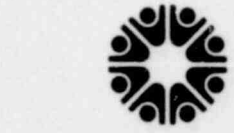
COBRA-TF DEVELOPMENT



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COBRA-TF DEVELOPMENT

COBRA-TF is a two-fluid, three-field thermal hydraulic model being developed for best estimate safety analysis of light water reactors. In particular it is being developed for hot bundle analysis and analysis of Upper Head Injection System equipped PWR's.

In COBRA-TF, entrained liquid is treated as a separate field, allowing it to have a velocity different than the continuous liquid field. This is an essential feature if one is to compute reflood hydrodynamics correctly. A model for the reflood entrainment rate is under development and has been used to perform some reflood simulations of FLECHT data.

Although COBRA-TF began as a subchannel code, the momentum equations have been extended to model full three-dimensional flow. The code has been generalized to allow the nodalization of the entire reactor vessel and its internals. Nodalization of any complexity may be used to form anything from a simple one-dimensional representation to complex three-dimensional vessel models. In addition, COBRA-TF has been implemented into TRAC-PIA as the vessel module by the Pacific Northwest Laboratories. The resulting code, referred to as COBRA/TRAC has the capability to model the entire primary system using COBRA-TF to model vessels and TRAC-PIA to model one-dimensional components.

COBRA/TRAC is currently being used to simulate semiscale and FLECHT experiments and to perform pretest calculations for the JAERI SCTF blocked reflood experiments. Future work plans call for the use of COBRA/TRAC in simulating semiscale UHI experiments and performing full scale UHI LOCA calculations as well as continuing present efforts on JAERI and FLECHT.

OUTLINE

- BACKGROUND
- OBJECTIVES
- MODEL HIGHLIGHTS
- SEMISCALE SIMULATIONS
- REFLOOD MODEL AND SIMULATIONS (J. M. KELLY)
- JAERI SCTF SIMULATION

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PERSONNEL

FLUID DYNAMICS AND NUMERICS - M. J. THURGOOD, T. L. GEORGE

HEAT TRANSFER - J. M. KELLY, K. L. BASEHORE

SIMULATIONS - J. M. CUTA, K. L. BASEHORE

GRAPHICS - A. S. KOONTZ

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BACKGROUND

- FULL VESSEL SIMULATION
  - SIX-EQUATION MODEL
  - BLOWDOWN THROUGH REFLOOD
  - BOUNDRY CONDITIONS FROM SYSTEM CODE
- INITIAL REFLOOD CALCULATIONS WITH REZONING MESH ROD MODEL
- INITIAL ENTRAINMENT CALCULATIONS

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OBJECTIVES

- DEVELOP HOT BUNDLE ANALYSIS CAPABILITY
  - COMPATIBLE WITH TRAC
  - UTILIZE FRAP-T
  - INCLUDE RADIATION
- DEVELOP UHI SYSTEM SIMULATION CAPABILITY
  - COMPLEX VESSEL GEOMETRY
  - LOOP

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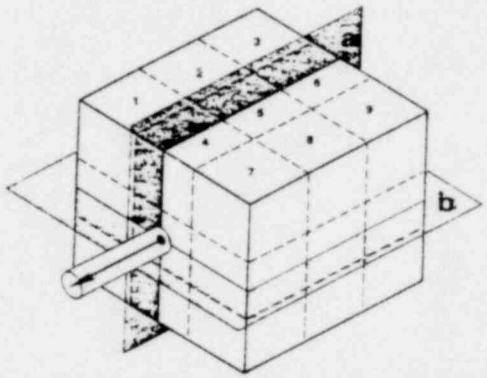
STATUS

- HOT BUNDLE
  - FRAP-TS IMPLEMENTATION BEGUN
  - RADIATION MODEL UNDER DEVELOPMENT
- UHI SYSTEM CAPABILITY
  - VESSEL MODEL USED TO SIMULATE:
    - FULL SCALE PWR WITH UHI
    - SEMISCALE MOD 3
    - FLECHT REFLOOD EXPERIMENTS
  - COBRA-TF IMPLEMENTED INTO TRAC-P1A
  - COBRA/TRAC BEING USED TO SIMULATE:
    - SEMISCALE MOD 3
    - JAERI SCTF
    - FLECHT REFLOOD

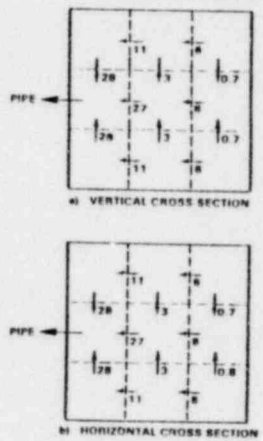
MODEL HIGHLIGHTS

- TWO-FLUID, THREE-FIELD FORMULATION
  - FULL 3-D CARTESIAN COORDINATES
  - NUMERICAL ENTRAINMENT BY DIFFUSION ELIMINATED
- GENERALIZED NODALIZATION
  - MODELING OF COMPLEX REACTOR INTERNALS
  - MULTIPLE VESSELS MODELED WITH SINGLE VESSEL COMPONENT
  - VARIABLE NODING
- SYSTEM SIMULATION CAPABILITY - COBRA/TRAC
  - TRAC-P1A 1D COMPONENTS AND CODE STRUCTURE
  - COBRA-TF VESSEL
- EFFICIENT NUMERICAL SOLUTION SCHEME
  - BASED ON NUMERICAL SCHEME DEVELOPED AT LASL

THREE DIMENSIONAL TREATMENT



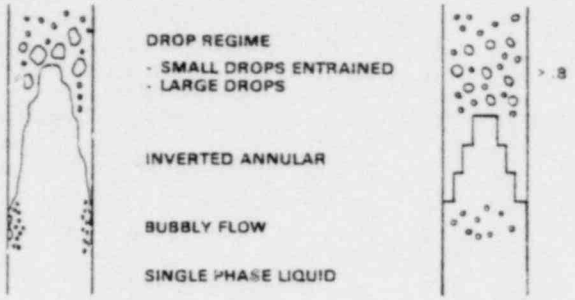
VELOCITIES AT VERTICAL AND HORIZONTAL CROSS SECTIONS THROUGH CENTER CELL



a) VERTICAL CROSS SECTION

b) HORIZONTAL CROSS SECTION

HOT WALL FLOW REGIME



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REFLOOD ENTRAINMENT MODEL

- MODEL ENTRAINMENT RESULTING FROM LIQUID CORE BREAK UP
- MAXIMUM STABLE DROP SIZE:

$$D_s = \frac{12\,\sigma_f}{\rho_v V_v^2}$$

- DROP SIZE SPECTRUM: NUKIYAMA-TANASAWA

$$PDI = 32\,\frac{\sigma^4}{D_s^3}\,e^{-4\,D_i/D_s}$$

- MAXIMUM DROP SIZE LIFTED BY VAPOR:

$$D_{max} = \frac{3/4\,C_D\,\rho_v V_v^2}{(\rho_f - \rho_v)\,g}$$

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REFLOOD ENTRAINMENT MODEL

- FRACTION OF LIQUID ENTRAINED:

$$\eta = \frac{\text{VOLUME OF LIQUID CONTAINED IN DROPS SMALLER THAN } D_{max}}{\text{TOTAL VOLUME OF LIQUID}}$$

- ENTRAINMENT RATE FOR FINITE DIFFERENCE EQUATIONS

$$S_e = \frac{D_{max}}{\Delta t}$$

- LIQUID CORE BREAKUP ASSUMED FOR LIQUID FRACTIONS LESS THAN 0.3

  (MECHANISTIC CORRELATIONS BEING INVESTIGATED)

- SAUTER MEAN DIAMETER USED TO COMPUTE INTERFACIAL TERMS

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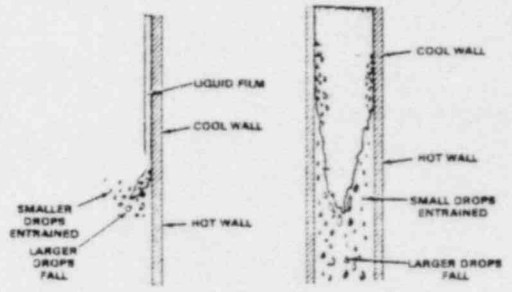
TOP FLOODING MODELS



FALLING FILM (A)

LIQUID DELUGE (B)

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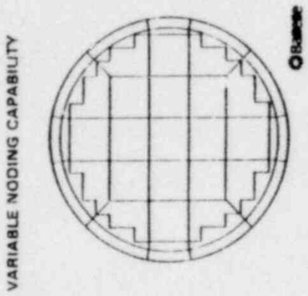
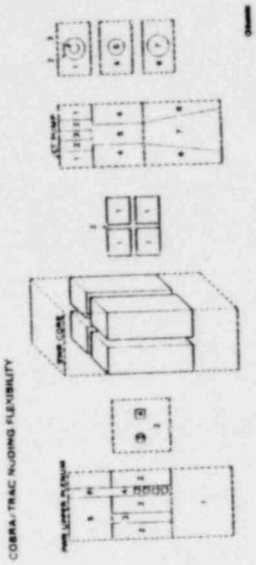
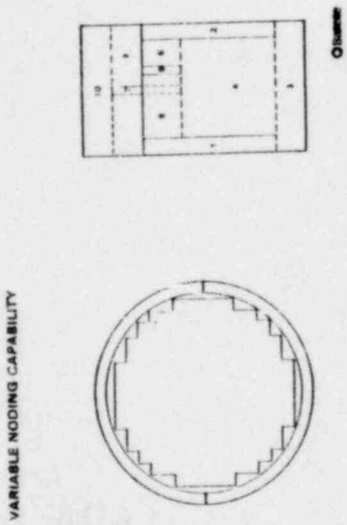
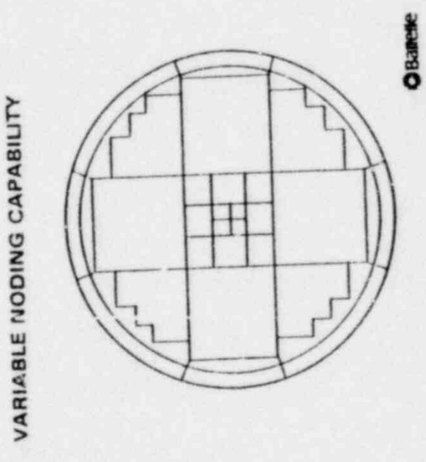
POOR ORIGINAL









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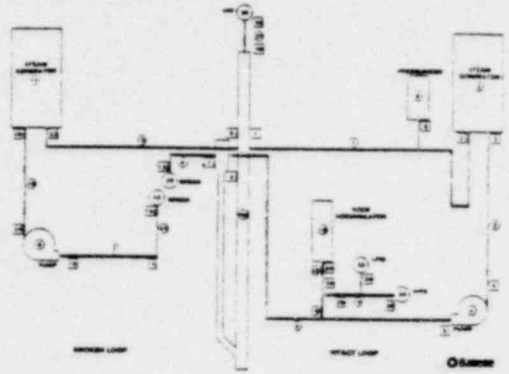
SEMISCALE MOD 3 SYSTEM



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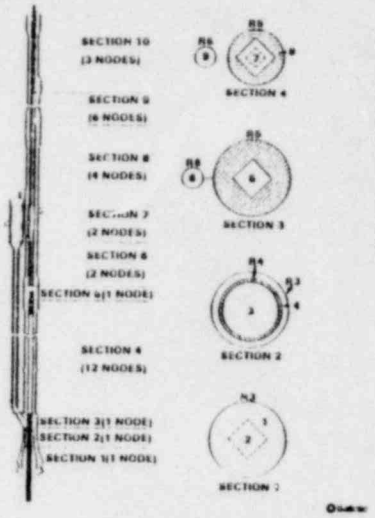
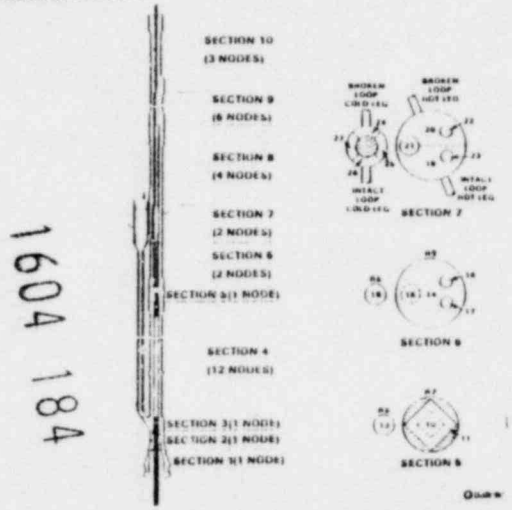
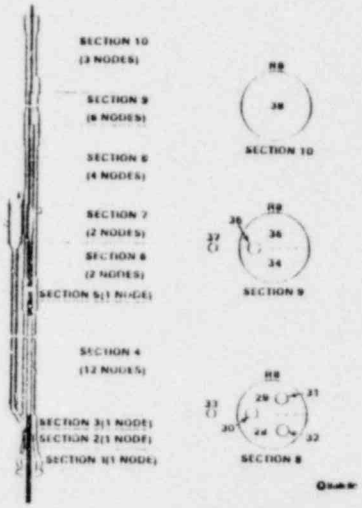


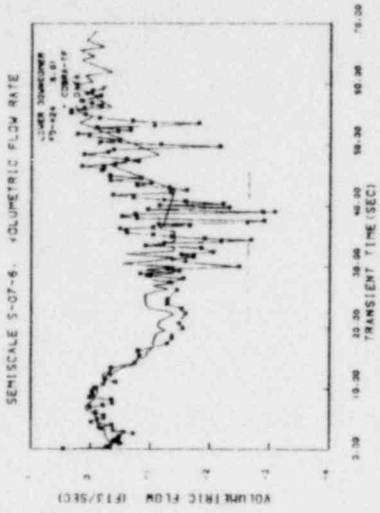
SEMISCALE MOD-3

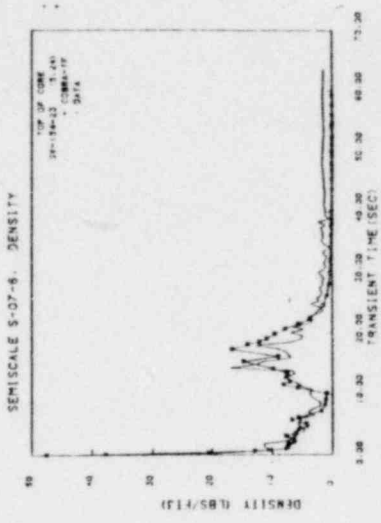


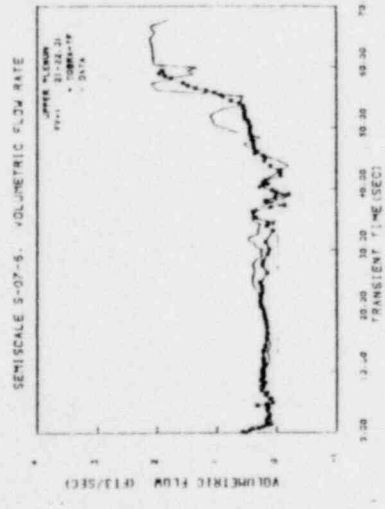
SEMISCALE MOD-3

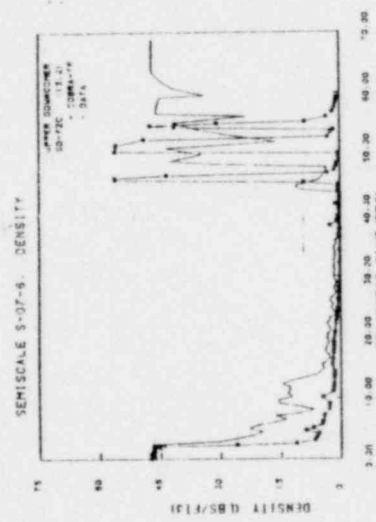


POOR ORIGINAL









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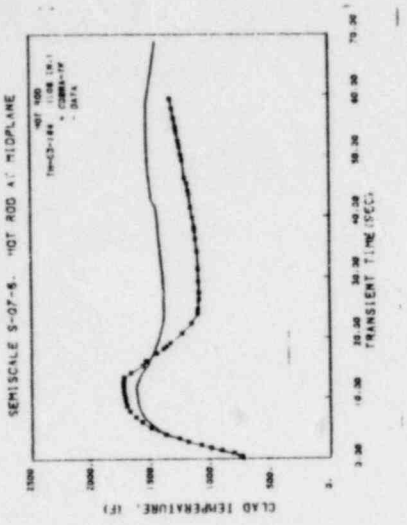

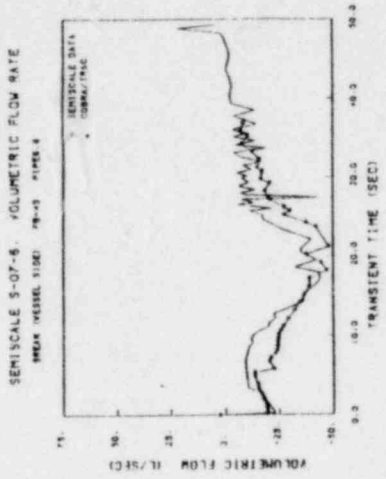

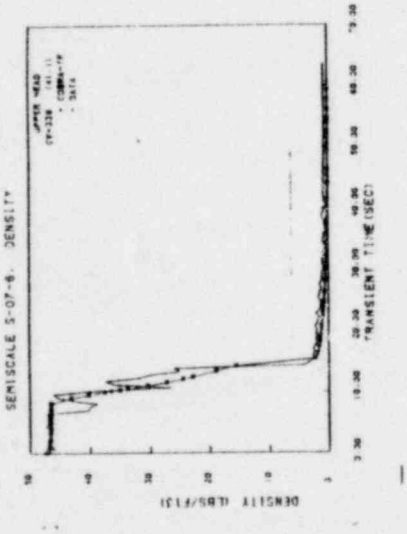

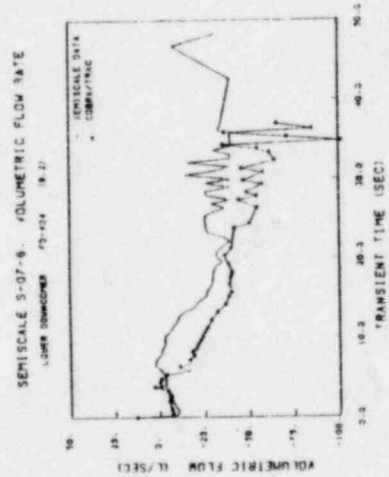

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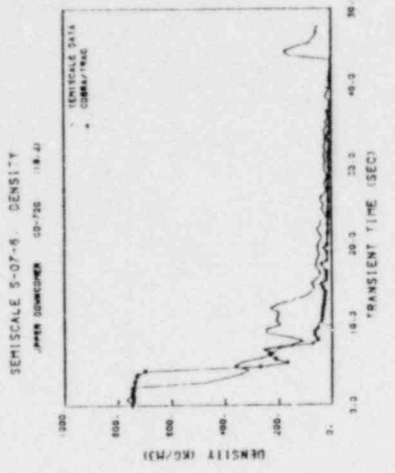

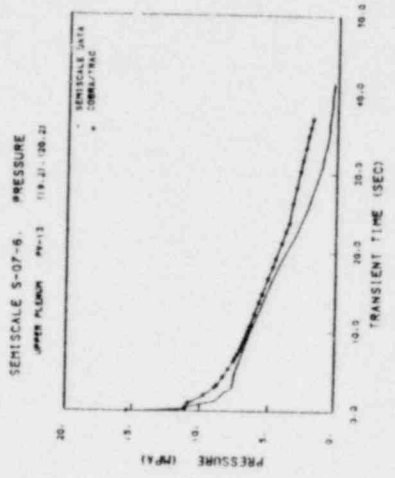

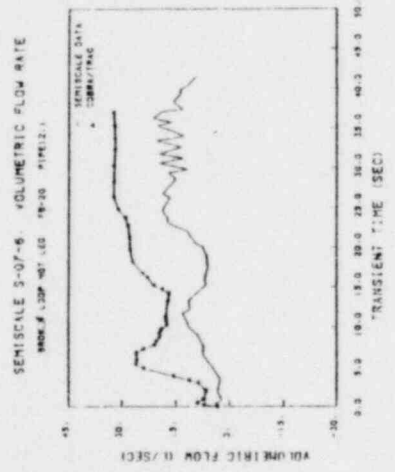

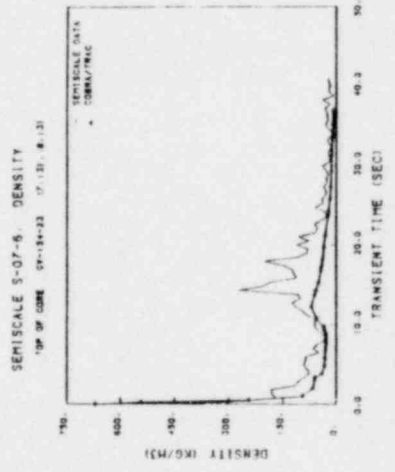

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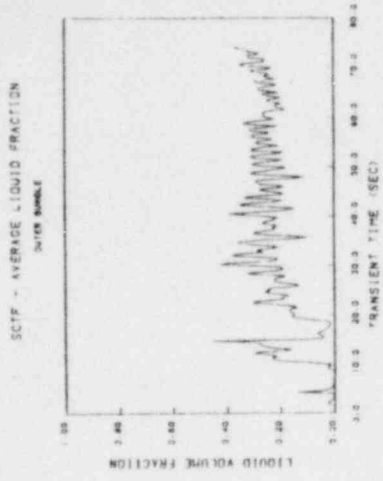

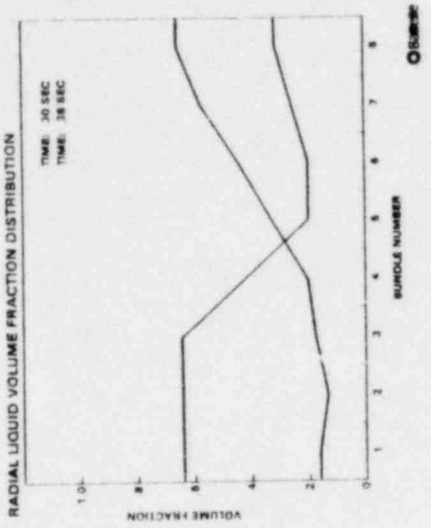

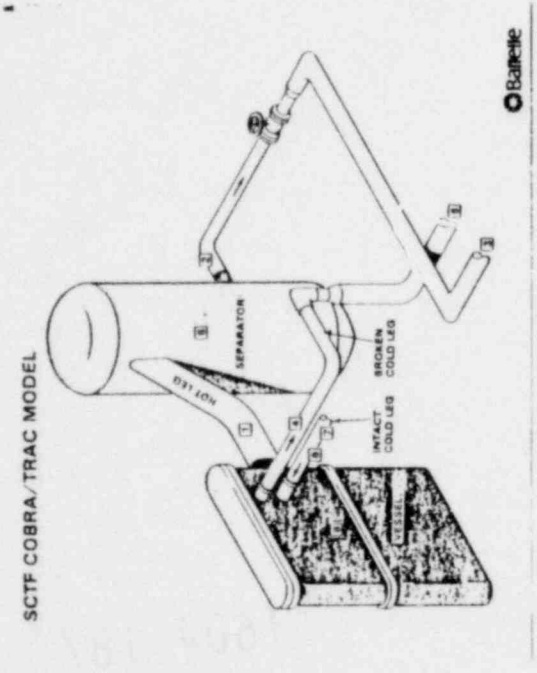

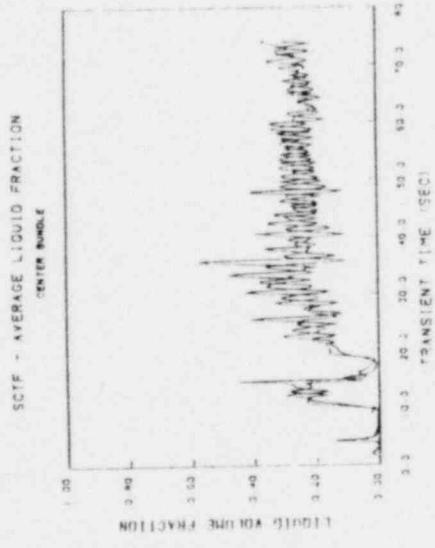

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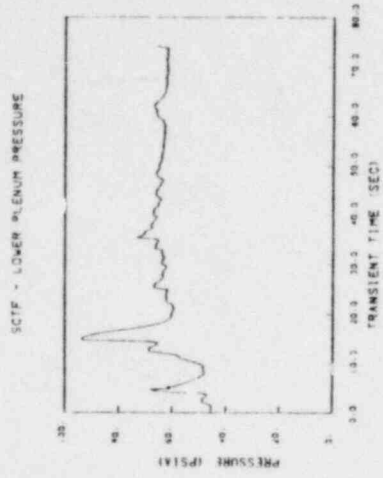

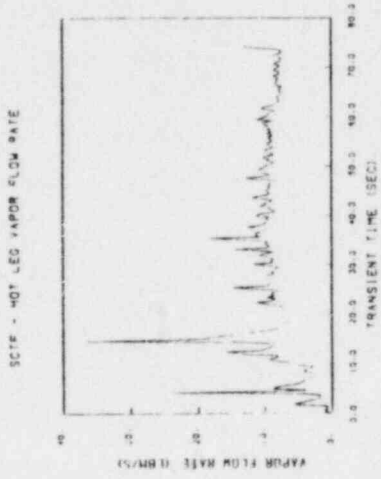

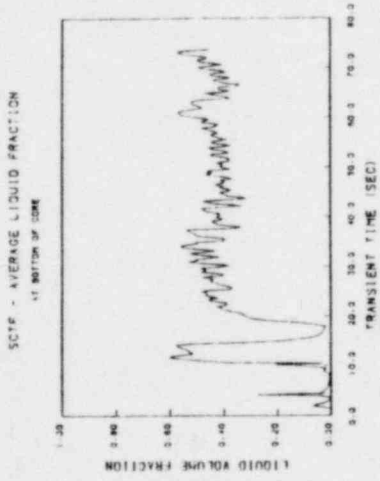

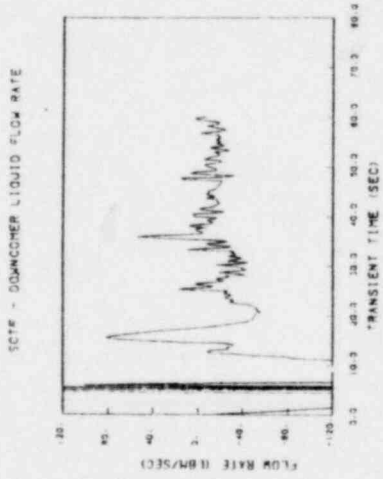

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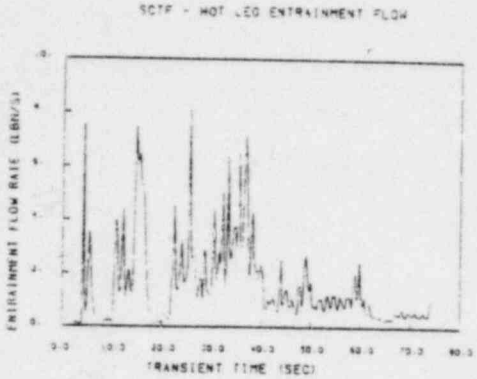

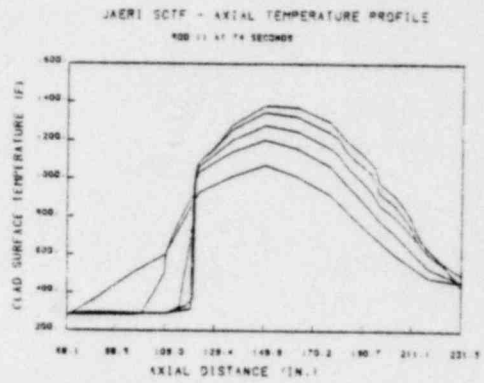

POOR ORIGINAL

PROBLEM STATISTICS

TRANSCIENT TIME: 74.4 sec

HYDRODYNAMIC CELLS: 216

AXIAL HEAT TRANSFER CELLS: 460

TOTAL EXECUTION TIME: 4.23 CP HOURS

EXECUTION TIME NORMALIZED TO HYDRODYNAMIC CELLS: $\frac{0.0043 \text{ sec}}{\Delta t \cdot \text{CELL}}$

EXECUTION TIME NORMALIZED TO HEAT TRANSFER CELLS: $\frac{0.002 \text{ sec}}{\Delta t \cdot \text{CELL}}$

AVERAGE TIME STEP: 0.0048 sec

TIME STEP LIMITATION: COURANT

SUMMARY

- MODEL ADAPTABLE TO WIDE VARIETY OF GEOMETRIES
- COBRA/ TRAC PROVIDES SYSTEM SIMULATION CAPABILITY WITH FULL THREE-DIMENSIONAL FLOW IN VESSEL
- DEVELOPING MECHANISTIC MODEL FOR REFLOOD THERMAL-HYDRAULICS

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