# RELAP5 - CODE DEVELOPMENT AND APPLICATIONS

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The RELAP5 project objective is to produce an economic and user-convenient code for application in light water reactor (LWR) loss-of-coolant accident (LOCA) experimental programs being conducted at INEL. RELAP5 is an advanced, one-dimensional, fast-running system analysis code under development for the U.S. Nuclear Regulatory Commission, Reactor Safety Research (USNRC-RSR). It is a completely new code based on nonhomogeneous, nonequilibrium hydrodynamic model and features top-down structural design, with the significant programming of elements coupled in modular fashion. To a great extent, the development of RELAP5 has been influenced by the experience gained through the development and usage of the RELAP4 series of codes.

The RELAP5 code includes the thermal-hydraulic and mechanical models used to describe the processes that occur during blowdown of a LWR. Component process models are included for pipes, branches, abrupt flow area changes, pumps, check valves, plant trips, heat transfer and critical flow. These, as well as other models, have been integrated into a versatile and user-convenient system code framework. The code is now operational and has been tested on hypothetical problems as well as for simulation of actual experiment systems.

The RELAP5 hydrodynamic model is a five field equation, two-fluid model. The model consists of the two phasic continuity equations, the two phasic momentum equations, and an overall energy equation. In this model only two interphase constitutive relations are required, those for interphase drag and interphase mass exchange. An additional specification that one of the phases exists at the local saturation state eliminates the need to specify any energy transfer partitioning, either interphase or from the wall. Experience has shown that the least massive phase can be assumed to exist at the saturation state.

Special process models have been developed for abrupt area changes, branching, choking, pumps, accumulators, and valves. This approach eliminates the need for localized fine nodalization and the attendant computational speed limitations. Some of the process as well as constitutive models have been obtained with little or no development work by converting existing RELAP4 models to SI units and dynamic storage to be compatible with RELAP5. Models obtained in this manner include pumps, valves, trips, heat transfer correlations, and some input features.

The RELAP5/MOD"0" CDC 7600 blowdown version of the code is complete and has been sent to the National Energy Software Center (NESC). A three volume code description and users manual is available from NESC. A version of the code compatible with the entire CDC 6600-7600 and 175 class machine is being sent to NESC and in the interim is available from INEL. The current code development effort consists of extending the code to include consideration reflood, small break and operational transient phenomena. This development effort is scheduled to culminate with a RELAP5/MOD1 version of the code.

The modeling additions/improvements to be included in the RELAP5/MOD1 code are: (1) polytropic expansion accumulator model, (2) a noncondensable component, (3) reflood heat transfer correlations, (4) small break horizontal flow and break flow stratification models, (5) reactor kinetics, and (6) several general code improvements for increased user convenience and faster run time.

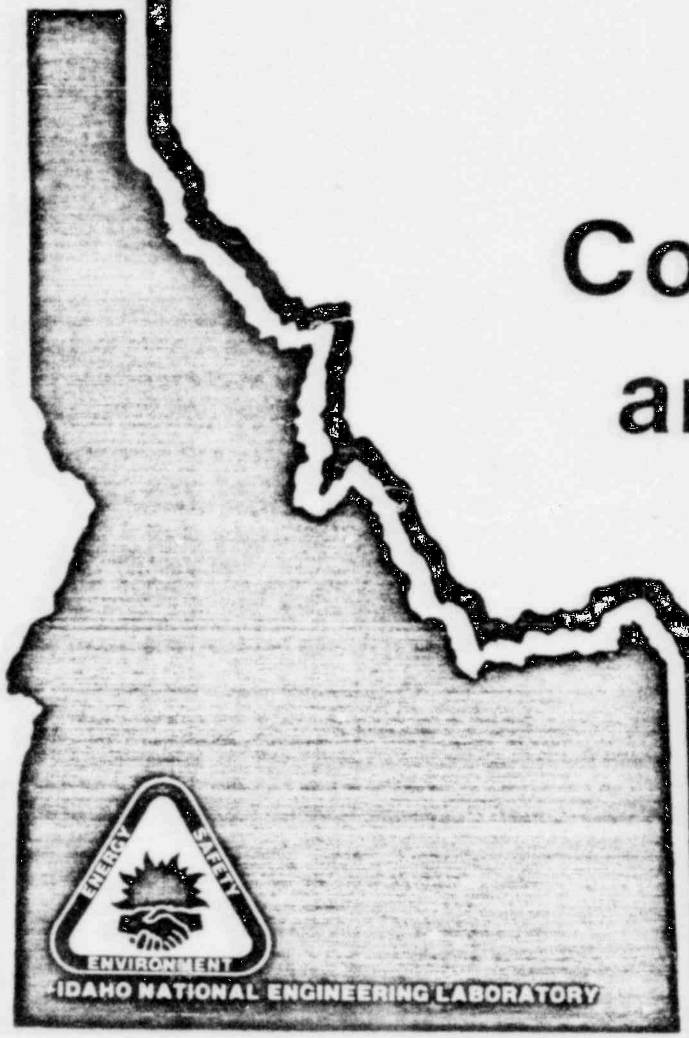
Recent applications of the RELAP5 code include analysis of the Semiscale test S-07-6 downcomer depletion phenomena,analysis of the Semiscale UHD1 (Upper Head Drain Test 1) upper head and system behavior, and the pre and post prediction of the LOFT L3-0 test. These applications of the code demonstrate the ability of the hydrodynamic and thermal model to accurately represent the complex two-phase flow with heat transfer which is present in simulated loss-of-coolant accidents.

The RELAP5 code is a fast-running code and test calculations have demonstrated the potential of several improvements (now under development) to significantly increase calculational speed. As an example, the L3-0 simulation to 2400 s required 2.[illegible] hrs of CDC 7600 CPU time. However, the post calculations using degeneration to equilibrium has shown that the CPU time can be reduced to less than 1400 CPU second for 2400 s of simulated system transient.

# RELAP5

## Code Development and Applications

Presented by
V.H. Ransom

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# RELAP5 Program Objective

- Economic advanced 1-D BE code

  Approach

  - User convenience
  - Advanced two-phase model
  - Fast numerical scheme
  - Utilize RELAP4 technology

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# RELAP5 Features

User conveniences

- Component oriented input
- Input diagnostics
- Modular structure
- SI/British I/O - SI internal

Hydrodynamics

- Nonhomogeneous - nonequilibrium
- Four constitutive relations
- Mechanistic process models
- 2-D to 1-D mapping

System code

- Linear semi-implicit solution
- Time step control algorithim
- Dynamic storage

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# RELAP5 Hydrodynamic Model

- Five field equation two fluid
  - Overall mass continuity
  - Difference of phasic mass continuity
  - Overall momentum
  - Difference of phasic momentum
  - Overall internal energy
- Primary dependent variables

  $P, X_s, X_a, V_g, V_f, U_g, U_f$

- Supplemental specification

  $Xa + Xs < 0.5$ vapor phase saturated $U_s = U_s^s (Ps)$

  $Xa + Xs \geq 0.5$ liquid phase saturated $U_f = U_f^s (Ps)$



INEL-S-9212

# RELAP5/MOD"0"

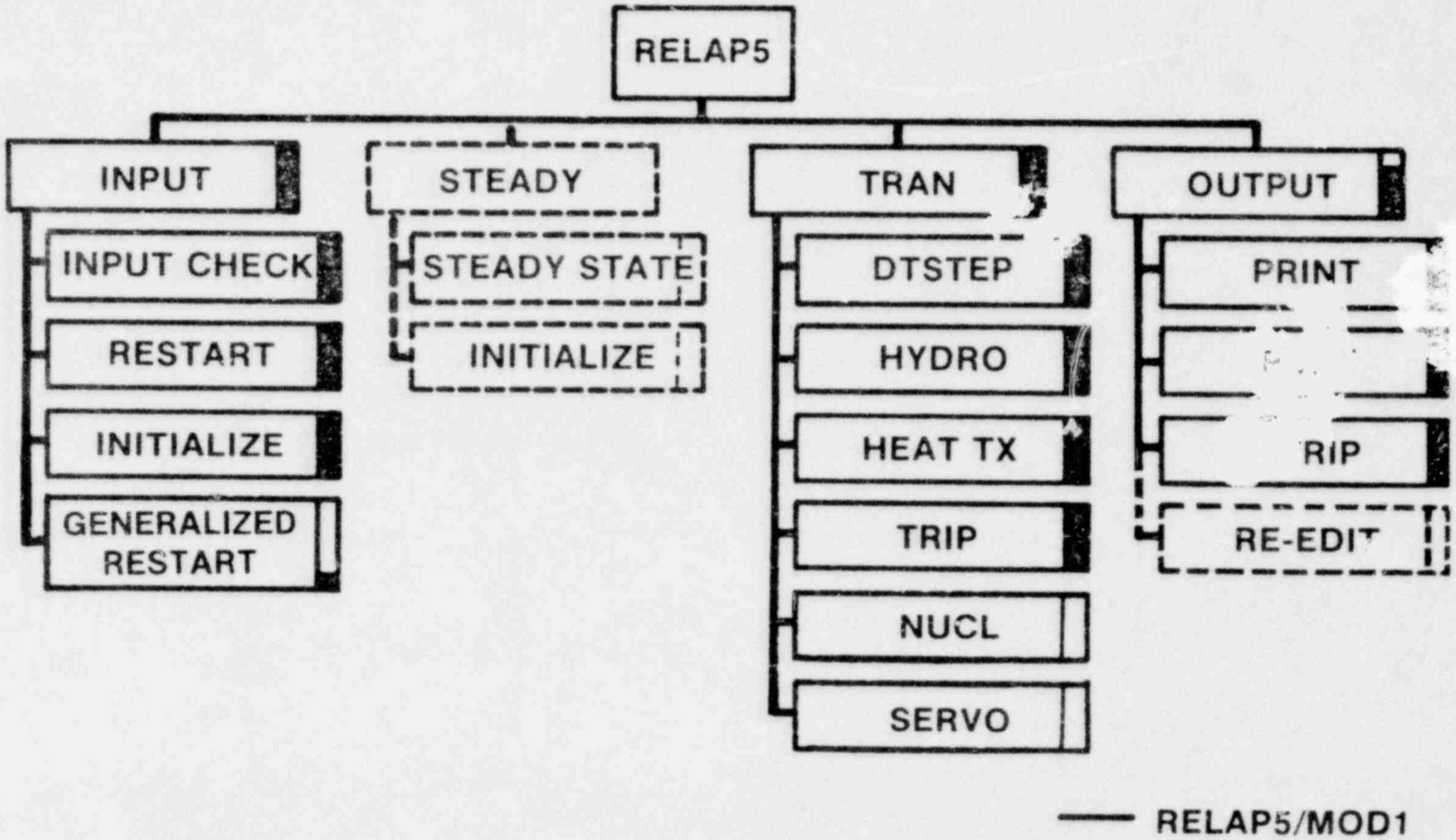
- Thermal hydraulics system code
  - Blowdown heat transfer
  - Single component
  - Specified system inflows
- Released to NESC - 5/17/79
- Documentation complete - 3 volume manual

INEL-S-22 607

# RELAP5/MOD1 Development (FY-80)

- Accumulator
- Noncondensible component
- Reflood heat transfer
- Small break stratification model
- Point kinetics
- Control systems models
- General code improvements
    - Generalized restart
    - Auto nonequ.-equ.

# RELAP5 Top Level Structure

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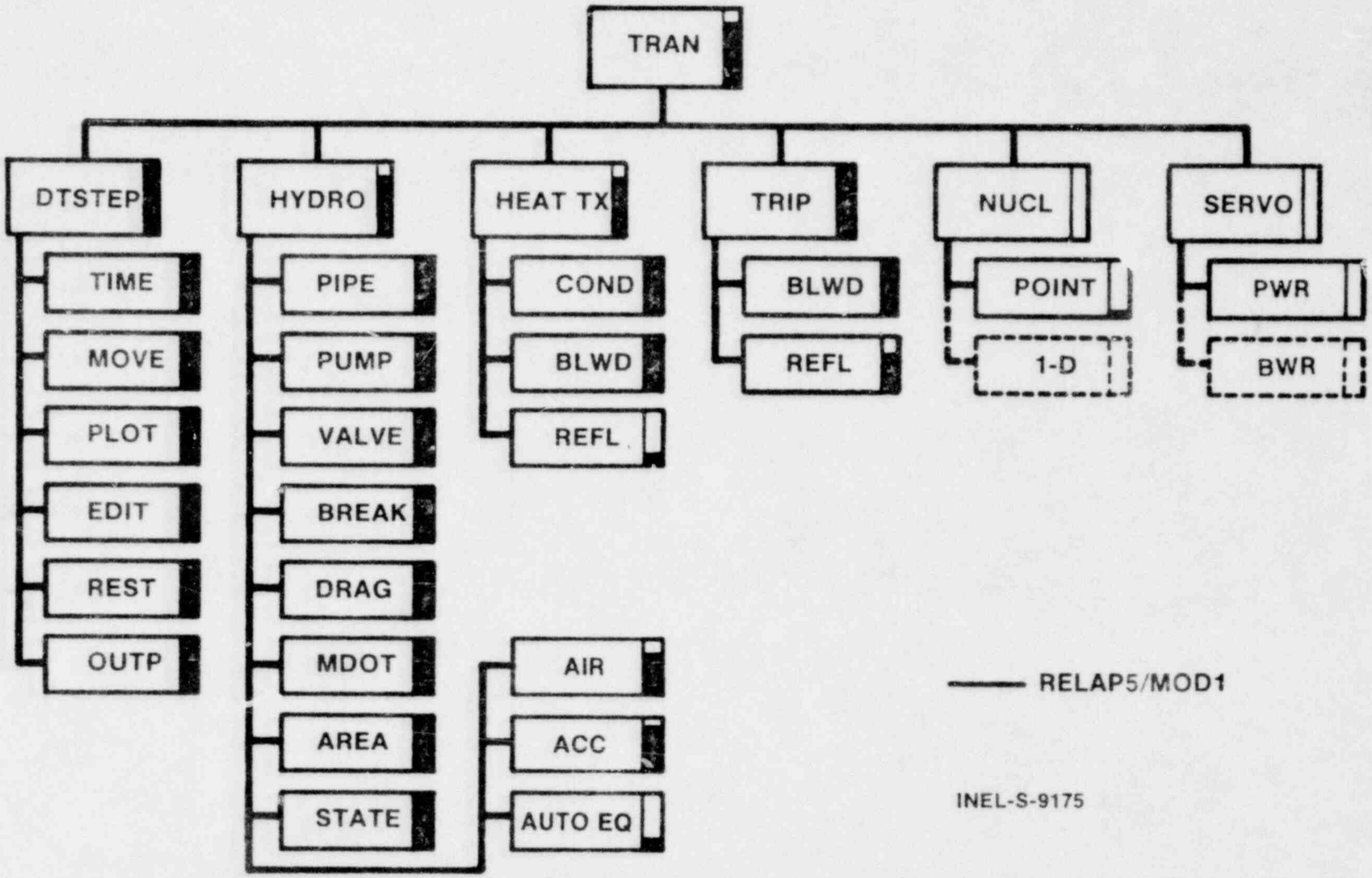
# RELAP5 Substructure

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# RELAP5 Recent Applications

- Semiscale S-07-6
- Semiscale UHDI
- LOFT L-3-0

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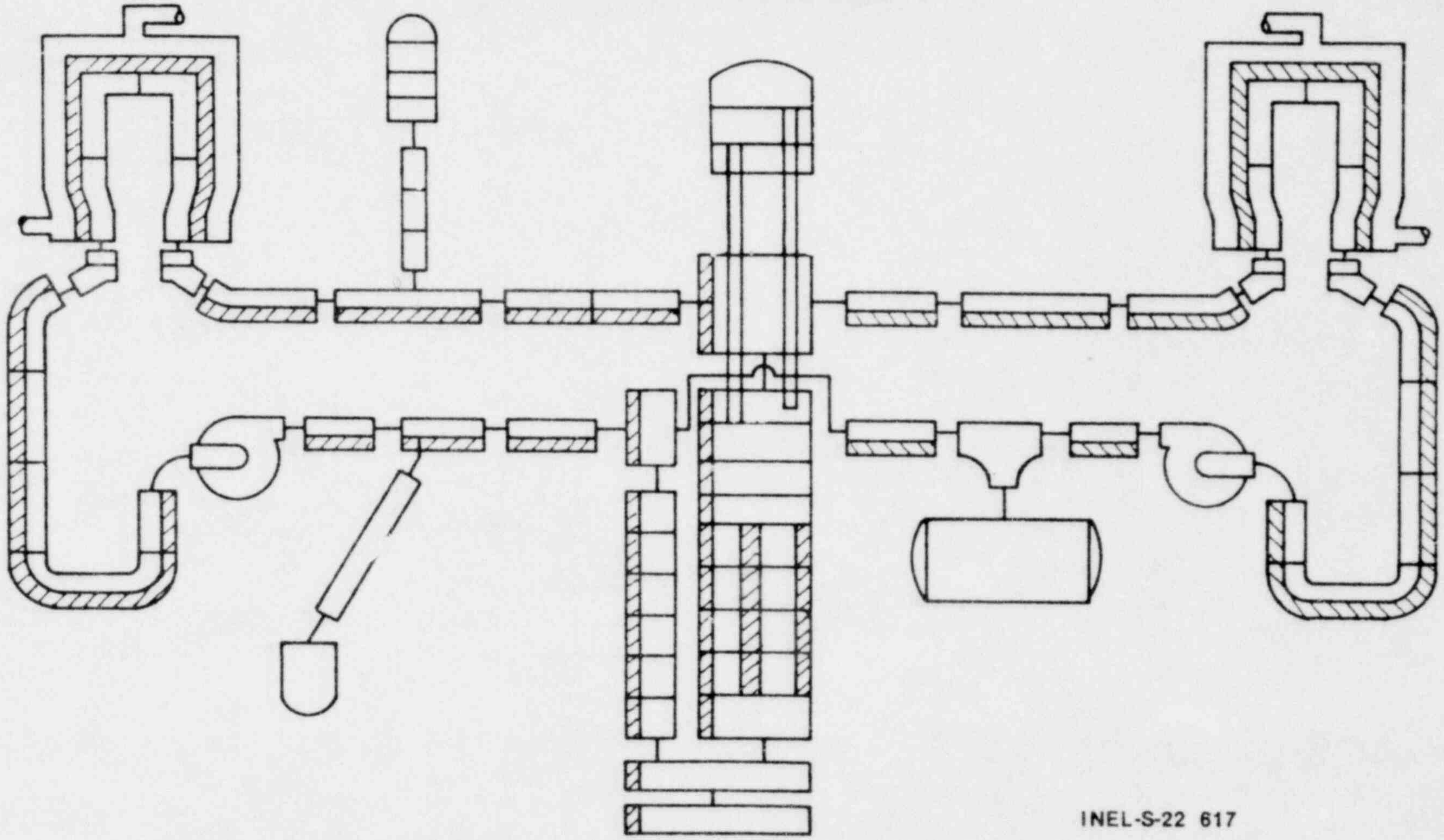
# RELAP5 Semiscale S-07-6 Model



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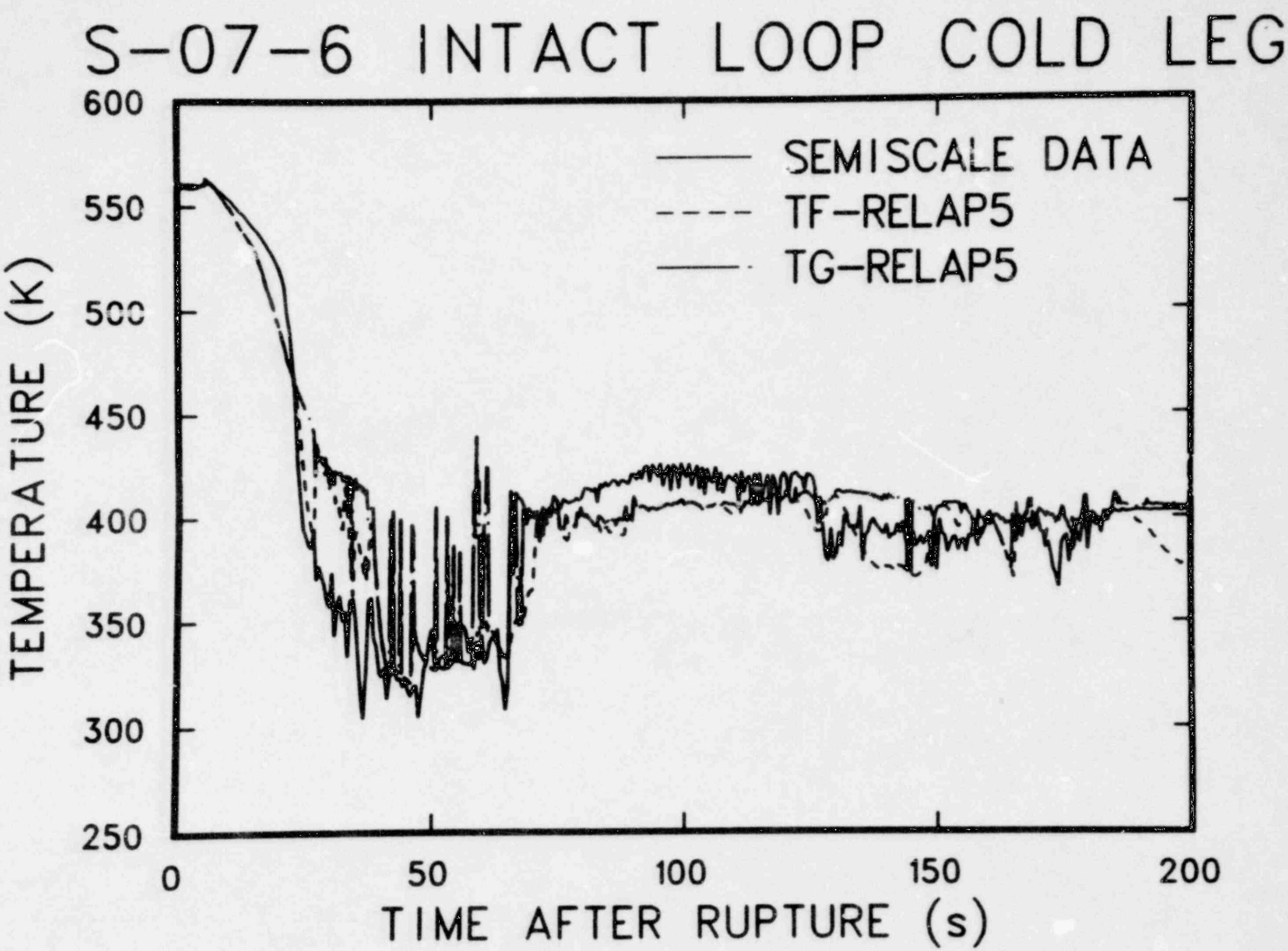
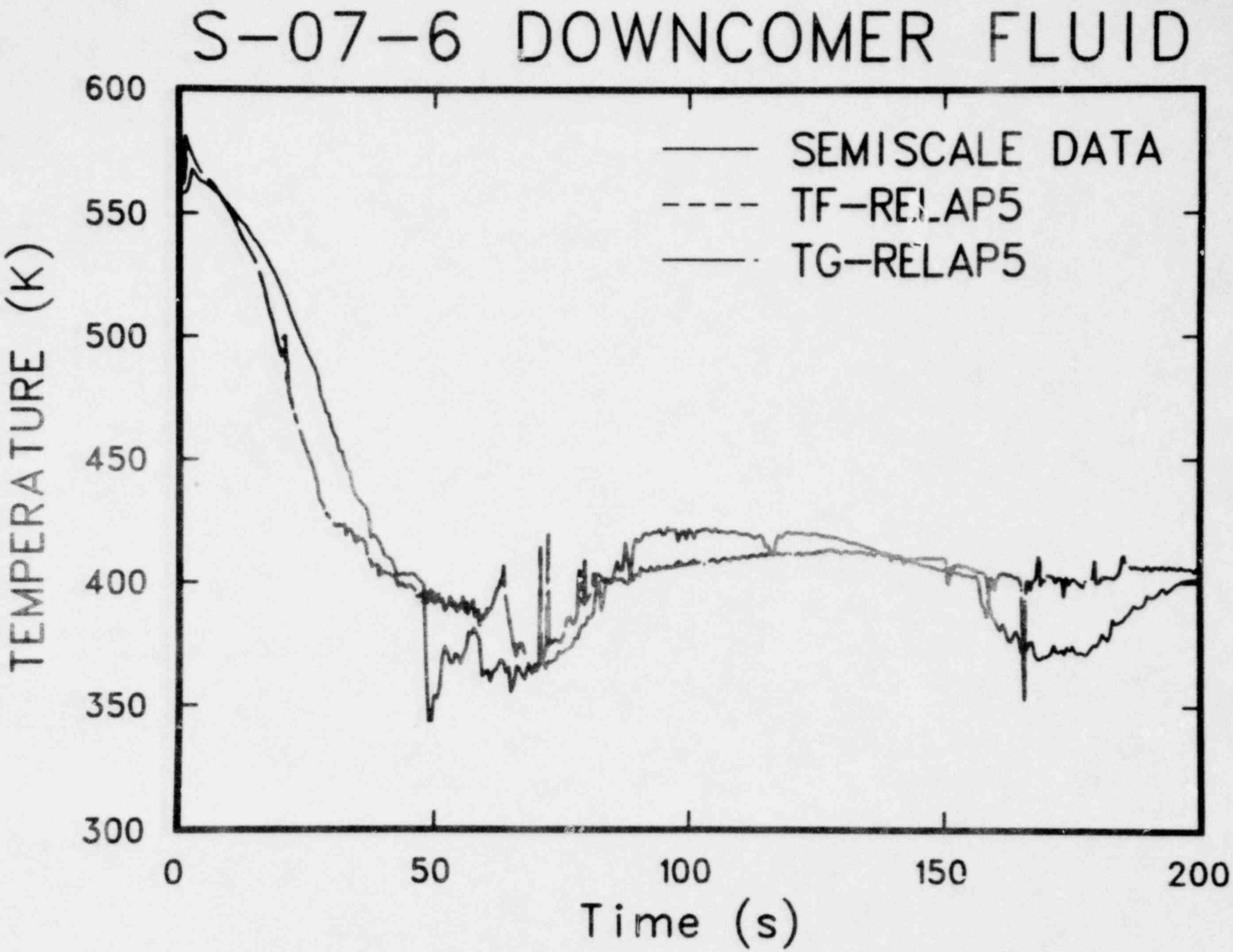
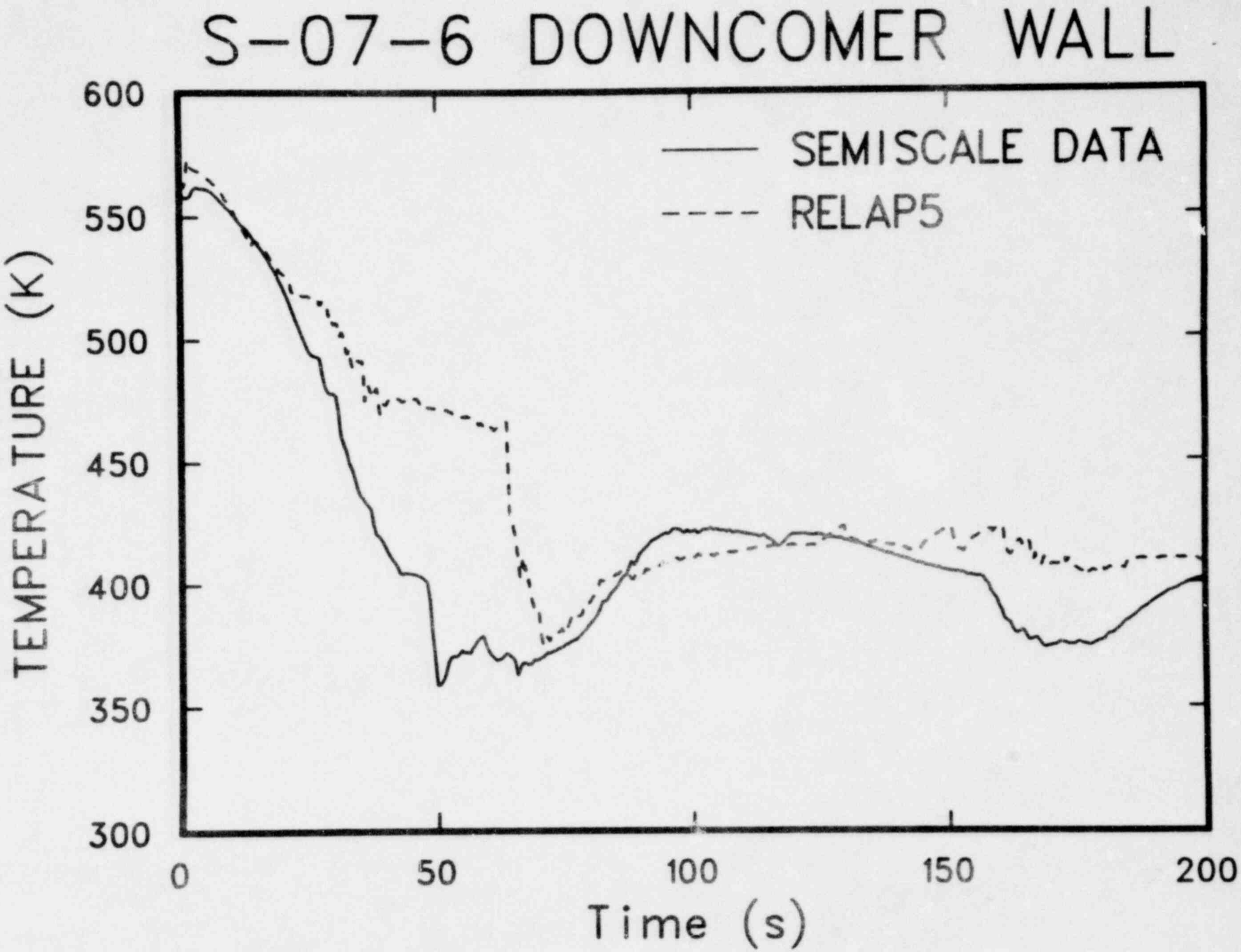

S-07-6 INTACT LOOP COLD LEG
SEMISCALE DATA
TF-RELAP5
TG-RELAP5
TEMPERATURE (K)
600
550
500
450
400
350
300
250
0
50
100
150
200
TIME AFTER RUPTURE (s)

1604 020



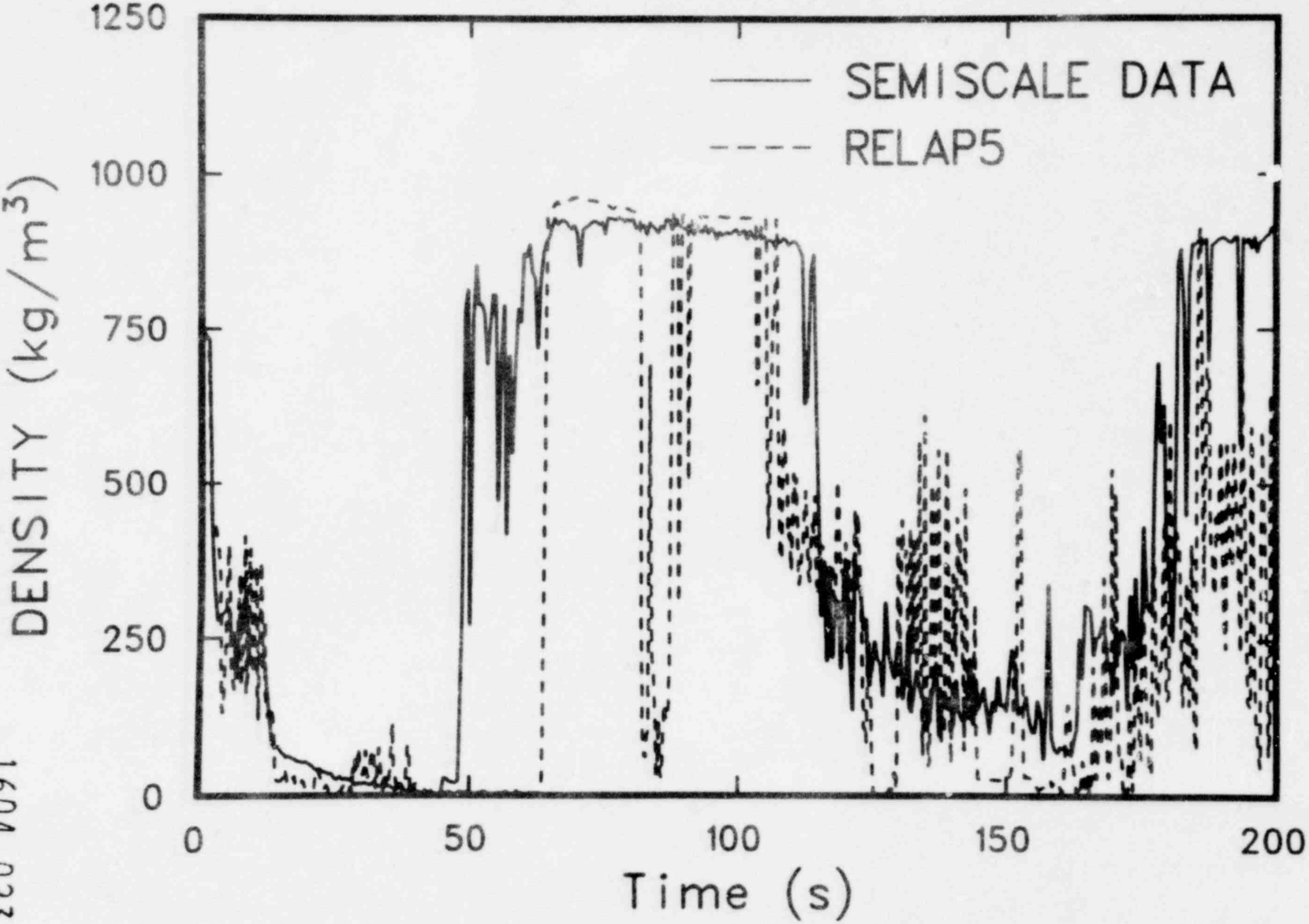
S-07-6 DOWNCOMER FLUID
SEMISCALE DATA
TF-RELAP5
TG-RELAP5
TEMPERATURE (K)
600
550
500
450
400
350
300
0
50
100
150
200
Time (s)


1604 021


S-07-6 DOWNCOMER WALL
SEMISCALE DATA
RELAP5
TEMPERATURE (K)
600
550
500
450
400
350
300
0
50
100
150
200
Time (s)

1604 022

## S-07-6 DOWNCOMER DENSITY

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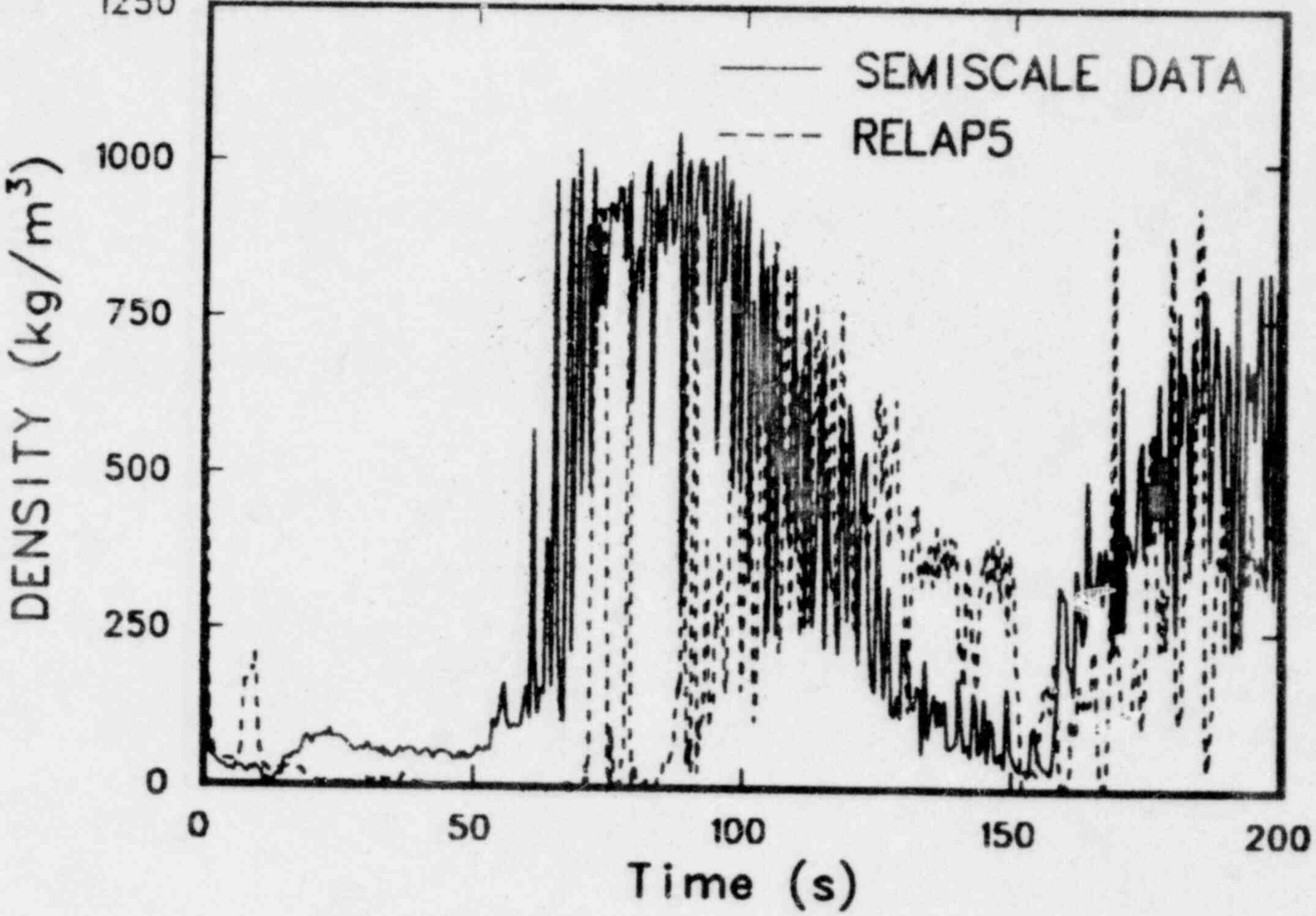
S-07-6 CORE INLET DENSITY

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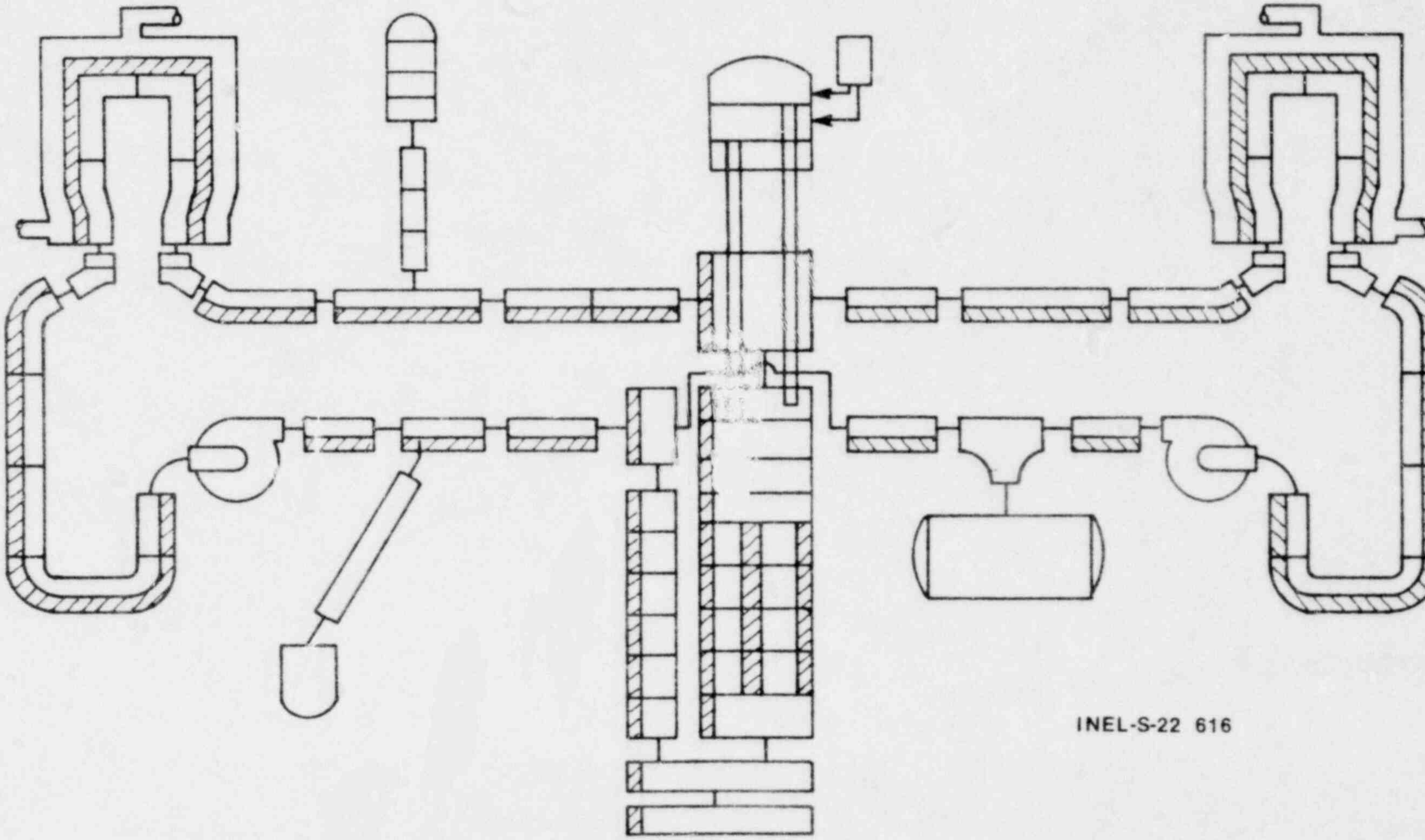
# RELAP5 Semiscale UHDI Model



INEL-S-22 616

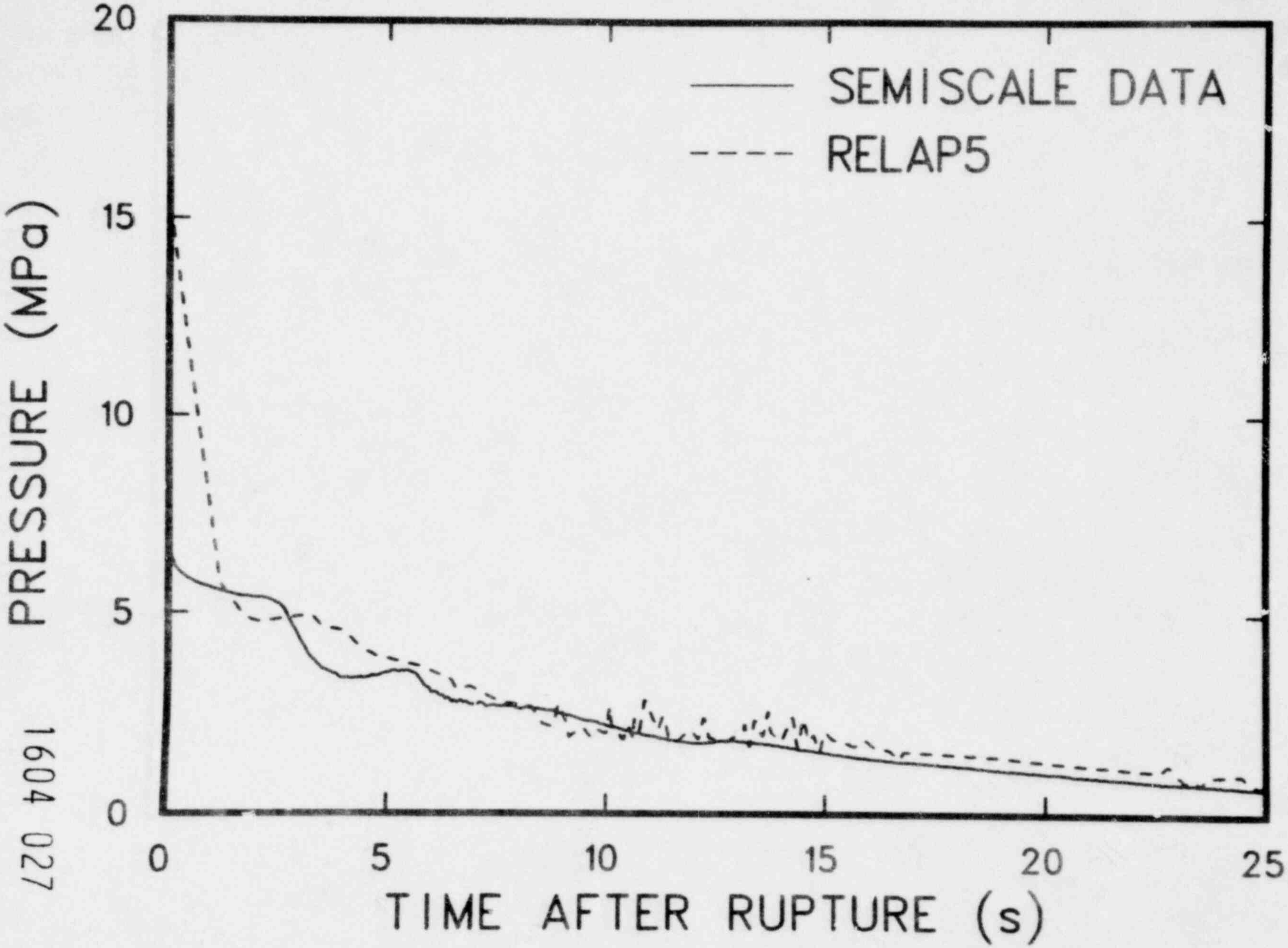
1604 025

# Semiscale UHDI Test

- Semiscale upperhead drain test
- 200% cold leg break
- Zero core power 2 s prior to rupture
- 15.5 MPa initial pressure
- Upperhead ECC at 7.75 MPa

INEL-S-22 606

# UHD1 PRESSURE UPSTREAM OF BREAK

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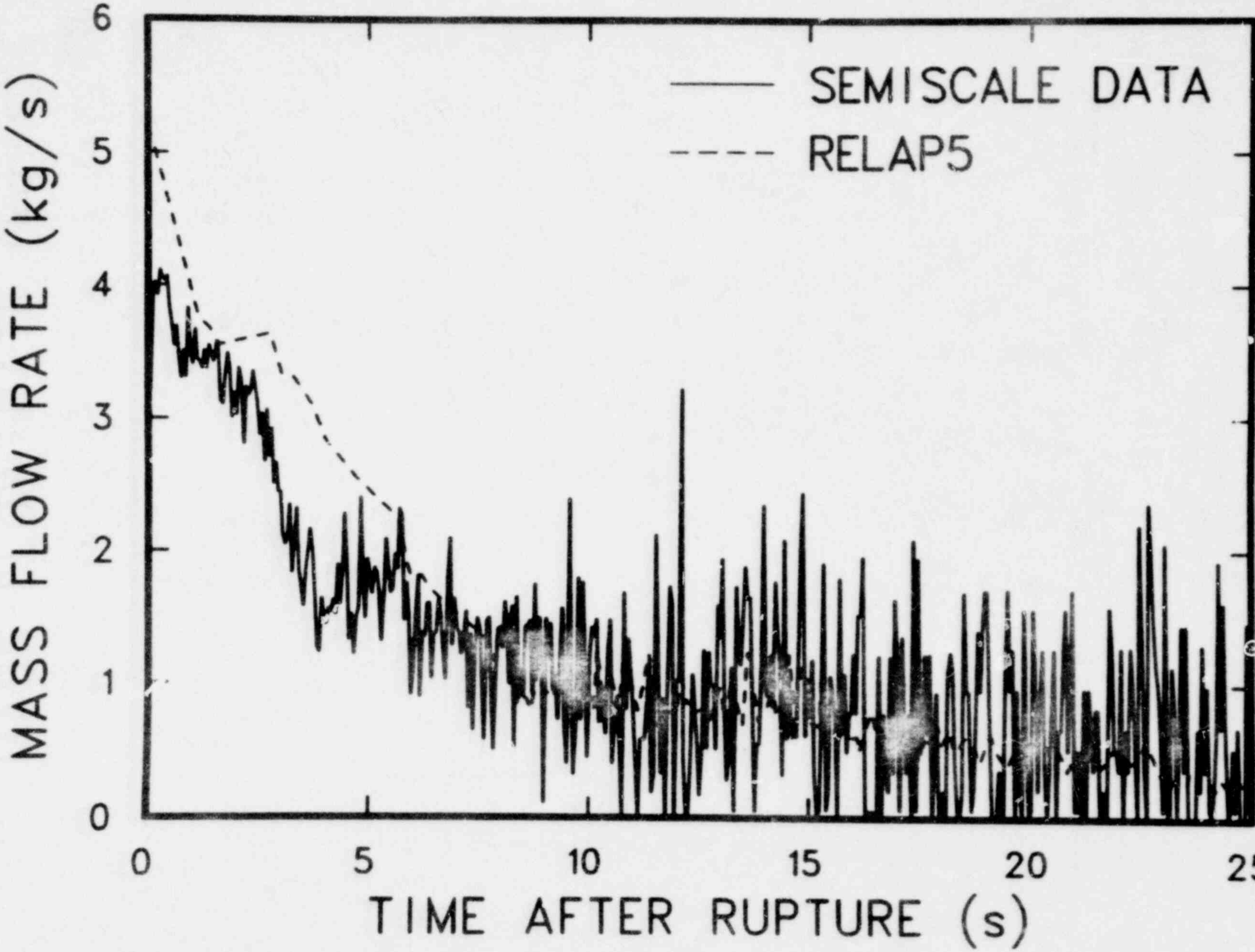
UHD1 PUMP SIDE BREAK FLOW

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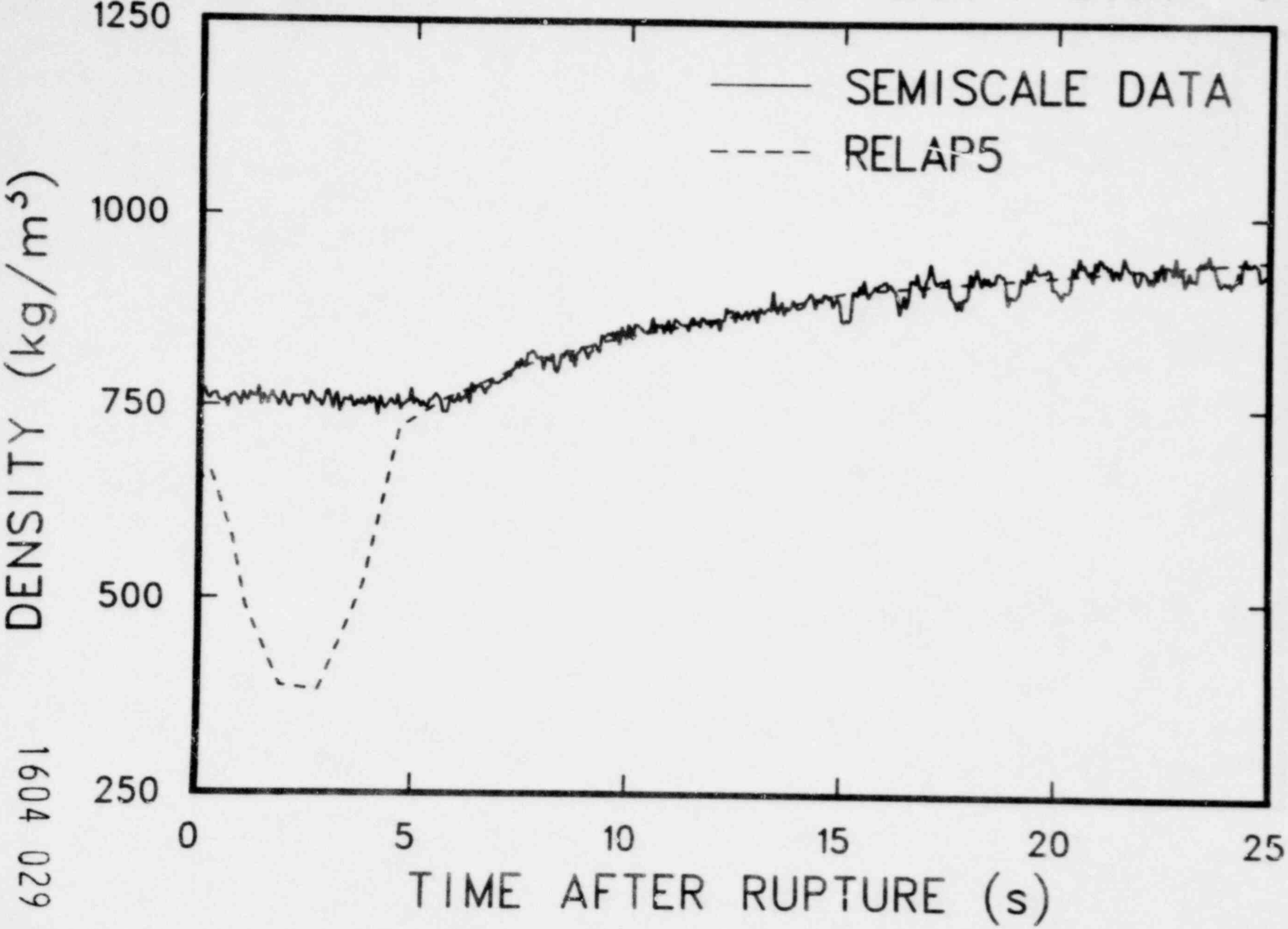
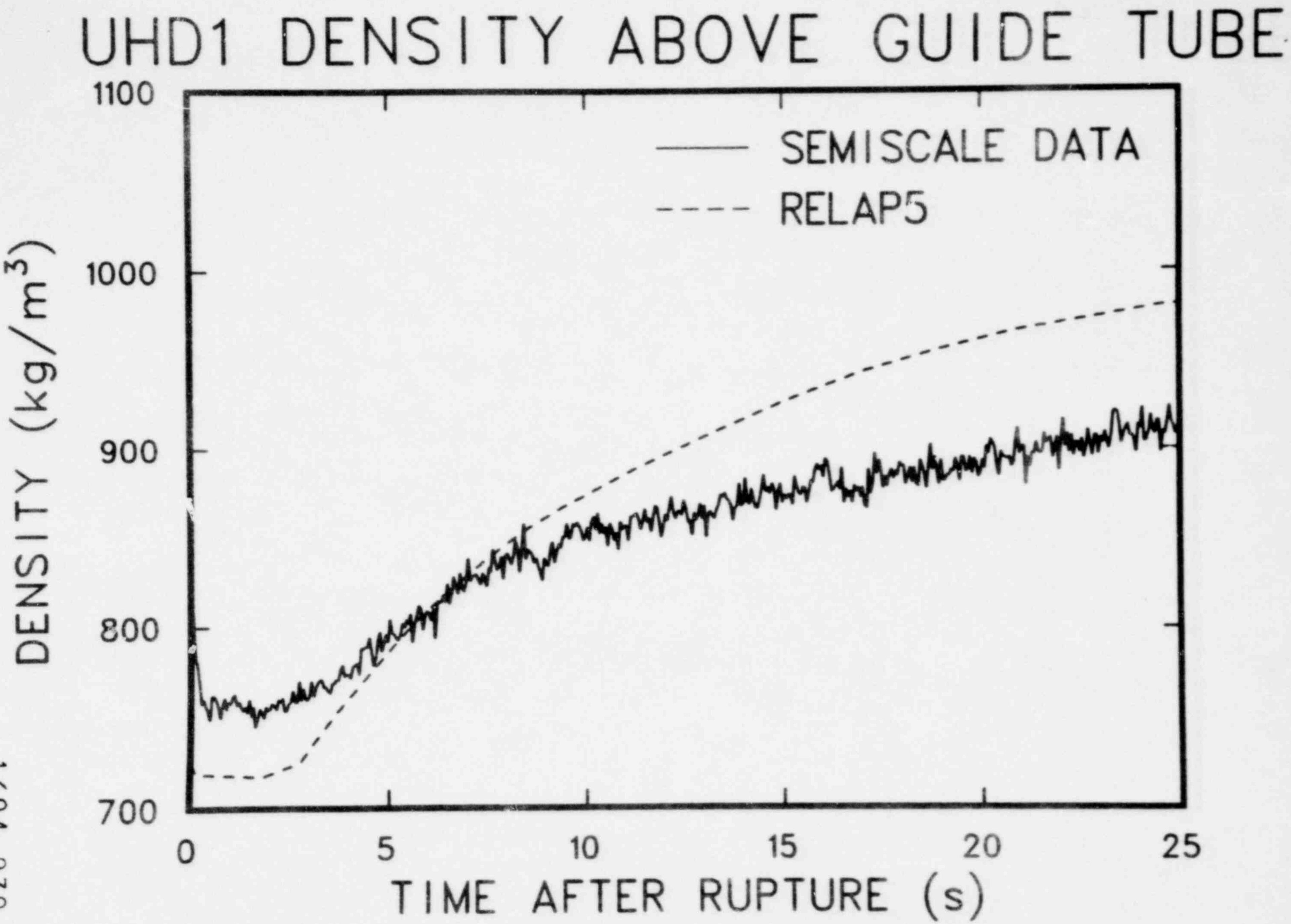
# UHD1 DENSITY ABOVE SUPPORT TUBES

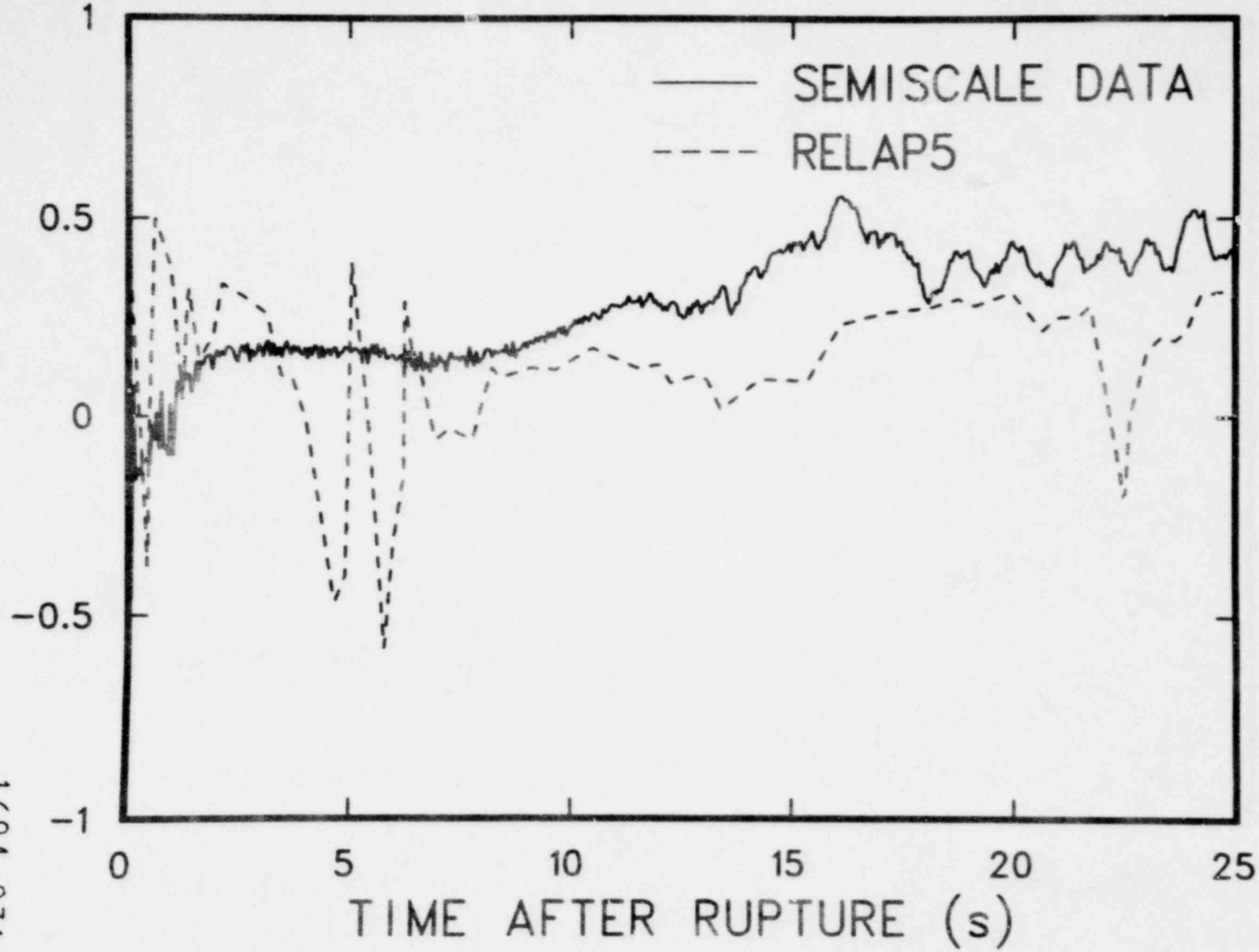



1604 029


UHD1 DENSITY ABOVE GUIDE TUBE
SEMISCALE DATA
RELAP5
DENSITY (kg/m³)
1100
1000
900
800
700
0
5
10
15
20
25
TIME AFTER RUPTURE (s)

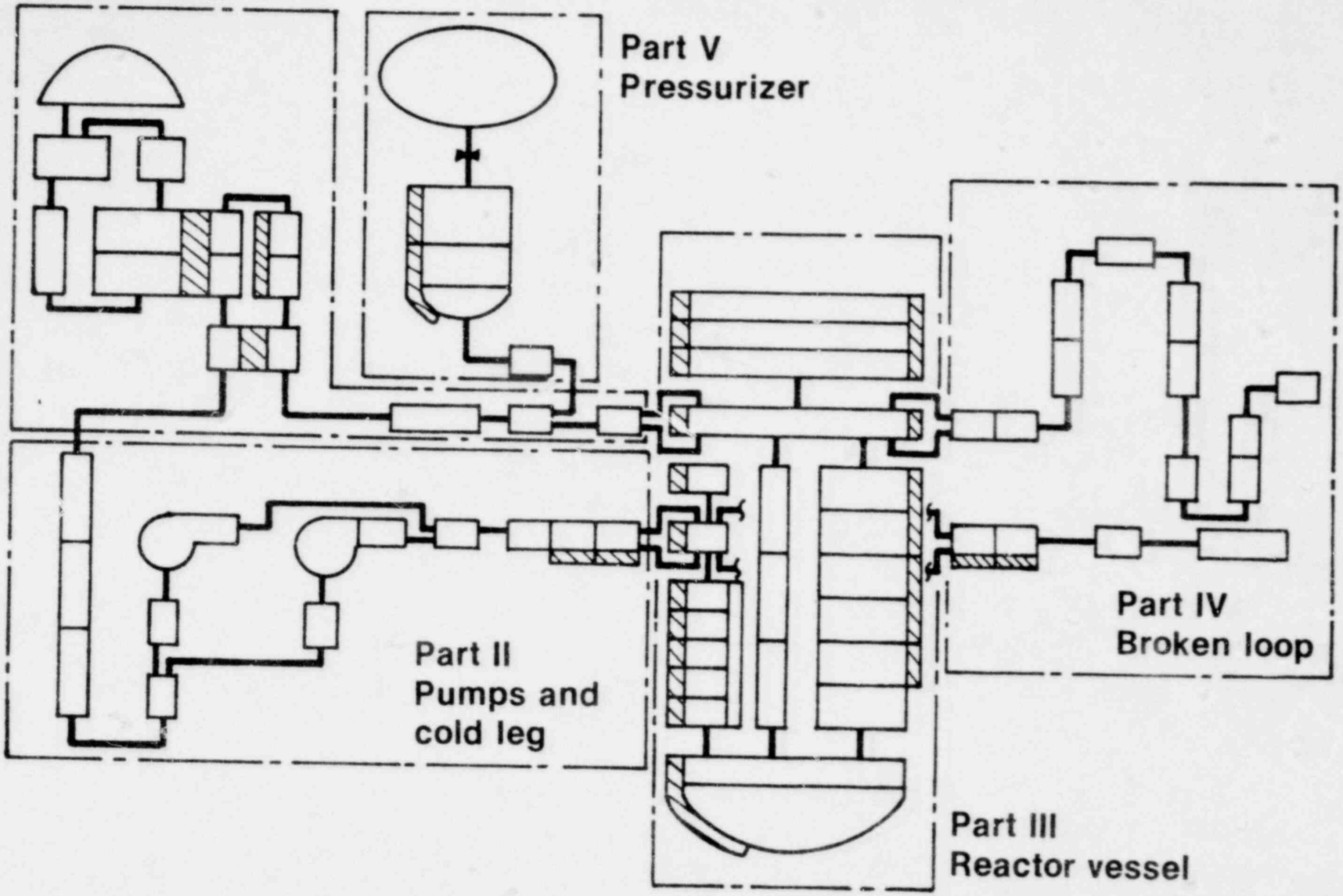
1604 030

# UHD1 INLET FLOW TO GUIDE TUBE



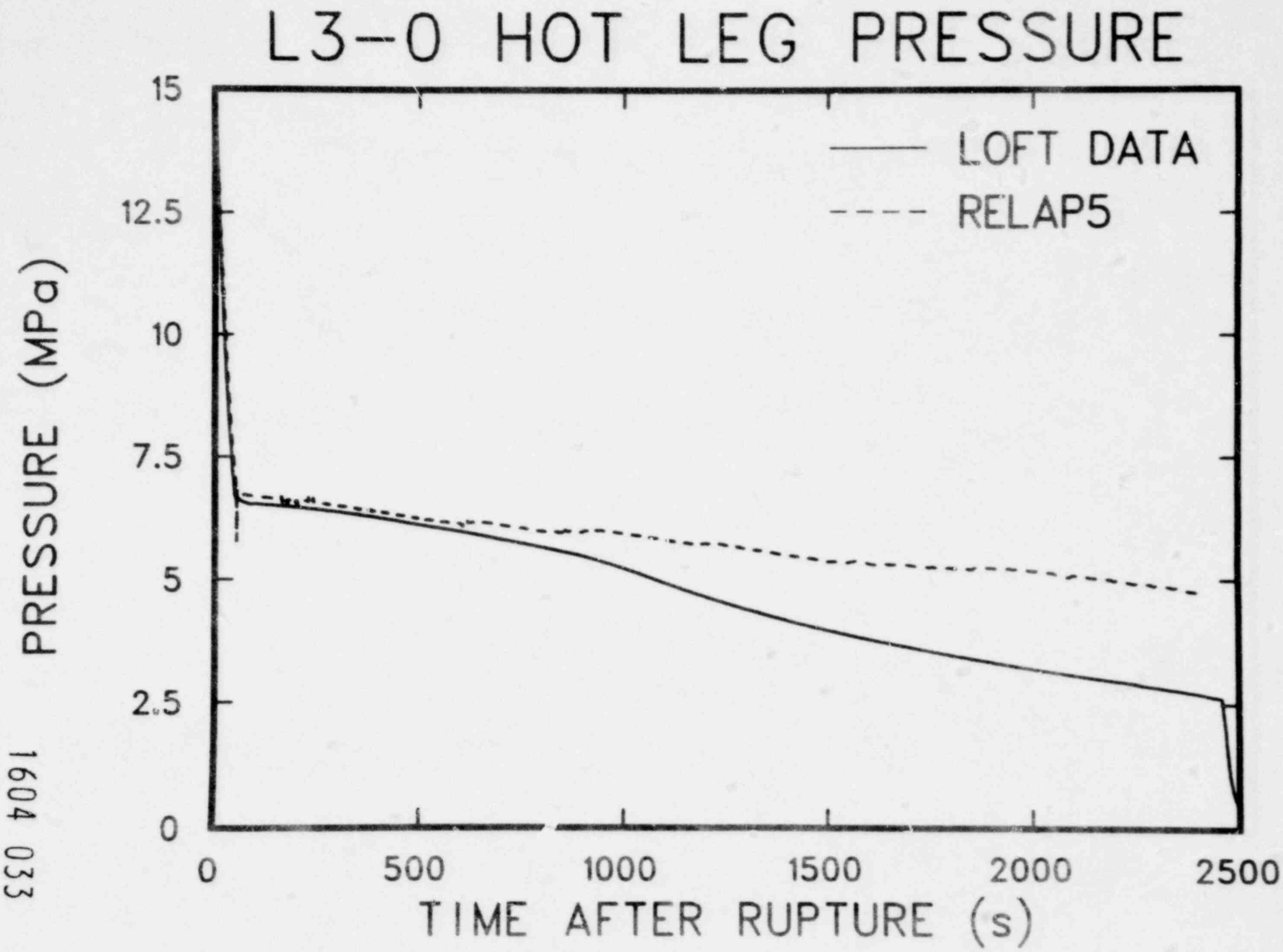

1604 031

# RELAP5 LOFT L-3-0 Model



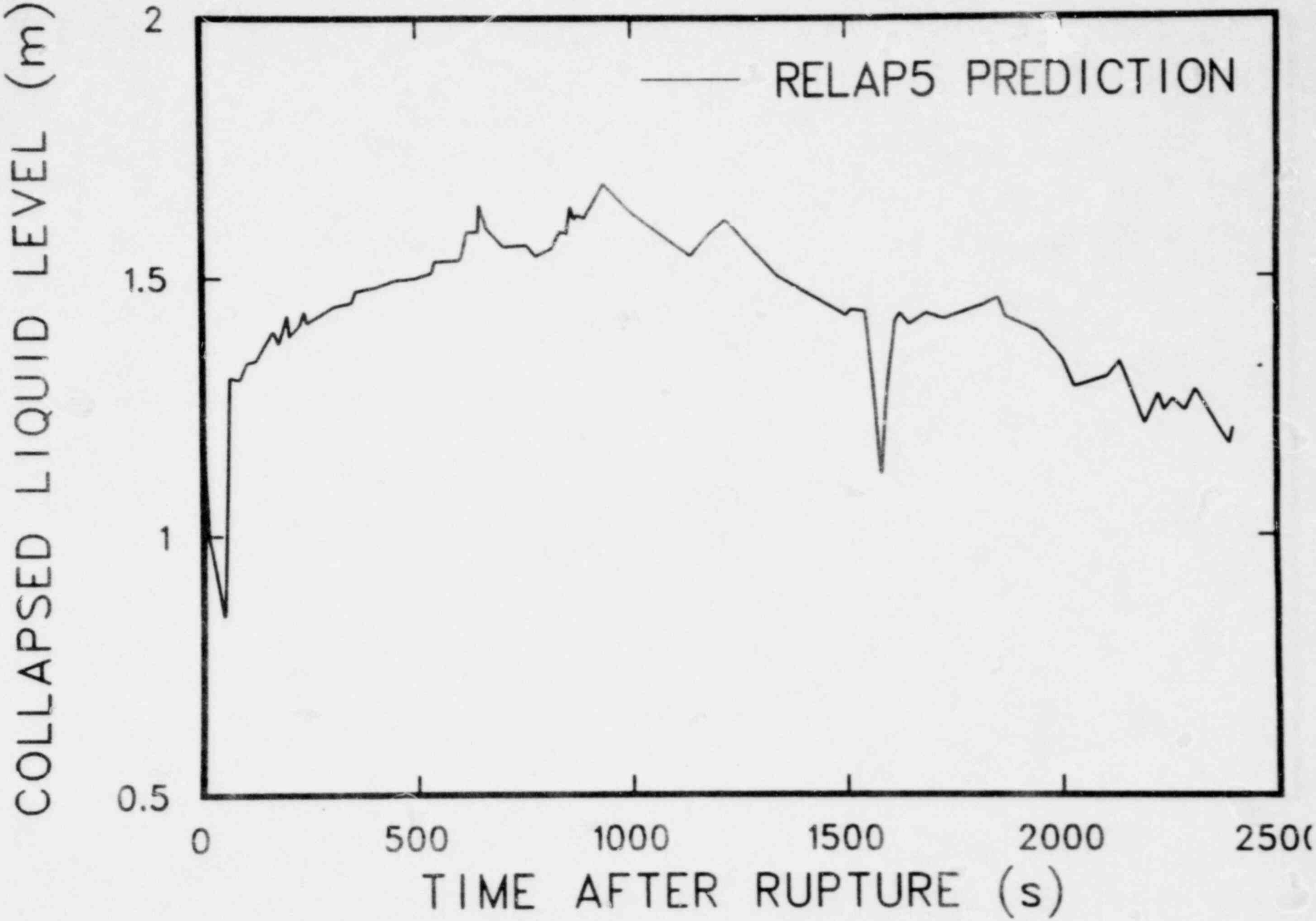

INEL-S-22 604

1604 032

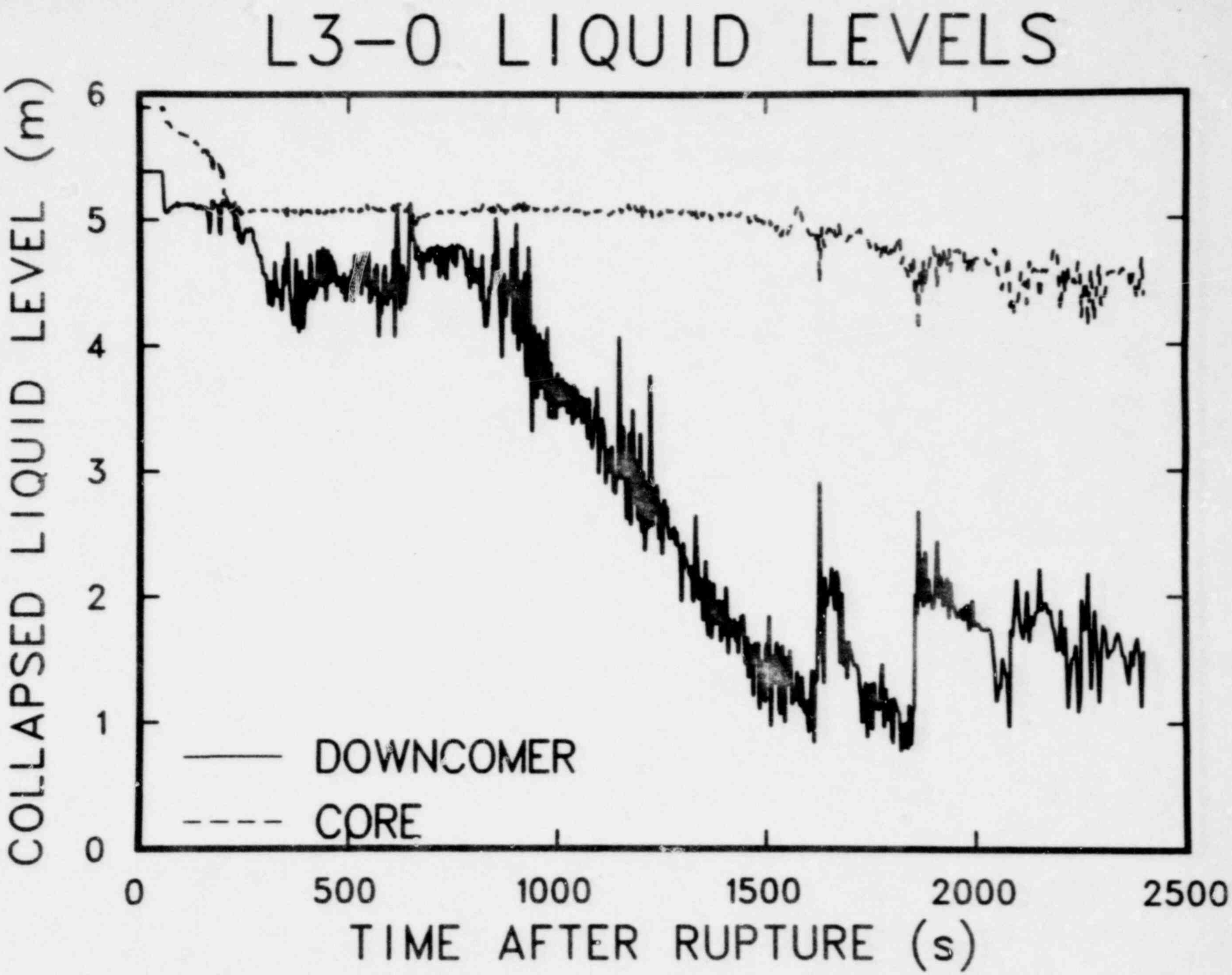

L3-0 HOT LEG PRESSURE
LOFT DATA
RELAP5
PRESSURE (MPa)
15
12.5
10
7.5
5
2.5
0
0
500
1000
1500
2000
2500
TIME AFTER RUPTURE (s)

1604 033

# L3-0 PRESSURIZER LEVEL

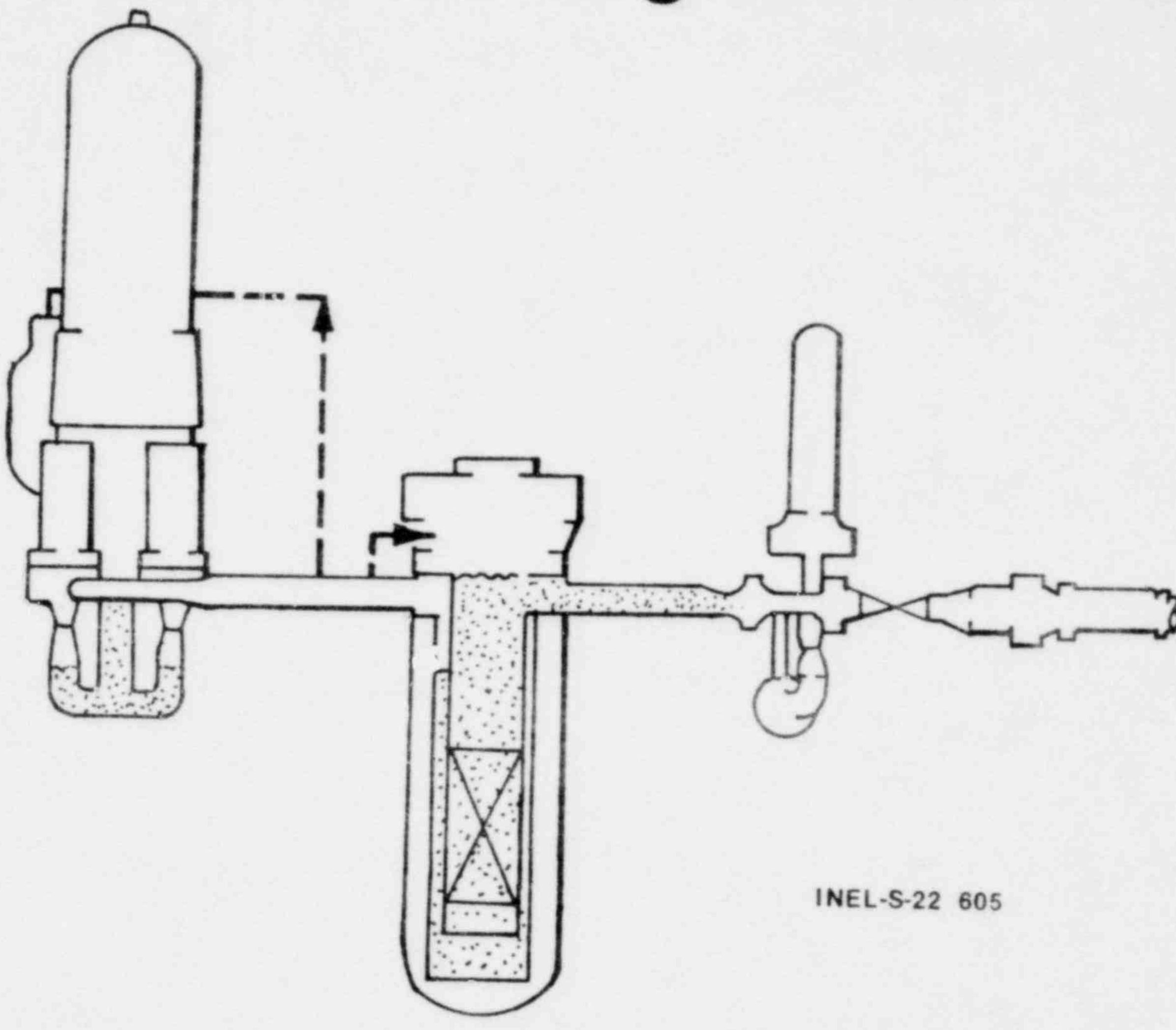



1604 034


L3-0 LIQUID LEVELS
COLLAPSED LIQUID LEVEL (m)
TIME AFTER RUPTURE (s)
0
1
2
3
4
5
6
0
500
1000
1500
2000
2500
DOWNCOMER
CORE

1604 035

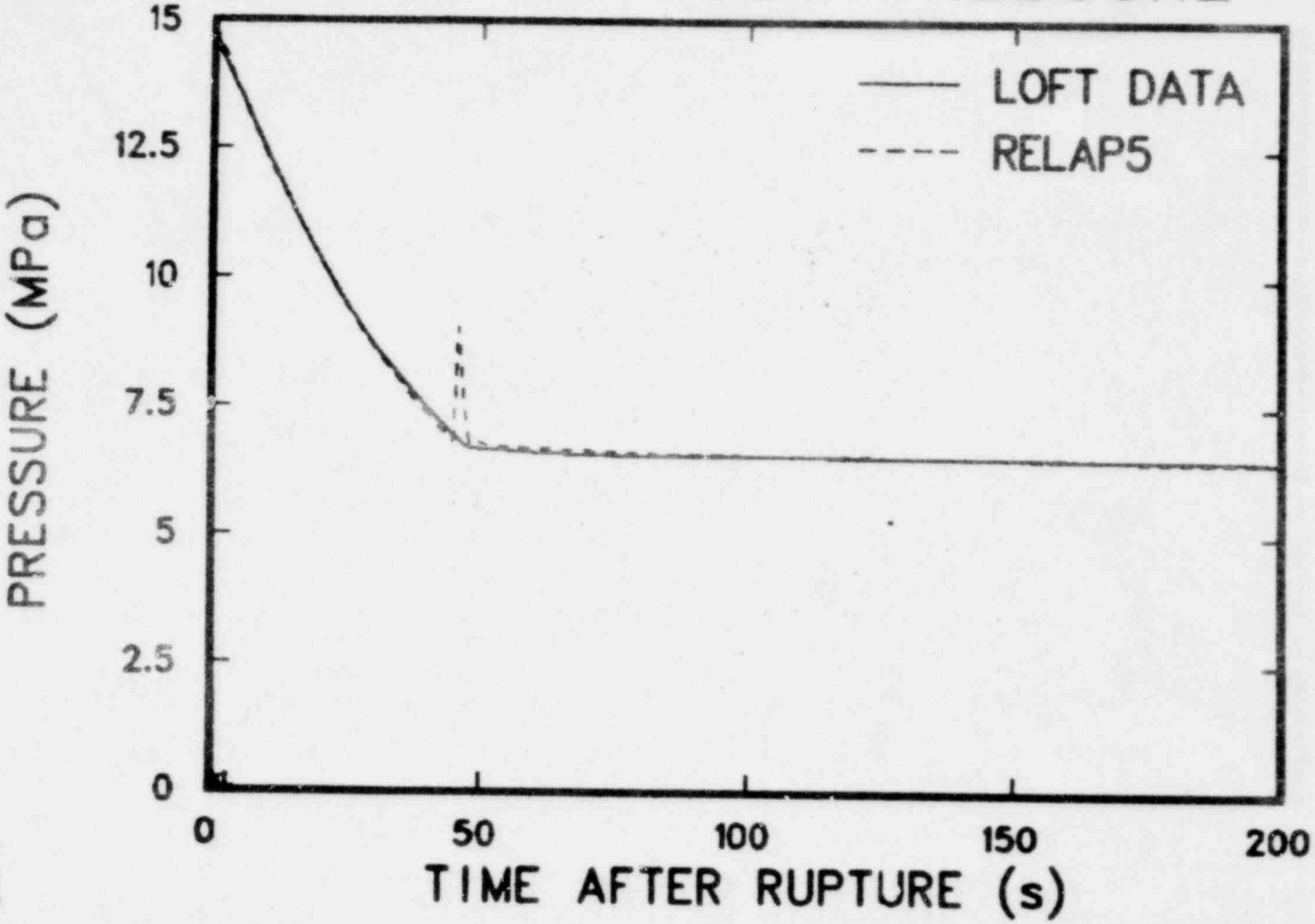
# LOFT L-3-0 Minor Flow Paths and Cold Leg Steam Trap



INEL-S-22 605

1604 036

L3-0 HOT LEG PRESSURE

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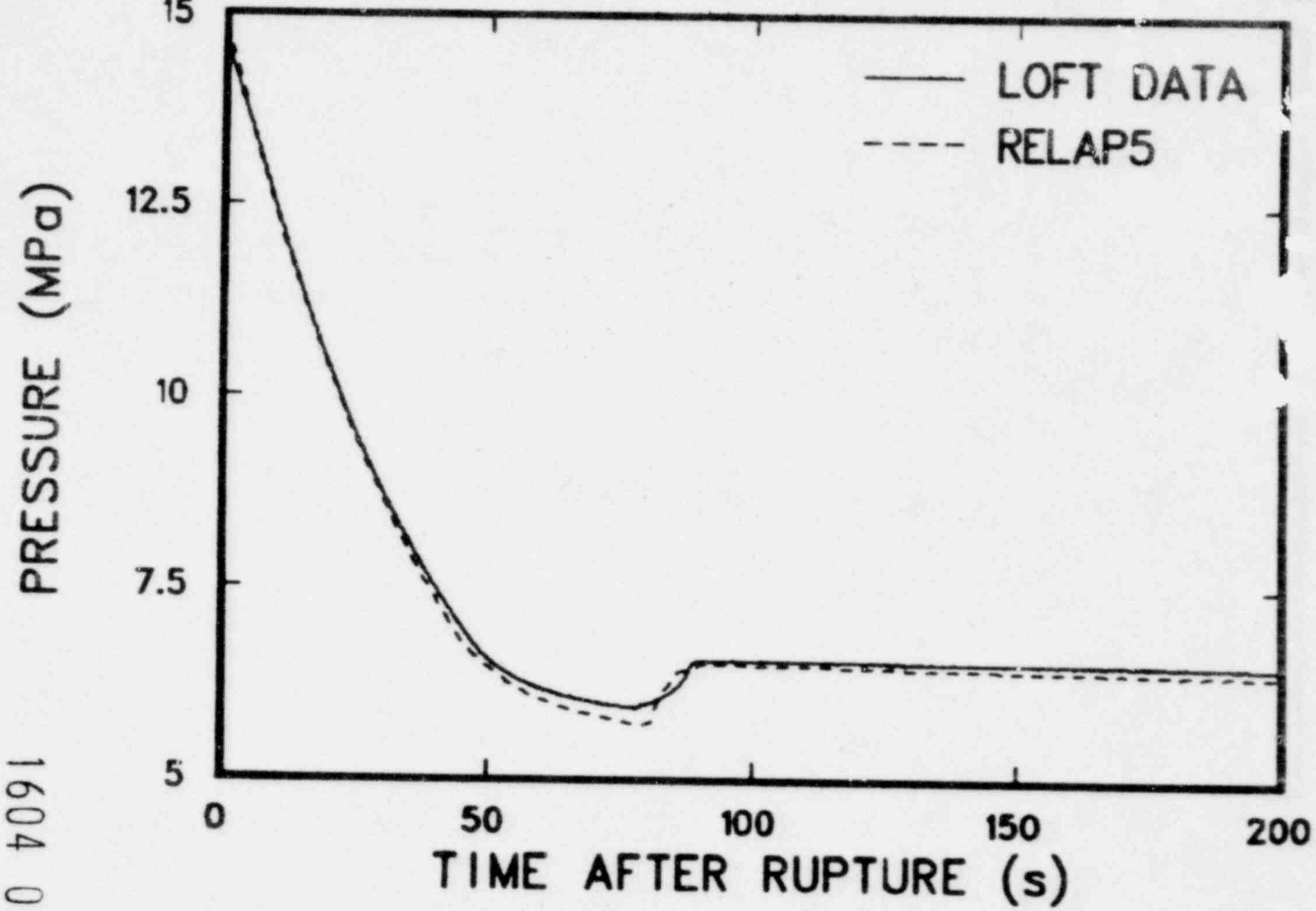
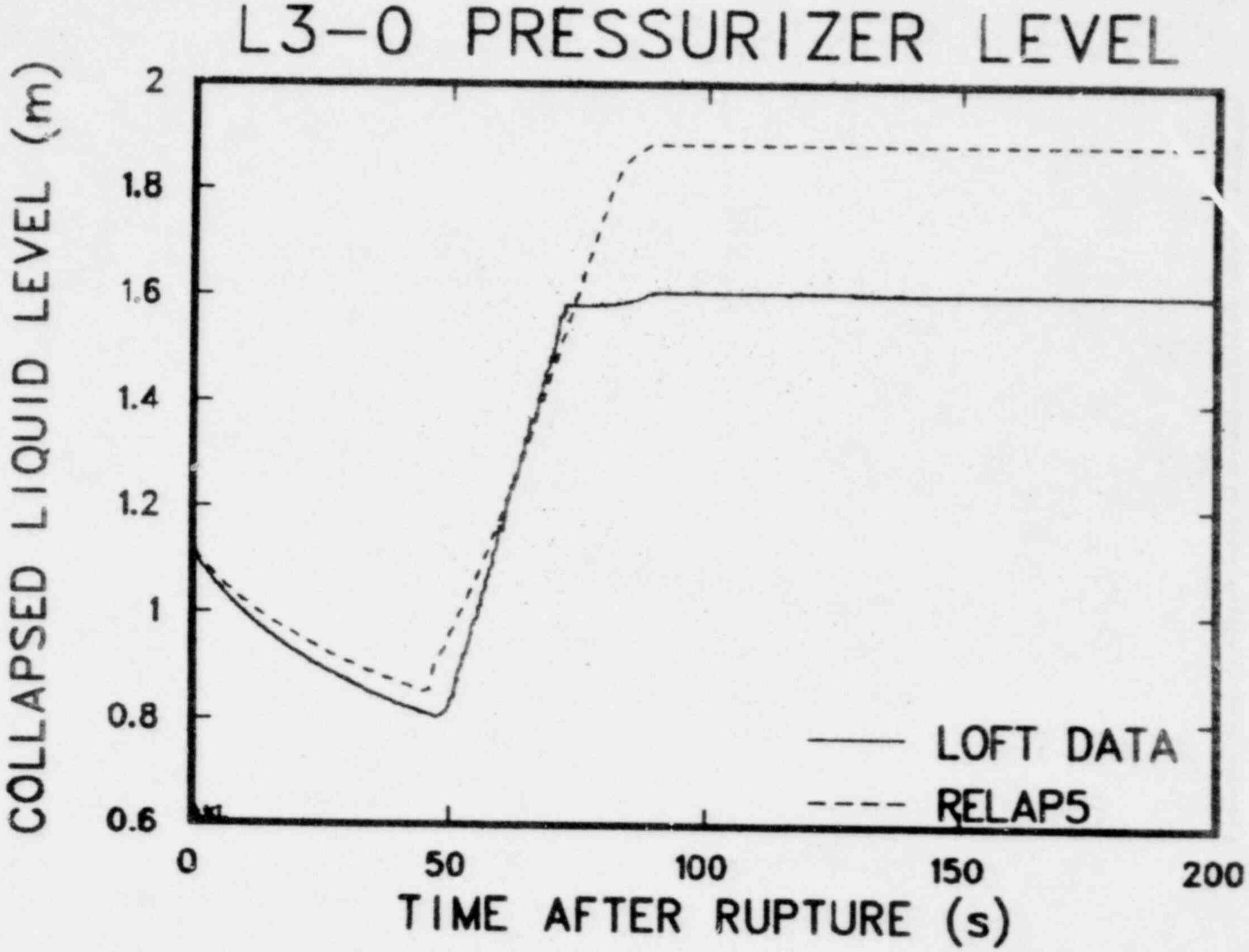
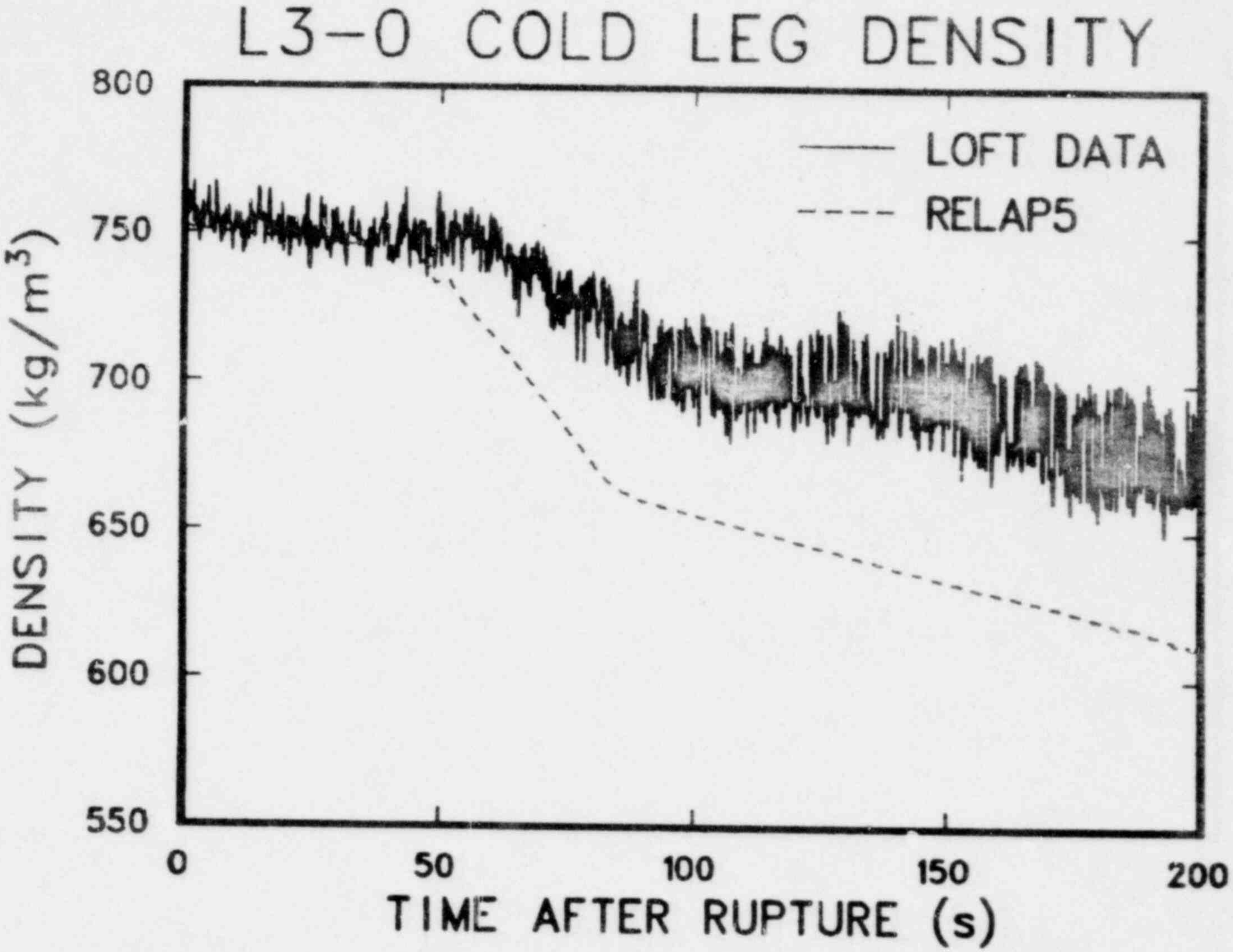
## L3-0 PRESSURIZER PRESSURE



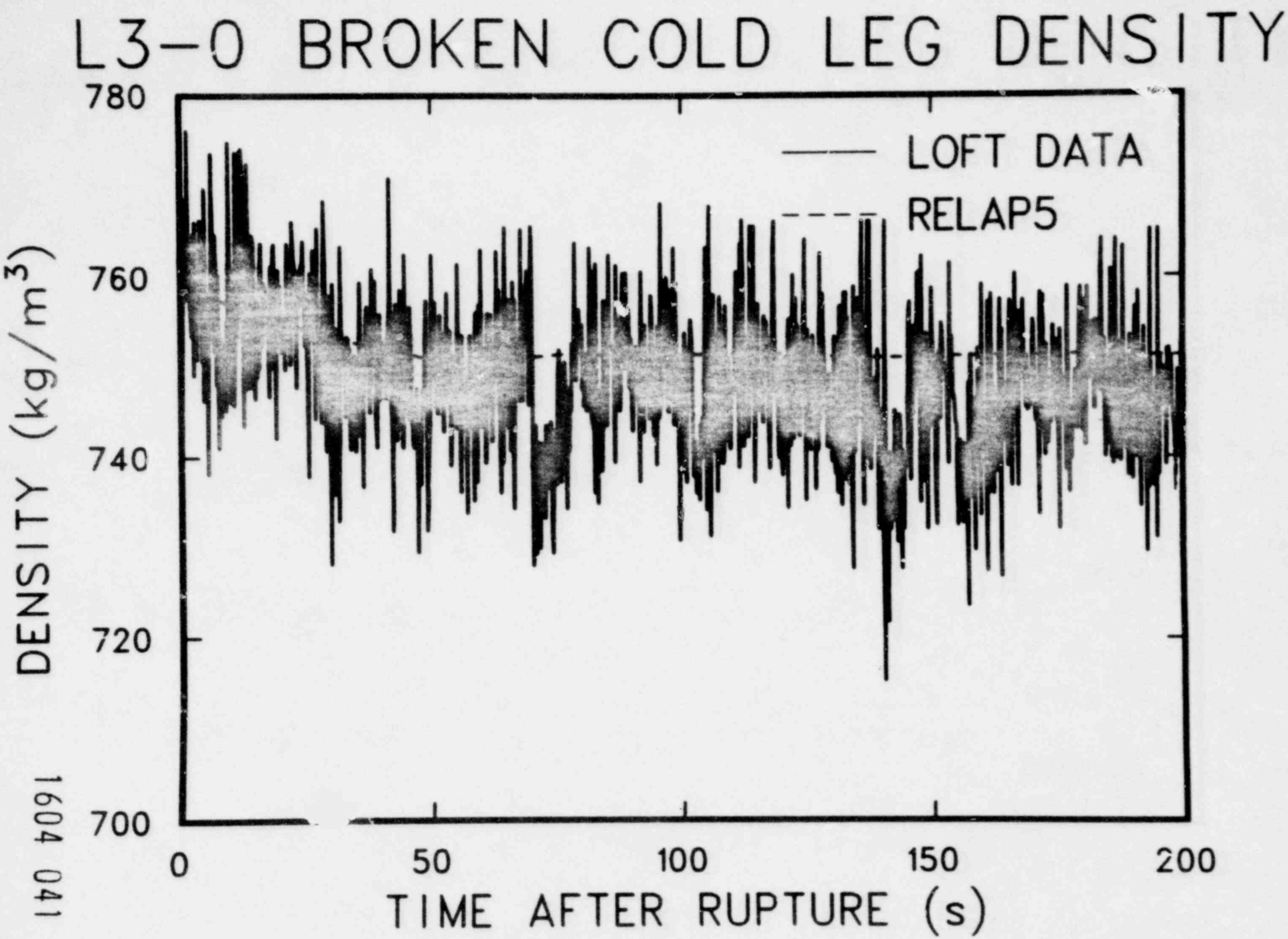

1604 038


L3-0 PRESSURIZER LEVEL
COLLAPSED LIQUID LEVEL (m)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0
50
100
150
200
TIME AFTER RUPTURE (s)
LOFT DATA
RELAP5

1604 039


L3-0 COLD LEG DENSITY
LOFT DATA
RELAP5
DENSITY (kg/m³)
800
750
700
650
600
550
0
50
100
150
200
TIME AFTER RUPTURE (s)

1604 040


L3-0 BROKEN COLD LEG DENSITY
780
760
740
720
700
DENSITY (kg/m³)
0
50
100
150
200
TIME AFTER RUPTURE (s)
LOFT DATA
RELAP5

1604 041