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TITLE: TRAC INDEPENDENT ASSESSMENT AT LASL

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TRAC INDEPENDENT ASSESSMENT AT LASL*

by

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TRAC-P1A[1] was released to the public in April, 1979 following completion of a set of developmental assessment tests.[2] This paper summarizes independent assessment analyses performed with a "frozen" version of TRAC-P1A. That is, no code model changes were made during these analyses but corrections of programming errors were included. These corrections are specified in detail in the first TRAC Newsletter[3] which was sent to all TRAC users and the National Energy Software Center. Assessment of the TRAC version currently under development is described in the TRAC Developmental Assessment paper.[4]

The primary objective of the independent assessment work at LASL is to determine the predictive capability of TRAC. Therefore emphasis is placed on pretest and posttest predictions in which the transient test results are not available. (For the pretest prediction the initial and boundary conditions are estimates of those anticipated in the test). After all the test data become available, posttest analyses are performed to resolve differences between the code results and the test data. Independent assessment of TRAC-P1A has to date mainly involved separate-effects tests in Marviken III and integral-effects tests in the LOFT, Semiscale Mod-3, PKL, and LOBI facilities.

A pretest prediction and a posttest analysis were performed for the first nuclear heated LOFT test (L2-2). The pretest calculation[5] failed to predict the early (5 s) core flow reversal and rewetting of the entire core and as a result overpredicted the peak clad temperature (PCT) by 130 K. The posttest

* Work performed under the auspices of the U.S. Nuclear Regulatory Commission.

analysis[6], performed with the actual initial conditions, yielded very good agreement with the thermal-hydraulic response of most of the system. This result shows that the transient behavior can be significantly affected by deviations from the anticipated initial conditions. The PCT from the posttest analysis was overpredicted by 50 K (a considerable improvement over the pretest prediction) because early rewetting of the hot rod was still not calculated. Reasons for this discrepancy were investigated and much improved results were obtained with a modified rewet criterion (those results are presented in another paper[4] at this meeting).

A pretest prediction[7] of the second LOFT nuclear test (L2-3) yielded results very similar to the L2-2 posttest analysis except that the PCT was overpredicted by only 20 K. The actual core ΔT differed significantly from the anticipated value; a posttest analysis is in progress using the actual initial conditions.

A posttest prediction was also performed for the first small-break test (L3-0) in LOFT. Based on comparisons[8] with the limited data in the Quick Look Report, good agreement is obtained for the first 1 000 s of the transient. The calculated system pressure for the remainder of the transient (1 000 - 2 500 s) is overpredicted. A detailed comparison will be performed when the Experiment Data Report becomes available. Uncertainties in the break geometry and difficulties with mass conservation for this long-term transient are being investigated.

Posttest predictions[9] were completed for two Marviken III critical flow tests (22 and 24). These predictions and posttest analyses of other tests show that agreement improves with increasing nozzle length independent of diameter. The flow rate is underpredicted during the subcooled blowdown period; this appears to be due to delayed nucleation effects which are not currently modeled in TRAC and which become increasingly important for the shorter nozzles.

Pretest predictions were completed for the first LOBI test (A1-01)[10] and for a small-break test (S-07-10B)[11] in Semiscale Mod-3. Experimental results from these tests are not yet available.

A posttest analysis[12] was performed for the first integral test (S-07-6) in the Semiscale Mod-3 facility. Good agreement was obtained for the blowdown stage but there was insufficient penetration of liquid in the downcomer pipe during the refill stage. As a result the heater rod temperature response was not well predicted during reflood. Analysis of countercurrent air/water tests in vertical tubes shows that the interfacial shear coefficient is too high for low gas velocities.

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7. A. C. Peterson and K. A. Williams, "TRAC-P1A Pretest Prediction of LOFT Nuclear Test L2-3," Los Alamos Scientific Laboratory report LA-UR-79-1134 (May 1979).

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12. J. J. Pyun, "TRAC Calculations of Semiscale Mod-3 Test S-07-6," in "Nuclear Reactor Safety Quarterly Progress Report, April 1 - June 30, 1979," J. F. Jackson and M. G. Stevenson (Compilers), Los Alamos Scientific Laboratory report LA-7968-PR (NUREG/CR-0993) (August 1979).

INDEPENDENT ASSESSMENT CREDITS

LOFT:	K. WILLIAMS, A. PETERSON
SEMISCALE MOD-3:	T. KNIGHT, J. PYUN
MARVIKEN III:	G. WILLCUTT
LOBI:	C. WATSON, A. FORGE
PKL:	J. SPORE, T. KNIGHT

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INDEPENDENT ASSESSMENT OBJECTIVES

- Assess Predictive Capabilities and Limitations of TRAC Release Version
- Provide Guidance for Future TRAC Development
- Identify Needed Experiments
- Determine Applicability to LPWR (Scaling Capability)

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INDEPENDENT ASSESSMENT CALCULATIONS

- PRETEST PREDICTIONS

  ASSUMED OPERATING/BOUNDARY CONDITIONS

  INITIAL CONDITION AND TRANSIENT PREDICTIONS

- POSTTEST PREDICTIONS

  ACTUAL INITIAL/BOUNDARY CONDITIONS

  TRANSIENT PREDICTION

- POSTTEST ANALYSES

  UNDERSTAND PHENOMENA/RESOLVE DIFFERENCES

  COMPONENT, SYSTEM, INTEGRAL BEHAVIOR

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P1A INDEPENDENT ASSESSMENT
SUMMARY STATUS

TEST	PRETEST PREDICTION	POSTTEST PREDICTION	POSTTEST ANALYSIS
L2-2	COMPLETED	NONE	COMPLETED
L2-3	COMPLETED	NONE	IN PROGRESS
L3-0	NONE	COMPLETED	IN PROGRESS
S-07-6	NONE	NONE	COMPLETED
S-07-10B	NONE	COMPLETED	IF NECESSARY
MARV. TEST 22	NONE	COMPLETED	NONE
MARV. TEST 24	NONE	COMPLETED	NONE
PKL K1.3	NONE	NONE	TERMINATED
PKL K5.4A	NONE	NONE	IN PROGRESS
PKL K9	NONE	IN PROGRESS	IF NECESSARY
LOBI A1-01	COMPLETED	IF NECESSARY	IF NECESSARY

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LOFT TEST L2-2

- FIRST TEST IN POWER ASCENSION SERIES.
- 200% CL BREAK WITH CL INJECTION.
- TRAC MODEL.

    27 COMPONENTS.

    300 FLUID CELLS (192 IN VESSEL).

- PRETEST PREDICTION AND POSTTEST ANALYSIS.

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L2-2 STEADY STATE

Parameter	L2-2 Data	TRAC (Posttest)	TRAC (Pretest)
Intact hot-leg temperature (K)	580.6	580.8	593.0
Intact cold-leg temperature (K)	558.8	559.0	566.0
Core ΔT (K)	21.8	21.8	26.6
Intact loop mass flow (kg/s)	197.5	207.1	186.6
Pump ΔP (Pa)	9.1×10^4	9.2×10^4	7.8×10^4
Pressurizer pressure (Pa)	155×10^5	155×10^5	155×10^5
Steam generator secondary pressure (Pa)	63×10^5	62.0×10^5	63×10^5
Maximum linear heat generation rate (kW/m)	26.38	26.38	28.87

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TRAC-P1A PRETEST PREDICTION
OF TEST L2-2

- PCT Over-Predicted by ~ 130 K
- Core Flow Reversal at ~ 5 s Not Predicted
- Early Core Rewet Not Predicted
- ECC Bypass Over-Predicted
- Actual Initial and Boundary Conditions Different From EOS Values
  1. Intact Loop Hot-Leg T (580 vs 587 K)
  2. Core ΔT (21.8 vs 23.9 K)
  3. Broken Loop Hot-Leg T (543 vs 582 K)
  4. Containment Pressure History
- Error in Thermodynamic Package (Liq. Int. E. Function)
- Input Errors
  1. Max. Linear Heat Gen. Rate 10% High
  2. Steam Generator Active H.T. Area Low
  3. Reflood Assist Bypass System Volume Not Included.

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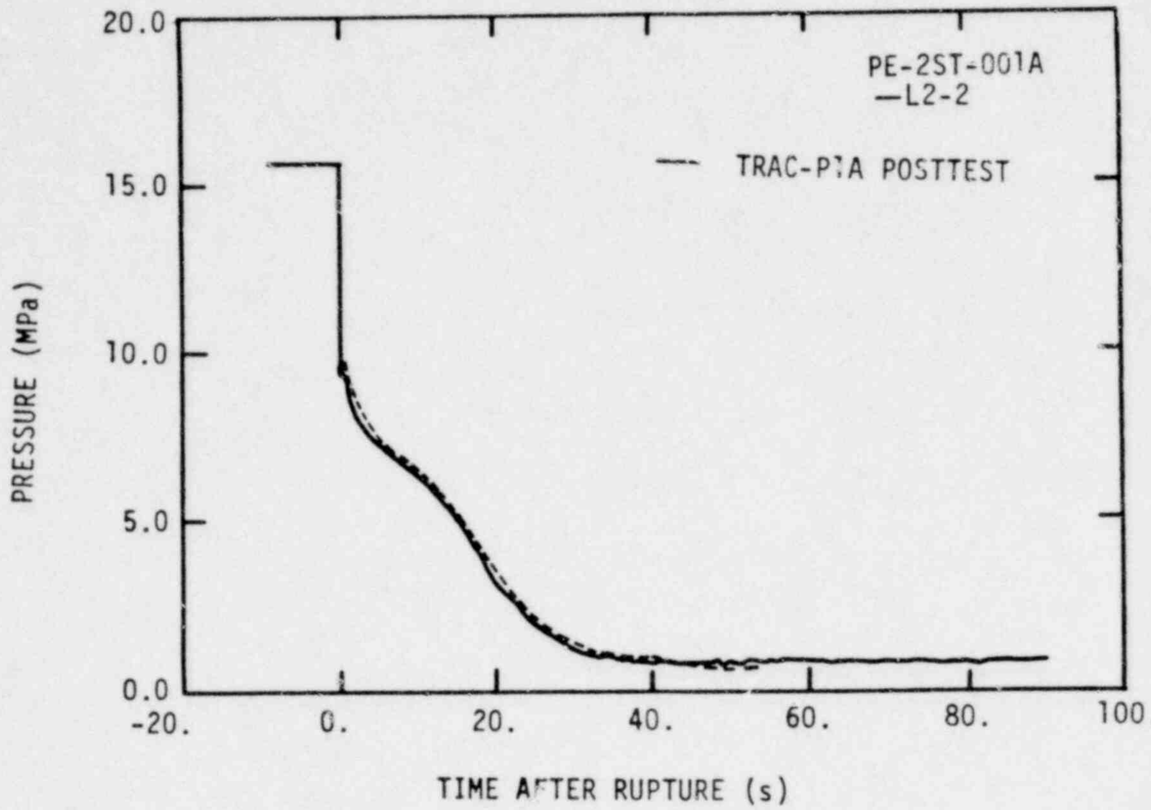

PRESSURE IN REACTOR VESSEL DOWNCOMER

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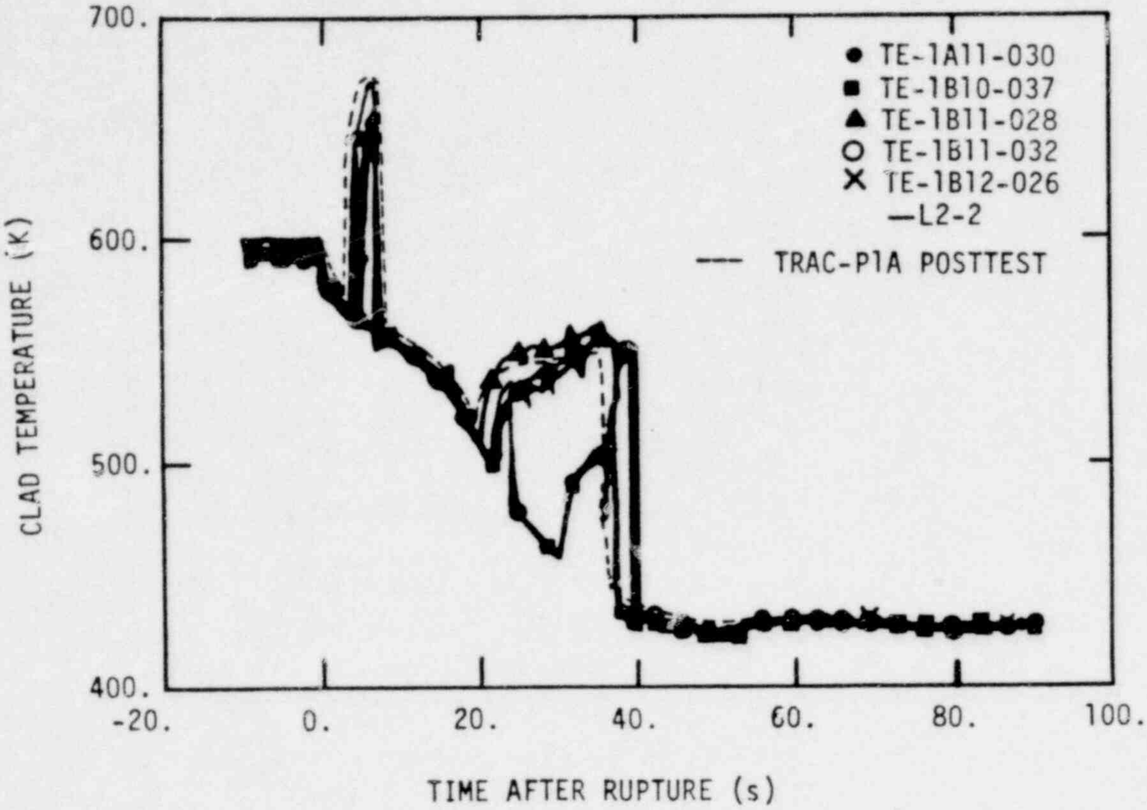

TEMPERATURE OF CLADDING OF LOW POWER RODS ON ASSEMBLY 1

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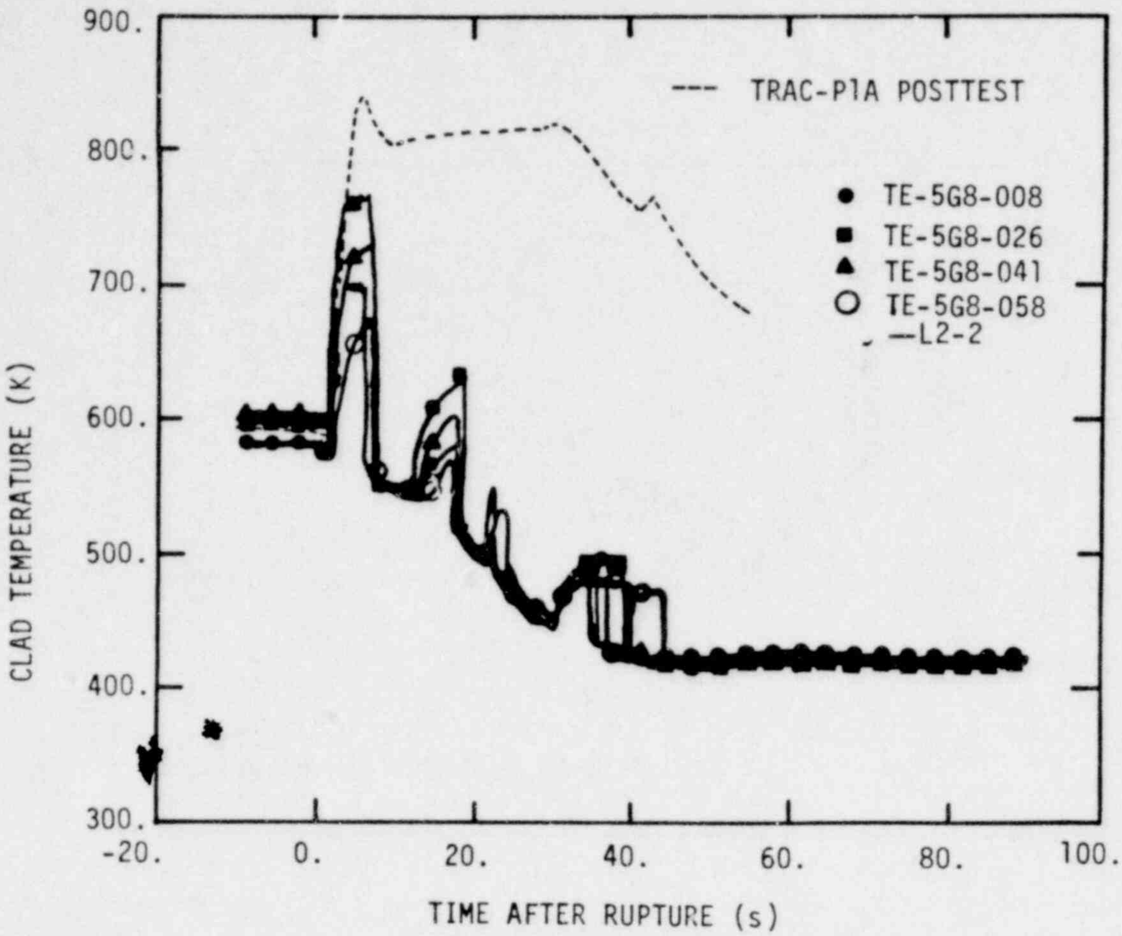

TEMPERATURE OF CLADDING OF HIGH POWER RODS IN CENTER ASSEMBLY

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TRAC-P1A POSTTEST ANALYSIS
OF TEST L2-2

A. Very Good Agreement with Thermal-Hydraulic Response of Entire System Except for Hot Rods
   1. System Pressures, Pressurizer Level, ECC Injection Times and Rates
   2. Core Flow Reversal, Start of Refill and Reflood
   3. Time to DNB and PCT (840 vs 790 K), Multiple Rewets and Dryouts on Some Low Power Rods
   4. Quench Time for all Low-Power Rods and for Hot Rods Below Core Midplane

B. Phenomena Not Predicted
   1. Early Rewet of Hot Rod and Subsequent Dryouts/Rewets
   2. Time to Final Quench of Hot Rods

C. Possible Reasons for Discrepancies
   1. Rewet Criterion
   2. Transition and Film Boiling H.T. Correlations
   3. Need for Dynamic Fuel Rod Gap Model
   4. Modeling of U.P. Flow Restrictions (Water Retention in U.P.)
   5. Effect of Thermocouples on Rewet Behavior

D. Recommendations
   1. Improve Reflood H.T. Models
   2. Use Lower Initial Rod Temperatures for Reflood Separate-Effects Tests

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LOFT TEST L2-3

- Second Test in Power Ascension Series
- Test Same As L2-2 Except Nuclear Core Initially at 75% Rated Power (37 MW)
- TRAC Model Essentially Same As L2-2
  1. U.P. Volume Increased Per INEL Revision
  2. Volume of Reflood Assist Lines Added to Broken Loop
- Pretest (Double-Blind) Prediction Using TRAC-P1A

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INITIAL CONDITIONS FOR LOFT TEST L2-3

Parameter	TRAC-P1A Pretest	EOS	Actual
Core Power (MW)	37.2	37.2	36.7
Maximum Linear Heat Generation Rate ($\frac{kW}{M}$)	39.4	39.4	39.4
Hot Leg Temp (K)	591.4	591.5 ± 1.1	592.9 ± 1.8
Core ΔT (K)	35.6	35.8	32.2
Intact Loop Flow (kg/s)	185.4	187.7	199 ± 6
System Pressure (MPa)	15.0	15.0	15.0

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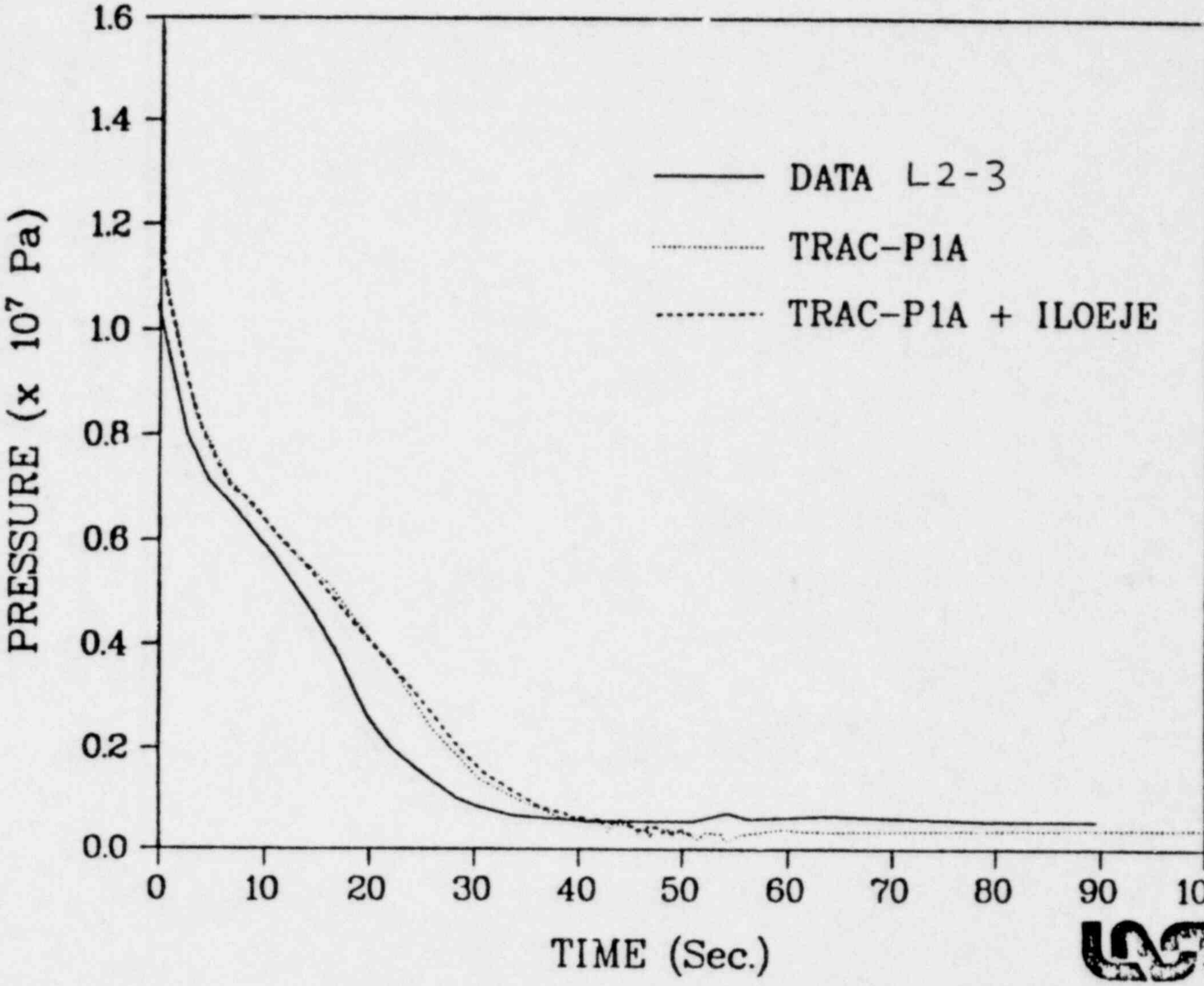
PRESSURE IN THE INTACT LOOP COLD LEG



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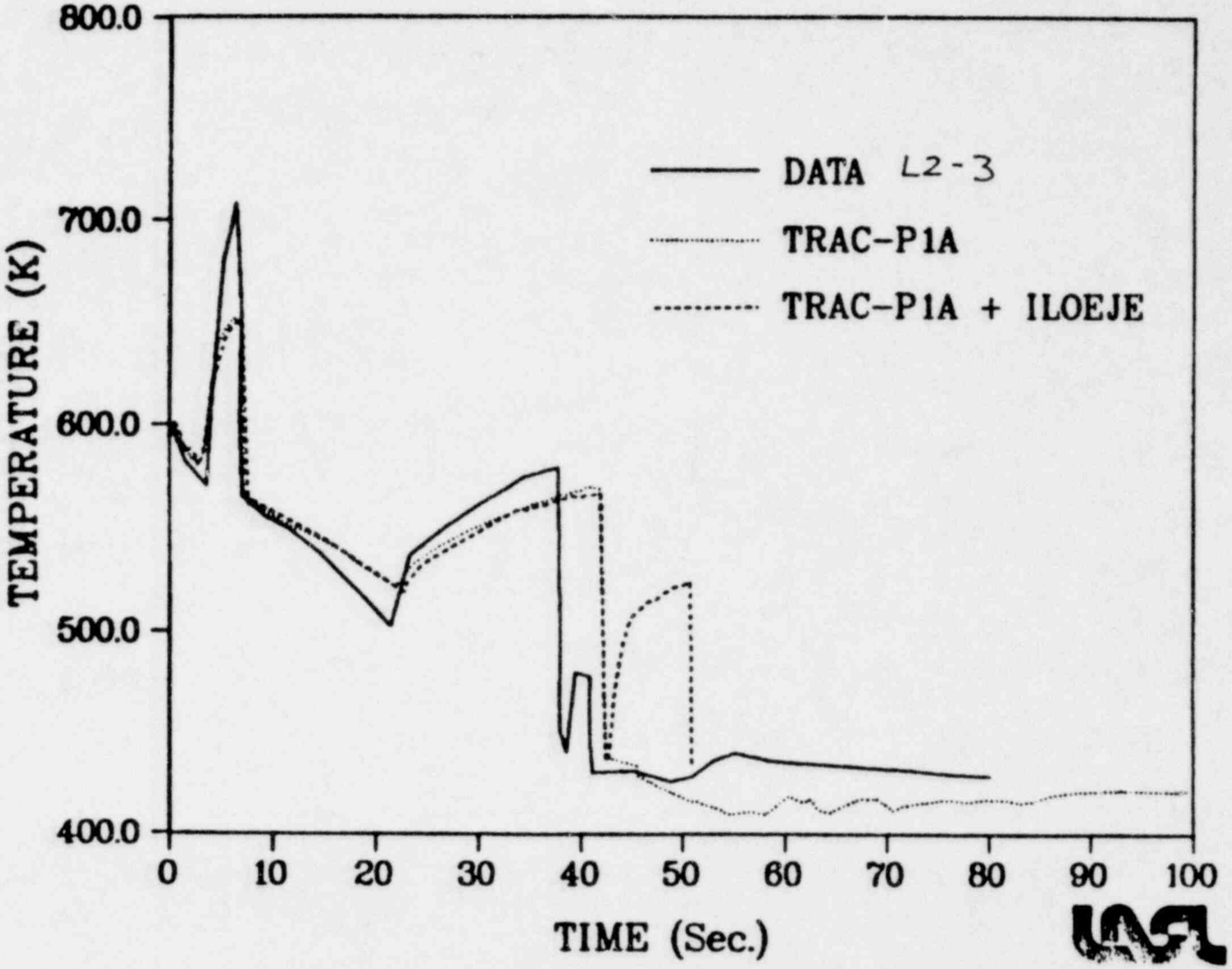
FUEL MODULE 1 ROD B11

CLAD TEMPERATURE



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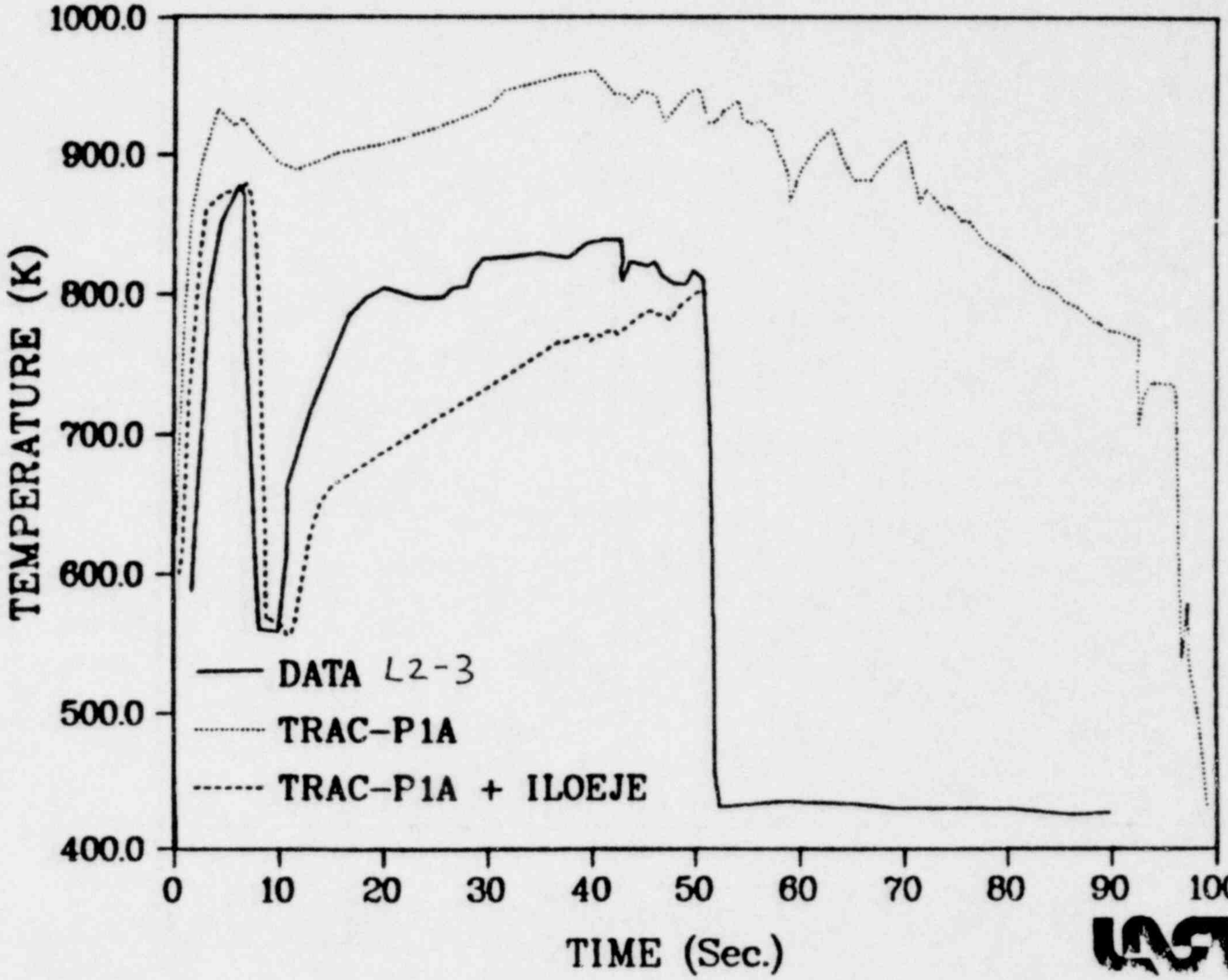
FUEL MODULE 5 ROD D6

CLAD TEMPERATURE



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TRAC-P1A PRETEST PREDICTION OF TEST L2-3

- Results Similar to L2-2 Posttest Calculation
- PCT Over-Predicted by ~ 20 K (930 vs 910 K)
- PCT with P1A + Iloeje Right On Data
- Detailed Comparisons with EDR Data in Progress
- Posttest Calculation to be Performed

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LOFT TEST L3-0

- Isothermal Small Break (PRV)
- No ECC Injection/Pumps Tripped
- TRAC Model

  20 Components
  94 Fluid Cells (32 in Vessel)
- Post-Test Prediction Using TRAC-P1A
- Only QL Report Available at This Time

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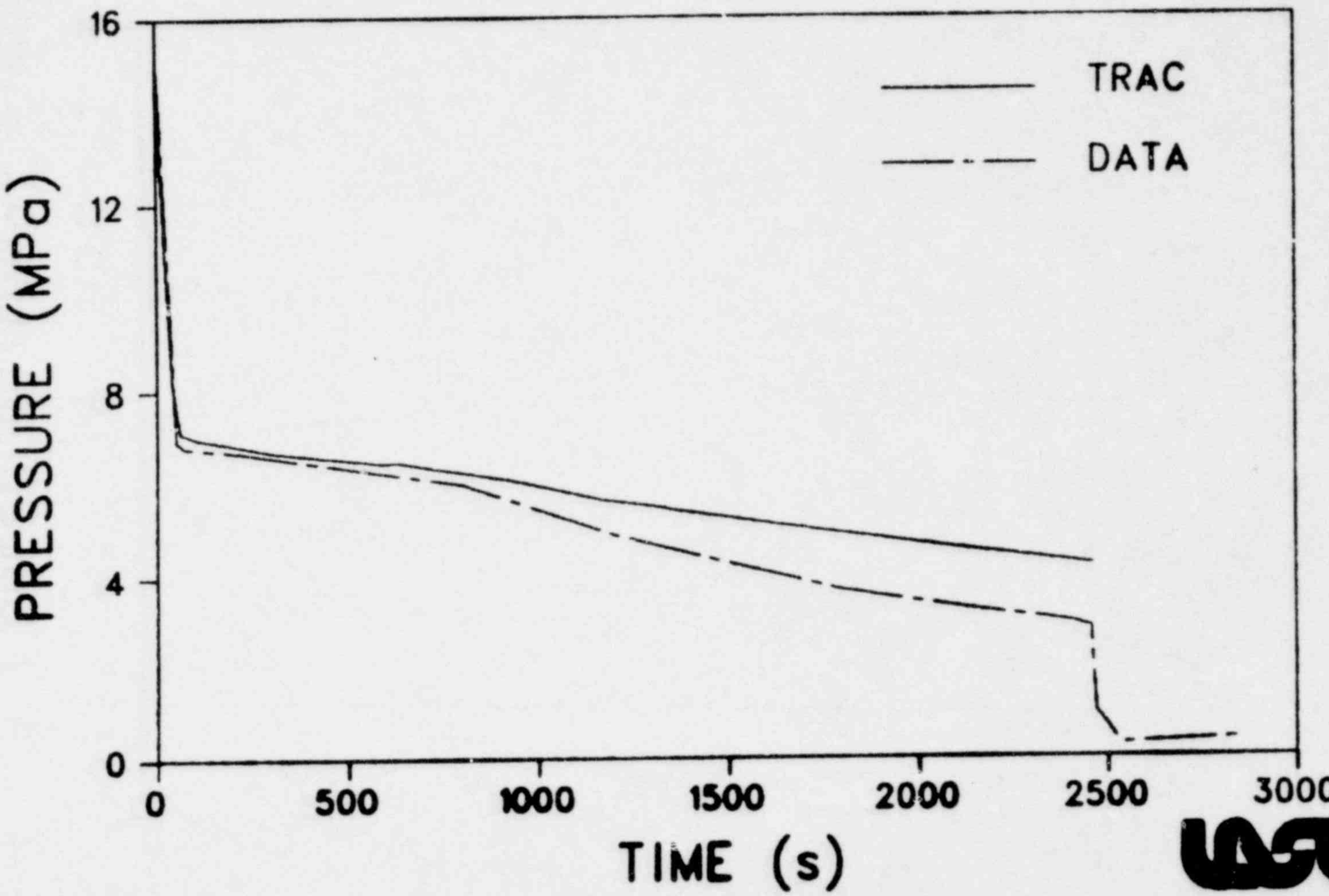
LOFT L3-0

PRIMARY SYSTEM PRESSURE



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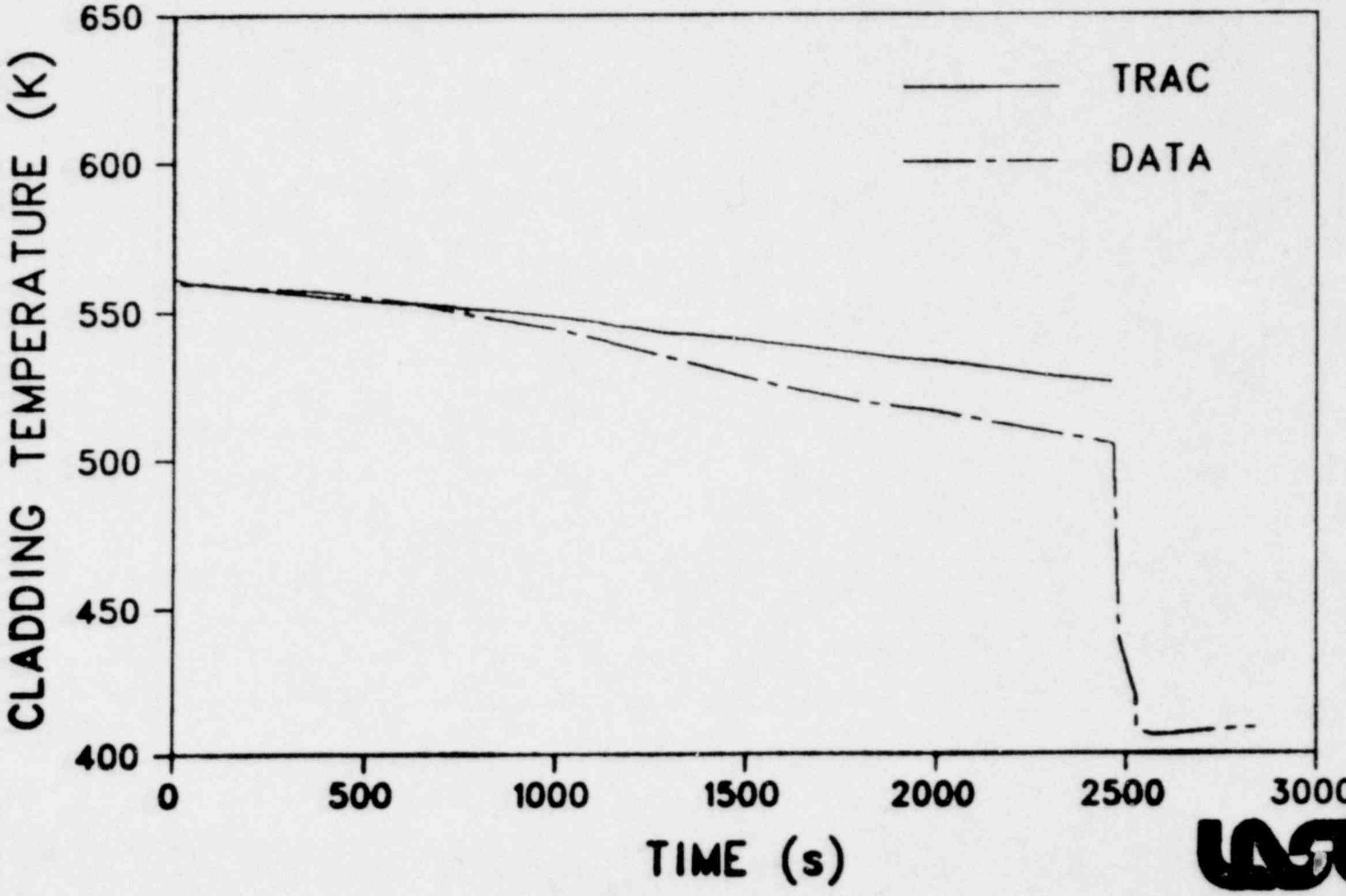
LOFT L3-0

CORE THERMAL RESPONSE



TRAC-P1A POSTTEST PREDICTION OF TEST L3-0

- Good Agreement with Limited Data in QL Report
  1. Subcooled Blowdown Period (55 vs 48 s) and Saturation P (7.0 vs 6.8 MPa)
  2. Surge Line Flow (0-150 s)
  3. Saturated Cooldown with no Core Uncovery
  4. Refill of Pressurizer in Interval 50-100 s

- Problems
  1. Uncertainty in P. Relief Valve Geometry
  2. Mass Cons. and Comp. Time for Long-Term Transients

- Recommendations
  1. Improve Mass Conservation for Long-Term Transients
  2. Incorp. Break Flow Model for Small-Break Calcs.

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MARVIKEN TESTS 22 AND 24

- Full-Scale Vessel BD and Nozzle CF

Test 22:	L = 0.727	D = 0.5 m	L/D = 1.45
Test 24:	0.166	0.5	0.33

- TRAC Model

  Two 1-D PIPE Modules

  54 and 42 Fluid Cells

- Posttest Prediction Using TRAC-P1A

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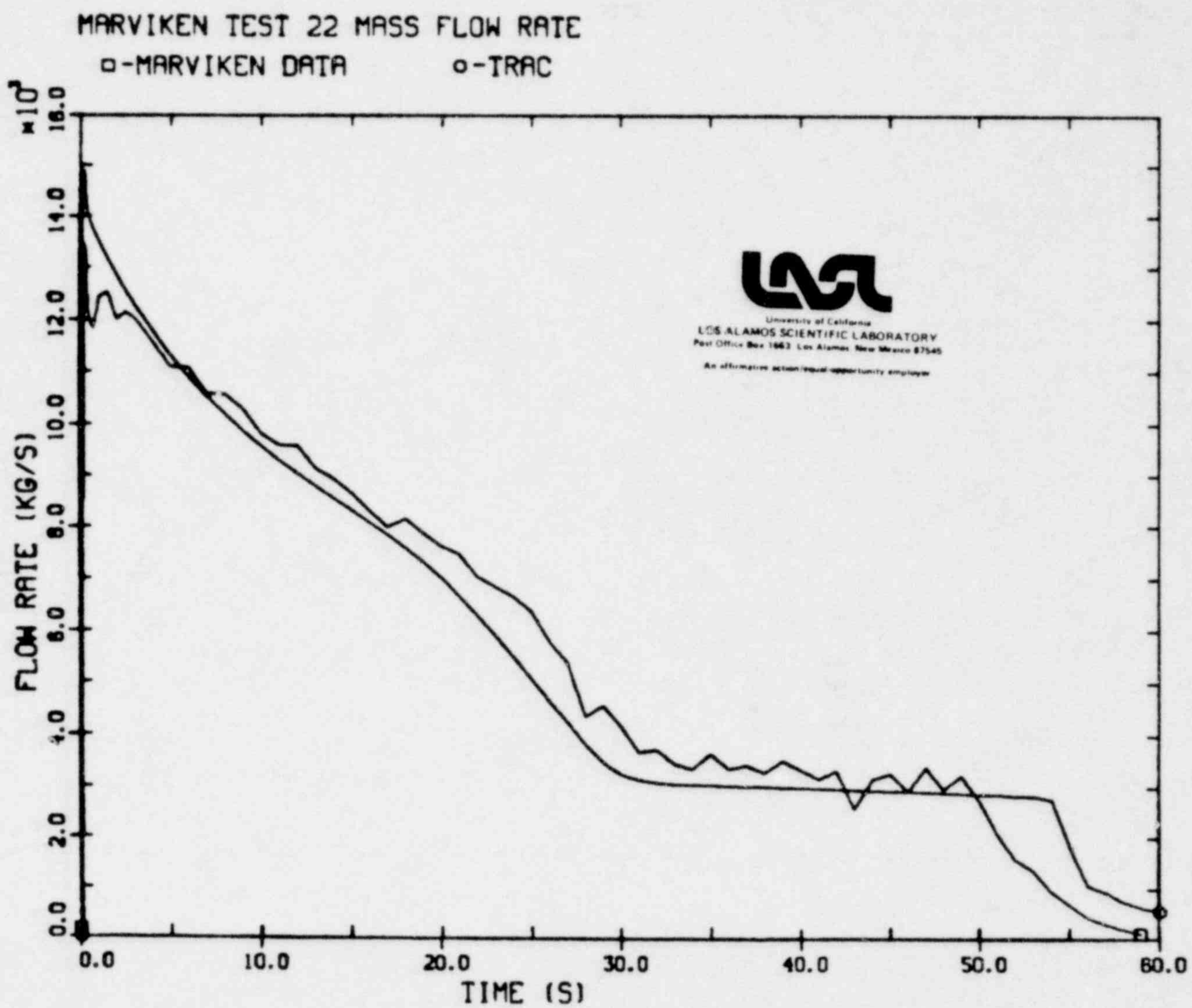
MARVIKEN TEST 22 MASS FLOW RATE
□-MARVIKEN DATA
○-TRAC
×10³
FLOW RATE (KG/S)
TIME (S)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
10.0
20.0
30.0
40.0
50.0
60.0
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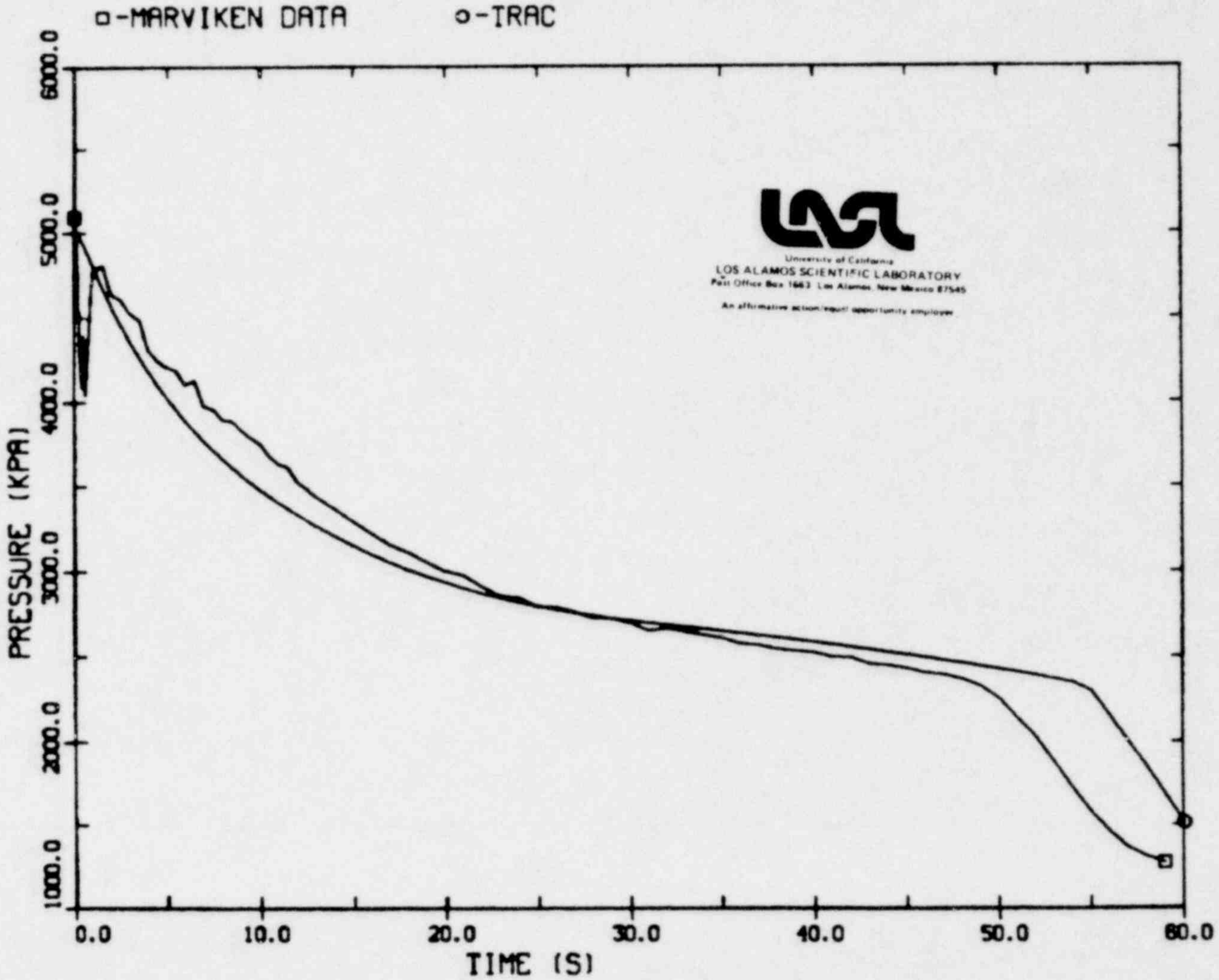
MARVIKEN TEST 22 VESSEL PRESSURE 106 AT 0.525 M LEVEL



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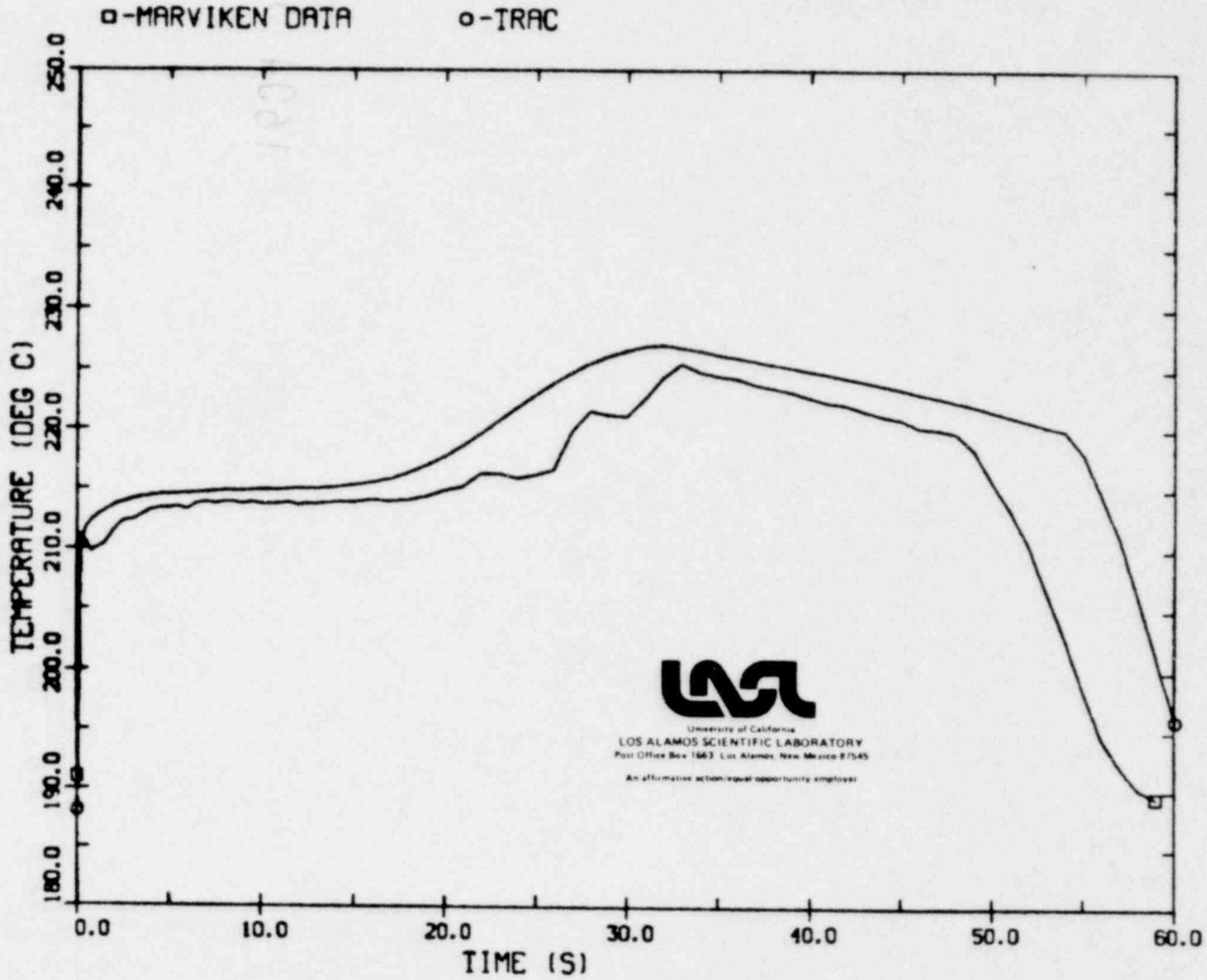
MARVIKEN TEST 22 TEMPERATURE 556 AT INSTRUMENT. RING II



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TRAC-P1A POSTTEST PREDICTIONS OF MARVIKEN TESTS 22 AND 24

- RESULTS SUMMARY
  1. Quant. Agree. Improves with Incr. Nozzle L Indep. of D
  2. Flow Rate Under-Predicted During Subcooled Period
  3. Initial Dip in Steam Dome P not Predicted
- RECOMMENDATION

  Incorporate Delayed Nucleation Model

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SEMISCALE MOD-3 TEST S-07-10B

- Test Description
  Communicative Small Break in Cold Leg
  Delayed ECC Injection in Intact Loop
- TRAC Model
  26 Components (1 Vessel with 3 Re-entrant Pipes)
  222 Fluid Cells (76 in Vessel)
- Posttest Prediction Using TRAC-P1A
- Good Agreement with Test Initial Conditions
- Transient Test Data Not Yet Available

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Semiscale Test S-07-10B Initial Conditions

Parameter	Actual	Calculated
Upper Plenum Pressure	15.700 MPa	15.701 MPa
Intact Loop Fluid Temperatures		
Hot leg	591 K	591.6 K
Cold leg	556 K	555.7 K
Broken Loop Fluid Temperatures		
Hot leg	591 K	591.6 K
Cold leg	556 K	556.2 K
Flow Rate		
Intact Loop	7.45 kg/s	7.541 kg/s
Broken Loop	2.27 kg/s	2.315 kg/s
Upper Head Bypass	4.2%	4.20%

LOBI TEST A1-01

- "Virgin" Test (200% CL Break with Accum. Injection)
- TRAC Model
  22 Components
  150 Fluid Cells (96 in Vessel)
- TRAC-P1A Pretest Prediction Completed
- Posttest Prediction if Necessary After Initial and Boundary Conditions are Received

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CALCULATED AND NOMINAL INITIAL CONDITIONS FOR

LOBI TEST A1-01

Parameter	Nominal	TRAC
Power (MW)	5.28	5.28
ΔT (K) Core	34.0	33.3
T (K) Hot-leg Average	597.0	596.3
T (K) Cold-leg Average	563.0	563.0
P (bars)	155.0	158.0
W (kg/s) Intact Loop	21.07	21.02
W (kg/s) Broken Loop	7.03	6.98

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SEMISCALE MOD-3 TEST S-07-6

- Mod-3/Mod-1 Differences
  3.66 vs 1.66 m Core
  Active vs Passive Broken Loop
  External DC Pipe vs Internal DC Annulus

- Test Description
  First Integral LOCA Test
  200% CL Break with ECC Injection (Accum, HPIS,LPIS)
  Long-Term DC and Core Liquid Level Oscillations

- TRAC Model
  36 Components (2 Vessels)
  307 Fluid Cells (87 in 3-D Components)
  Downcomer Wall Heat Flux Specified

- Posttest Analysis Using TRAC-P1A

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INITIAL STEADY STATE CONDITIONS
(TEST S-07-6)

	MEASURED	CALCULATED
C.L. FLUID TEMPERATURE (K)	559	560
H.L. FLUID TEMPERATURE (K)	594	595.0
COOLANT TEMPERATURE RISE (K)	35	35
CORE MASS FLOW RATE (KG/S)	9.5	9.5
CLAD T-HIGH POWER ZONE (K)	687.0	670.0
CLAD T-LOW POWER ZONE (K)	585.0	584.0
SYSTEM PRESSURE (MPA)	15.2	15.0
PUMP DIFFERENTIAL PRESSURE (MPA)		
INTACT LOOP	0.48	0.46
BROKEN LOOP	0.34	0.32
VESSEL DIFFERENTIAL PRESSURE (MPA)	0.11	0.10

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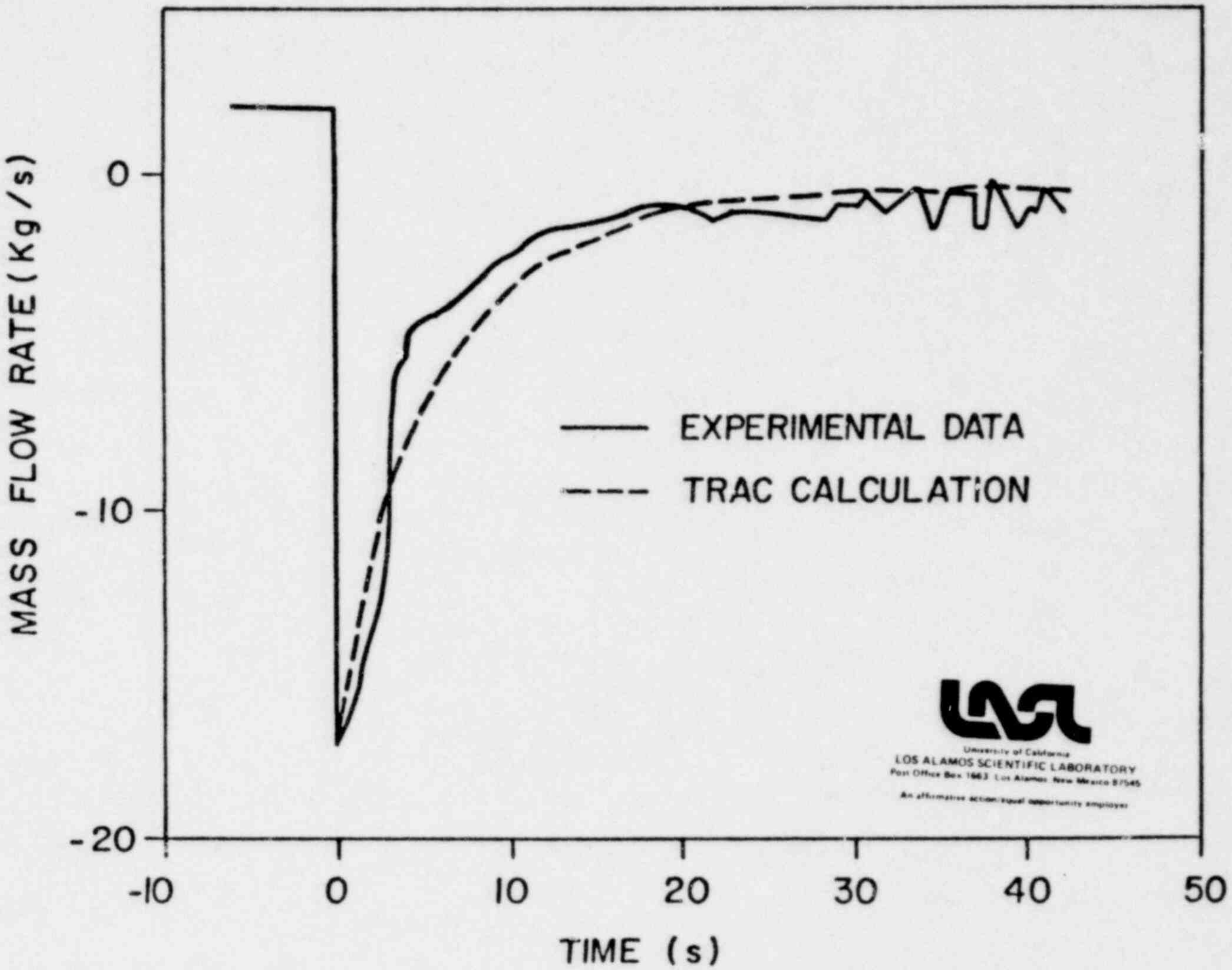

Mass flow rate from vessel side of broken loop for Test S-07-6.

TRAC-P1A POSTTEST ANALYSIS OF TEST S-07-6

- Results Summary
  1. Good Agree. with ICs and BD Portion of Transient
  2. Insufficient DC Penetration During Refill Stage
  3. No Periodic Liquid Depletions in DC and Core
  4. Heater Rod T Response Not Well Predicted During Reflood

- Possible Reasons for Discrepancies
  1. Interfacial Shear Coeff. Too High at Low CC Gas Velocities (Verified Against Dartmouth Air-Water Tests)
  2. Effectiveness of Insulation Uncertain
  3. Reflood Models Inadequate for Low Flooding Rates
  4. Effect of Accumulator Nitrogen

- Recommendations
  1. Upgrade D-F Formulation for 1-D Components to 2-F
  2. Improve Interfacial Friction Correlation and Reflood Models
  3. Incorporate Conduction Solution in Heat Slabs
  4. Add Noncondensable Gas Field
  5. Design More Prototypical Facilities and Perform More Precise Tests

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PKL ANALYSIS STATUS

- COMBINED INJECTION TEST K1.3

  <u>STATUS</u>

  TRAC-P1A POSTTEST ANALYSIS DISCONTINUED AFTER 85 s

  QUENCH TIME OF LOW & INTERMEDIATE P RODS CONSISTENT WITH EXPERIMENT

  HOT ROD T IS 940 K AND RISING AT 85 s (MEASURED PEAK WAS 920 K AT 40 s)

  <u>PROBLEMS</u>

  USE OF PIPE MODULES TO MODEL DC PIPES GIVES INCORRECT REFILL RATE

  MgO THERMAL PROPERTIES NOT IN CODE (SIGNIFICANTLY DIFFERENT FROM BN)

  DEFICIENCIES IN REFLOOD HEAT TRANSFER PACKAGE

- COLD-LEG INJECTION TEST K5.4A

  DC PIPES MODELED WITHIN VESSEL COMPONENT

  GENERAL RESULTS TO 50 s IN REASONABLE AGREEMENT WITH DATA

  EFFORT DIVERTED TO TMI ANALYSIS

- GERMAN STANDARD PROBLEM K9

  TRAC INPUT MODEL COMPLETED, POSTTEST PREDICTION IN PROGRESS.

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