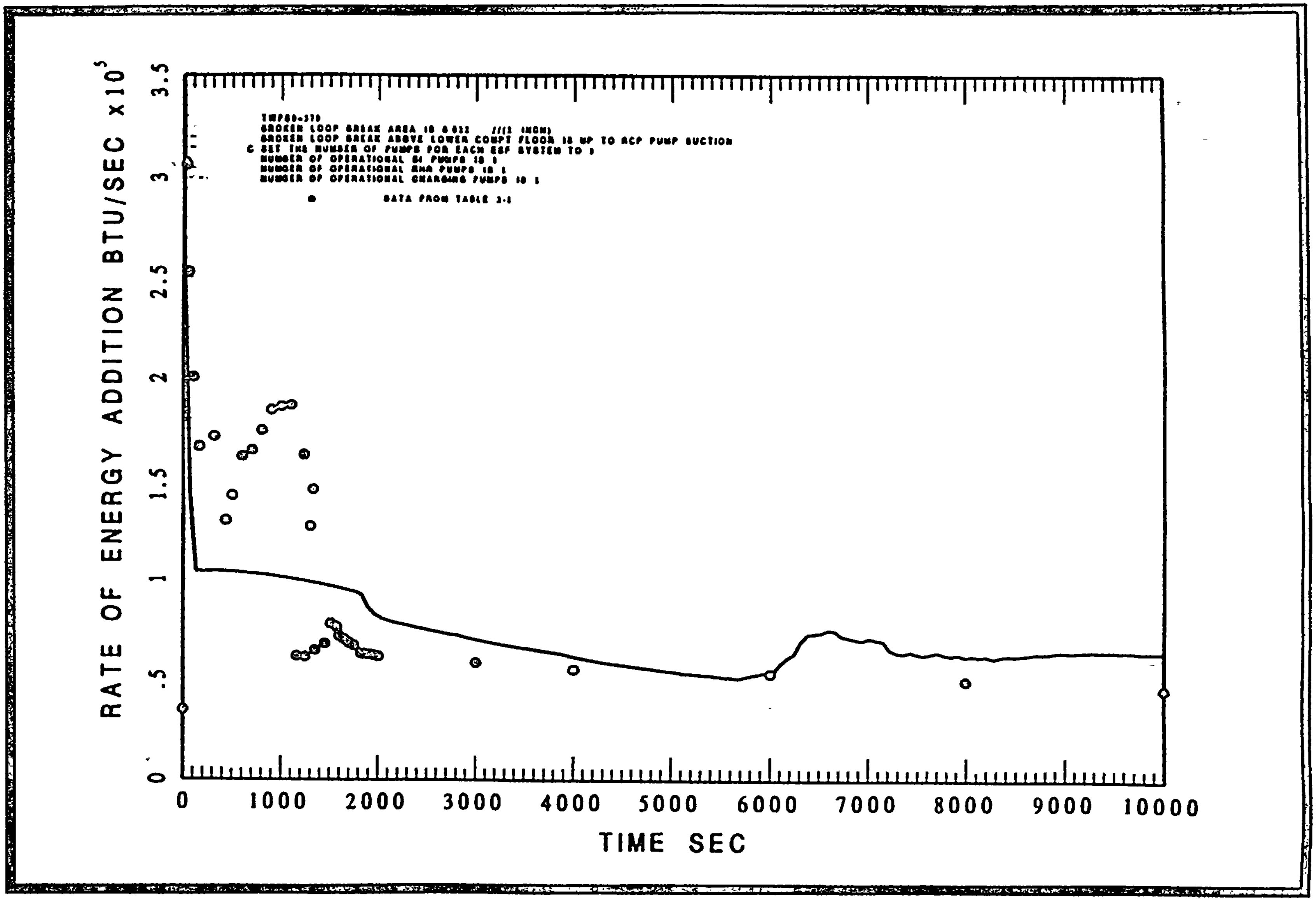
A comparison of the integral mass release to containment for NOTRUMP and the MAAP4 RCS model assuming a six-inch cold leg LOCA.



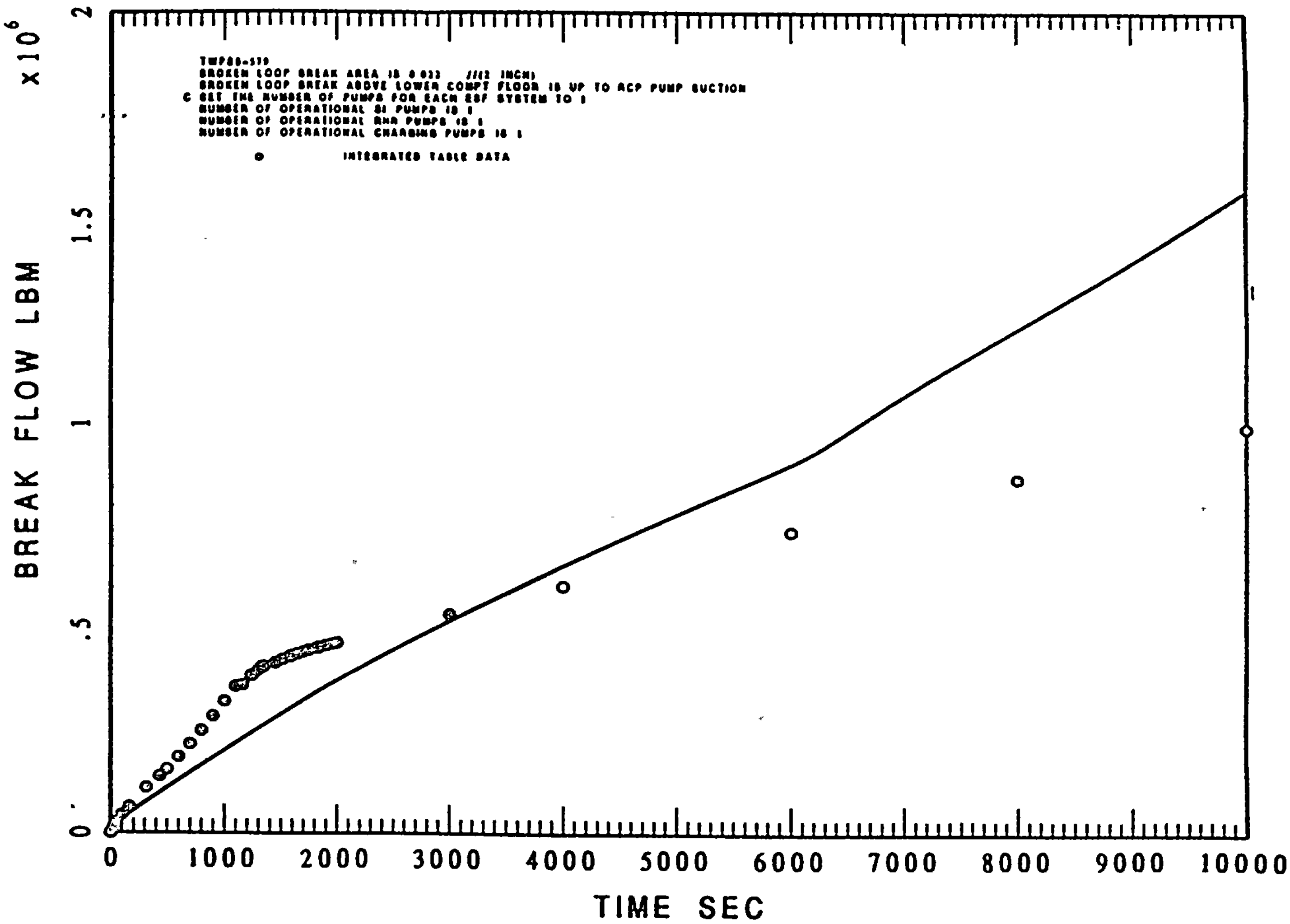
The integral energy released to the containment for NOTRUMP and the MAAP4 RCS models assuming a six-inch cold leg LOCA.



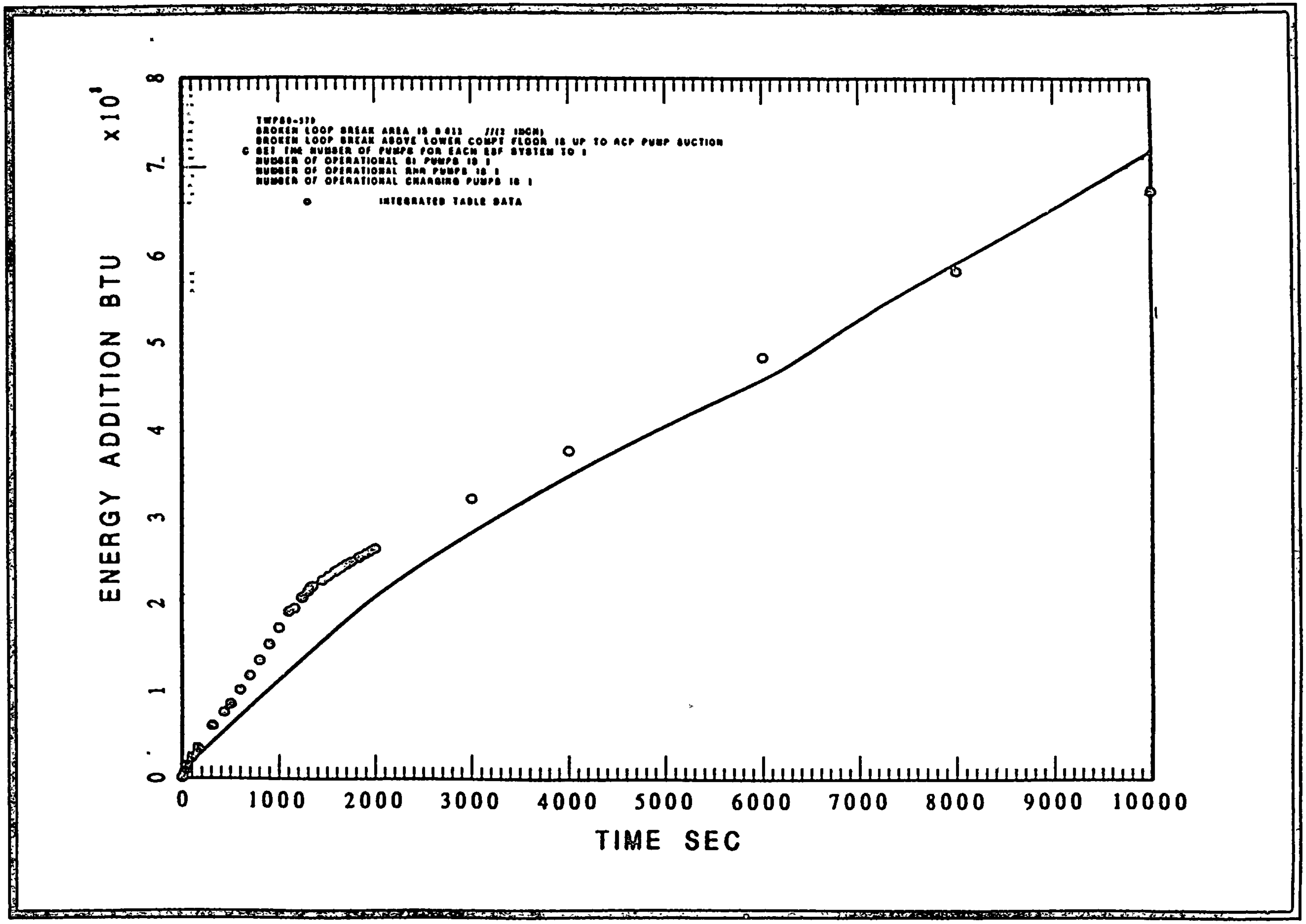
Comparison of the MAAP4 and NOTRUMP instantaneous mass flow rates for a two-inch cold leg LOCA.



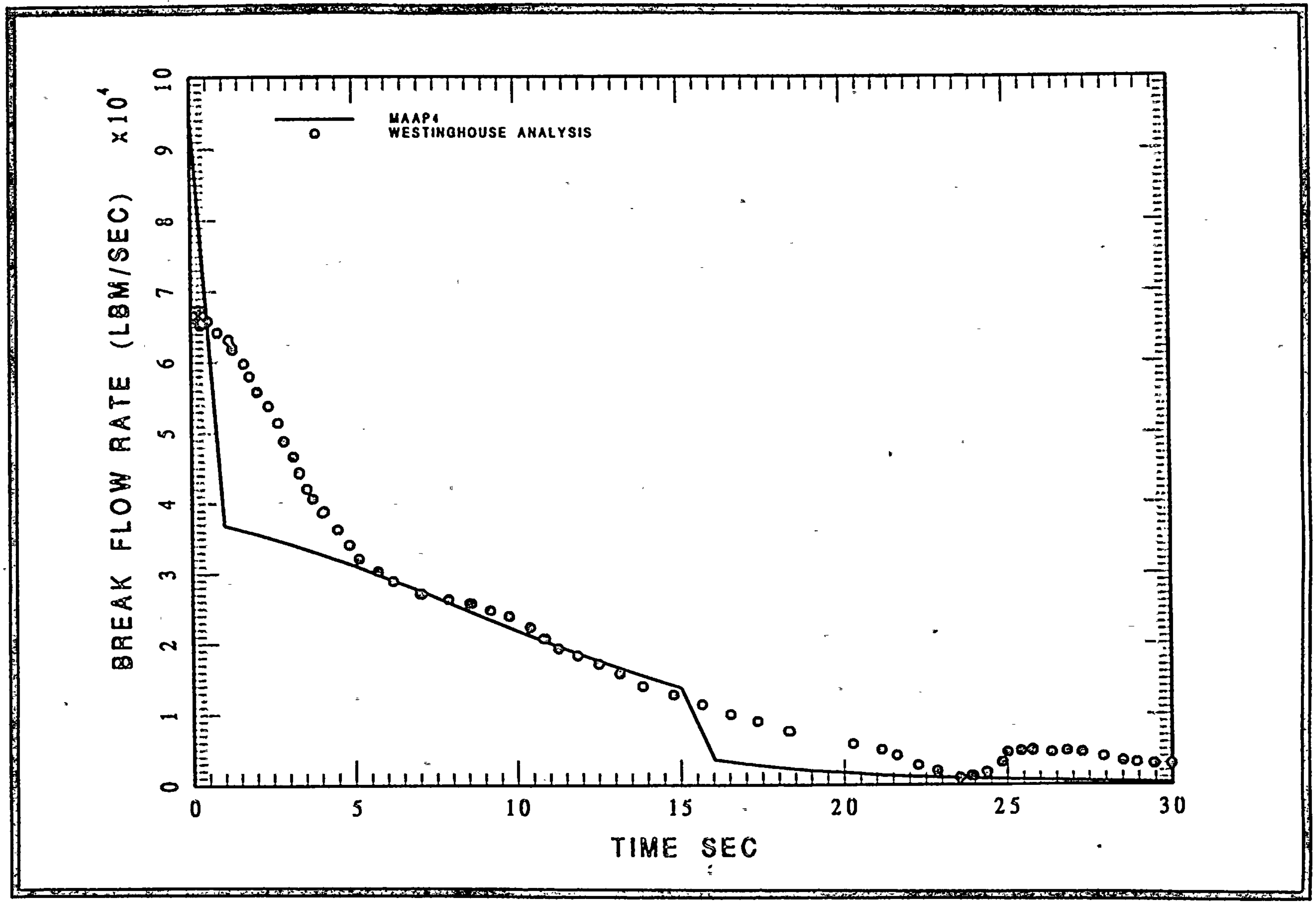
Comparison of the MAAP4 and NOTRUMP values for instantaneous energy flow to the containment for a two-inch cold leg LOCA.



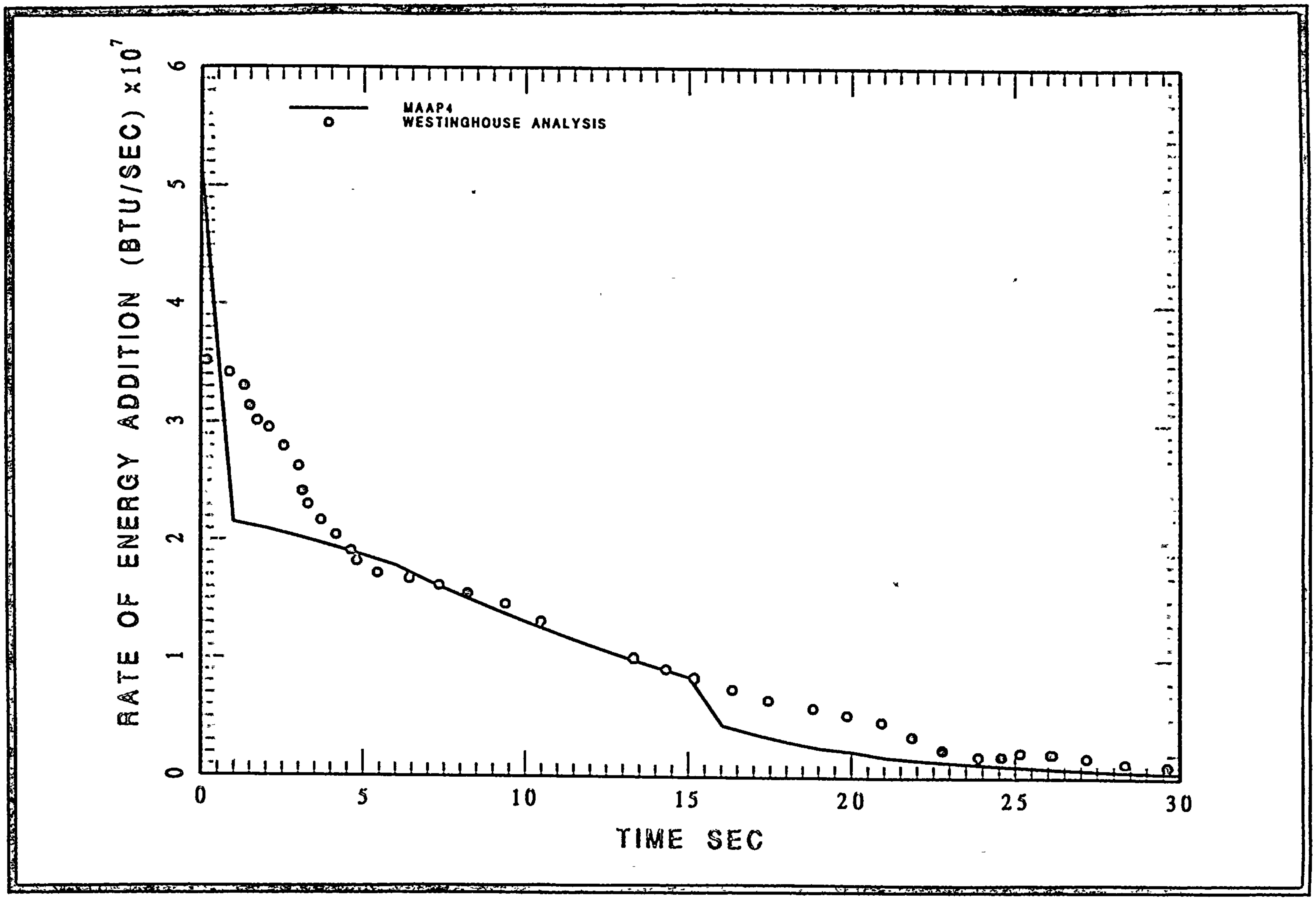
Comparison of the integrated mass releases for the MAAP4 and NOTRUMP for a two-inch cold leg LOCA.



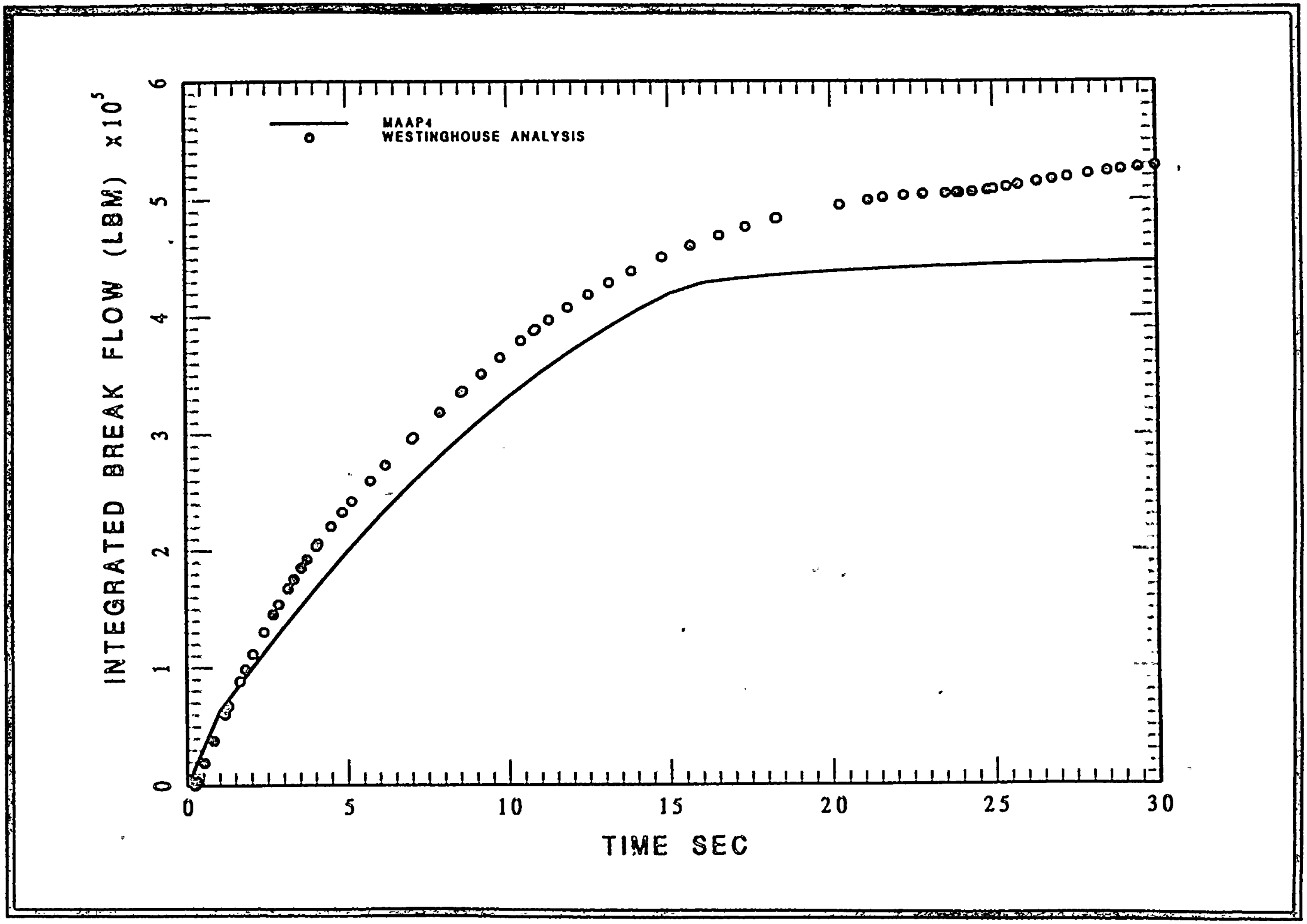
Integrated energy release to the containment for MAAP4 and NOTRUMP for a two-inch cold leg LOCA.



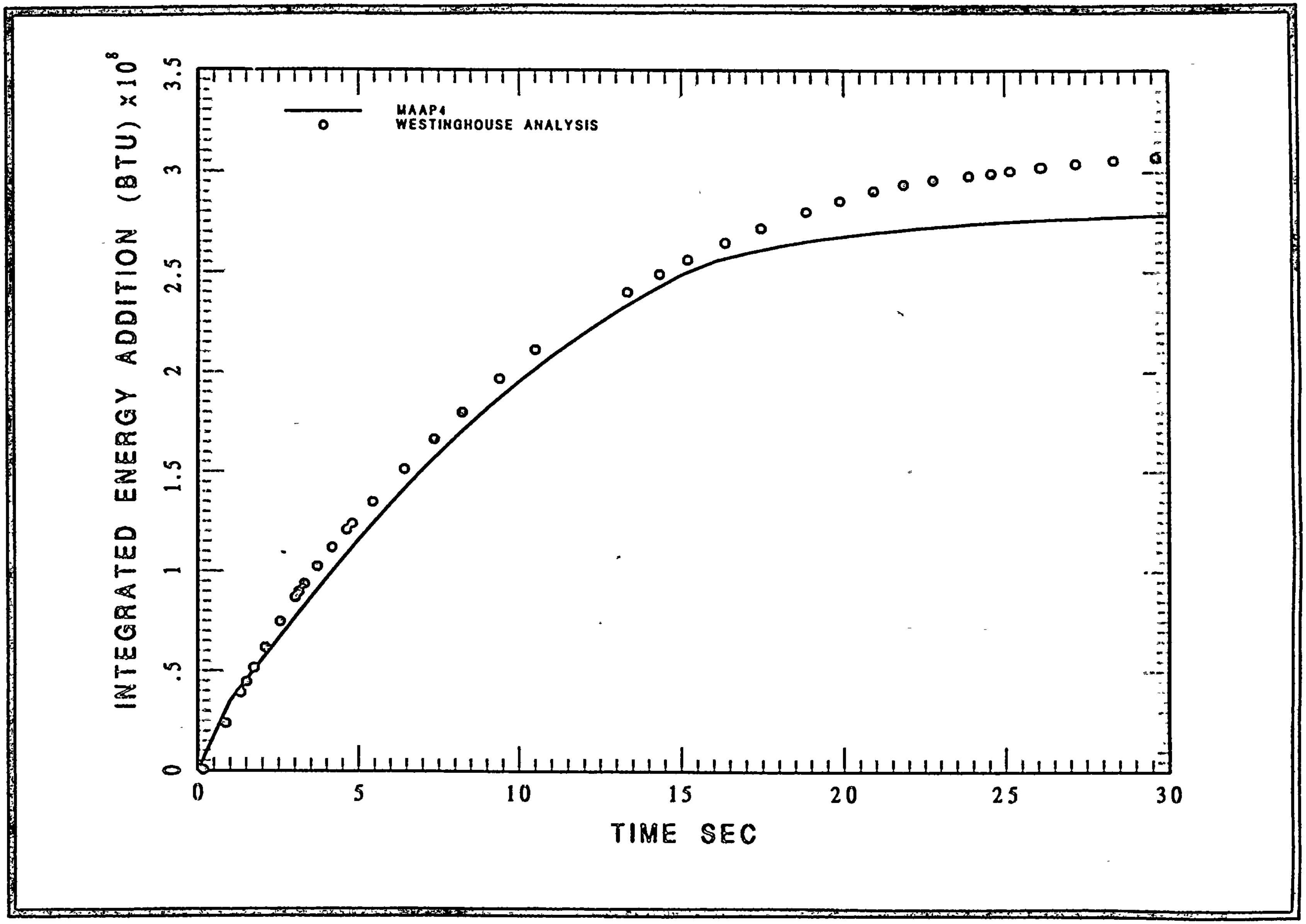
Comparison of the MAAP4 break flow rate for a large break LOCA with that used in D.C. Cook design basis analyses.



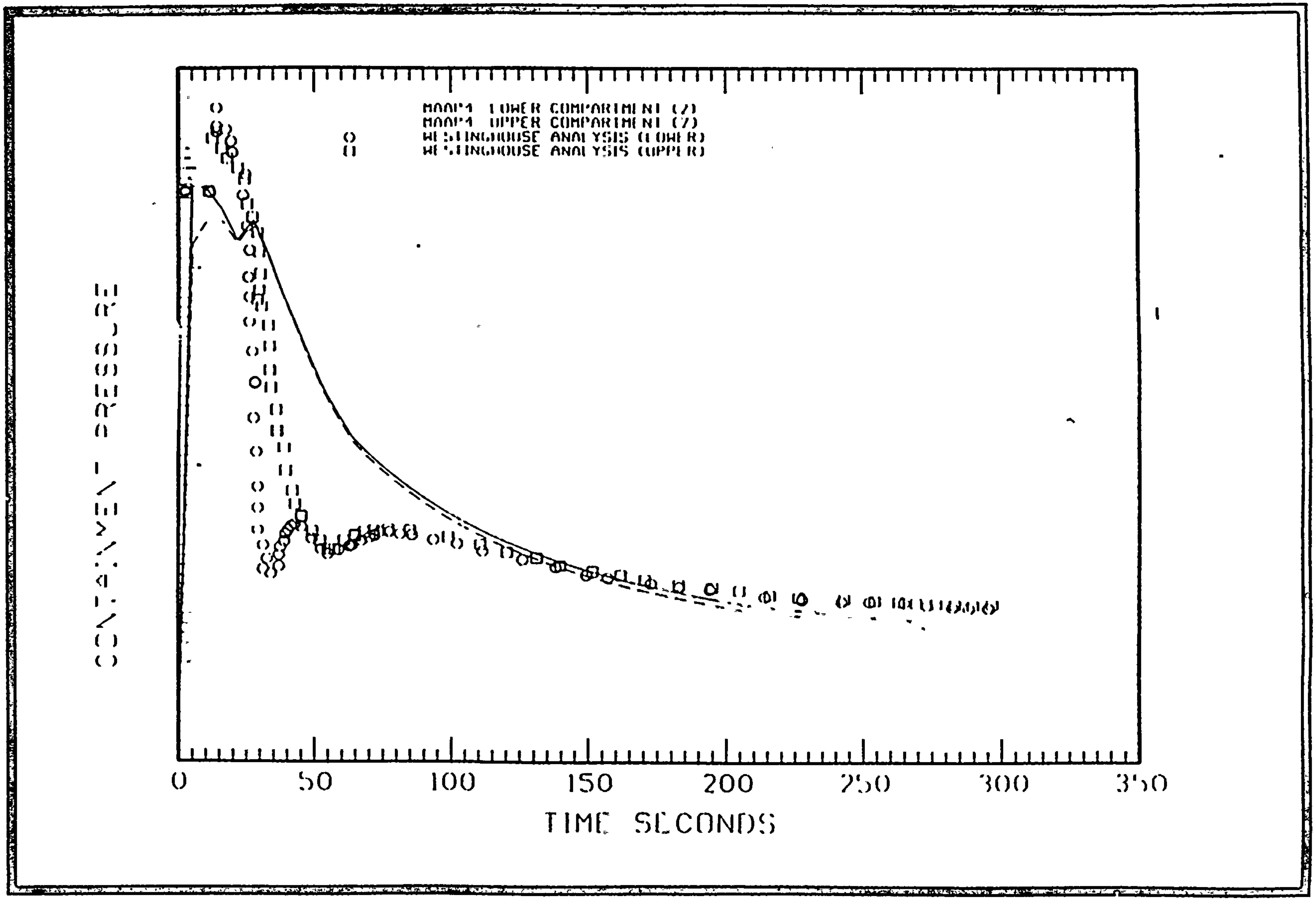
Comparison of the MAAP4 and design basis calculations for the rate of energy release into the D.C. Cook Unit 1 containment.



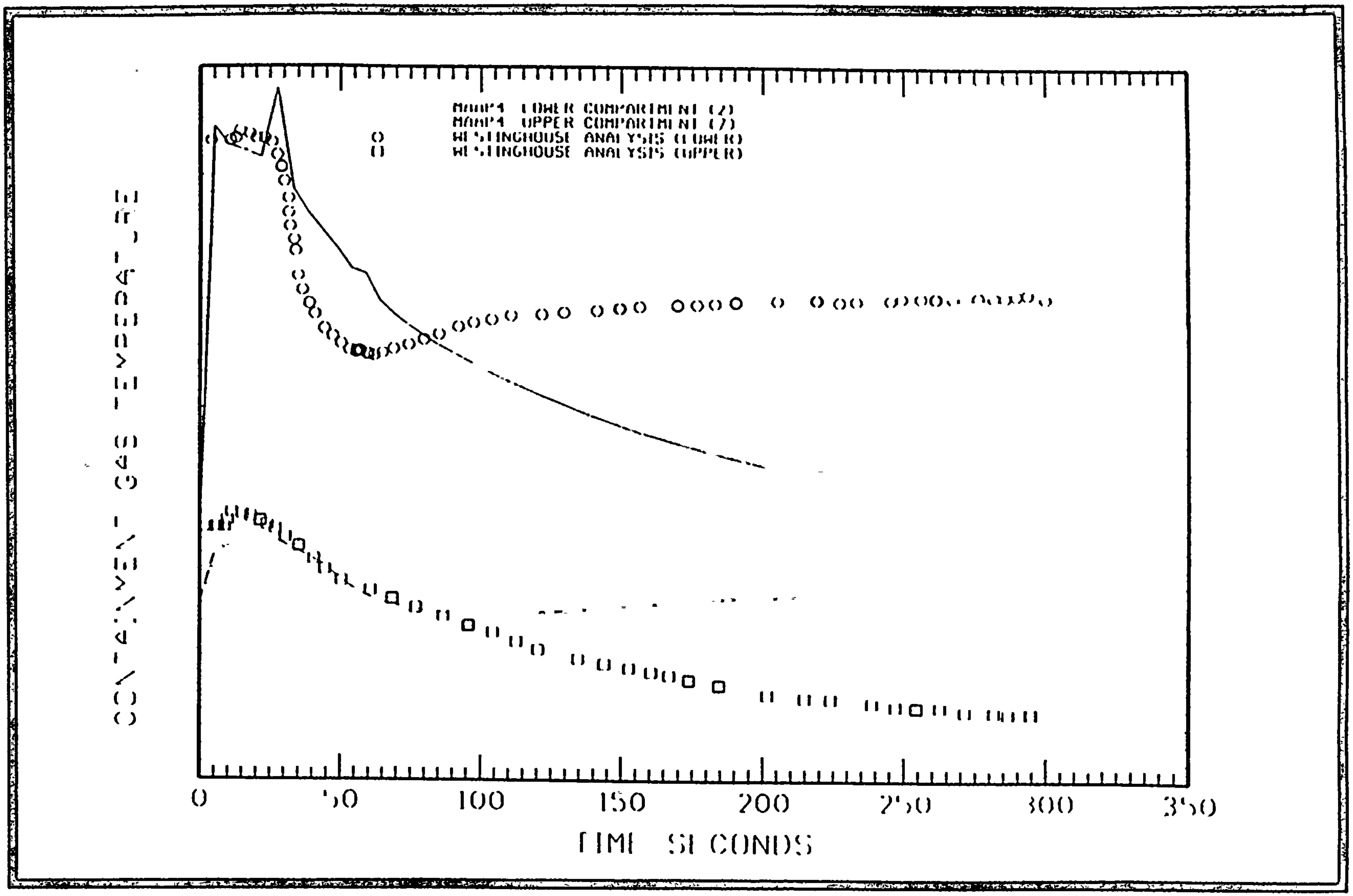
Comparison of the integrated break flow rate to containment for MAAP4 and the design basis assessment.



Comparison of the integrated energy release to containment for MAAP4 and the design basis calculation.



Comparison of the upper and lower compartment containment pressures using the MAAP4 code with design basis calculation input for mass and energy releases.



Comparison of the temperatures in the lower and upper containment compartments between the MAAP4 code and the design basis calculations using the existing design basis calculations for mass and energy releases into the containment atmosphere.

Table

Summary of Comparisons of the MAAP4 Best Estimate Approach and Selected Design Basis Analyses

Comparison	Result
1. Comparison of the MAAP4 containment model and the LOTIC-3 calculations for a six-inch cold leg LOCA.	Good comparison between the calculated ice consumption rates for both codes and the transient containment pressure history.
2. Comparison of the MAAP4 containment model and the LOTIC-3 code for a two-inch cold leg LOCA.	Good comparison between the ice melting rate, as well as consistent representations of the containment pressure history and the calculated temperature histories in the upper and lower compartments.
3. Comparison of the MAAP4 and NOTRUMP mass and energy releases for a six-inch cold leg LOCA.	Agreement between the integral mass and energy releases to the containment.
4. Comparison of the MAAP4 and NOTRUMP mass and energy releases for a two-inch cold leg LOCA.	Agreement between the integral mass and energy releases to the containment atmosphere.
5. Comparison of the MAAP4 and large break LOCA mass and energy releases.	Agreement between the integral mass and energy releases to the containment atmosphere.
6. Comparison of the MAAP4 containment response with the design basis analysis.	Good agreement between the transient containment pressure and temperature histories in the upper and lower compartments.

BENCHMARKING WITH THE WESTINGHOUSE ICE CONDENSER EXPERIMENTS

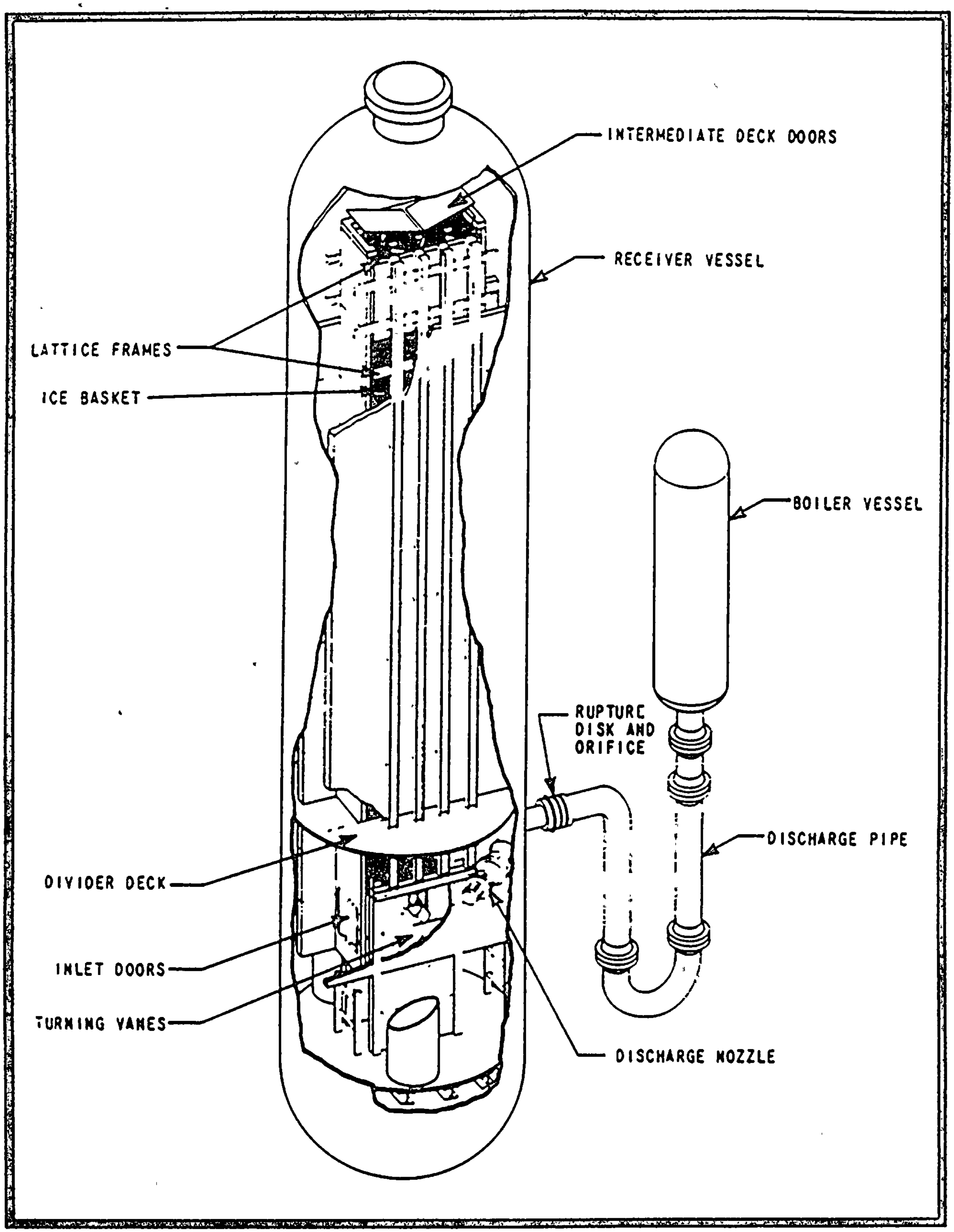
- The Westinghouse ice condenser experiments have been run for a variety of break sizes.

- These experiments were performed for a full scale segment of the ice condenser with an ice basket height that is three-fourths of the plant.

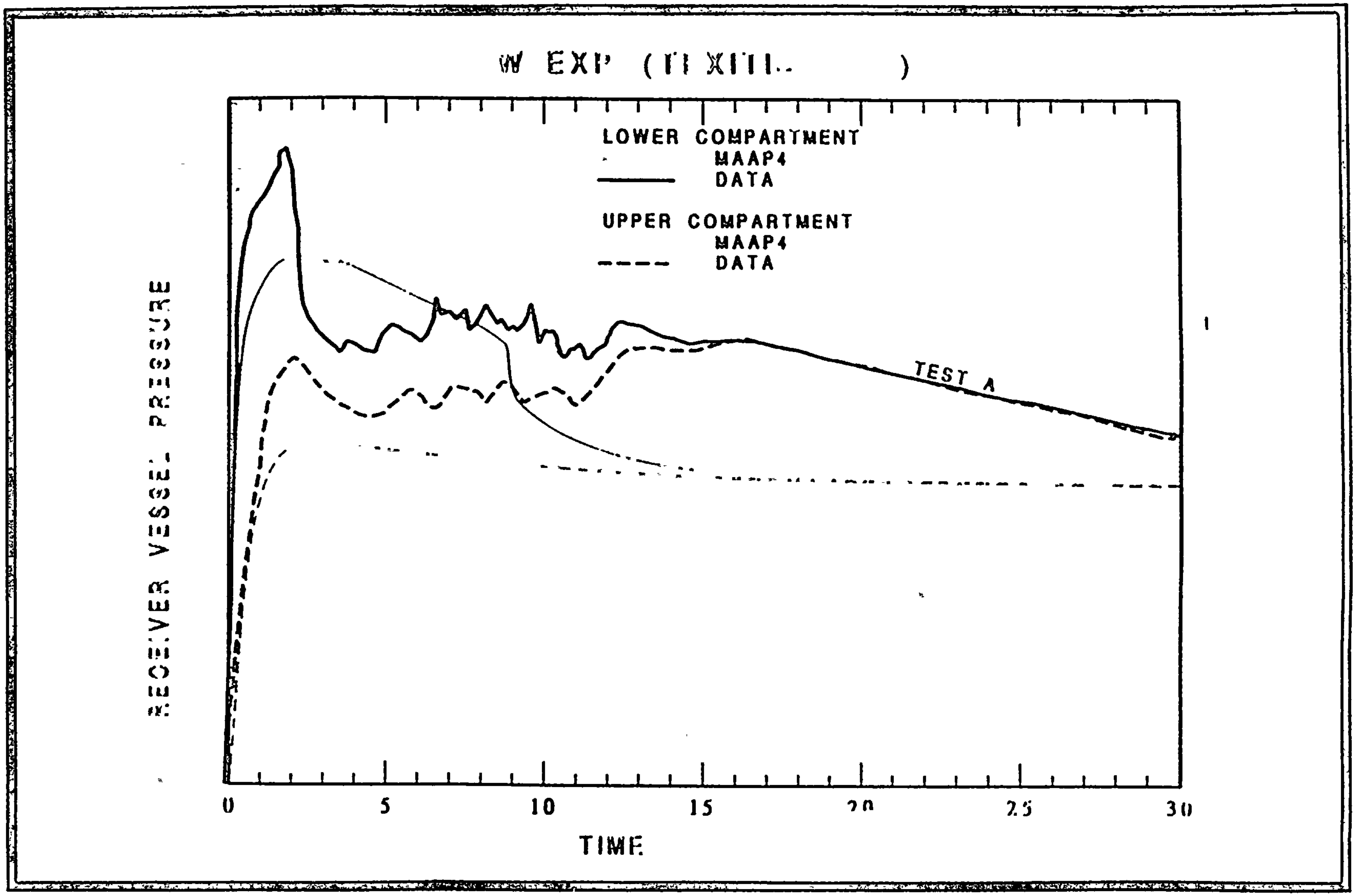
- The principal information from the experiments is the depressurization of the simulated RCS, the pressure in the containment lower compartment, the pressure in the containment upper compartment, the temperatures of gases exiting the top of the ice condenser, the drain temperature of water leaving the ice condenser and the approximate ice melted.

- It is important that the integral system model be consistent with the experiments since the ice melt rate is a major contribution to the integral containment response and is also an important component of the water inventory in the circulation sump.

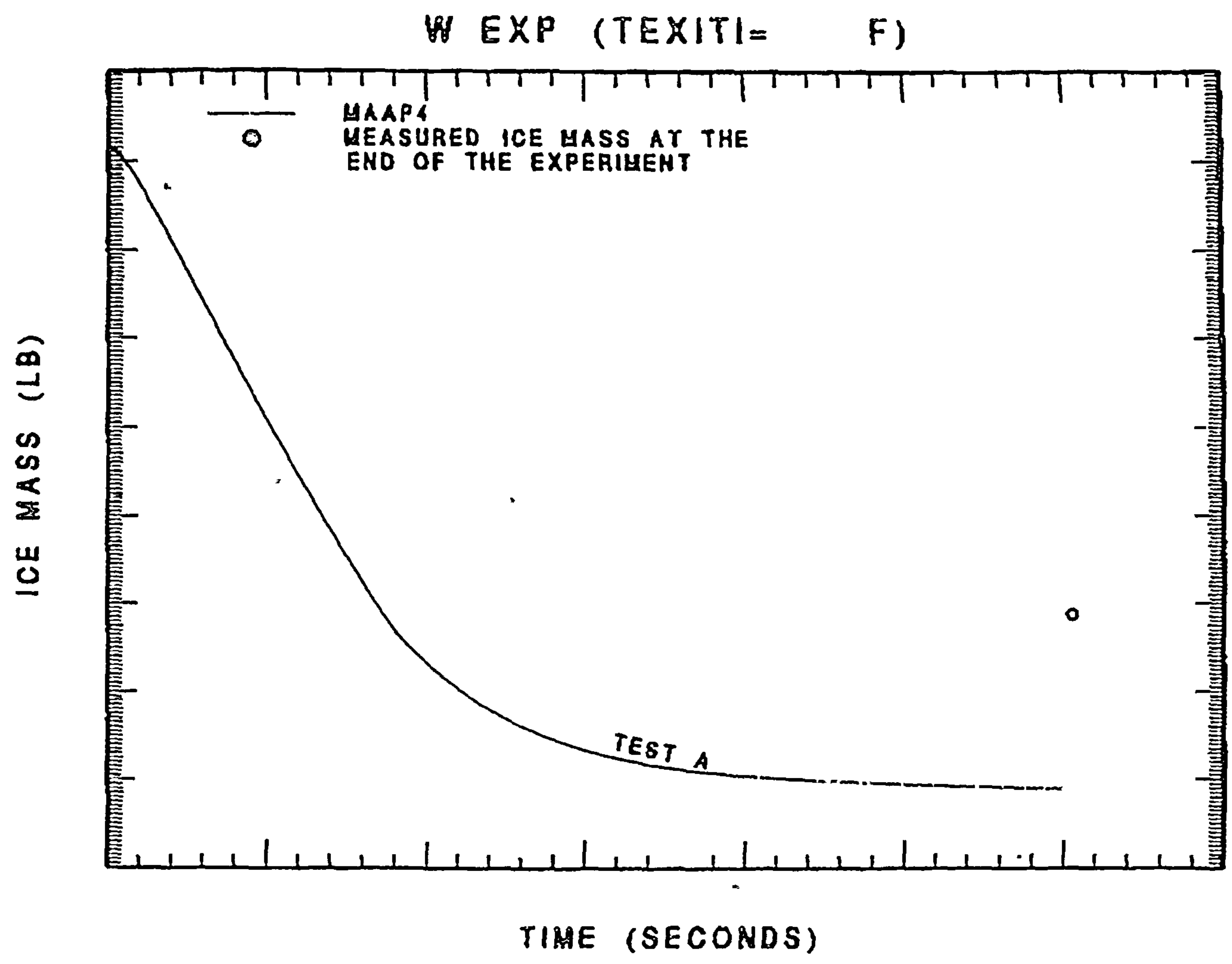
- MAAP dynamic benchmarks are being performed for three different break sizes investigated in these experiments which are generally representative of a large LOCA (Test A), a medium size LOCA (Test C) and a small LOCA (Test F), and decay heat steaming condition (Test K). These benchmarks are performed using the dynamic benchmarking capability in the MAAP4 code.



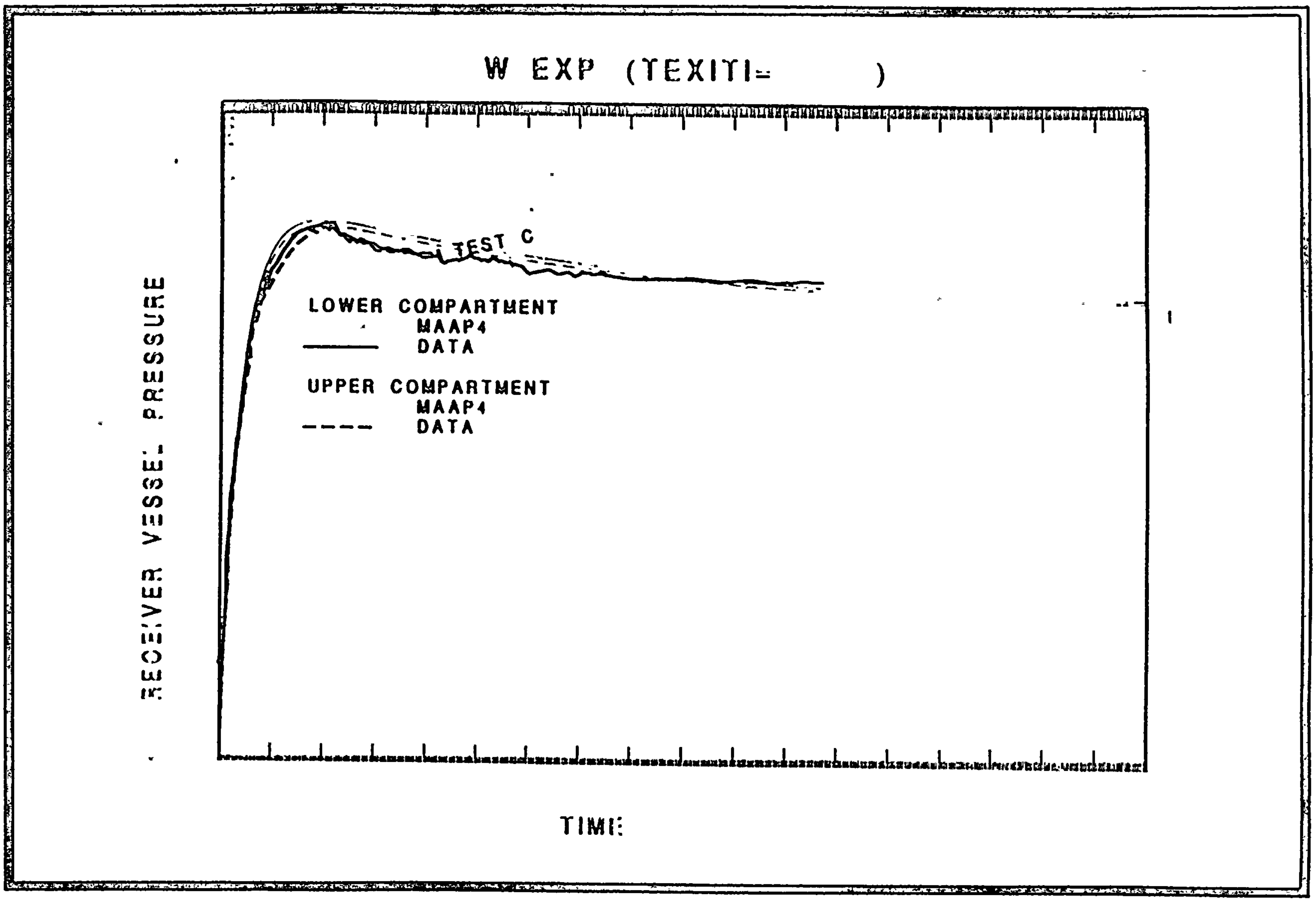
Isometric view of boiler and receiver vessels at the Waltz Mill test facility.



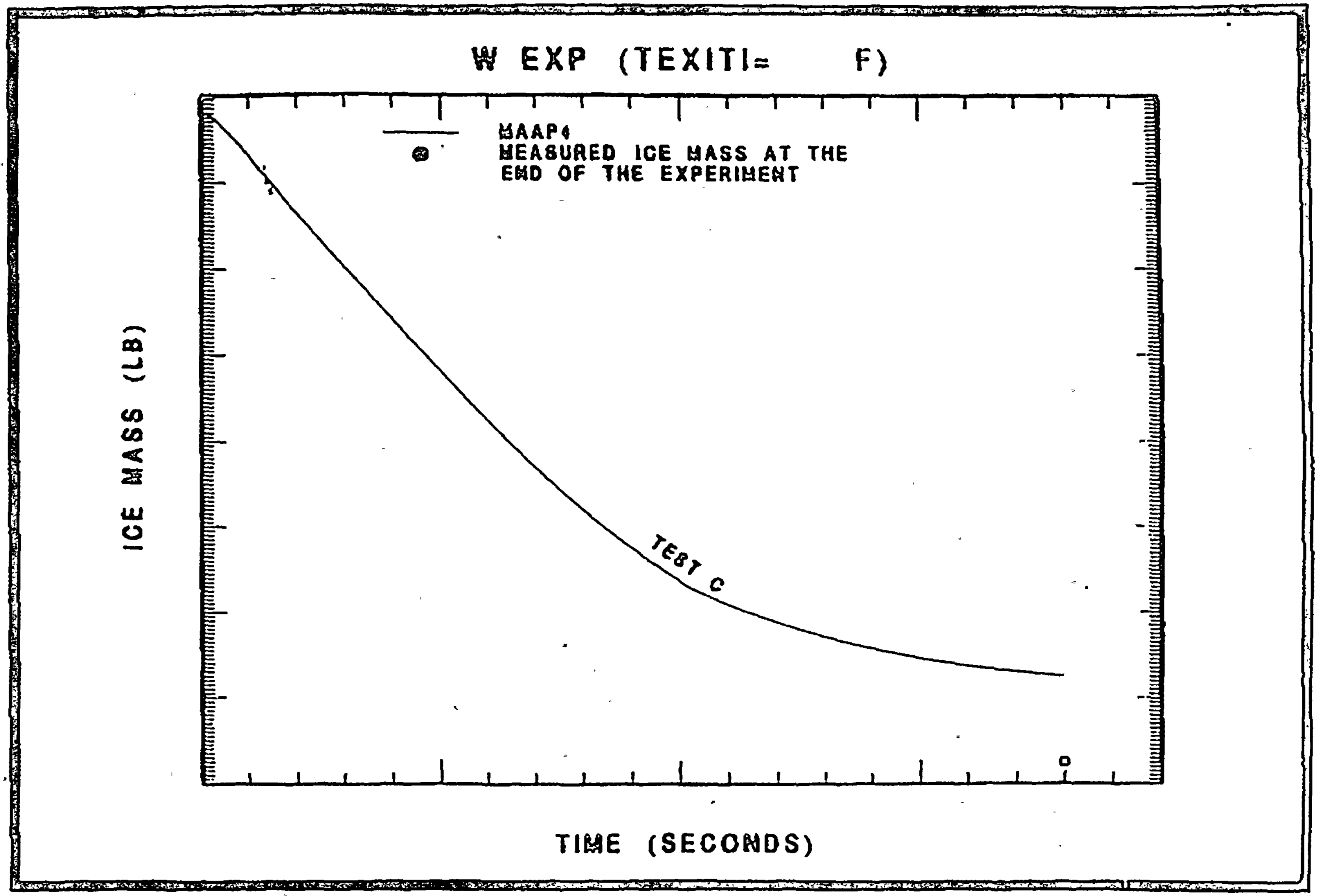
Comparison of the upper (solid lines) and lower compartment pressures (dashed lines) for the MAAP4 containment model with an ice condenser exit temperature of   and the experimental data from Test A (large break LOCA) of the Westinghouse ice condenser experiments.



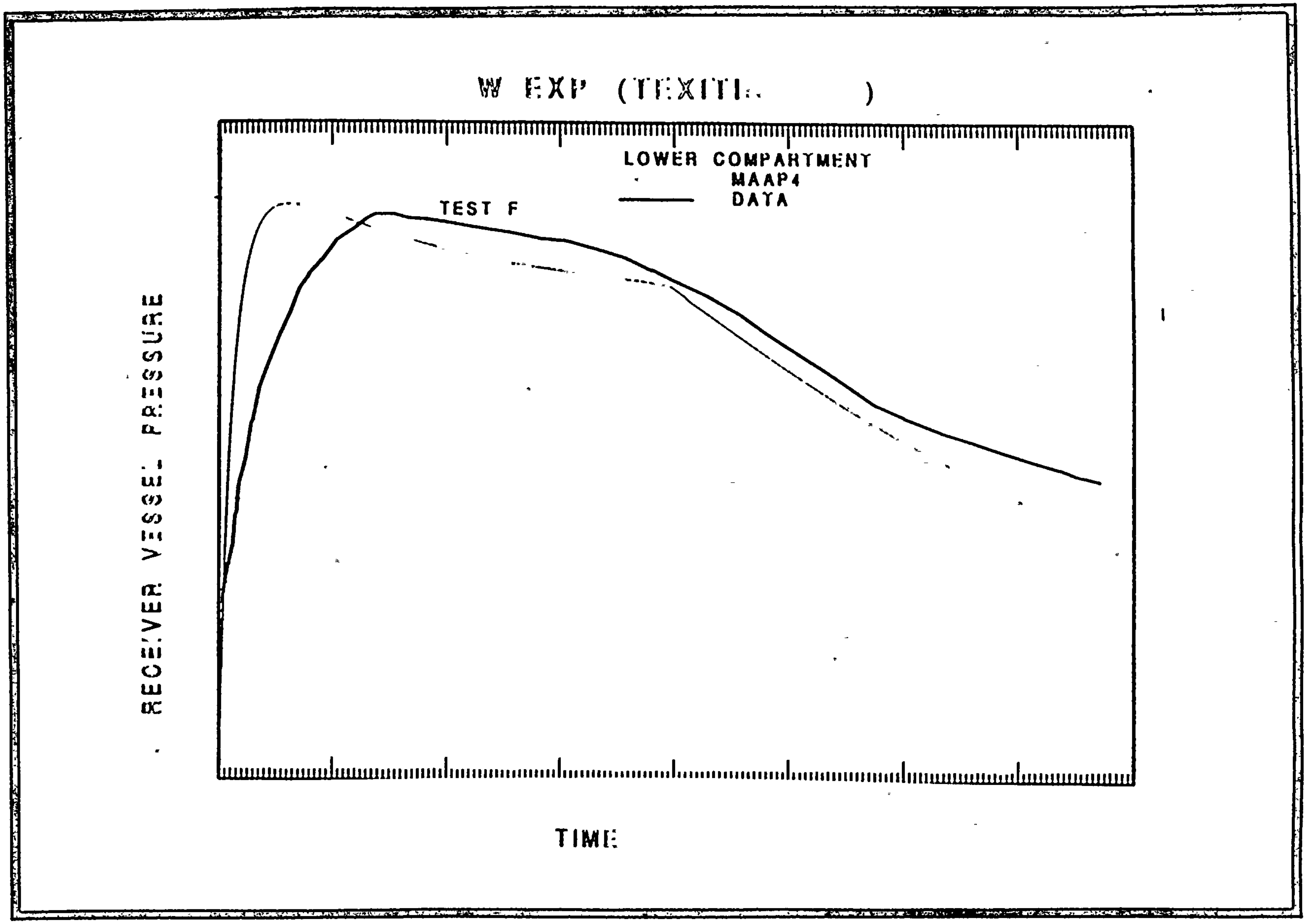
Comparison of the calculation of ice melting for the MAAP4 model with an ice condenser exit temperature of °F and the end point remaining ice mass for Test A (large break LOCA).



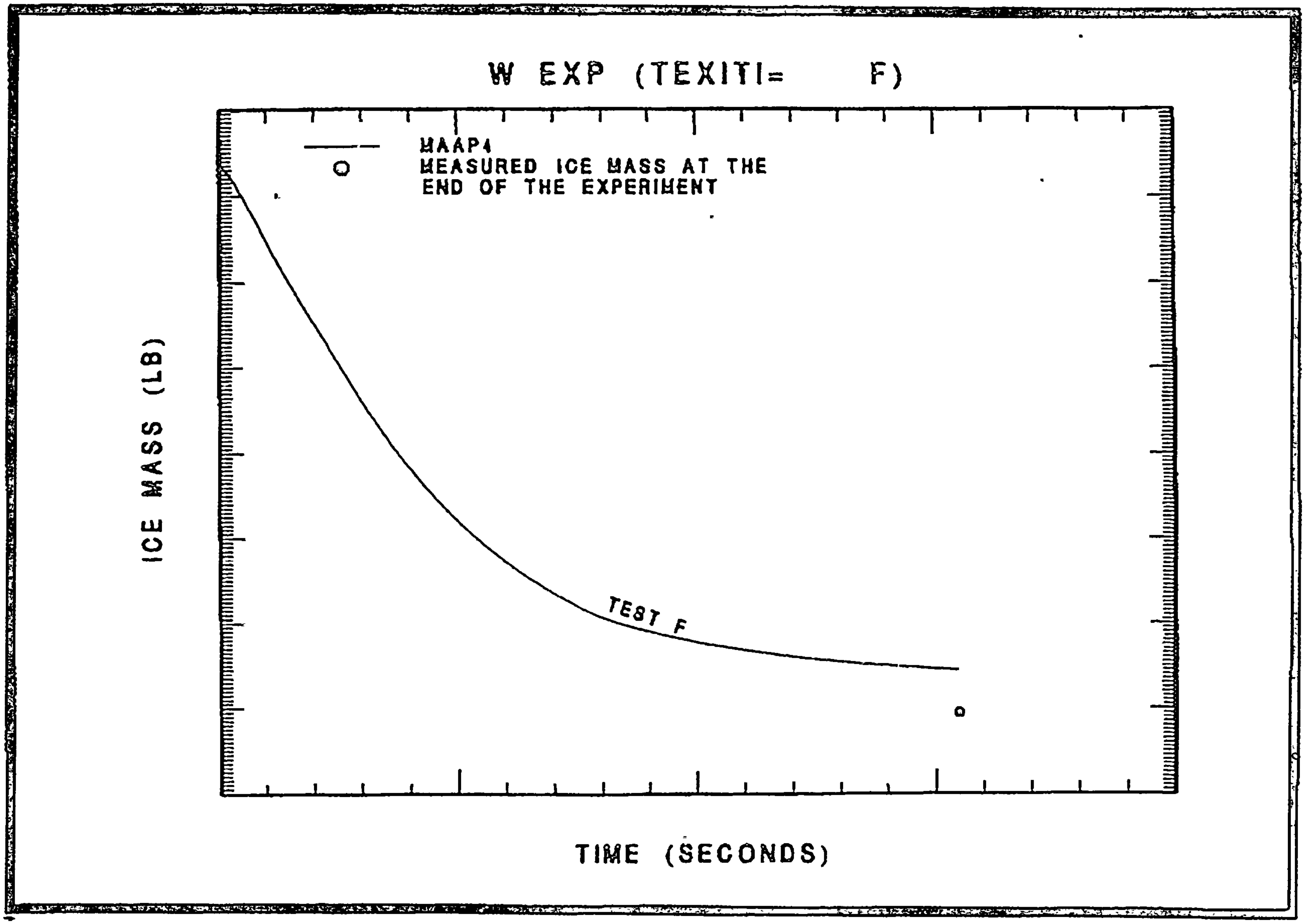
Comparison of the upper and lower compartment pressures for the MAAP4 model using an ice condenser exit temperature of with the measured behavior of Test C (medium LOCA).



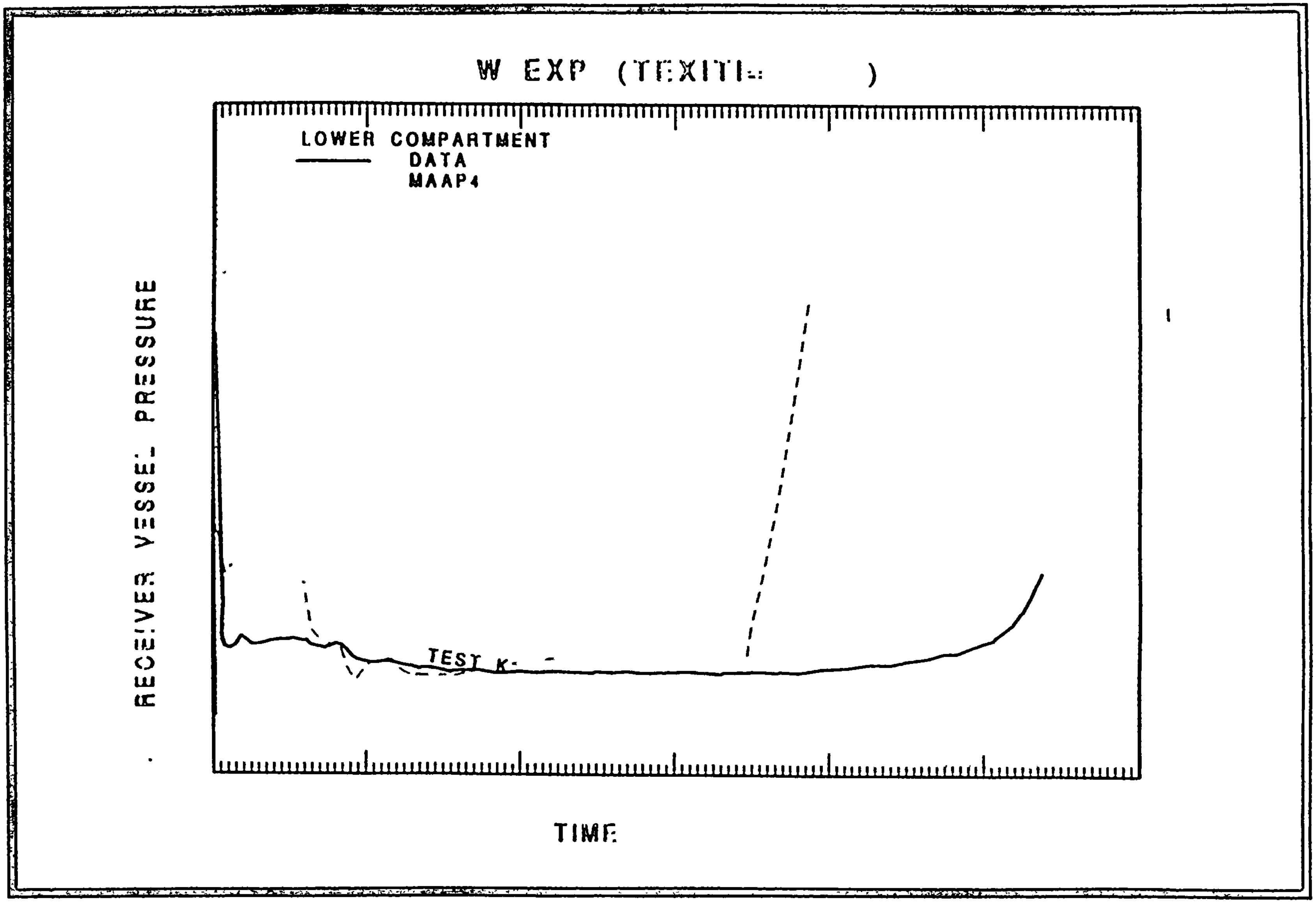
Comparison of the MAAP4 ice melt history with an ice condenser exit temperature of °F with the measured ice at the end of Test C (medium LOCA).



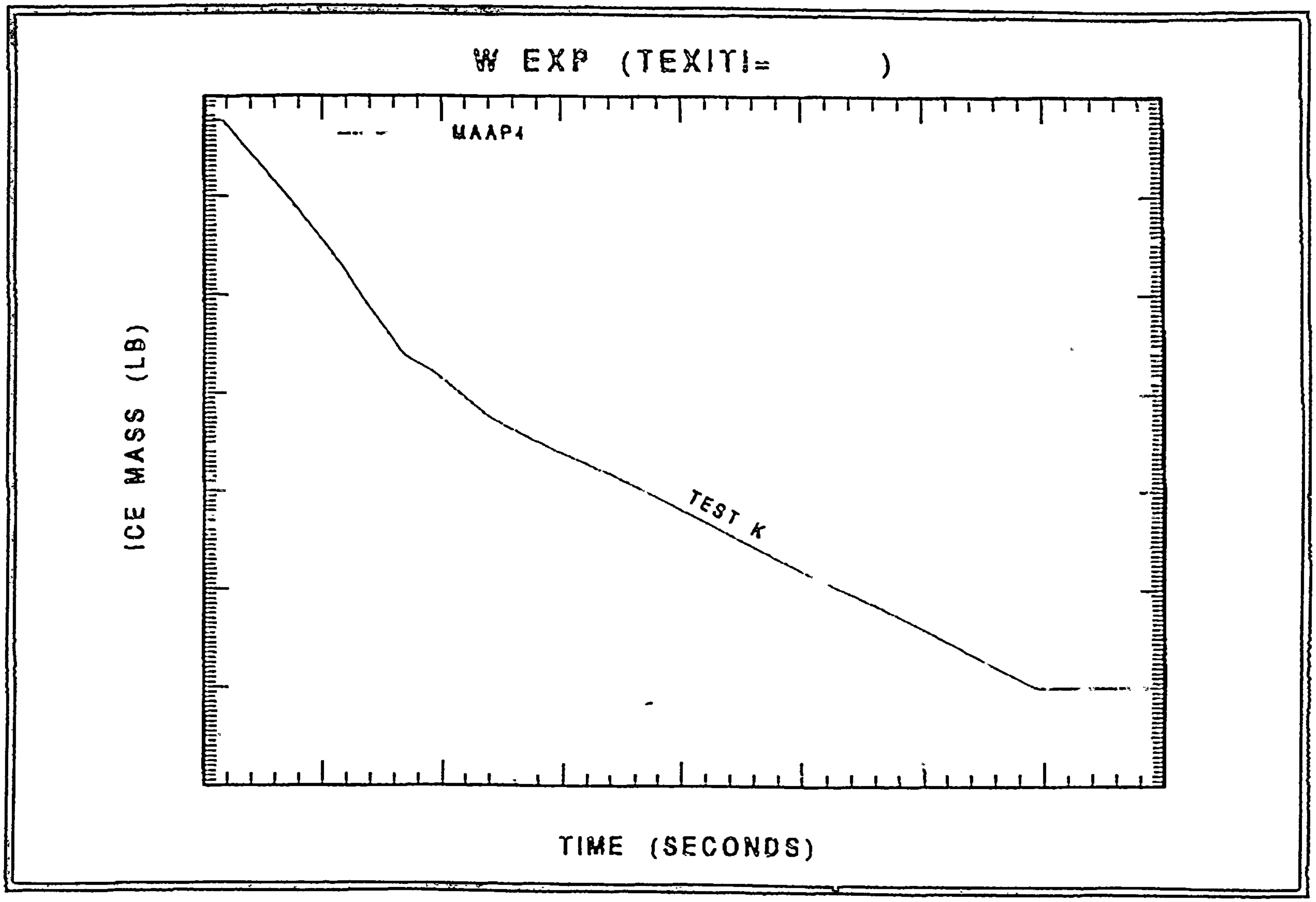
Comparison of Test F pressure versus time for an ice condenser outlet temperature of



Comparison of the calculated remaining ice mass and the end point measurement for Test F.



Comparison of the measured lower compartment pressure for the long term decay heat removal experiment (Test K) and the MAAP4 containment model using an ice condenser exit temperature of



Calculated ice mass melting history for Test K using an ice condenser exit temperature of

CONCLUSIONS WITH RESPECT TO THE BENCHMARKING ACTIVITIES

- The comparison of the MAAP4 containment model and LOTIC-3 for the 2″ and 6″ cold leg LOCA show good agreement between the ice melt rate and the transient containment pressure history with LOTIC-3 having a somewhat higher ice melt rate and higher containment pressure consistent with the design basis philosophy of the code.

- The integral break flow and energy flow considered by MAAP4 are in agreement with the flow rates from NOTRUMP. Also, the spectrum of LOCAs considered in the MAAP4 analysis span those which are to be investigated by the DBA codes.

- Comparisons of the MAAP4 best-estimate model with the full scale experiments show a consistent response of the containment with the measured behavior. This is true for both the containment pressure response and the ice melt conditions.

- The composite of these benchmarking activities shows a consistent representation of the containment response for the best-estimate scoping model (MAAP4) and the design basis calculations (NOTRUMP and LOTIC-3). Furthermore, the best-estimate model is consistent with the results of the large scale experiments used to characterize the response of an ice condenser containment to variety of LOCA conditions.

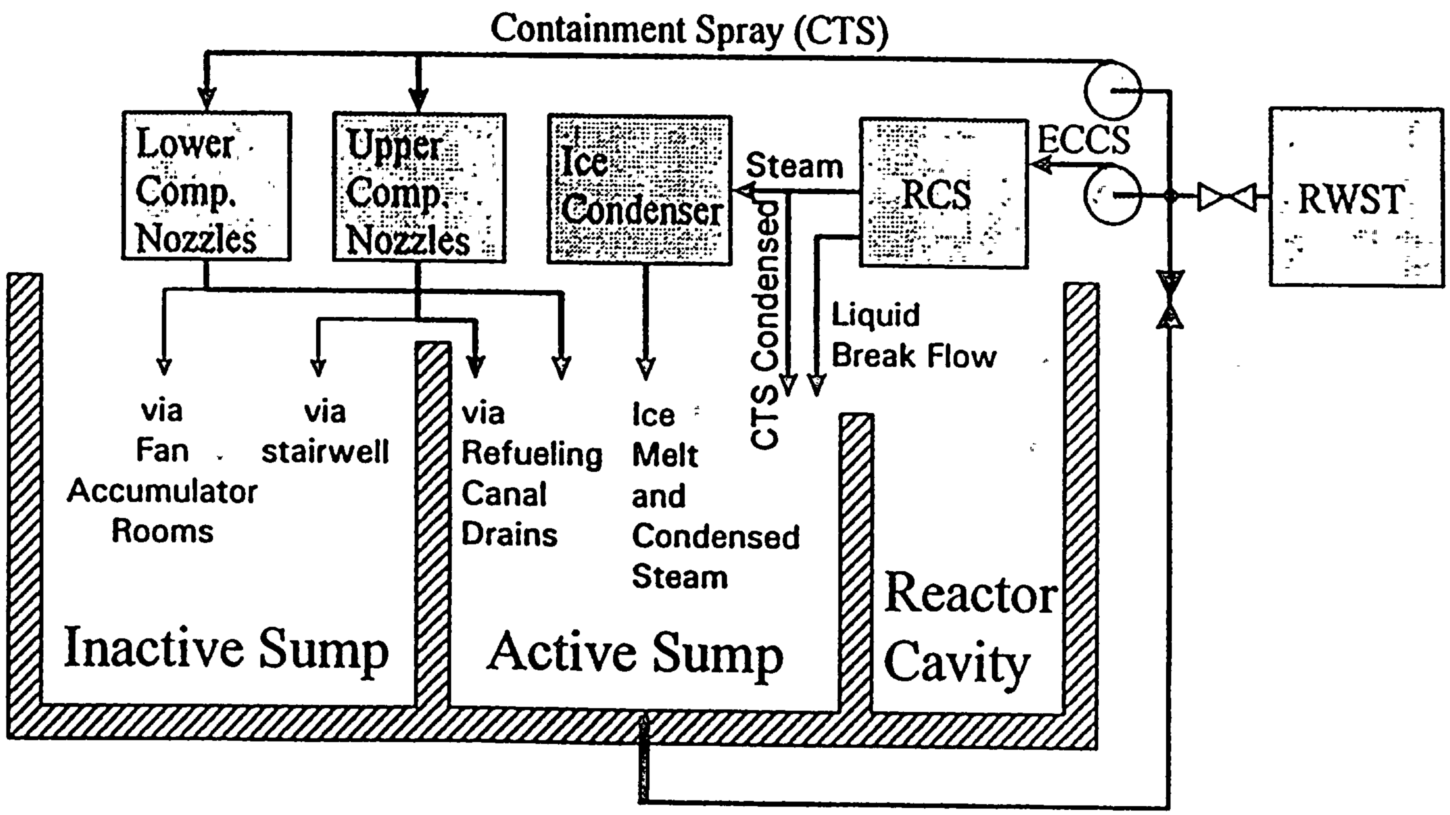
SENSITIVITY STUDIES FOR THE COOK NUCLEAR PLANT SUMP FILL EVALUATIONS

- The most important sensitivity calculation is to consider a variety of break sizes. In this regard, the MAAP4 sensitivity studies will investigate LOCAs from one-half inch to six inches in diameter. This encompasses the entire small LOCA range.

- The particular issue of interest for this evaluation is the sump depth for the containment spray pumps. Consequently, the duration of the containment sprays is an important variable in this evaluation. Therefore, the variations in plant parameters, within tech spec limits, are assessed to determine the influence that these could have on the use of containment sprays. The influence of conditions whereby the sprays would be turned on at 2.9 psig and turned off at 1.5 psig or run continuously once they are activated will be evaluated.

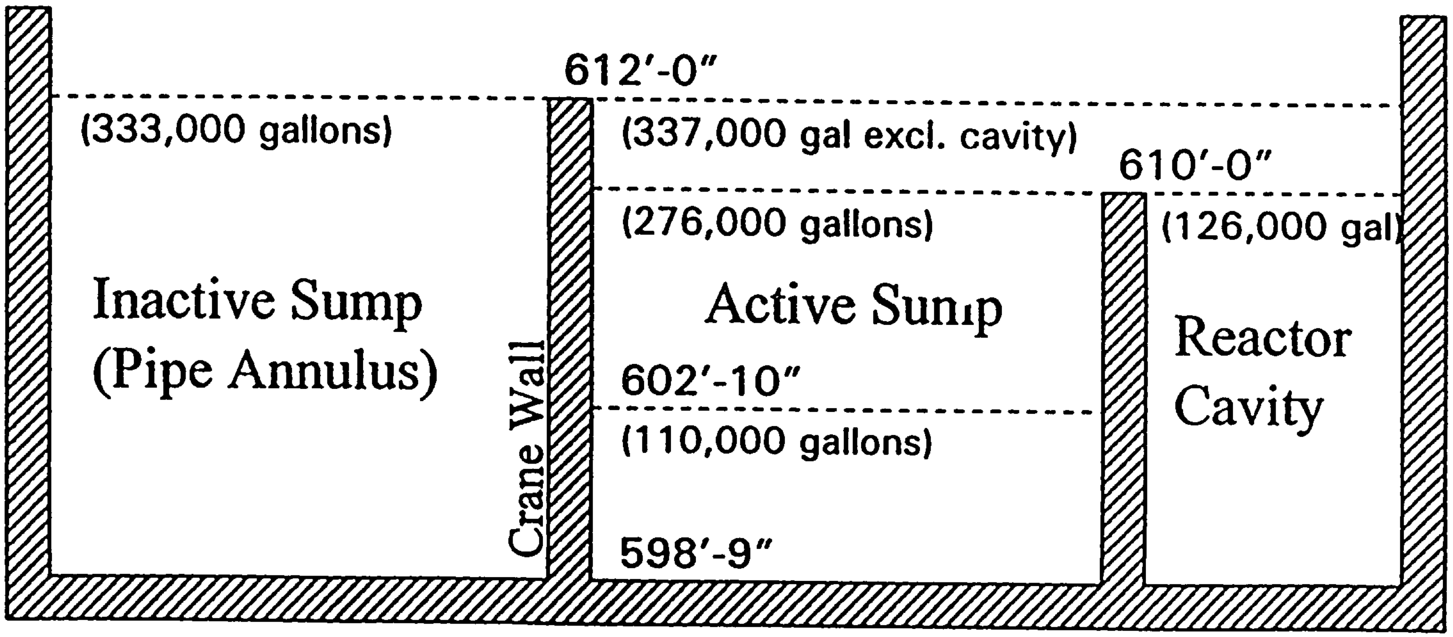
- Other plant parameters influence the mass of air in containment, the condensing capability of the sprays, etc. These will also be investigated in these sensitivity calculations.

Containment Spray & ECCS Simplified Flow Schematic



Water flow paths to the active and inactive sump regions.

Lower Containment Simplified Schematic



Important levels and volumes for the active and inactive sumps.

Water Inventory Available

Volume Description	Volume/Mass
Available RWST Water Inventory	295,000 gal
Available Ice Mass	2.43×10^6 lbm (291,472 gal)
TOTAL	586,472 gal
Accumulators	4 x 921 ft^3 (27,500 gal)
TOTAL WITH ACCUMULATORS	613,972 gal

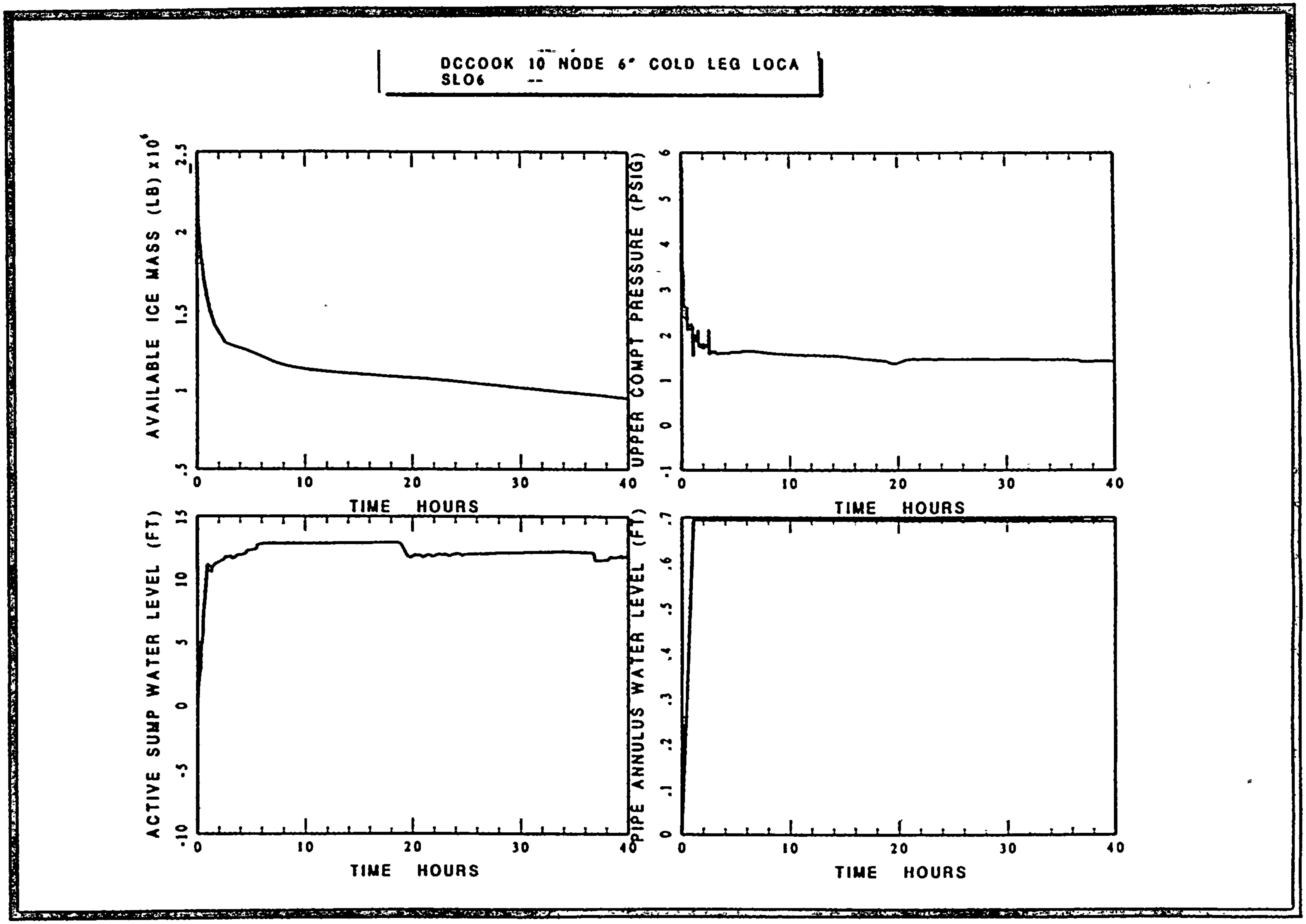
Volumes Controlling Water Accumulation in the Analysis

Volume Description	Volume/Mass
Reactor Coolant System (including the pressurizer)	11,159 ft^3 (83,469 gal)
Volume of the Pressurizer	1800 ft^3 (13,464 gal)
Approximate Inventory Needed to Keep RCS Full During Cool Down	~ 20,000 gal
Inactive Sump Reference Water Volume	335,960 gal
Net Volume for Water Accumulation in the Inactive Sump	319,000 gal
Active Sump Reference Water Volume to the 602′10″ Level	117,320 gal
Net Volume for Water Accumulation in the Active Sump to the 602′10″ Level	116,000 gal
Water Volume for the Reactor Cavity	117,795 gal
TOTAL	572,795 gal

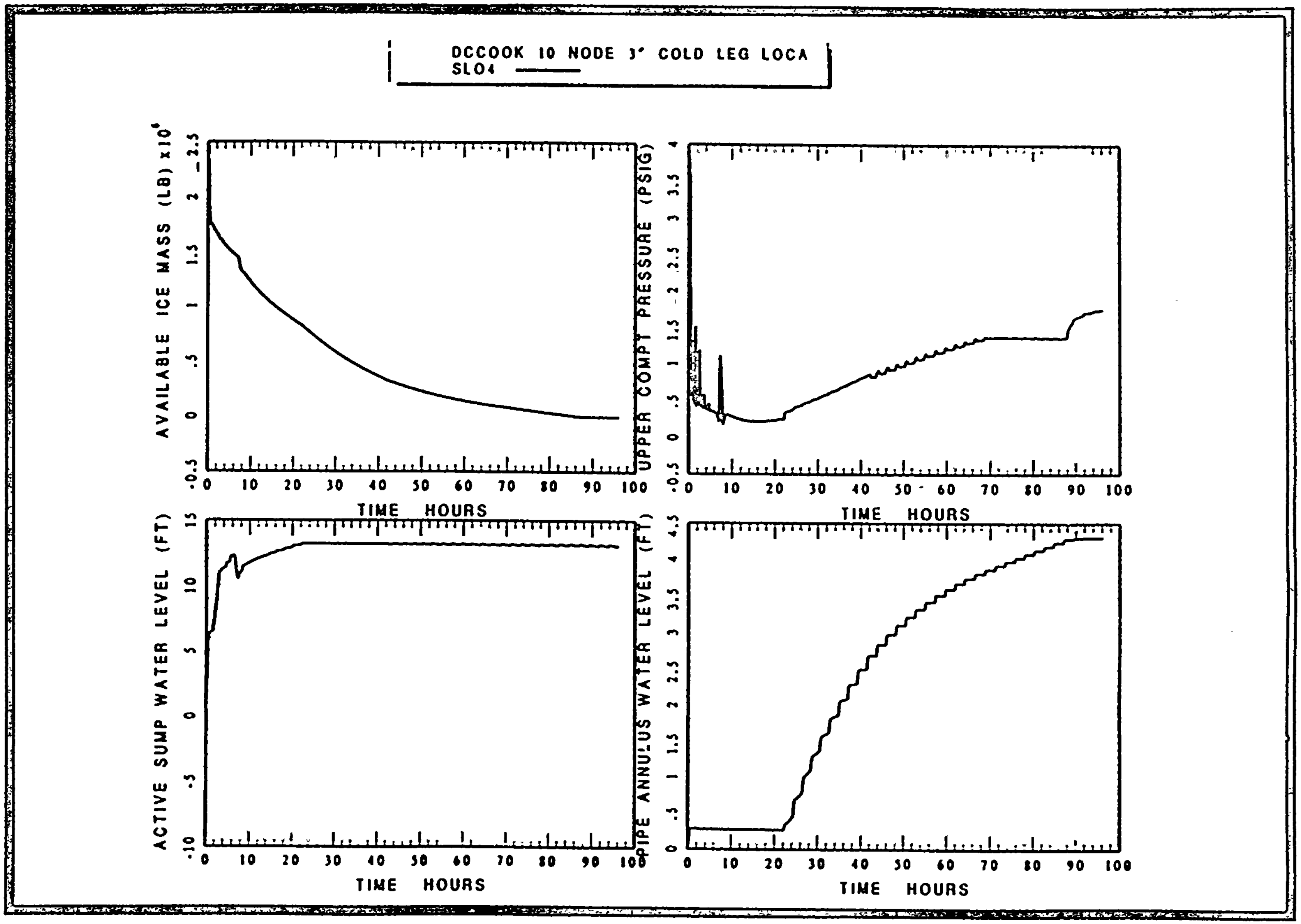
Table 4-3

Potential Locations of Water Holdup

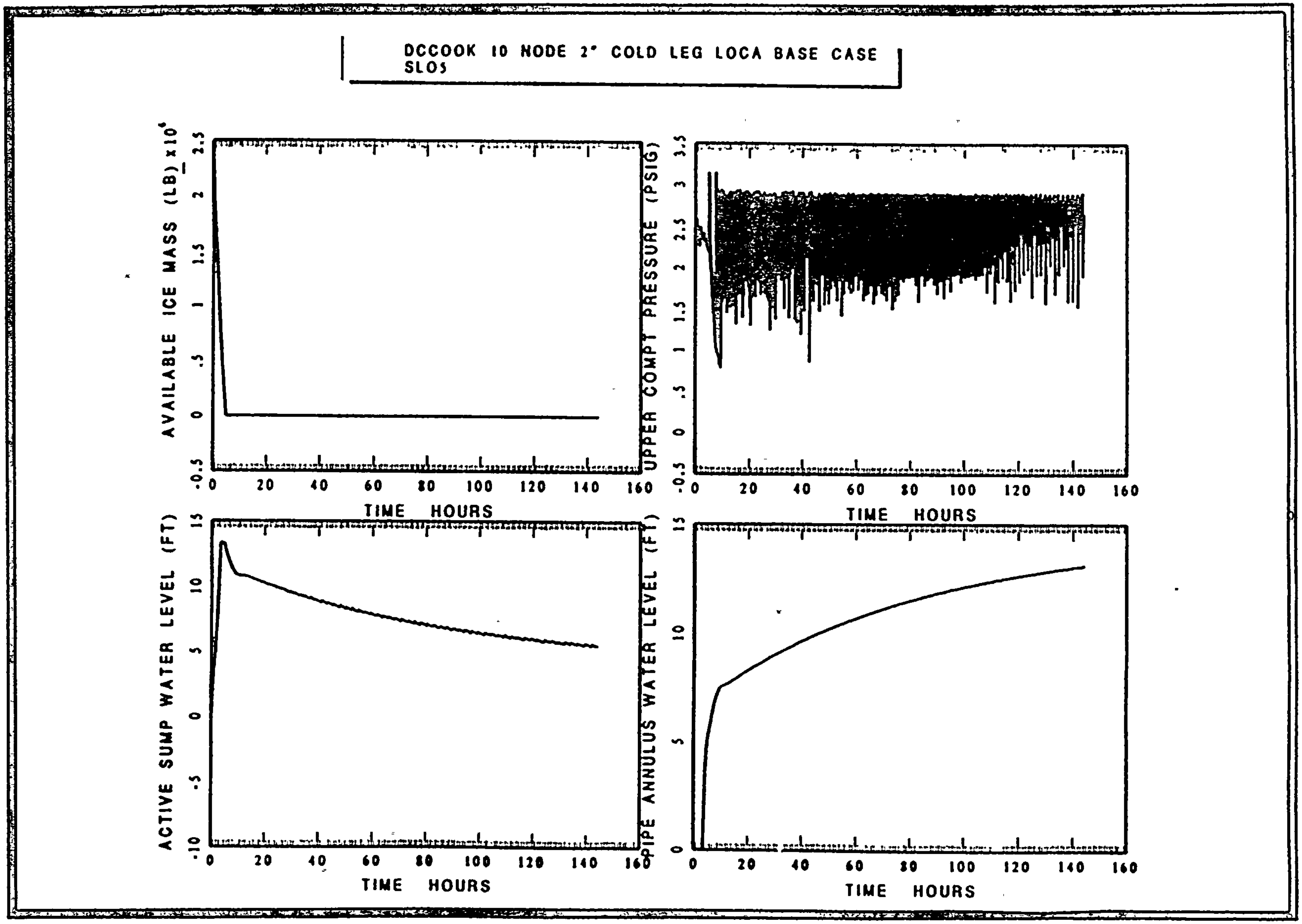
Location	Magnitude of Water Holdup
Water required to fill the containment spray and RHR piping but not the RHR spray lines.	7,789 gal
Water in-flight during spray operation	
• upper compartment (h = 80.2 ft),	267 gal
• lower compartment (h = 50.9 ft),	93 gal
• annular compartment (h = 36.75 ft).	13 gal
Sprays impinging upon walls and draining as a film	
• upper compartment (42,000 ft^2),	206 gal
• lower compartment (15,000 ft^2),	74 gal
• annular compartment (10,000 ft^2).	49 gal
TOTAL	8,491 gal



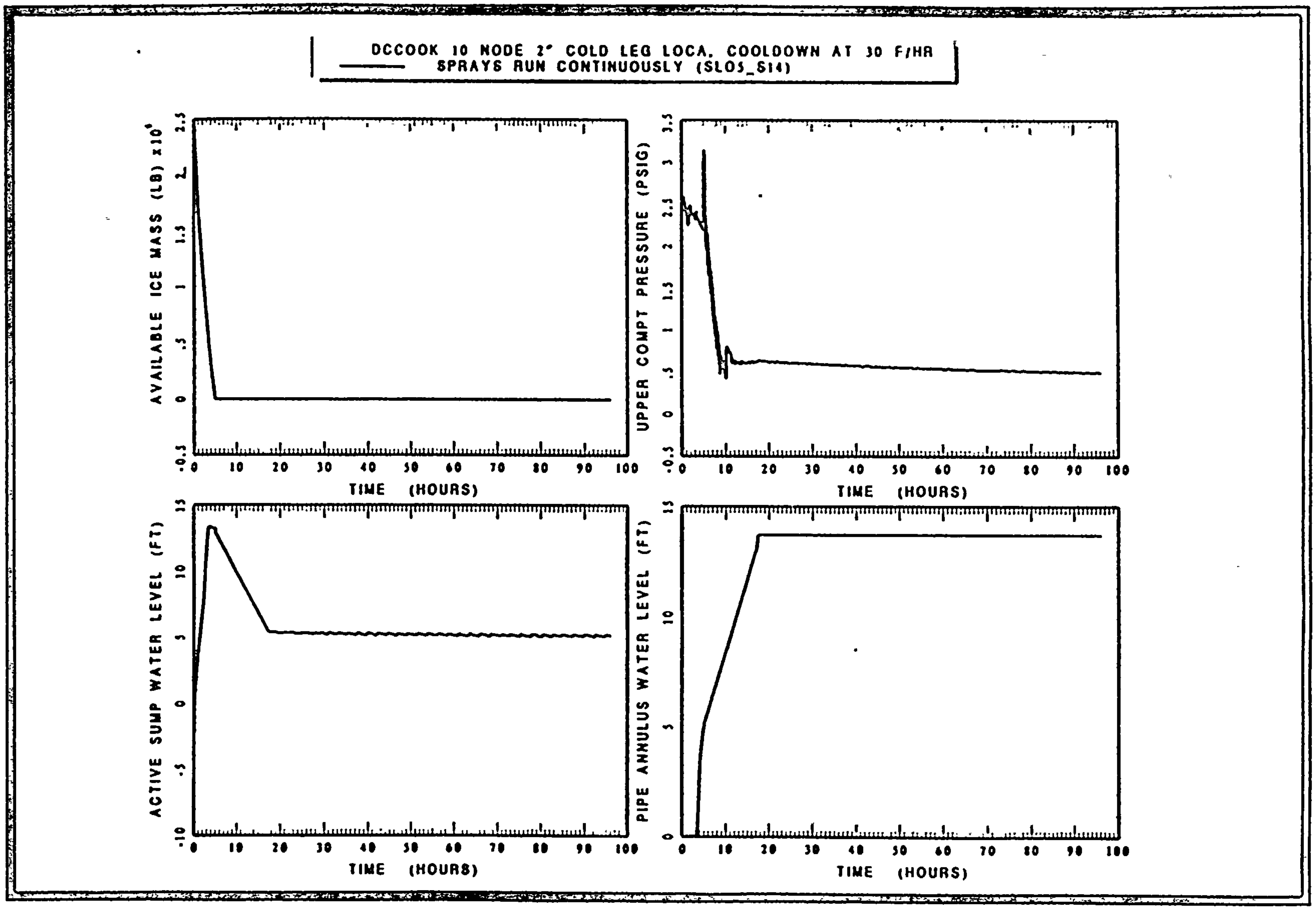
Summary of the containment system response for a six inch diameter cold leg LOCA.



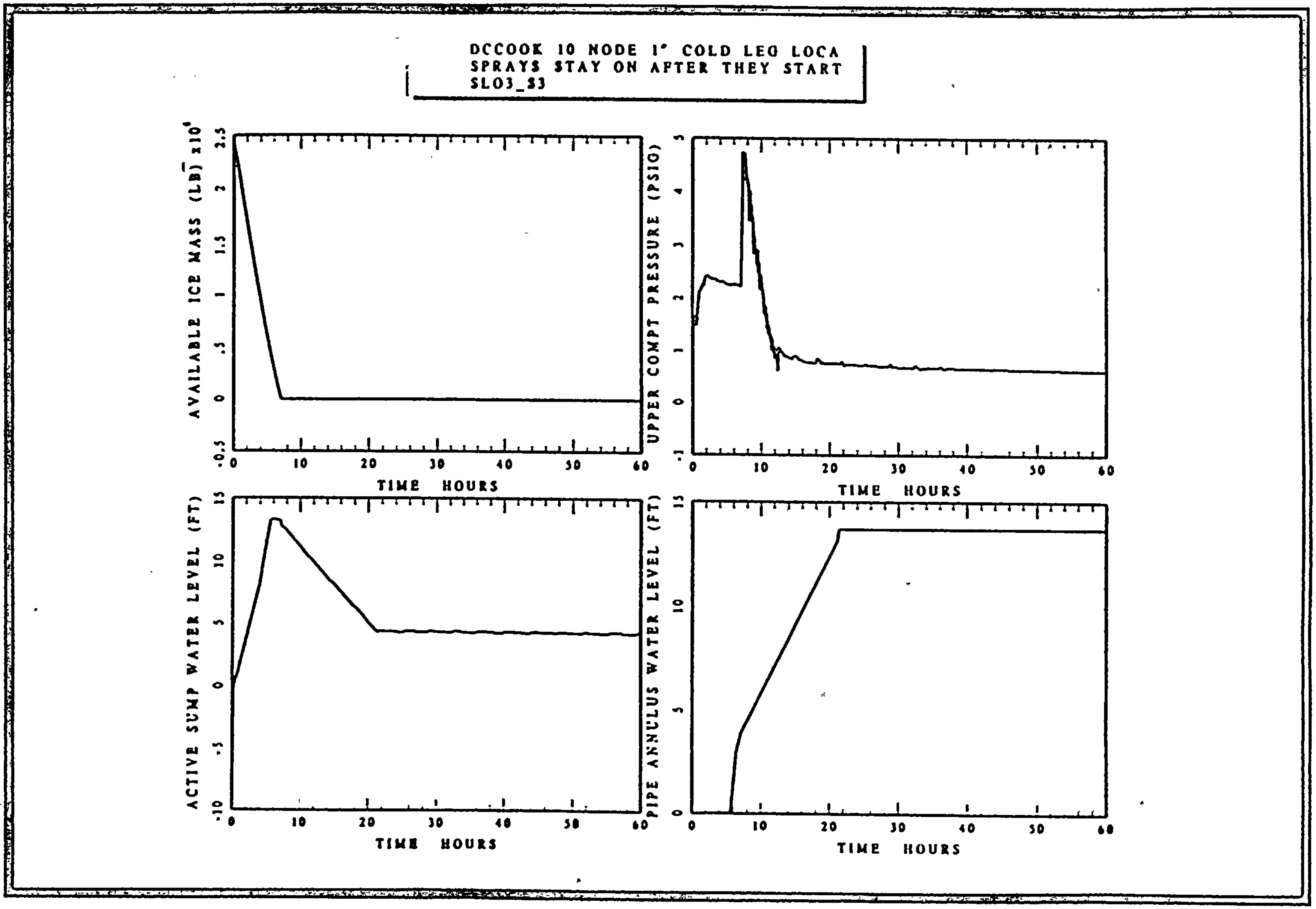
Summary of the containment system response for a three inch diameter cold leg LOCA.



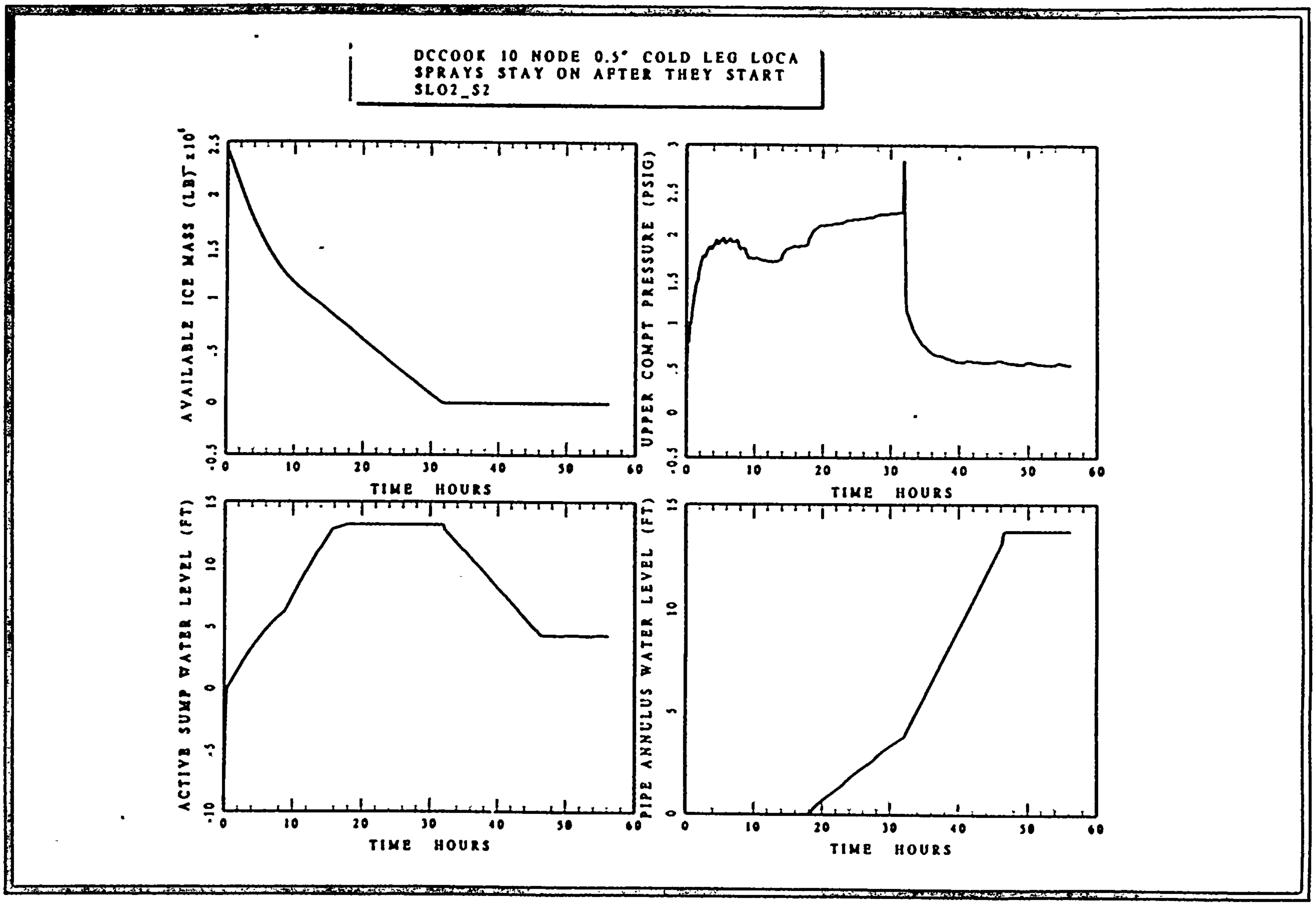
Summary of the containment system response for a two inch diameter cold leg LOCA.



Summary of the containment system response for a two inch diameter cold leg LOCA with containment sprays operating continuously once they are activated.



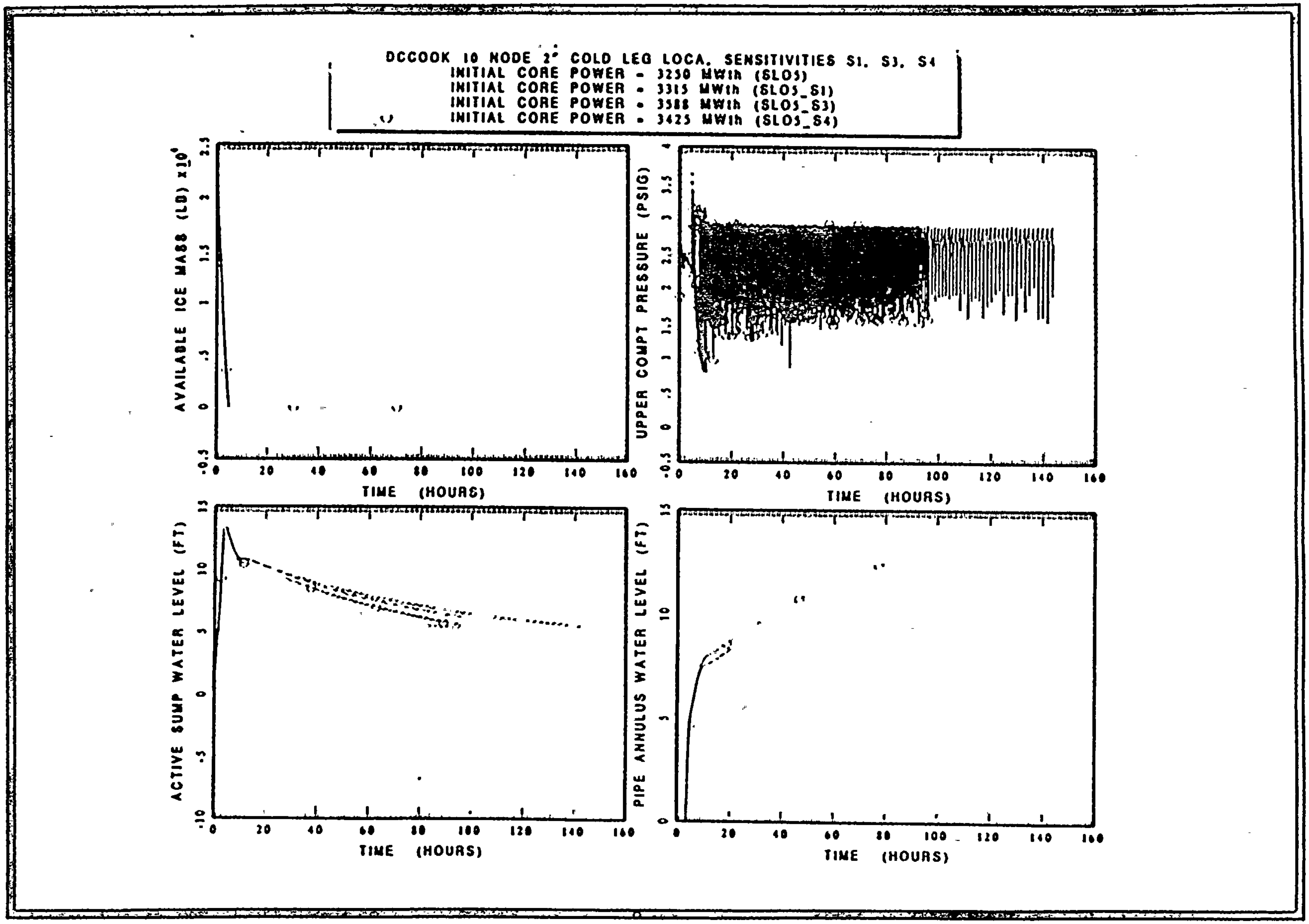
Summary of the containment system response for a one inch diameter cold leg LOCA with the accumulators assumed to be blocked and the sprays operating continuously once they have been started.



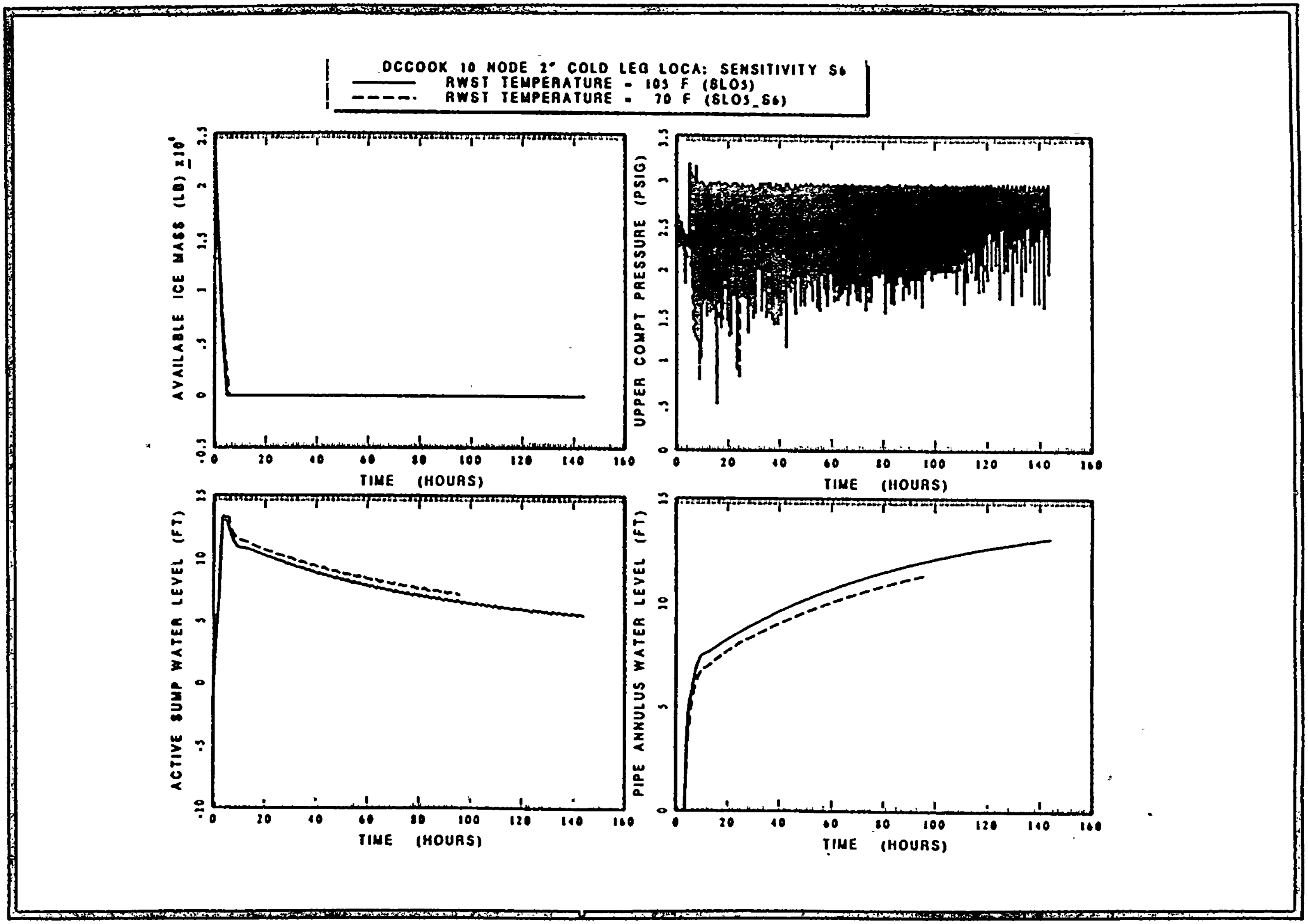
Summary of the containment system response for a one-half inch diameter cold leg LOCA assuming the accumulators are blocked and with the containment sprays operating continuously once they have been started.

Sensitivity Analyses for the D.C. Cook Plant Using MAAP4

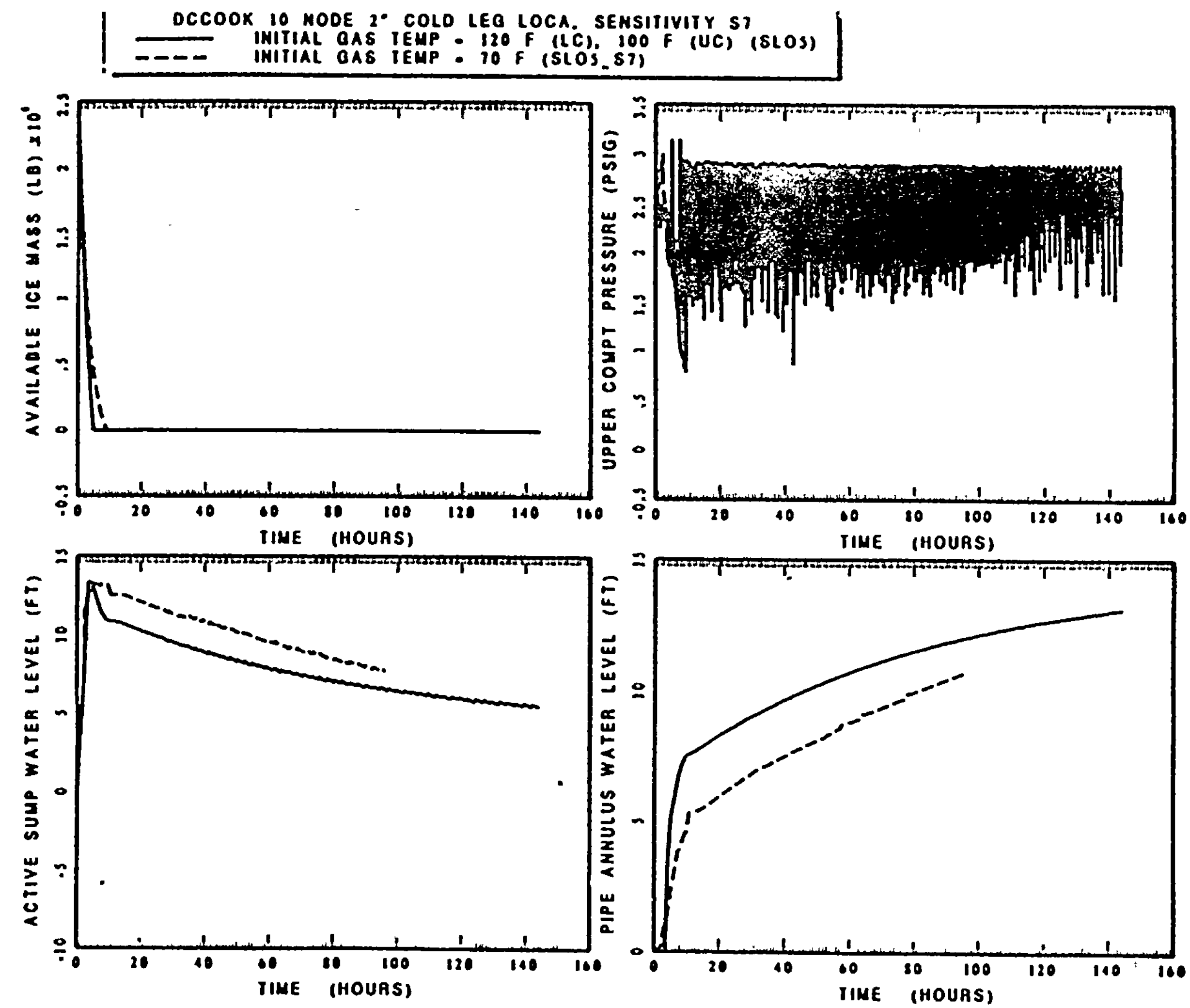
Sensitivity Run No.	Parameter Changed	Nominal Value	Comments
S1	Core power = 3315 MWt.	3250	Licensing value for Unit 1.
S2	Core power = 3588 MWt.	3250	Licensing value for Unit 2.
S3	Core power = 3425 MWt.	3250	Nominal operating power for Unit 2.
S4	RWST temperature = 70°F.	105	Minimum tech spec value.
S5	Containment gas temperature = 70°F.	UC = 100°F, LC = 120°F, DEC = 120°F	Lowest value to maximize the mass of air in containment.
S6	Thermal conductivity of containment structural heat sinks decreased by a value of 1.4.	1.0	Minimize the influence of containment structural heat sinks.
S7	Thermal conductivity of containment structural heat sinks increased by a factor of 1.4.	1.0	Maximizes the influence of containment structural heat sinks.
S8	Heat exchanger cooling rates set at minimum lake water temperature = 45°F.	87°F	Minimizes ice melt.
S9	200 gpm of upper compartment spray flow drains to the inactive sump.	45 gpm	Upper bound of the flow that could be diverted to the inactive sump.



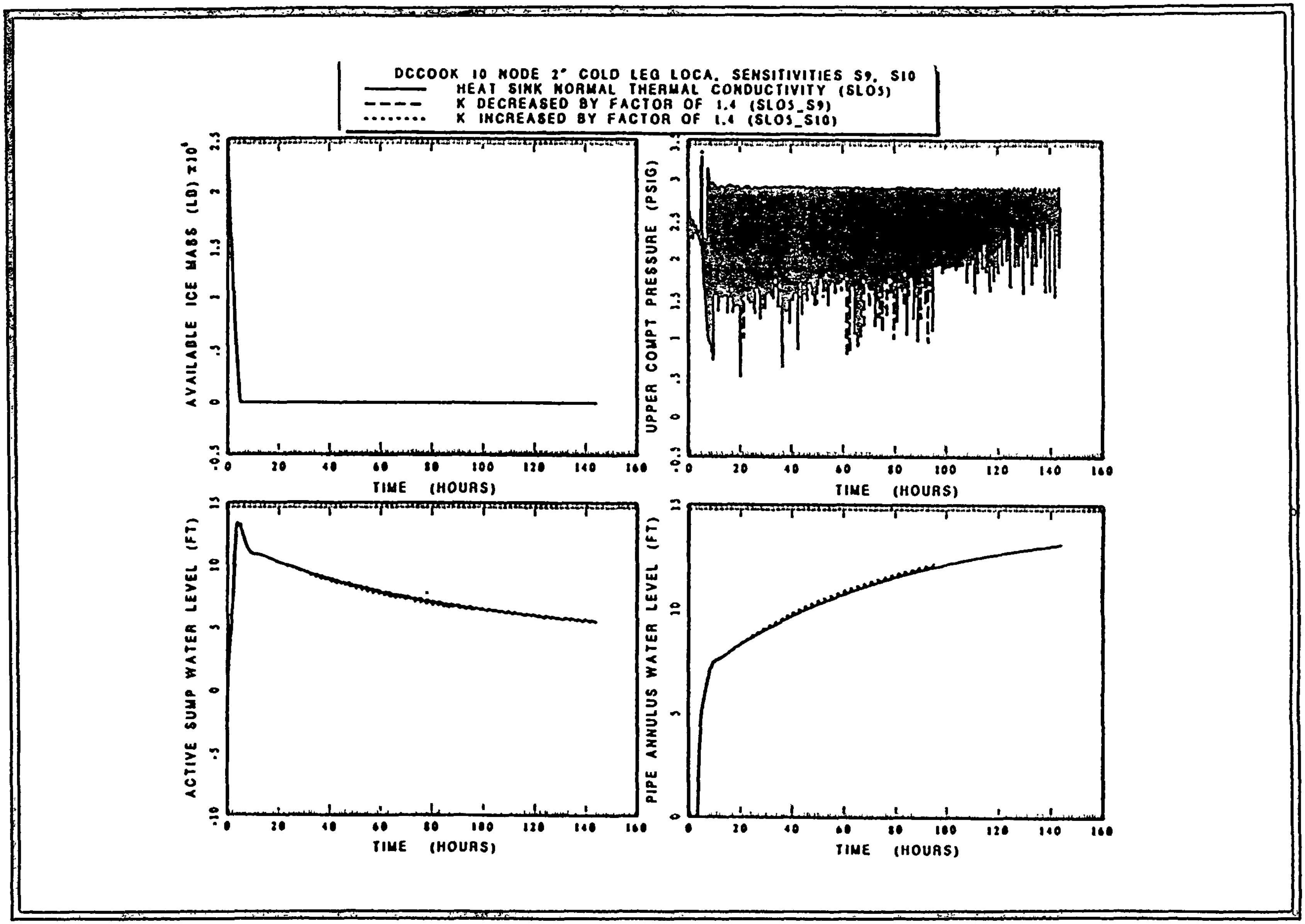
Summary of the containment response for sensitivity cases S1, S2 and S3.



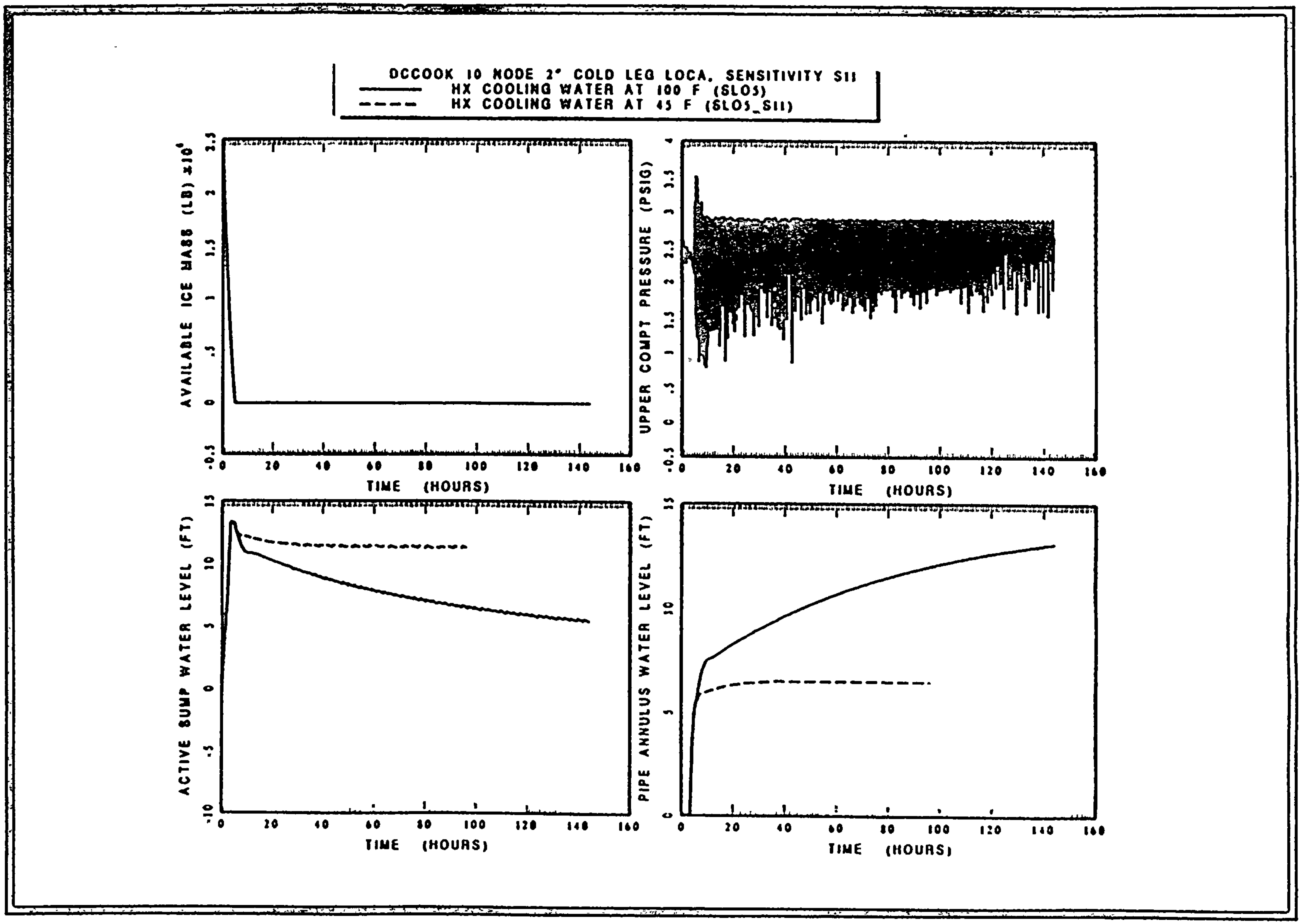
Summary of the containment response for sensitivity case S4.



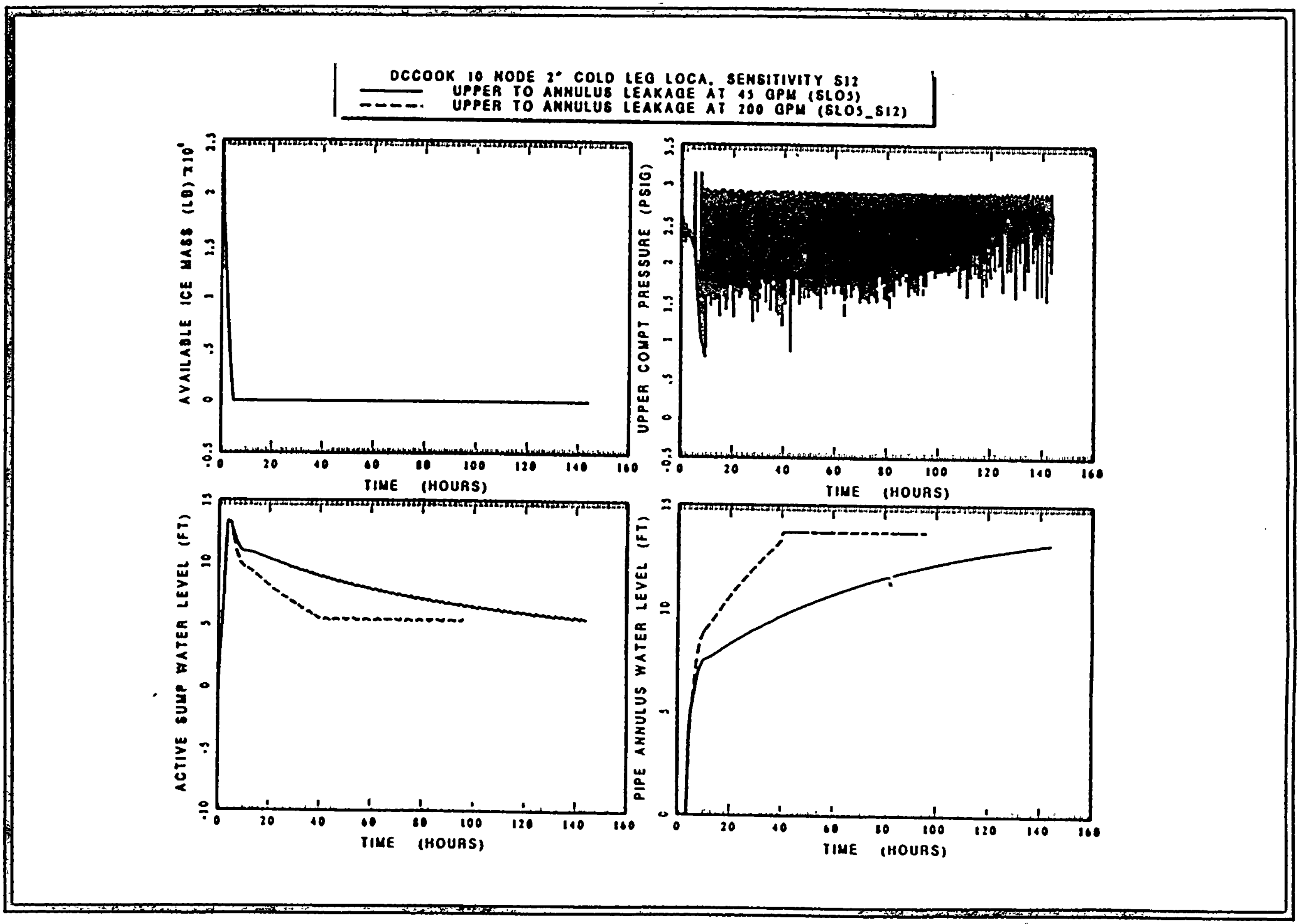
Summary of the containment response for sensitivity case S5.



Summary of the containment response for sensitivity cases S6 and S7.



Summary of the containment response for sensitivity case S8.



Summary of the containment response for sensitivity case S9.

CONSERVATISMS IN THE ANALYSES

- **The greatest conservatism in the analysis is that the ice mass credited in the calculation is 2.43 x 10^6 lbm. Realistically, the containment ice mass is approximately 2.7 x 10^6 lbm, which when melted, would add approximately 36,000 gallons of water inventory to the containment. At the equilibrium spill over criteria, this would increase the active sump water level by 16 inches.**

- **1″ and 2″ diameter break analyses do not credit unblocking of the accumulators by the operators. This would add 27,500 gals. And would increase the active sump level by 12 inches.**

- **These analyses do not credit other operator actions such as refilling of the RWST. Additional inventory into the containment would further increase the active sump water level.**

CONCLUSIONS FROM THE SENSITIVITY STUDIES

- All of the calculations considered for an ice mass of 2.43 x 10^6 lb_m show water levels in the lower compartment are sufficient to support the necessary containment spray pump operation.

- The most limiting LOCAs appear to be the 2″ diameter range since these minimize the amount of injection to the RCS, and therefore the RCS cooldown, while still requiring the containment sprays to be activated. However, even with these 2″ LOCAs there is no challenge to the containment spray pump operation for an ice mass of 2.43 x 10^6 lb_m.

- A conservative representation of 1″ and 1/2″ diameter cold leg LOCAs with the accumulators blocked and continuous spray operation results in a minimum water level in the active sump greater than 602′10″.