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

JAN 17 1986

Docket Nos. 50-416/417
50-461
50-458/459
50-440

LICENSEES: Mississippi Power & Light Company
Illinois Power Company
Gulf States Utilities
CLeveland Electric Illuminating Company

FACILITIES: Grand Gulf Nuclear Station, Units 1 and 2
Clinton, Unit 1
River Bend, Units 1 and 2
Perry, Unit 1

SUBJECT: SUMMARY OF DECEMBER 19, 1985 MEETING WITH MARK III CONTAINMENT HYDROGEN CONTROL OWNERS GROUP (HCOG) REGARDING HEAT SINK MODELING

The HCOG is performing tests of hydrogen combustion in a quarter scale mockup of the Mark III containment. The purpose of the December 19, 1985, meeting was to discuss revisions based on test data of the method for calculating heat transfer from hydrogen flames and air in the containment to the containment wall, drywell wall and equipment in the containment. Enclosure 1 is a list of attendees. Enclosure 2 is a copy of slides prepared by HCOG. As used herein, HCOG refers to the Hydrogen Control Owners Group or its consultants.

HCOG summarized the development of the heat loss (heat sink) model provided in its July 29, 1985 submittal (Enclosure 2, Sheets 2 through 9). HCOG also summarized model changes based on scoping test results from the Quarter Scale Test Facility (QSTF) and compared the revised model calculations with experiments (Sheets 10 through 26). The HCOG summary and conclusions are provided in Sheets 27 and 28.

The staff commented that several of its previous comments on the heat sink model appear to have been considered in the revised model; e.g. the geometry of flames and heated gas plumes, the threshold for start of diffusion flames, and water films on surfaces. The staff noted that increasing the heat transfer to the suppression pool brought the model calculations of pressure and temperature into closer agreement with the QSTF test results; however the staff questioned whether increased heat transfer to the HCU floor would also give close agreement. The latter assumption would adversely affect survivability of equipment on the HCU floor. Staff commented that the range of sensitivity studies should be extended.

The most significant item discussed in the meeting dealt with the disclosure by HCOG of the possibility that the QSTF insulation was inadequate; i.e., insulation above the pool became water soaked thereby increasing its thermal conductance. The staff regards this as a serious problem since it appears a significant fraction of the heat loss in the QSTF occurs in the wetwell region. While there may be compensating factors, the staff concludes that HCOG should continue to investigate this matter to confirm the actual heat transfer characteristics of the insulation and should if necessary take steps to ensure that heat transfer properties are scaled as Froude modeling required.

The staff said that comments, on heat sink modeling, if any, would be sent via letter to HCOG following completion of its review of the July 29, 1985 HCOG submittal. Comments on information provided in the December 19, 1985 meeting will be included in this letter.

Original Signed by

L. L. Kintner, Project Manager
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Division of BWR Licensing

Enclosures:
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Tne staff said that comments, on heat sink modeling, if any, would be sent via letter to HCOG following completion of its review of the July 29, 1985 HCOG submittal. Comments on information provided in the December 19, 1985 meeting will be included in this letter.

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Enclosure 1

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*Part Time

Enclosure 2

HEAT LOSS ANALYSIS FOR

MARK III CONTAINMENT GEOMETRIES

(POST TEST REVISION)

BY

ERDEM URAL
FRANCO TAMANINI
ROBERT ZALOSH

FACTORY MUTUAL RESEARCH CORP.

HCOG/NRC MEETING, DECEMBER 19, 1985
BETHESDA, MARYLAND

CONTENTS

BACKGROUND

- CONVECTIVE AND RADIATIVE HEAT TRANSFER MODES DO NOT FOLLOW FROUDE MODELING REQUIREMENTS EXACTLY (I.E. SQUARE ROOT VARIATION OF FLUXES WITH SCALE).

- IN REDUCED-SCALE EXPERIMENTS, HEAT TRANSFER BY ...
  ... CONVECTION IS GENERALLY HIGHER THAN NEEDED.
  ... RADIATION IS HIGHER/LOWER FOR OPTICALLY THICK/THIN MEDIA.

- THIS FACTOR ALONE WOULD LEAD TO GAS TEMPERATURES IN A REDUCED-SCALE MODEL WHICH ARE LOWER THAN CORRESPONDING TEMPERATURES AT FULL SCALE, IF ALL HEAT SINKS ARE ACCURATELY MODELED IN THE EXPERIMENT.

- EXPECTATION THAT ABSENCE OF HEAT SINK DUE TO EQUIPMENT IN 1/4-SCALE FACILITY WOULD OFFSET HIGHER HEAT TRANSFER.

- NEED TO QUANTIFY EXTENT OF COMPENSATING EFFECTS.

OBJECTIVE

- Determine, by analysis, the relationship between gas temperatures produced in the 1/4-scale facility and those expected in Mark III units.

- Analysis not intended to provide accurate estimate of absolute local temperature levels. However, the global parameter values calculated for the 1/4-scale facility should be approximately equal to those measured in 1/4-scale tests.

HEAT LOSS ANALYSIS
DEVELOPMENT HISTORY

MID 1984: FMRC DEVELOPED A COMPUTER CODE FOR THE CONTAINMENT LOADS WORKING GROUP (CLWG) TO PREDICT THE THERMAL ENVIRONMENT IN FULL SCALE MARK III CONTAINMENTS DUE TO HYDROGEN DIFFUSION FLAMES.

THREE INDEPENDENT RESEARCH LABORATORIES (LANL, SNL, FMRC) OBTAINED COMPARABLE RESULTS.

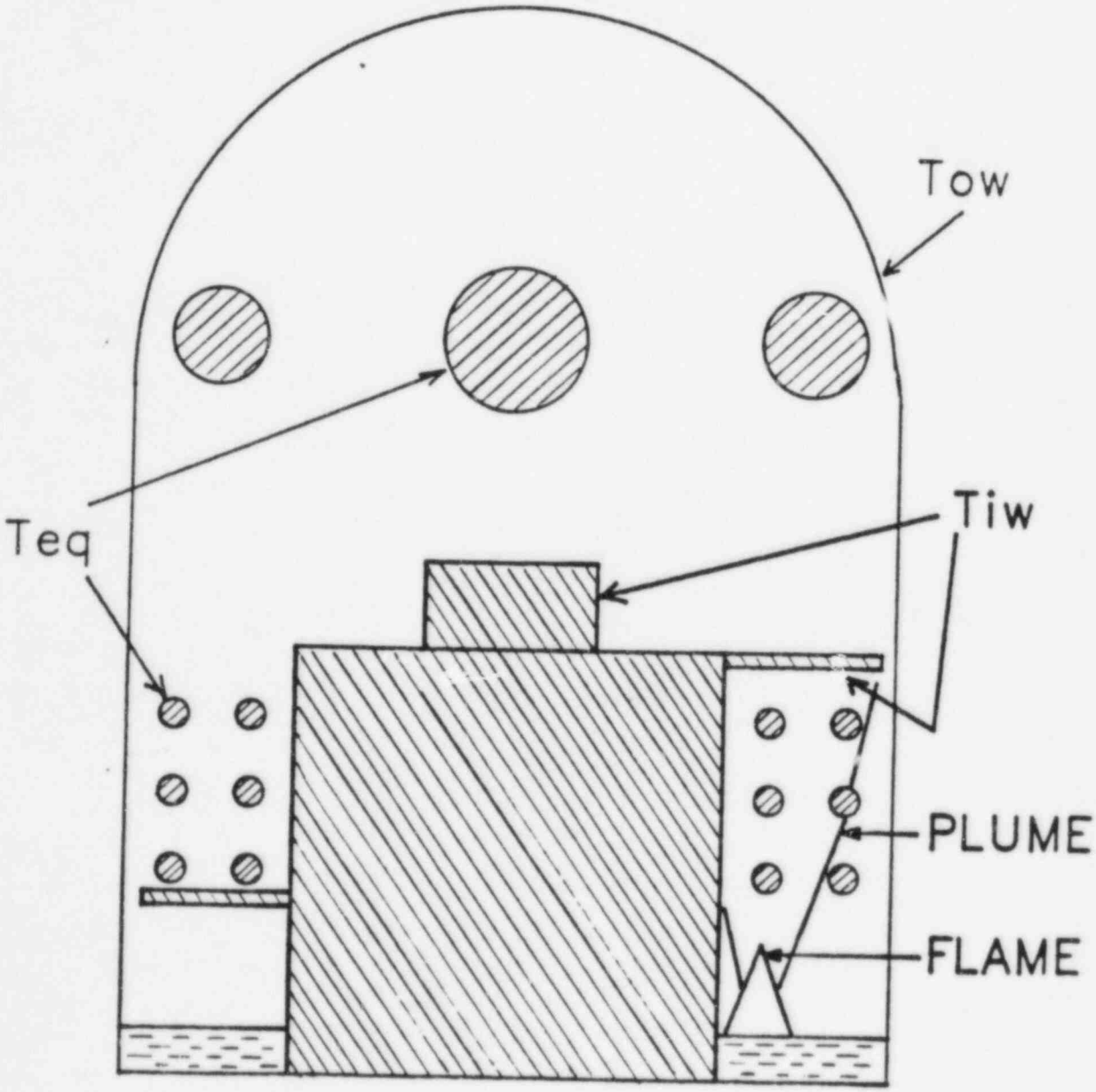
EARLY 1985: UTILIZING METHODOLOGY DEVELOPED FOR CLWG, FMRC PERFORMED CALCULATIONS FOR 1/4-SCALE TEST FACILITY AND A FULL SCALE MARK III PLANT FOR A SPECIFIC HYDROGEN RELEASE HISTORY TO BE TESTED.

MID 1985: 1/4-SCALE TESTS REVEALED THAT BACKGROUND TEMPERATURE AND PRESSURE INCREASE BY AN AMOUNT APPROXIMATELY 1/2 OF WHAT WAS CALCULATED, INDICATING INSUFFICIENT ACCOUNT OF HEAT LOSSES IN THE MATHEMATICAL MODEL.

LATE 1985: FMRC EFFORT FOR MORE REALISTIC MODELING OF HEAT LOSSES.

ANALYTICAL APPROACH

- ZONE MODELING OF DOMINANT COMPONENTS OF CONTAINMENT FLOW.
- GLOBAL CONSERVATION OF MASS/ENERGY FOR SELECTED SUBSYSTEMS: FLAMES, PLUMES, INNER WALL, OUTER WALL, EQUIPMENT, BACKGROUND GAS, ETC.
- HEAT EXCHANGE RATES CALCULATED FROM AVAILABLE HEAT TRANSFER CORRELATIONS.
- OVERALL APPROACH UNCHANGED IN REVISED METHODOLOGY.


Tow
Teq
Tiw
PLUME
FLAME

REVIEW OF MODELING APPROACH DOCUMENTED IN JULY SUBMITTAL

GAS TEMPERATURE/VELOCITY COMPUTATION

* Flame/Plume Temperatures/Velocity

  - Based on previous measurements of temperature/velocity distributions in hydrocarbon axisymmetric free plumes.

  - Convective heat loss to inner wall calculated from free plume data for local velocities/temperatures, in turn used as input to forced heat transfer correlations.

* Background Gas

  - Temperature calculated by mass and energy balances for prescribed addition and calculated losses.

  - Convective heat transfer based on natural convection.

MODEL OF JULY SUBMITTAL
HEAT LOSS EXCHANGE PATHS

	From Flames	From Plumes	From Background Gas
To outer wall	Radiation	None	Radiation Convection (natural) Condensation
To inner wall	Radiation	Convection (forced)	Radiation Convection (natural)
To equipment	None	Convection (forced)	Radiation Convection (natural)
To suppression pool	None	None	None

MODEL OF JULY SUBMITTAL
HEAT SINK MODELING

- INNER WALL/FLOORS
  - SEMI-INFINITE SOLID (DRY SURFACE)

- OUTER WALL
  - 1/4 SCALE
    - SEMI-INFINITE SOLID (INITIALLY DRY SURFACE)
  - MARK III UNIT
    - SEMI-INFINITE COMPOSITE (INITIALLY DRY SURFACE) (LINER ON CONCRETE)

- EQUIPMENT/GRATING ETC.
  - DISTRIBUTED UNIFORMLY IN ANNULUS ABOVE HCU FLOOR AND IN UPPER DOME
  - THERMALLY THIN

KEY MODEL CHANGES SINCE JULY SUBMITTAL

*NEW FLAME/PLUME MODEL

- 2-D WALL PLUME CORRELATIONS WITH A CONSTANT WIDTH EQUAL TO SPARGER DIAMETER (OLD MODEL: FREE PLUMES WITH WIDTH A FUNCTION OF HEIGHT).

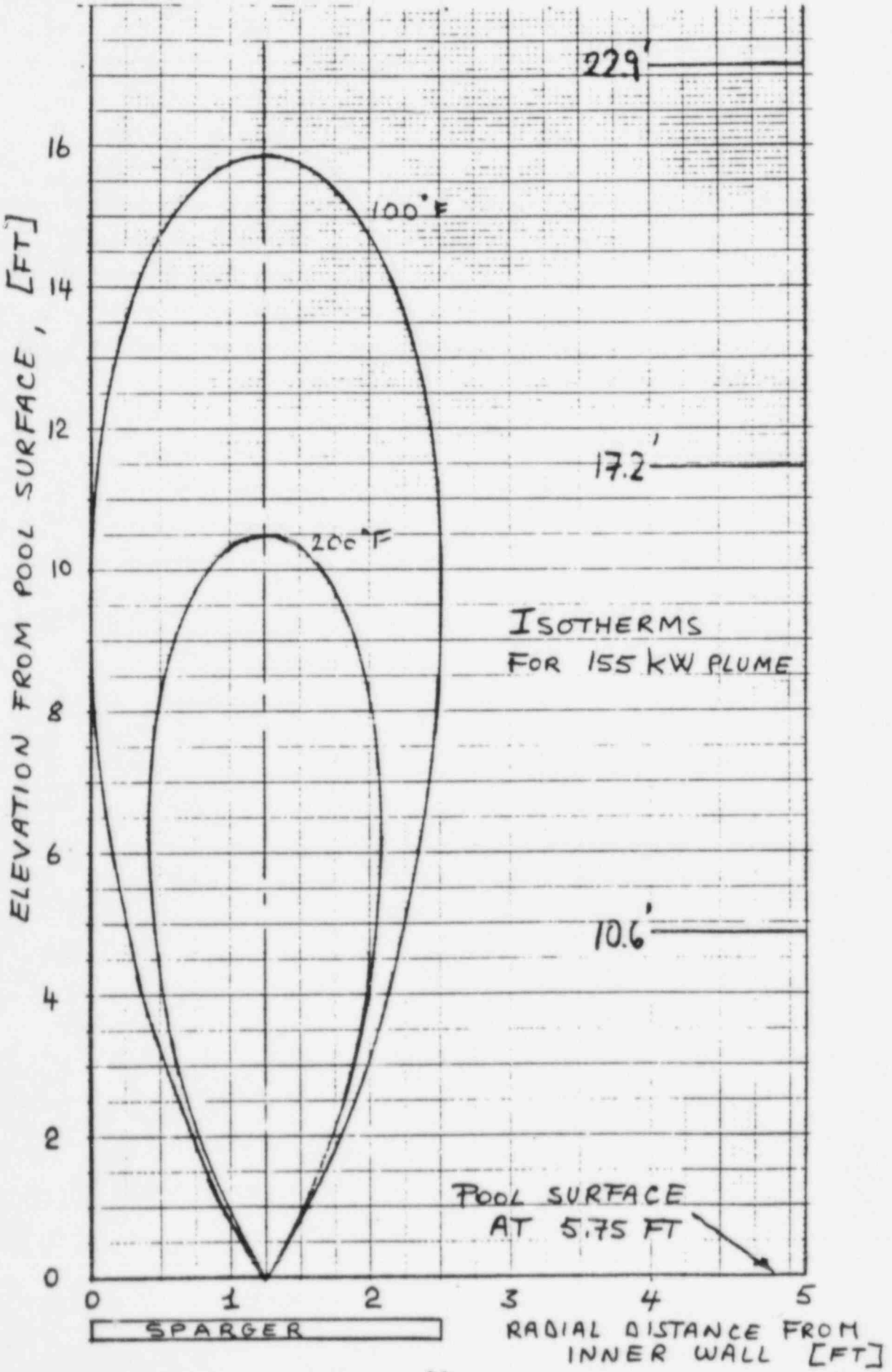
- CONVECTIVE FLAME HEAT FLUX TO INNER WALL 2.5 TO 3 W/CM^2 IMPOSED ON A RECTANGLE DEFINED BY SPARGER DIAMETER AND THE FLAME HEIGHTS (OLD MODEL: NO DIRECT CONVECTIVE HEAT TRANSFER TO INNER WALL).

- FLAME HEAT LOSS TO SUPPRESSION POOL (OLD MODEL: NO LOSS TO POOL).

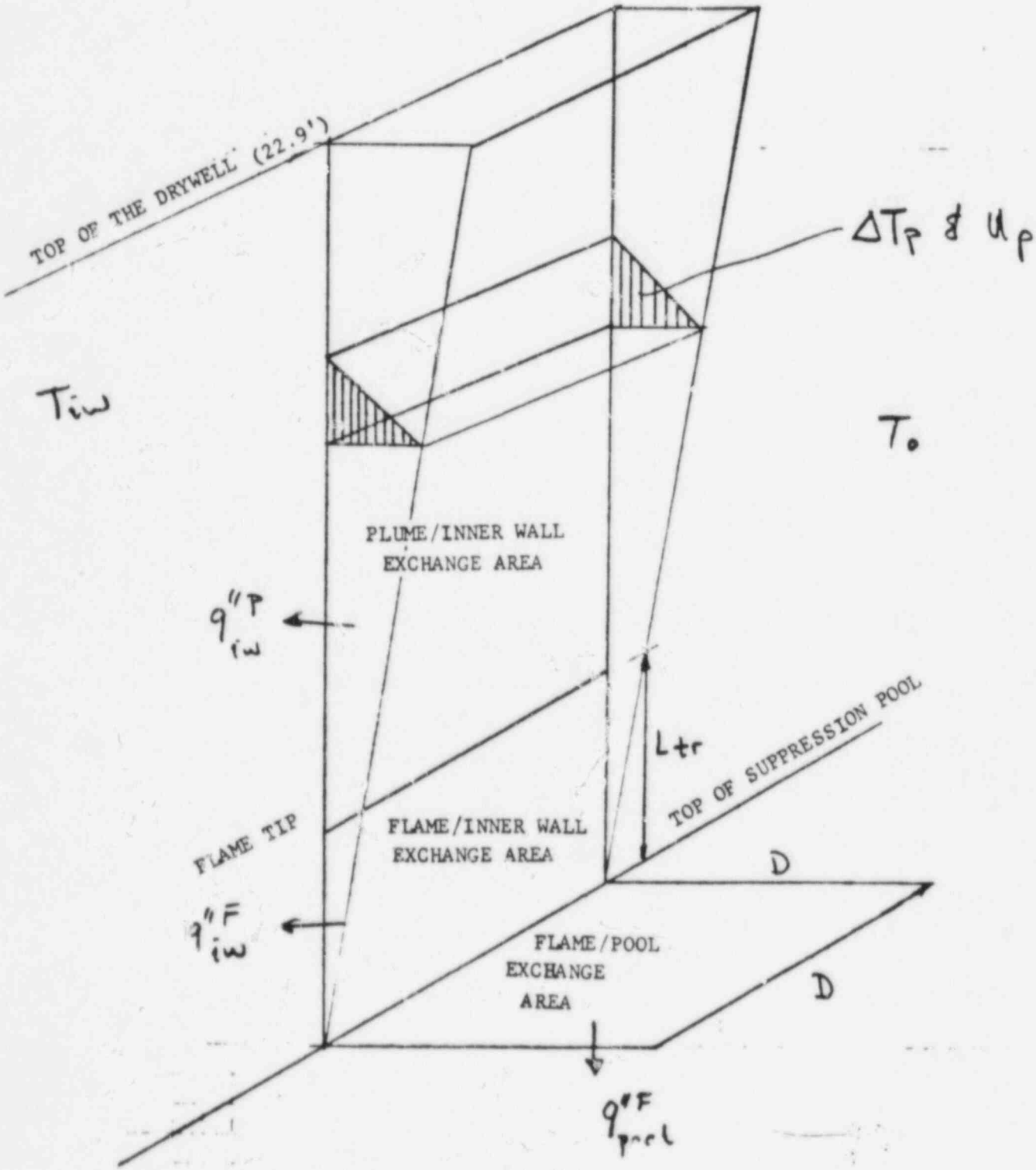
*MIXED CONVECTION TO EQUIPMENT

- AVERAGE BACKGROUND GAS VELOCITIES UP TO 4 FT/S INDUCED BY THE PLUMES (OLD MODEL: QUIESCENT ENVIRONMENT).

- MIXED (COMBINED) CONVECTION CORRELATIONS HAVE BEEN USED FOR BACKGROUND HEAT LOSS TO EQUIPMENT (OLD MODEL: NATURAL CONVECTION HEAT TRANSFER).


FREE PLUME
22.9'
17.2'
10.6'
100°F
200°F
ISOTHERMS
FOR 155 kW PLUME
POOL SURFACE
AT 5.75 FT
ELEVATION FROM POOL SURFACE, [FT]
0
2
4
6
8
10
12
14
16
0
1
2
3
4
5
SPARGER
RADIAL DISTANCE FROM
INNER WALL [FT]

WALL PLUME MODEL



KEY MODEL CHANGES SINCE JULY SUBMITTAL

(CONT.D)

*EQUIPMENT CHARACTERISTIC SIZE FOR BACKGROUND LOSSES

- OLD VALUES: 1 FT F/S, 5-3/4 IN. 1/4 SCALE
  (3 IN., 3/4 IN. RESPECTIVELY FOR PLUME LOSSES)
- NEW VALUES: 3 IN. F/S, 3/4 IN. 1/4 SCALE ARE MORE REASONABLE
  (SAME VALUES FOR PLUME LOSSES)

*BACKGROUND RADIATION

- IMPROVED TO ALLOW EXCHANGE AMONG GAS AND THREE SURFACES MODELED (OLD MODEL: SURFACE EMISSION AT OUTER WALL TEMPERATURE, WALL EMISSIVITY EQUAL TO THAT CALCULATED FOR BACKGROUND GAS).

*CONDENSATION/EVAPORATION

- CONDENSATION ON ALL <u>THREE</u> SURFACES IS ALLOWED.
- EVAPORATION FROM ALL THREE SURFACES ALLOWED UNDER FAVORABLE CONDITIONS, I.E. HIGH SURFACE TEMPERATURE AND LOW BACKGROUND STEAM CONCENTRATION.
- OLD MODEL: CONDENSATION ON OUTER WALL ONLY. NO EVAPORATION.

KEY MODEL CHANGES SINCE JULY SUBMITTAL

* HEAT LOSS EXCHANGE PATHS

	From Flames	From Plumes	From Background Gas
To outer wall	Radiation	None	Radiation Convection (natural) Condensation/Evaporation
To inner wall	Radiation Convection	Convection (forced)	Radiation Convection (natural) Condensation/evaporation
To equipment	None	Convection (forced)	Radiation Convection (mixed) Condensation/evaporation
To suppression pool	Convection	None	None

Note:

Underlined items represent changes from July submittal.

* HEAT SINK MODELING

All surfaces assumed to have sufficient water to allow for evaporation requirement. Film thickness neglected in heat conduction calculation. (Old model: dry surfaces.)

KEY MODEL CHANGES SINCE JULY SUBMITTAL

(CONT.D)

*1/4 SCALE FACILITY SPECIFIC MODELING CHANGES

- $\sqrt{K_g C}$ IS ASSUMED TO BE ABOUT 4 TIMES GREATER THAN THE NOMINAL VALUE BASED ON PRELIMINARY 1/4-SCALE DATA EVALUATION (FURTHER EVALUATION IN PROGRESS).
- CAMERA PURGES CAUSE AIR ADDITION TO THE TEST VOLUME AT THE RATE OF 0.013 KG/S CORRESPONDING TO 0.015 PSI/MIN

*H_2 RELEASE HISTORY

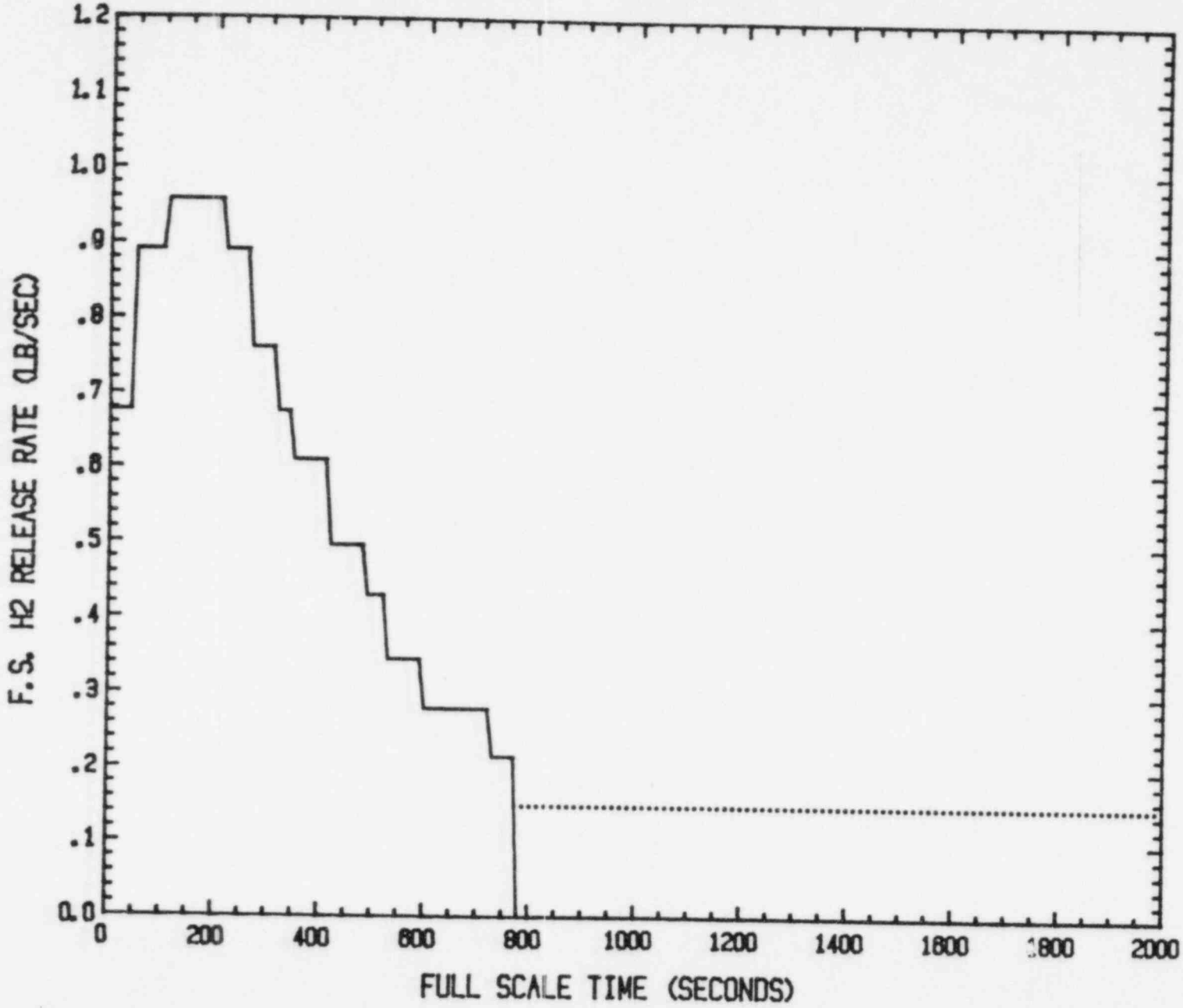
- CHANGED TO REFLECT THE OBSERVED COMBUSTION PORTION OF TEST S-05.1. (OLD MODEL: DIFFUSION FLAMES EXIST FOR HYDROGEN INJECTION RATES > 0.4 LBS/SEC.)

CASES CONSIDERED USING REVISED METHODOLOGY

- 1/4-SCALE FACILITY:
  BASELINE CASE, COMPARISON WITH THE EXPERIMENT (TEST S-05.1)

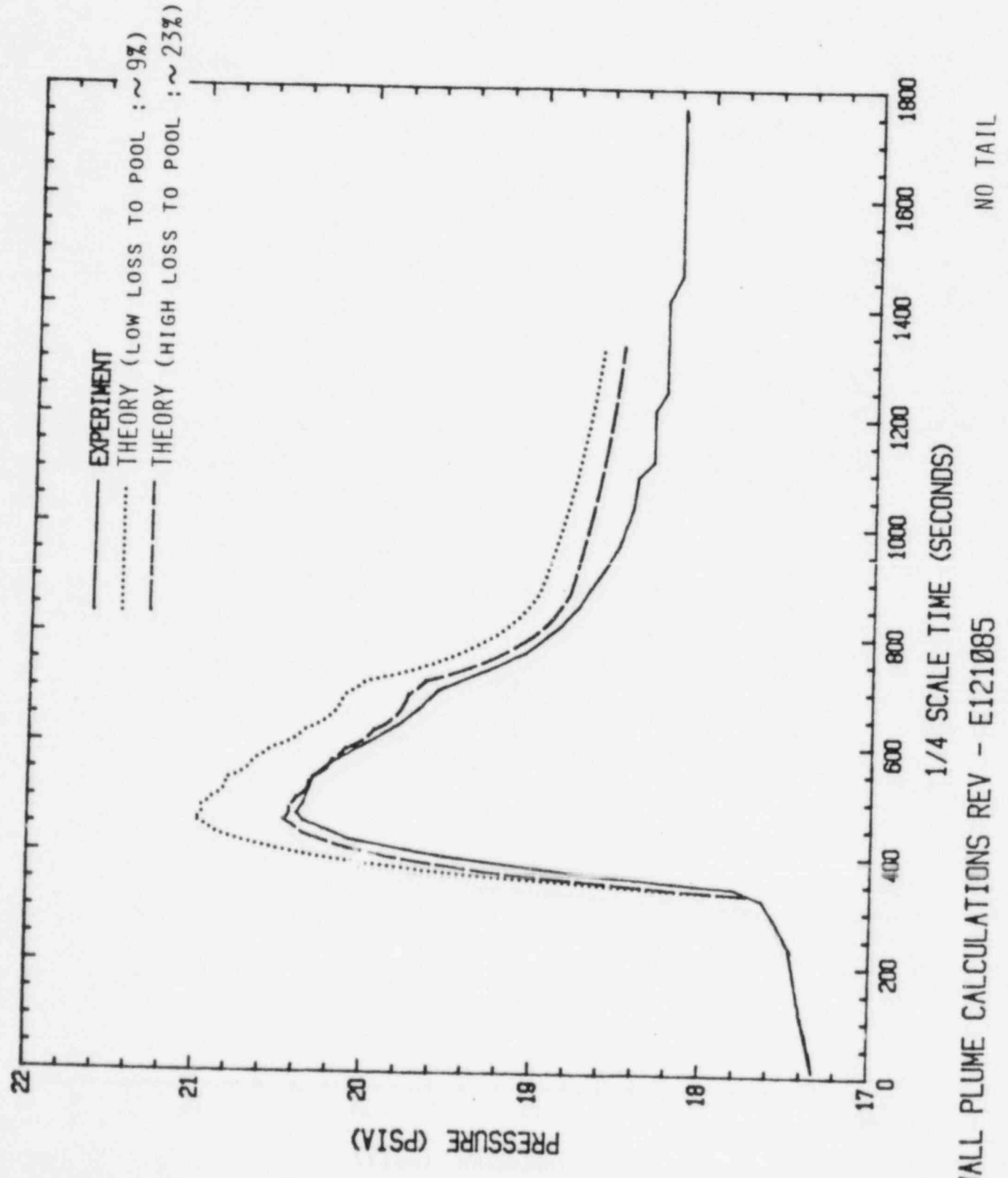
- MARK III UNIT WITH CONCRETE CONTAINMENT:
  TO EXAMINE THE EFFECT OF ACTUAL EQUIPMENT LOADINGS ON CONSERVATISM OF FROUDE SCALING

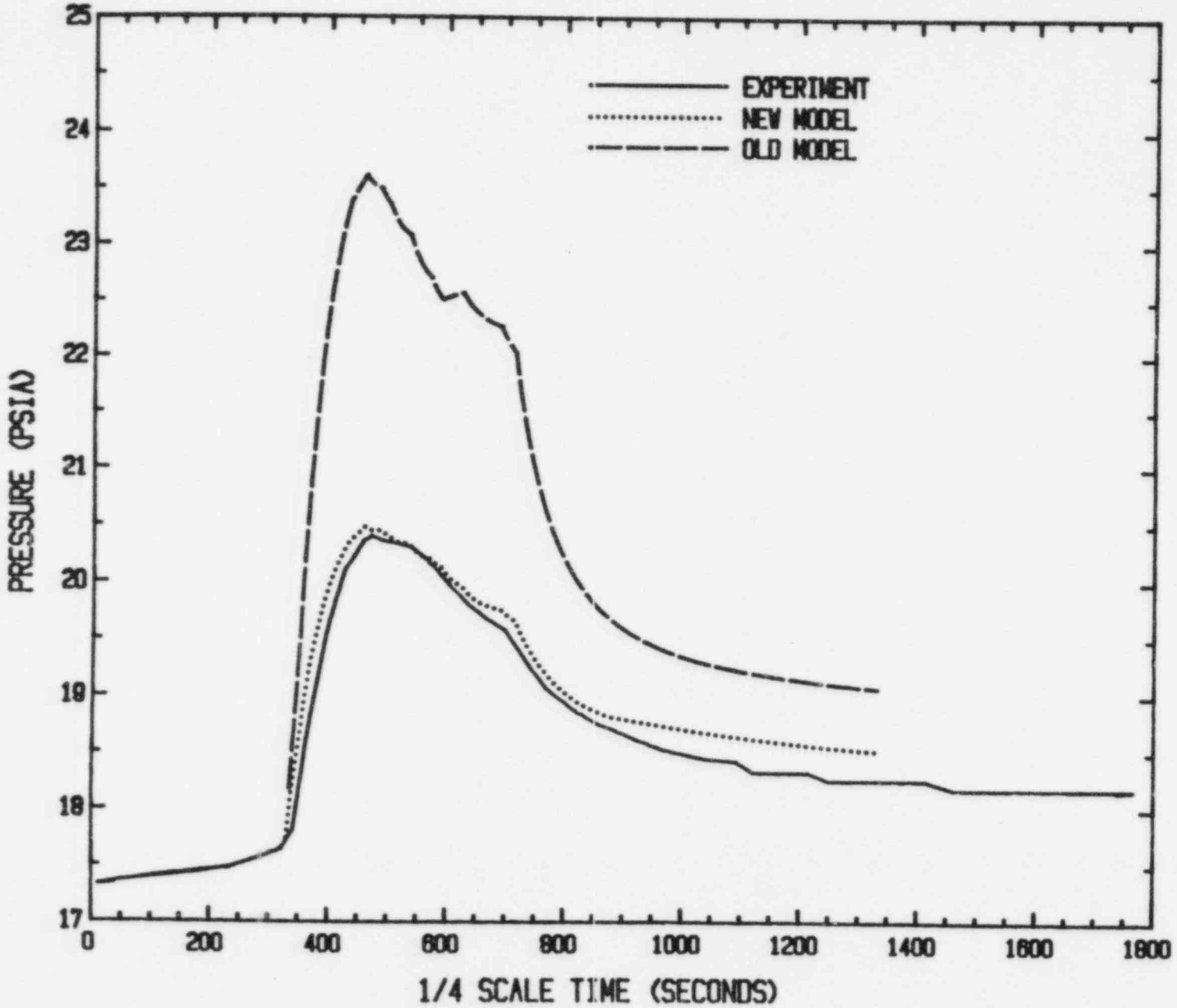
- EFFECT OF 0.15 LB/SEC (F/S) TAIL APPENDED TO CASE A RELEASE.



HYDROGEN RELEASE HISTORY

MODEL VERIFICATION
(TEST S 05.1)





WALL PLUME CALCULATIONS REV - E121085

MODELING OF POOL HEAT LOSSES

* ASSUMPTION OF:
  1. EXCHANGE AREA EQUAL TO D^2 (WHERE D IS SPARGER DIAMETER).
  2. HEAT FLUX TO POOL (PER UNIT SURFACE) EQUAL TO HEAT FLUX FROM FLAME TO INNER WALL (APPROXIMATELY CONSTANT WITH HYDROGEN FLOW AND SCALE).

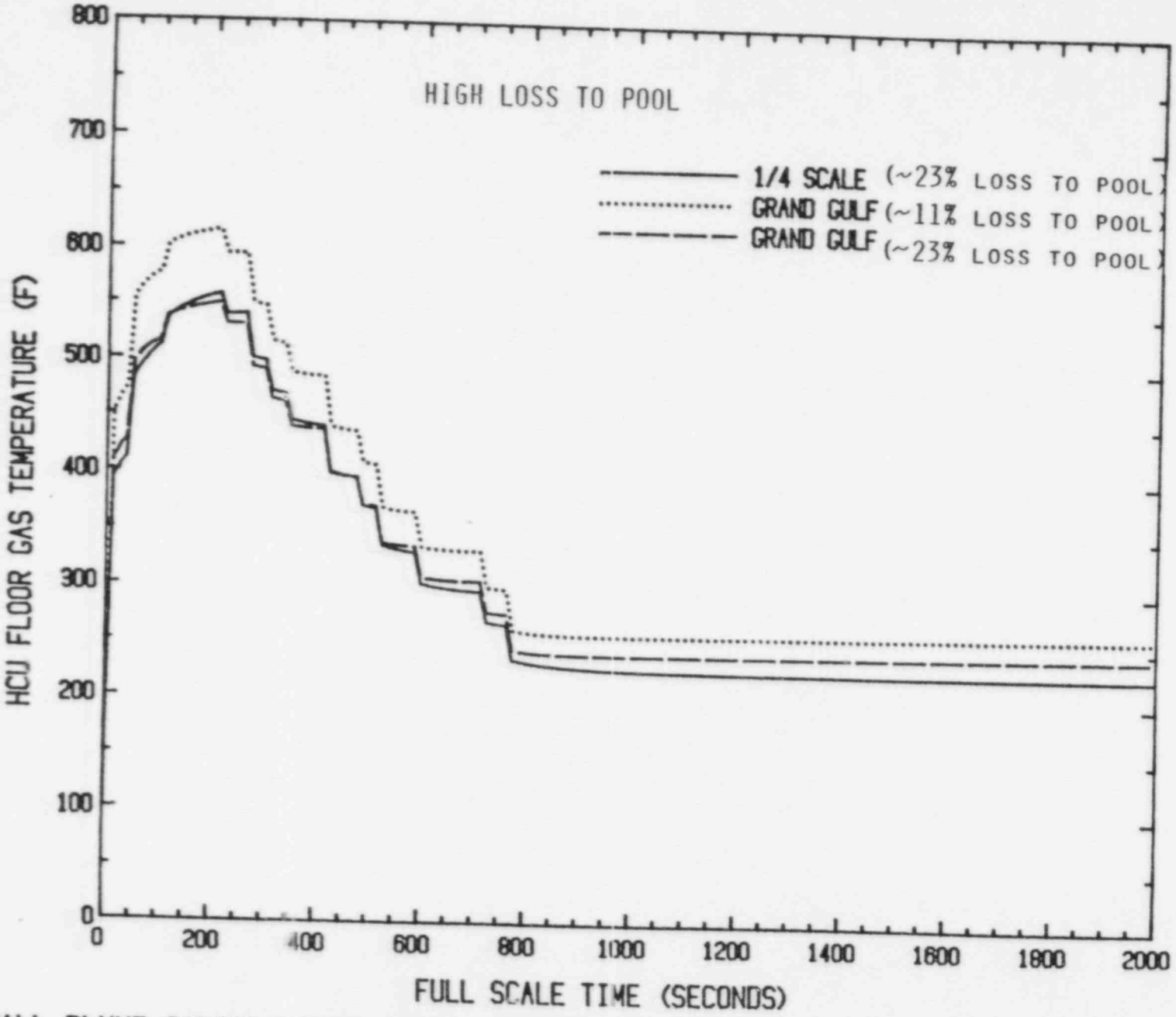
  LEADS TO:
  1. FRACTIONAL LOSS TO POOL AT 1/4 SCALE EQUAL TO ABOUT 9% AT PEAK RELEASE AND 54% DURING .15 LBS/SEC TAIL.
  2. POOL LOSSES AT FULL-SCALE ABOUT 4.5% AND 27% RESPECTIVELY (HEAT FLUX INVARIANT WITH SCALE, EXCHANGE AREA SCALED GEOMETRICALLY).
* FRACTIONAL HEAT LOSS AT PEAK RELEASE FOR 1/4 SCALE (~9%) APPEARS REASONABLE, LOSS AT LOW FLOW TAIL (~54%) IS NOT.

MODELING OF POOL HEAT LOSSES
(CONT.D)

* PRESENT CALCULATIONS
  1. ELIMINATE UNREASONABLY HIGH POOL LOSSES AT LOW FLOW BY SETTING POOL HEAT LOSS EQUAL TO CONSTANT FRACTION OF RELEASE RATE.
  2. SHOW EFFECT OF 9% AND 23% HEAT LOSS AT 1/4 SCALE.

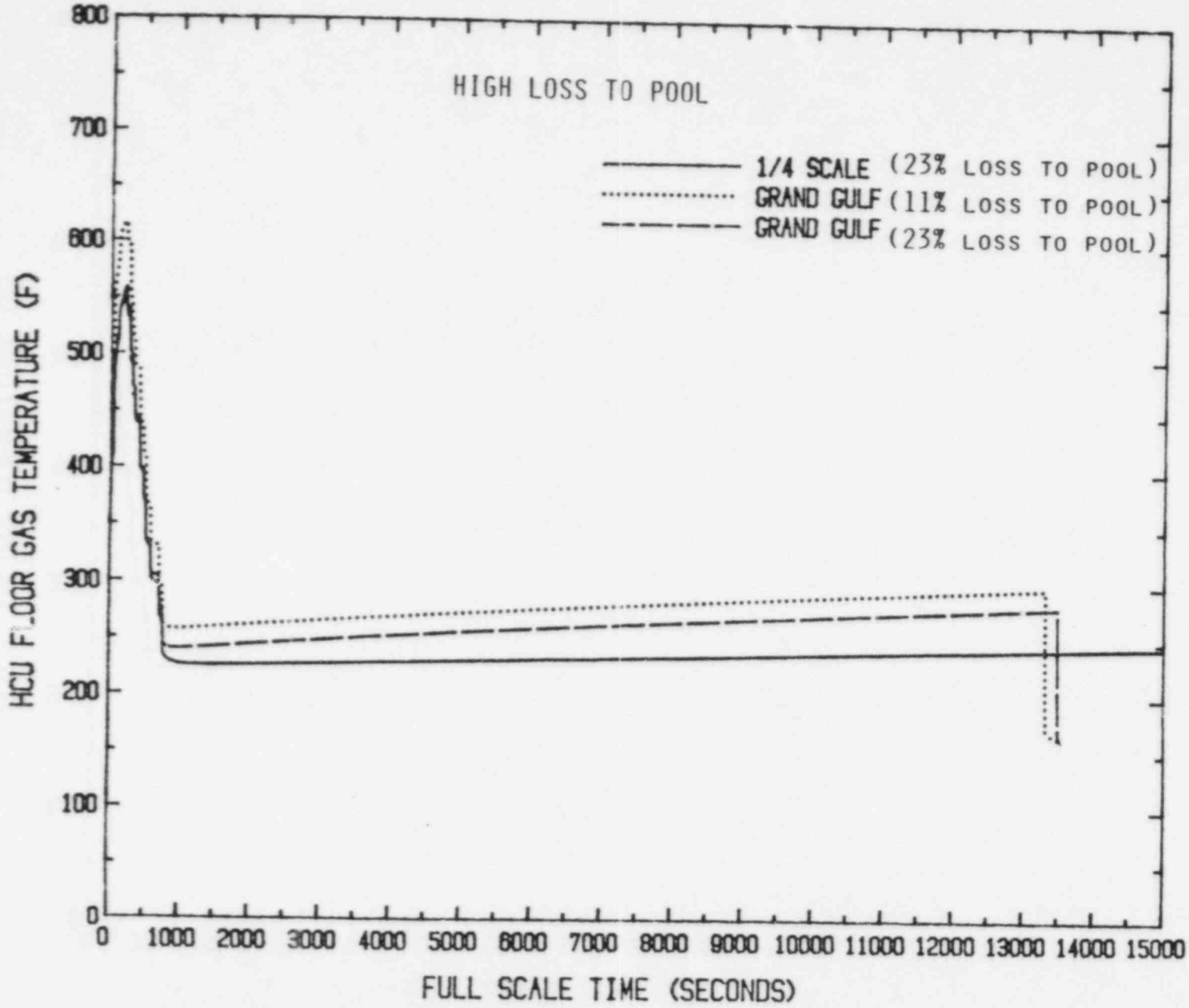
* VERSION UNDER DEVELOPMENT:

  MORE REALISTIC MODEL WILL ESTIMATE POOL LOSS AS $\dot{Q}_{POOL} = Q'' \times A$ UNTIL LOSS FRACTION (% LOSS = $\dot{Q}_{POOL}/\dot{Q}_{TOT}$) EXCEEDS SELECTED THRESHOLD (~25%). FROM THAT POINT ON % LOSS IS HELD AT THRESHOLD VALUE.

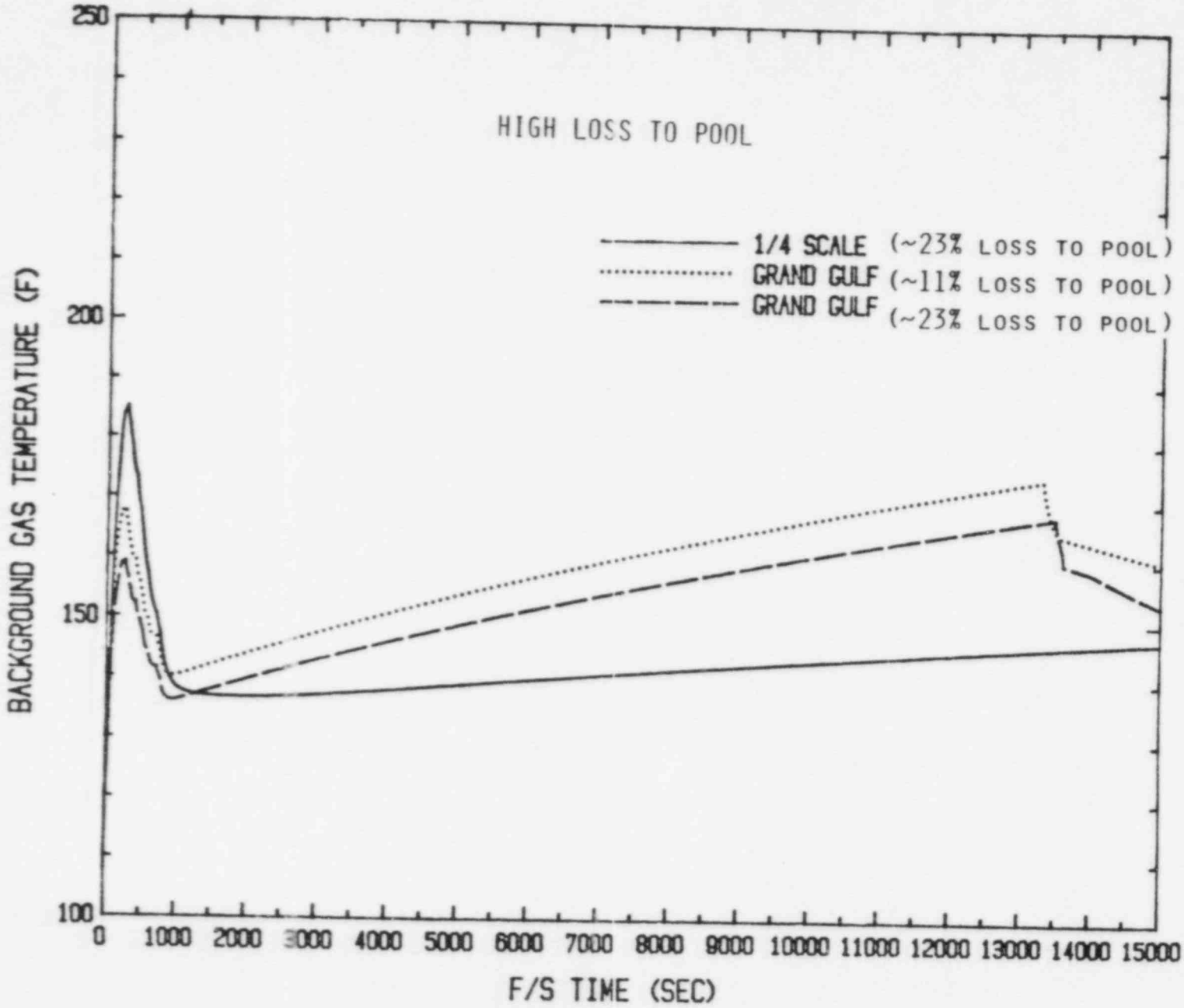


WALL PLUME CALCULATIONS REV - E121085

0.15 LB/S TAIL



WALL PLUME CALCULATIONS REV - E121085

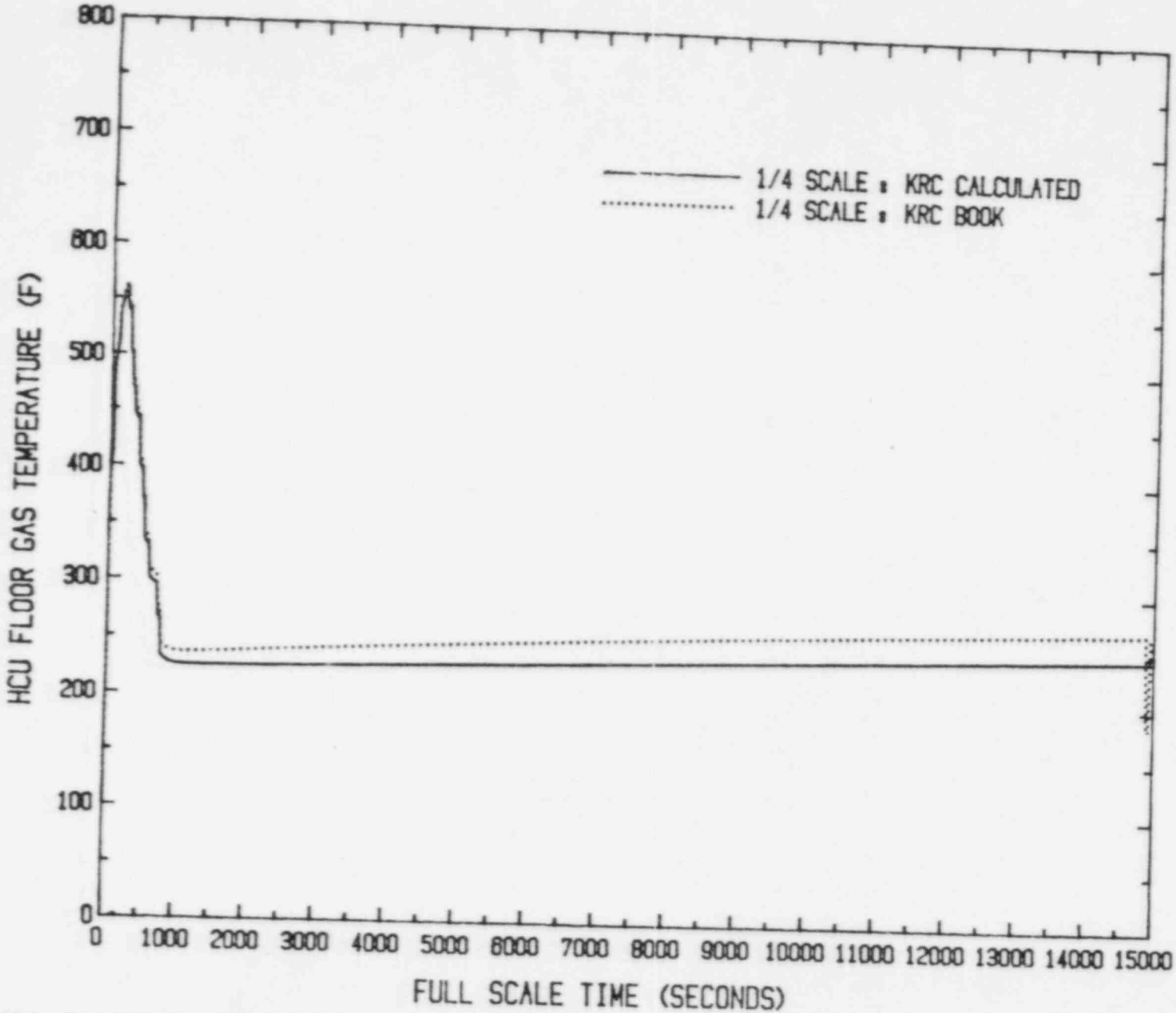


WALL PLUME CALCULATIONS REV - E121085

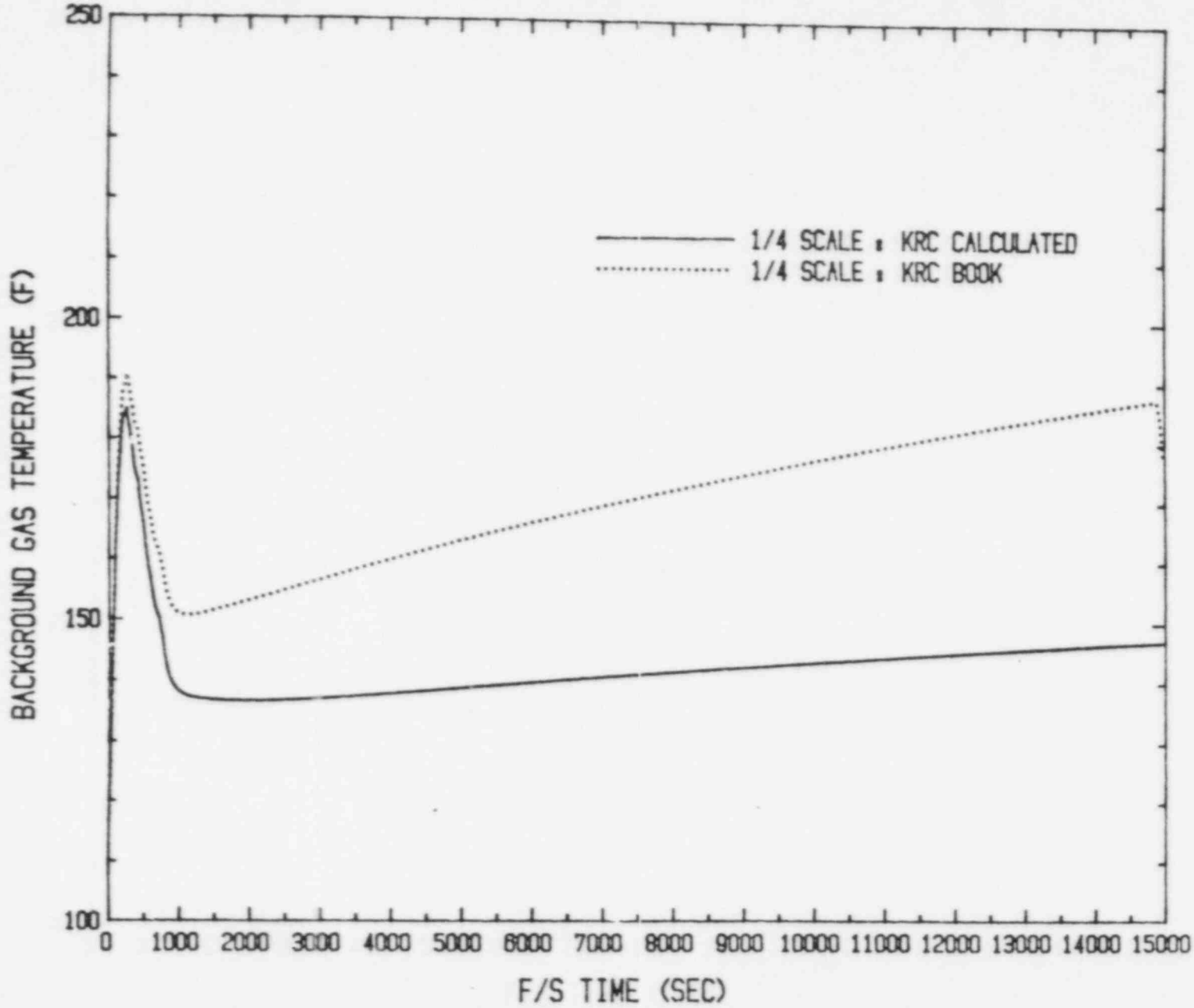
SENSITIVITIES STUDIES

CASE 1 INCREASE LINE PLUME LENGTH TO 1/9TH OF INNER WALL CIRCUMFERENCE, IN AN INTERMEDIATE VERSION OF THE MODEL. THE RELATIVE DIFFERENCES BETWEEN GRAND GULF AND 1/4-SCALE PRACTICALLY DID NOT CHANGE.

CASE 2 EFFECT OF $K_{\rho C}$ SEEN IN THE FOLLOWING PLOTS.



WALL PLUME CALCULATIONS REV - E121085



WALL PLUME CALCULATIONS REV - E121Ø85

SUMMARY

- Calculations made for a Mark III unit and 1/4-scale facility.
- Based on current model predictions, peak HCU floor gas temperatures calculated for the Mark III unit are equivalent to or slightly nonconservative relative to those for the 1/4-scale facility, depending on the treatment of pool heat losses.
- Gas temperature levels achieved during long tail at 0.15 lbs/sec are affected by wall property assumptions. Further evaluation in progress.

CONCLUSION

- WITHIN MODEL ACCURACY THE 1/4-SCALE FACILITY APPEARS TO PROVIDE A REASONABLE SIMULATION OF THERMAL ENVIRONMENT IN MARK III CONTAINMENTS.

- IMPROVED WALL THERMAL PROPERTY DATA FOR ACTUAL PLANT ARE NEEDED TO PROVIDE QUANTITATIVE ASSESSMENT OF APPLICABILITY OF 1/4-SCALE DATA TO FULL SCALE CONDITIONS.