LA-UR -79-2969

TITLE: TRAC DEVELOPMENTAL CODE ASSESSMENT

AUTHOR(S): K. A. Williams

SUBMITTED TO: Seventh Water Reactor Safety Research Meeting
Gaithersburg, MD
November 5-9, 1979

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

1604 223

Form No. 836 R2
St. No. 2629
1/78

DEPARTMENT OF ENERGY
CONTRACT W-7405-ENG. 36

TRAC DEVELOPMENTAL CODE ASSESSMENT

by

K. A. Williams

Energy Division
Los Alamos Scientific Laboratory
University of California
Los Alamos, NM 87545

The main objective of the Transient Reactor Analyses Code (TRAC) developmental code assessment effort is to validate, or more accurately, to assess the range of applicability of the models and correlations in the code. Secondary objectives are to determine code sensitivity to input parameters, model assumptions, and solution techniques. As a result of these efforts we hope to identify areas where code improvements and/or additional experimental data are needed. To achieve these objectives, TRAC is being used for posttest analyses and pretest analyses and pretest predictions of a wide range of experiments.

The current developmental assessment program can be divided into two categories. The first being the continued "reassessment" of the latest developmental code version. This task is concerned with assessing each change made to the methods, models, correlations and/or code structure before it becomes a permanent part of the current code. We have found this procedure to be extremely beneficial in that it tends to eliminate errors in the changes before they become imbeded in the code. However, the costs associated with a complete recalculation of our comprehensive assessment problem set prohibits such a full recalculation for each change. Rather, only the pertinent test problems for each change are rerun. For example, if a code change only affects the reflood quench propagation model, then only the assessment problems pertaining to reflood are recalculated. It is only after a number of major updates have been made to the code that a complete recalculation of the assessment problem set is made. Prior to the public release of new code version, that version is extensively tested by a final recalculation of the problem set as well as by analysis of other significant test problems. The detailed comparisons between these calculations and the experimental data are formally documented in a volume that is included with each code version. We have completed such an assessment documentation for TRAC-P1A.

The second major category of the developmental assessment program is providing pretest predictions using our latest inhouse code version. Although there is a formal program for independent code assessment using the frozen, public release version, it has occassionally been felt that the developmental code would produce significantly improved results. This has been due to the discovery of errors in the release version (that are not allowed to be modified), and due to model improvements. A particular case in point are the LOFT nuclear tests. Changes to the heat transfer correlation routine resulted in substantially different pretest predictions of the cladding temperature responses between the release code and the developmental version for LOFT test L2-3. Using the developmental version for a "double-blind" pretest prediction of L2-3, we were able to predict the core rewets and dryouts at the core high power locations. Specifically the predicted peak clad temperature was within 20 K of the measured data and the initial rewet time within 1 s. We feel that using our developmental code version for pretest predictions is a very valuable part of our developmental assessment program.

The details of these LOFT nuclear calculations are the main body of this paper. In general, we are very satisfied with the ability of TRAC to predict the overall system response for both of the LOFT nuclear tests to date. This paper also presents some very encouraging results from recent major modifications to the reflood package. Finally, our latest comprehensive code testing against the complete assessment set shows improved results over version P1A, and with a corresponding reduction in computational time.

CREDITS

TRAC DEVELOPMENTAL CODE ASSESSMENT

K. A. WILLIAMS
J. K. MEIER
R. K. FUJITA
J. S. GILBERT
D. A. MANDELL

University of California
LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663, Los Alamos, New Mexico 87545

An affirmative action / equal opportunity employer

TRAC DEVELOPMENTAL ASSESSMENT

OBJECTIVES

- VALIDATE MODELS AND CORRELATIONS
- DEFINE LIMITS OF VALIDITY
- DETERMINE SENSITIVITY
- SUGGEST CODE IMPROVEMENTS
- RECOMMEND STANDARD PROCEDURES
- IDENTIFY NEEDED EXPERIMENTS

1604 227

University of California
LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663, Los Alamos, New Mexico 87545

TRAC DEVELOPMENTAL CODE ASSESSMENT PROGRAM

"REASSESSMENT" OF CURRENT DEVELOPMENTAL VERSION(S)

- RECALCULATE PERTINATE ASSESSMENT PROBLEMS FOR EACH METHOD, MODEL, AND/OR CORRELATION CHANGES
- PROVIDE COMPREHENSIVE ASSESSMENT OF EACH TRAC VERSION PRIOR TO ITS PUBLIC RELEASE (WITH DOCUMENTATION)

PROVIDE PRETEST PREDICTIONS USING INHOUSE TRAC VERSION

- METHODS, MODEL AND/OR CORRELATION IMPROVEMENTS OFTEN WARRENT USING THE CURRENT INHOUSE TRAC VERSION FOR PRE-TEST PREDICTIONS (E.G. LOFT)

ASSESSMENT OF THE PREDICTIVE CAPABILITIES OF THE DEVELOPMENTAL VERSION OF TRAC

- HYDRODYNAMICS -

BLOWDOWN PHASE

LARGE BREAK (~100%):

VERY GOOD FOR A WIDE RANGE OF EXPERIMENTS. CHARACTERISTIC DIMENSIONS RANGE FROM 0.02 M TO 0.5 M. FLUID CONDITIONS RANGE FROM HIGHLY SUBCOOLED LIQUID TO TWO-PHASE MIXTURE, TO SATURATED AND SUPERHEATED VAPOR. EXPERIMENTAL FACILITIES: EDWARDS, CISE, MARVIKEN, SEMISCALE, LOFT

SMALL BREAK

VERY GOOD FOR SINGLE PHASE FLOW. INSUFFICIENT DATA COMPARISONS FOR TWO-PHASE FLOWS. CLOSELY COUPLED TO CALCULATED INLET FLUID CONDITIONS (E.G. LEVEL SWELL).

EXPERIMENTAL FACILITIES: CISE, LOFT, ANALYTICAL

1604 229

REFILL/BYPASS PHASE

DOWNCOMER (3-D CALCULATION)

EXCELLENT FOR SMALL SCALES (1/15 - 3/15). INSUFFICIENT DATA COMPARISONS AT FULL SCALE. WIDE RANGE OF ECC SUBCOOLINGS AND INJECTION RATES. TENDS TO SLIGHTLY OVERPREDICT DELIVERY. EXPERIMENTAL FACILITIES: CREARE, BATTELLE, LOFT

PIPES (1-D CALCULATION)

POOR FOR ALL FLOW REGIMES EXCEPT DISPERSED FLOW. TENDS TO UNDERPREDICT PENETRATION. INSUFFICIENT DATA FOR LARGE (~.5 M) PIPES. EXPERIMENTAL FACILITIES: SEMISCALE MOD-3, INEL AIR/WATER TESTS, DARTMOUTH

REFLOOD PHASE

STRONGLY COUPLED TO HEAT TRANSFER. VERY GOOD RESULTS FOR HIGH FLOODING RATES; POOR RESULTS FOR LOW FLOODING RATES AND LOWER PLENUM ECC INJECTION. UNDERPREDICTS LIQUID CARRYOVER AND PRECURSORY COOLING. PRESSURE SPIKES.

EXPERIMENTAL FACILITIES: FLECHT-SET, FLECHT-SEASET, UCB, LOFT

NEAR TERM OBJECTIVES - HYDRO ASSESSMENT

- ASSESS THE FEASIBILITY OF A BREAK FLOW MODEL FOR SMALL BREAKS. ALSO ASSESS THE CHOKING MODEL CURRENTLY IN THE SEMI-EXPLICIT 1-D.
- ASSESS TWO-FLUID ONE-DIMENSIONAL HYDRO, PARTICULARILY FOR CCFL, LEVEL SWELL AND PHASE SEPARATION
- ASSESS IMPROVED COUPLING BETWEEN HYDRO AND HEAT TRANSFER: CORE AND STEAM GENERATOR
- ASSESS IMPROVEMENTS TO OVERALL MASS CONSERVATION. APPARENT INCONSISTENCY IN VAPOR EOS FOR STEAM
- ASSESS 3-D VESSEL FOR CALCULATING SIMPLE WATER SLOSHING, SYMMETRY, AND LEVEL TRACKING PROBLEMS. IN GENERAL, ASSESS THE ABILITY OF TRAC TO CALCULATE SIMPLE, SLOW TRANSIENTS.

- HEAT TRANSFER -

BLOWDOWN PHASE

NUCLEATE BOILING REGIME ACCURATELY MODELED: TIME TO DNB VERY GOOD FOR A WIDE RANGE OF GEOMETRICS AND FLUID CONDITIONS. PEAK CLAD TEMPERATURE NORMALLY OCCURS DURING THIS PHASE - GENERALLY VERY GOOD AGREEMENT WITH DATA. ROD REWETS (OR RNB) ACCURATELY MODELED USING ILOEJE T_{MIN}.
EXPERIMENTAL FACILITIES: CISE, SEMISCALE, LOFT

REFILL/BYPASS PHASE

HEAT TRANSFER COEFFICIENTS BETWEEN RODS AND FLUID CALCULATED ACCURATELY FOR FILM BOILING AND SUPERHEATED VAPOR. UNDER PREDICTS PRECURSARY COOLING DUE TO ENTRAINED LIQUID AND SPUTTERING ON CLAD.
EXPERIMENTAL FACILITIES: SEMISCALE, LOFT

REFLOOD PHASE

CORE CONDITIONS AT THE BEGINNING OF REFLOOD MAY BE CONSIDERABLY DIFFERENT THAN PREVIOUSLY THOUGHT DUE TO EARLY ROD REWETS. THUS, PCT MAY NOT OCCUR DURING REFLOOD.
REFLOODING RATE GENERALLY UNDERPREDICTED BY A SUBSTANTIAL AMOUNT FOR COLD LEG ECC; STEAM GENERATION DUE TO ROD QUENCHING TENDS TO EXPELL LIQUID FROM THE CORE. NUCLEAR FUEL ROD MODEL NEED TO INCLUDE DYNAMIC FUEL GAP DIMENSION.
EXPERIMENTAL FACILITIES: FLECHT-SET, FLECHT-SEASET, U.C. BERKELEY, SEMISCALE, LOFT

NEAR TERM OBJECTIVES - HEAT TRANSFER ASSESSMENT

- ASSESS RECENT IMPROVEMENTS & CORRECTIONS TO THE HEAT TRANSFER/BOILING CURVE (HTCOR)

- ASSESS ILOEJE T_{MIN} FOR SEVERAL DIFFERENT EXPERIMENTAL FACILITIES

- ASSESS ROD GAP MODELS

- ASSESS NEW REFLOOD FINE MESH TECHNIQUE; HYDRO/HEAT TRANSFER COUPLING DURING REFLOOD.

TRAC CALCULATIONS OF LOFT NUCLEAR TEST L2-2

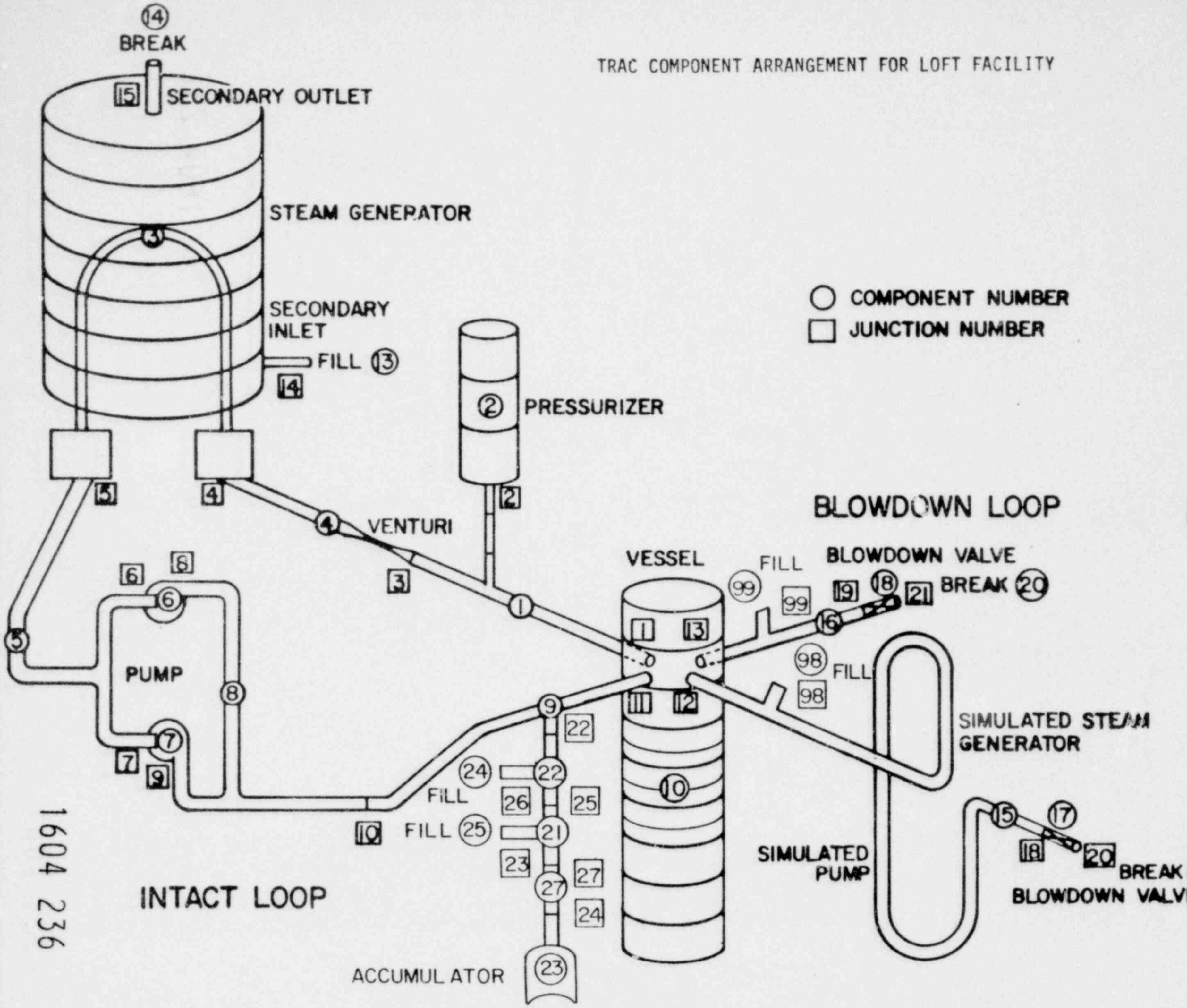
1604 234

University of California
LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663, Los Alamos, New Mexico 87545

L2-2 STEADY STATE

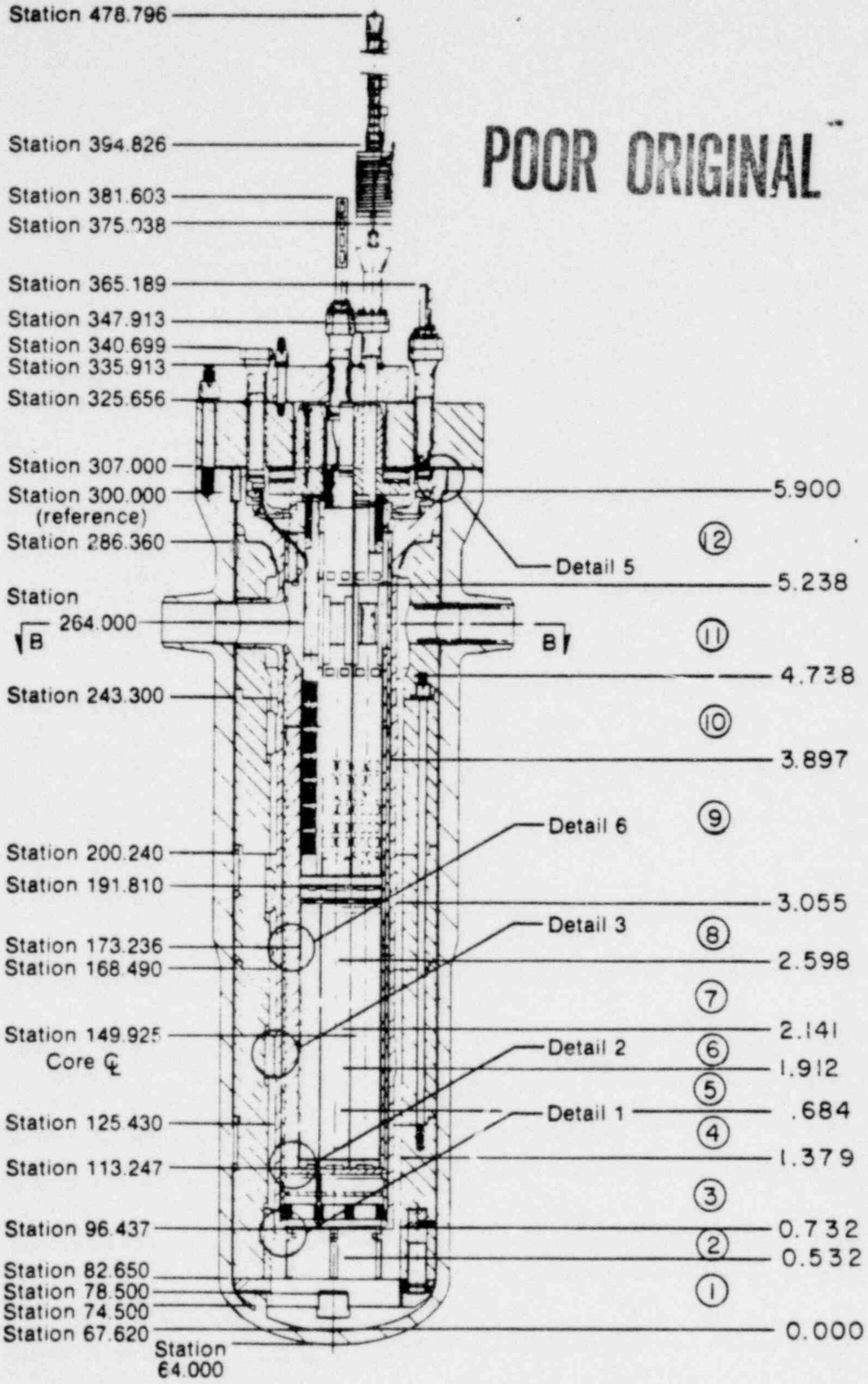
Parameter	L2-2 Data	TRAC (Posttest)	TRAC (Pretest)
Intact hot-leg temperature (K)	580.6	580.8	593.0
Intact cold-leg temperature (K)	558.8	559.0	566.0
Core ΔT (K)	21.8	21.8	26.6
Intact loop mass flow (kg/s)	197.5	207.1	186.6
Pump ΔP (Pa)	9.1×10^4	9.2×10^4	7.8×10^4
Pressurizer pressure (Pa)	155×10^5	155×10^5	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

TRAC COMPONENT ARRANGEMENT FOR LOFT FACILITY



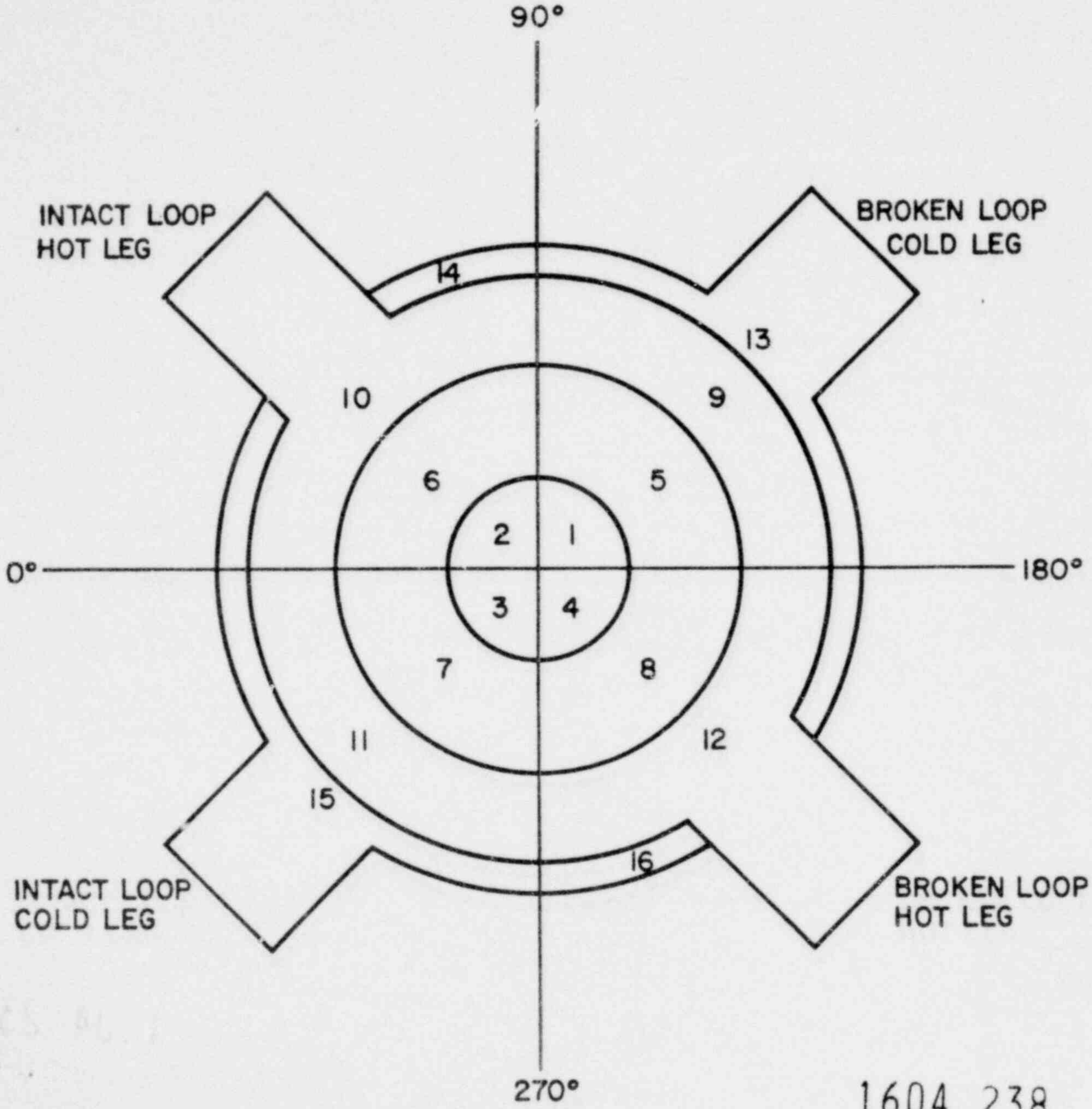
POOR ORIGINAL

1604 236



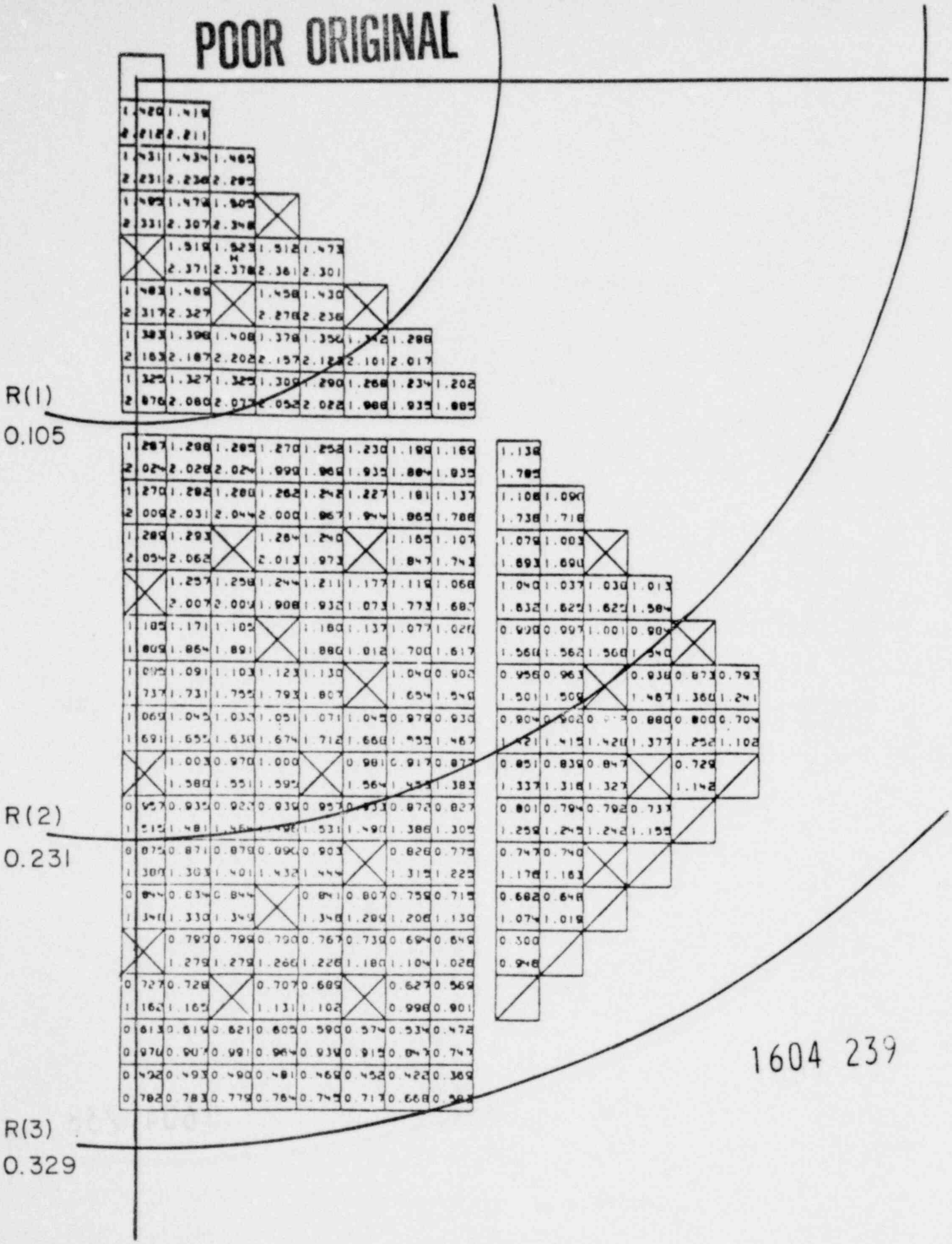
1604 237

TRAC VESSEL AXIAL NODING FOR LOFT



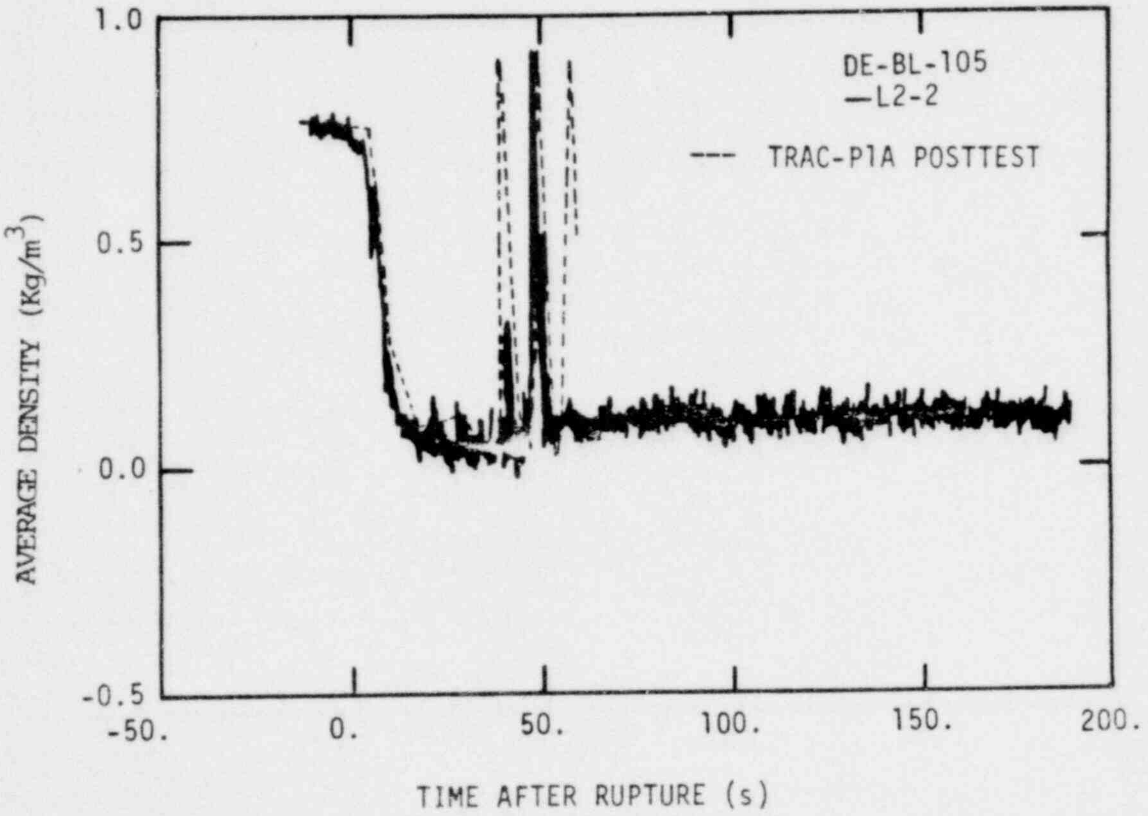
TRAC VESSEL LEVEL NODING FOR LOFT

POOR ORIGINAL



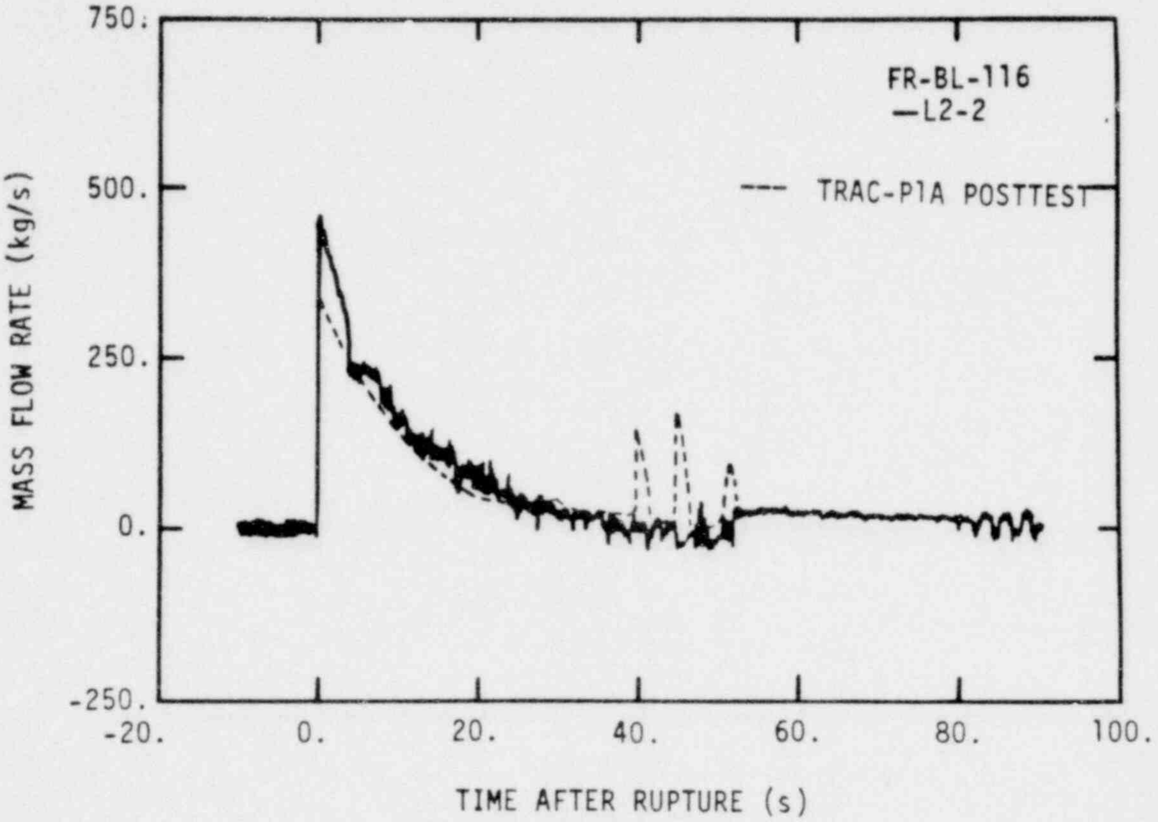
1604 239

TRAC CORE LEVEL NODING FOR LOFT RELATIVE TO FUEL ASSEMBLIES

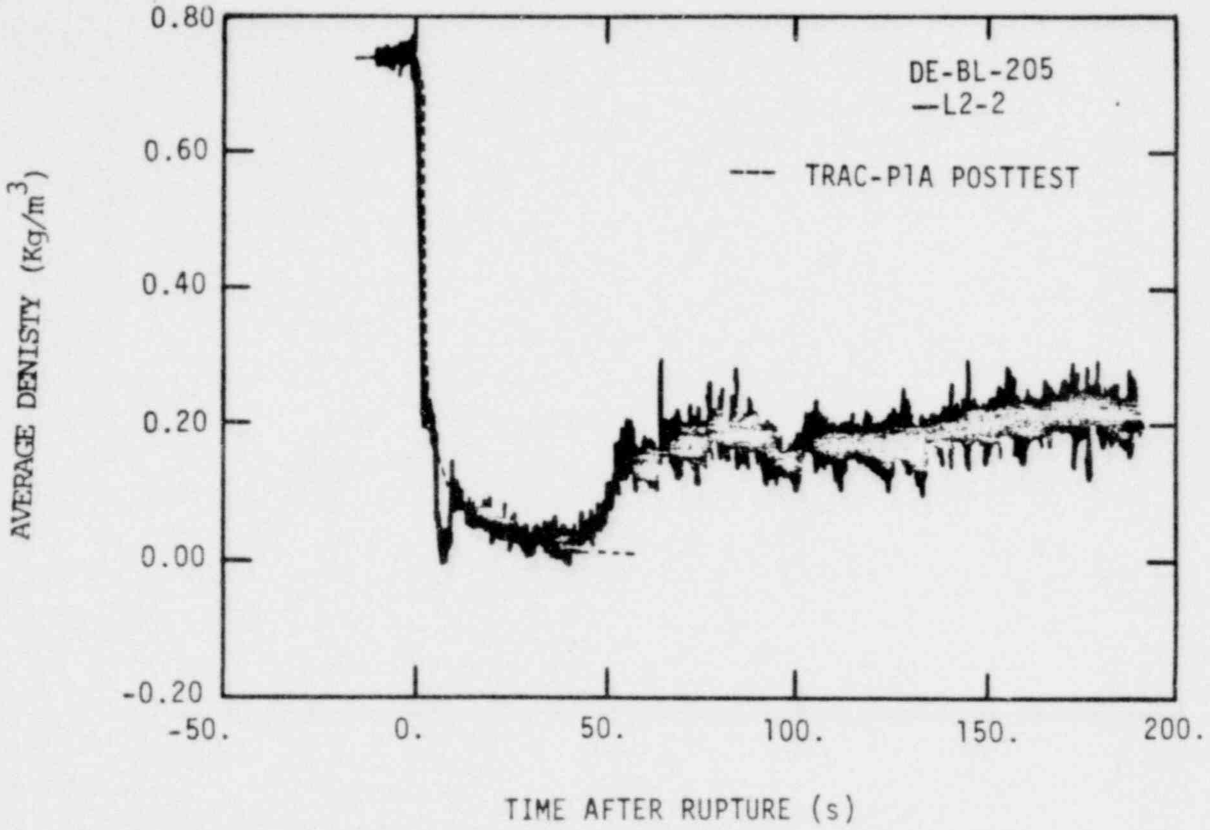


Average fluid density in broken loop cold leg.

1604 240

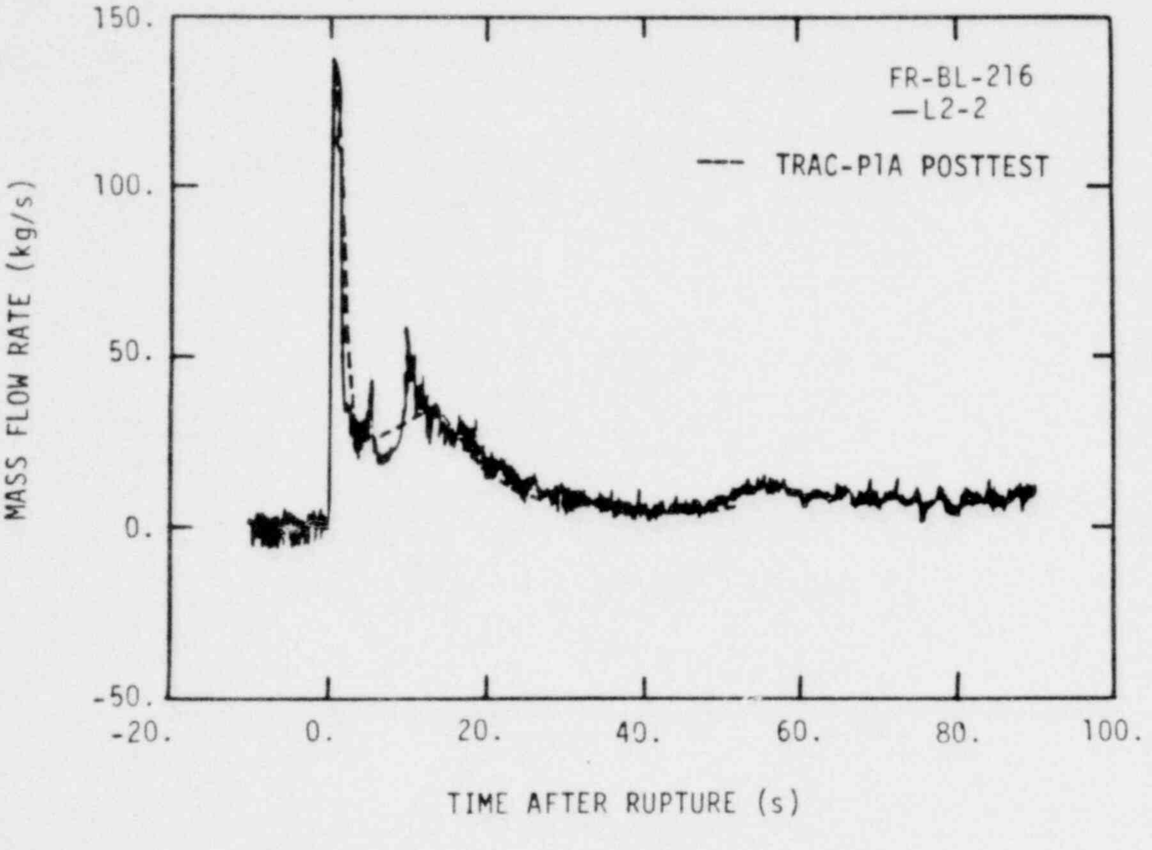


Mass flow rate in broken loop cold leg.

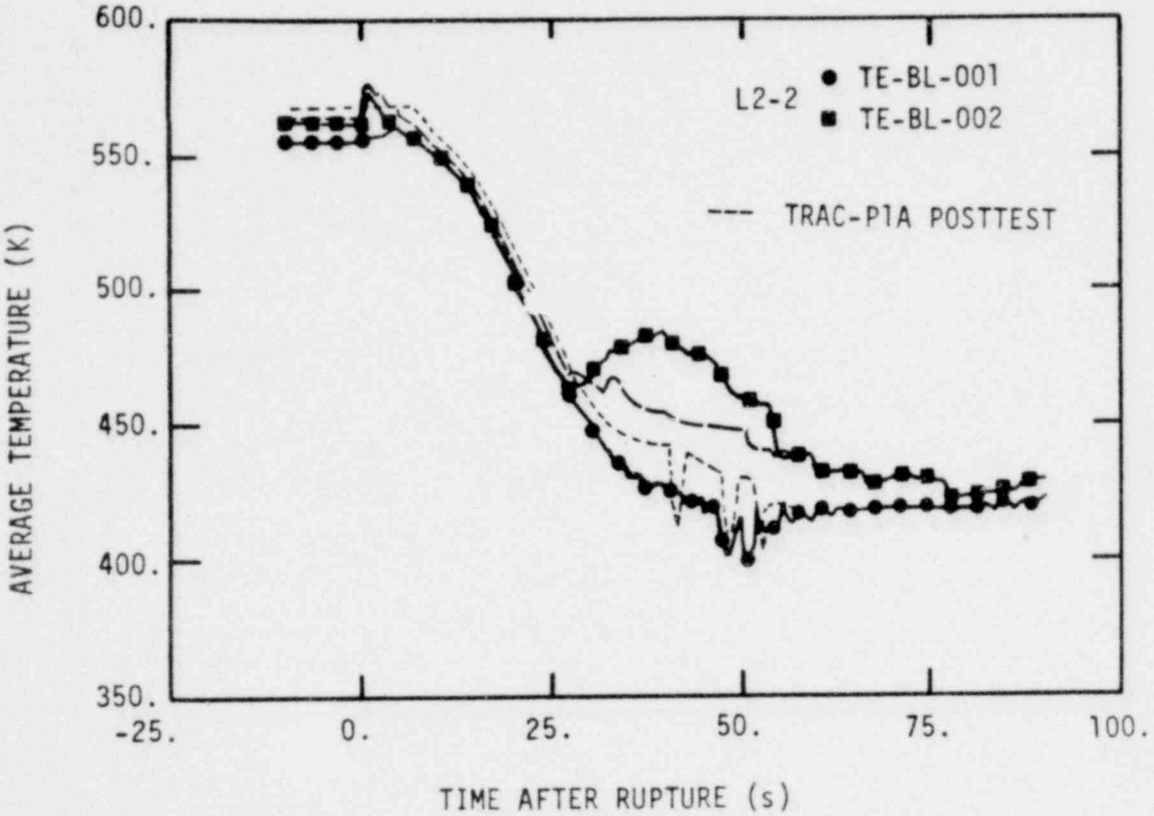


Average fluid density in broken loop hot leg.

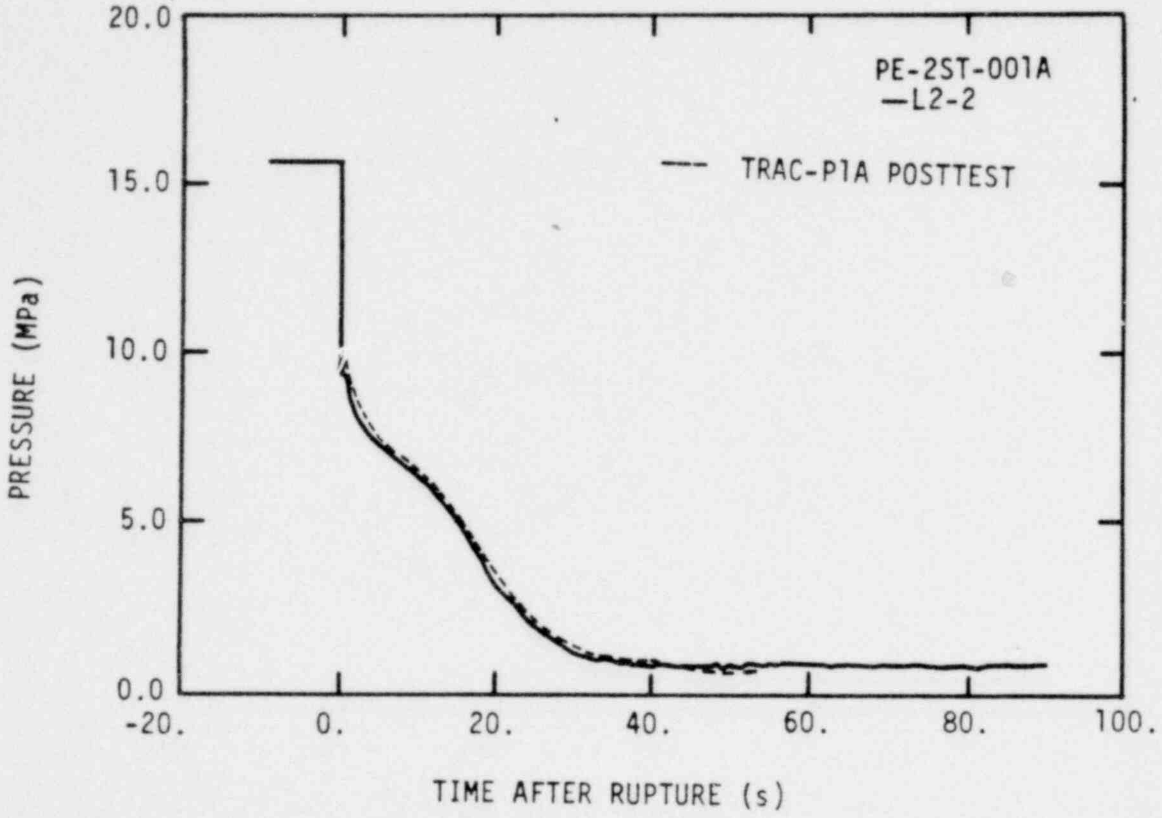
1604 242



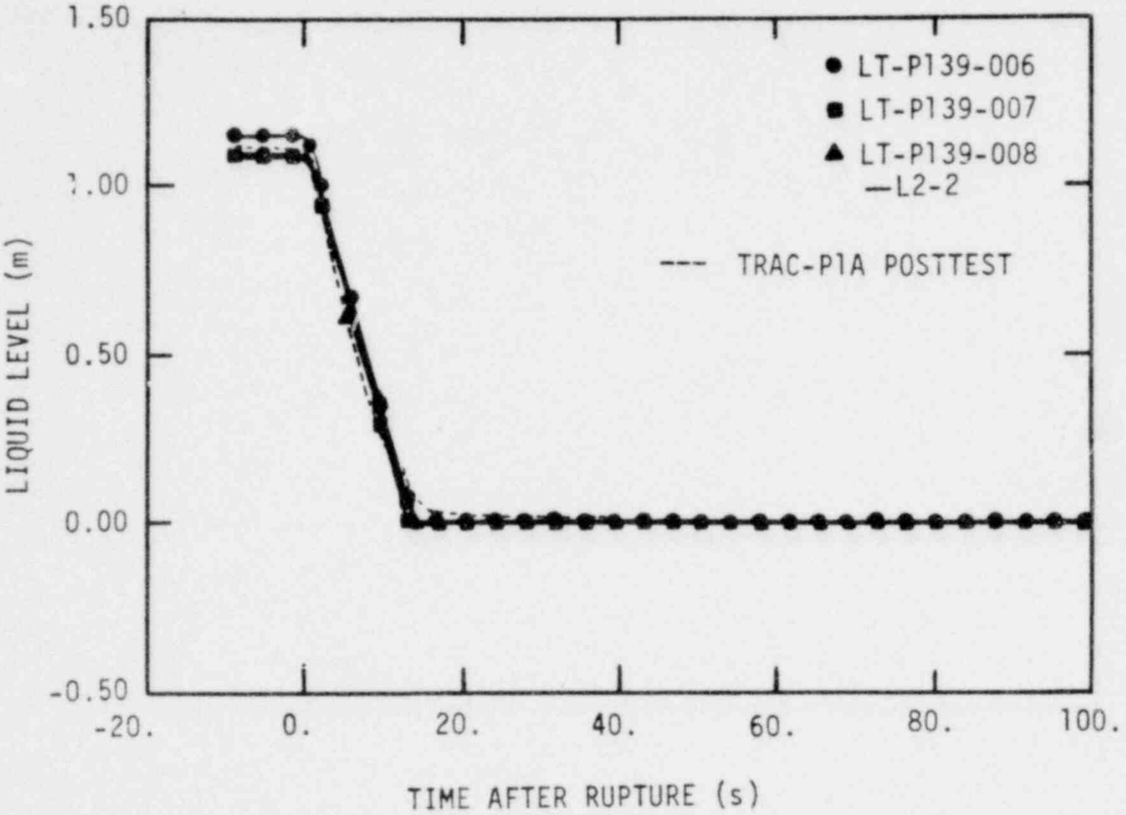
Mass flow rate in broken loop hot leg.



Average coolant temperature in broken loop cold leg and hot leg.

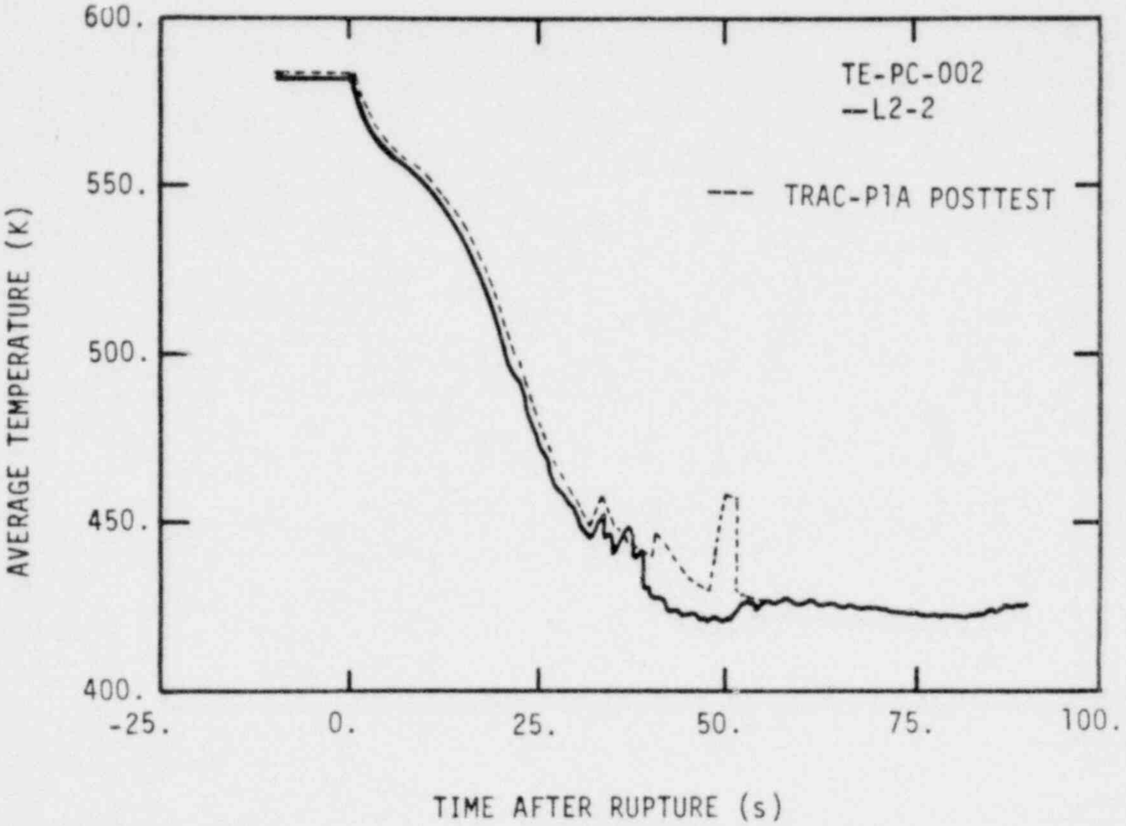


Pressure in reactor vessel downcomer.

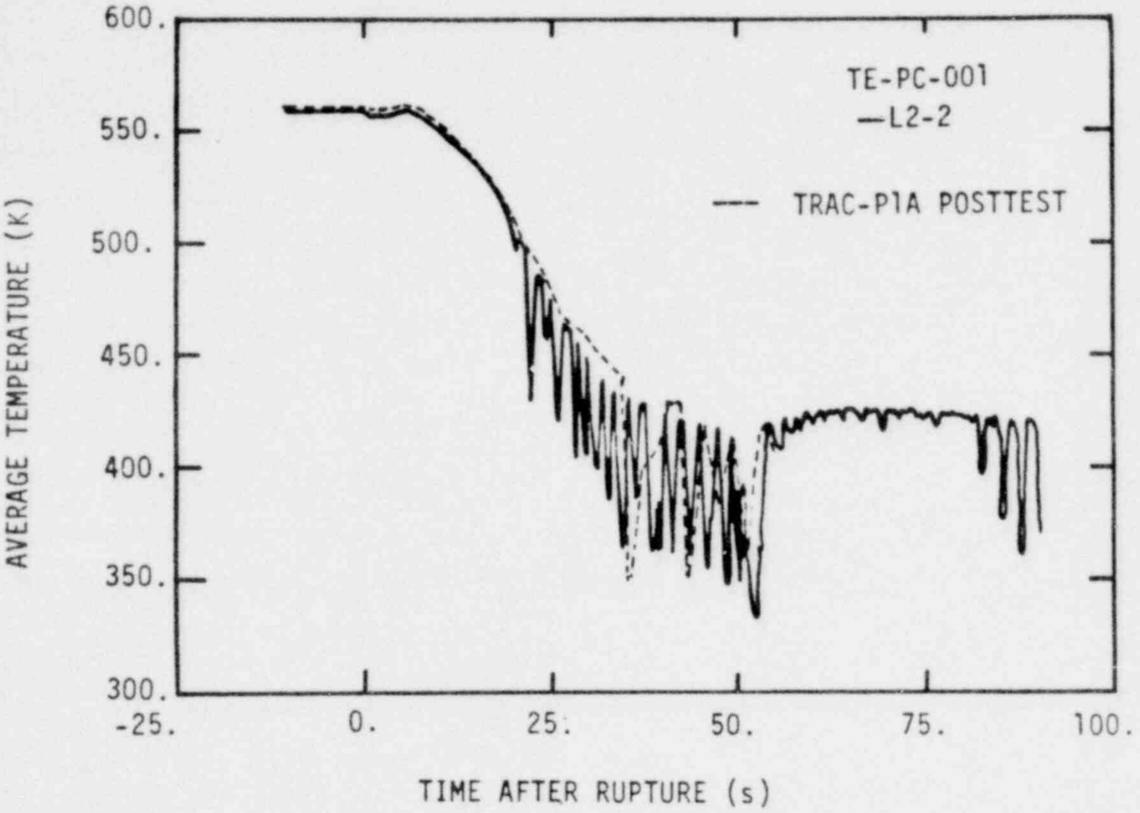


Liquid level in pressurizer.

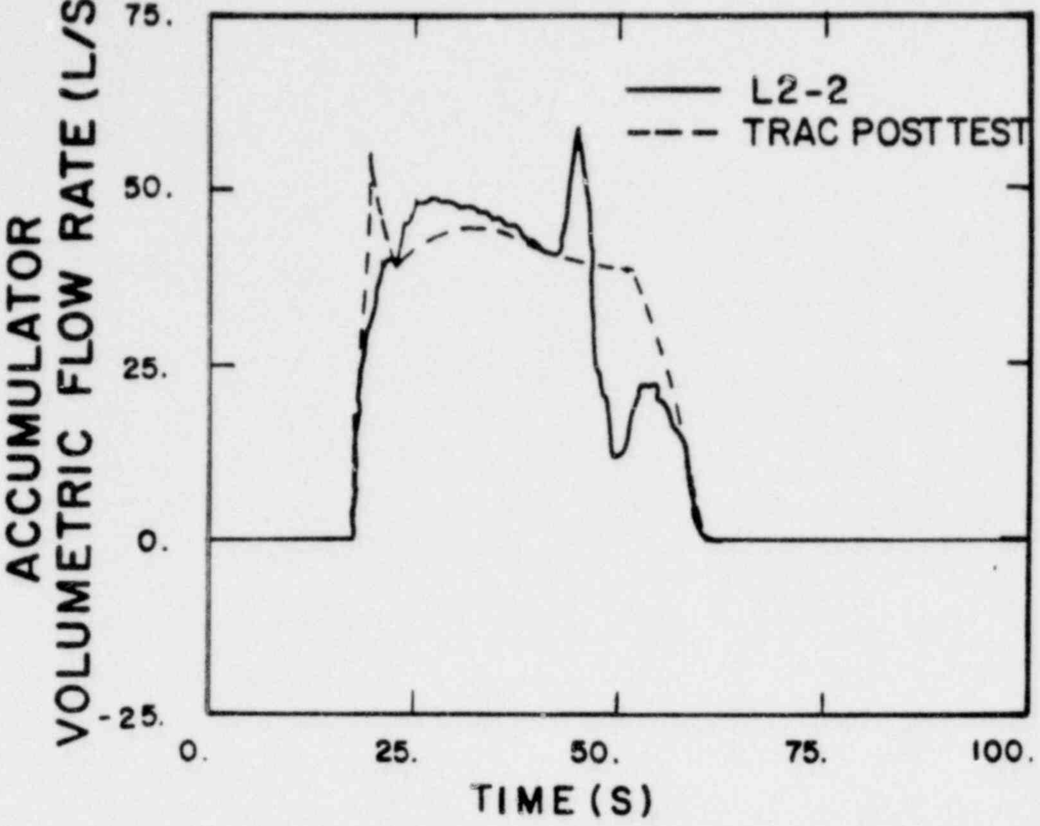
1604 246

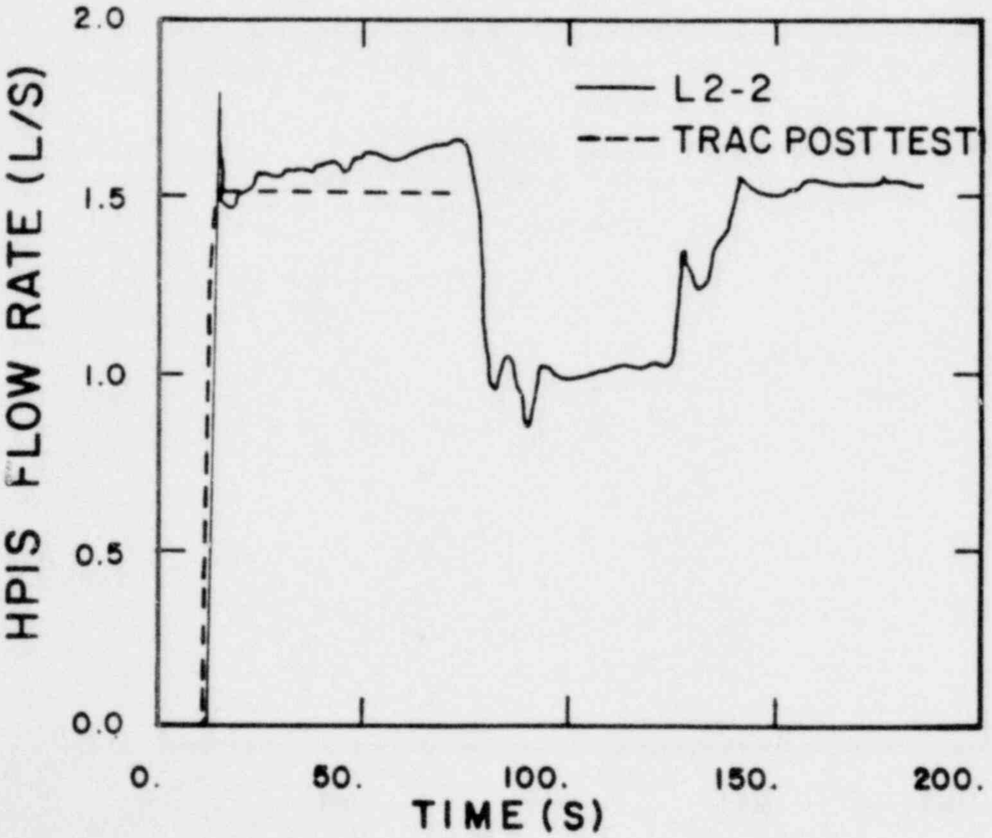


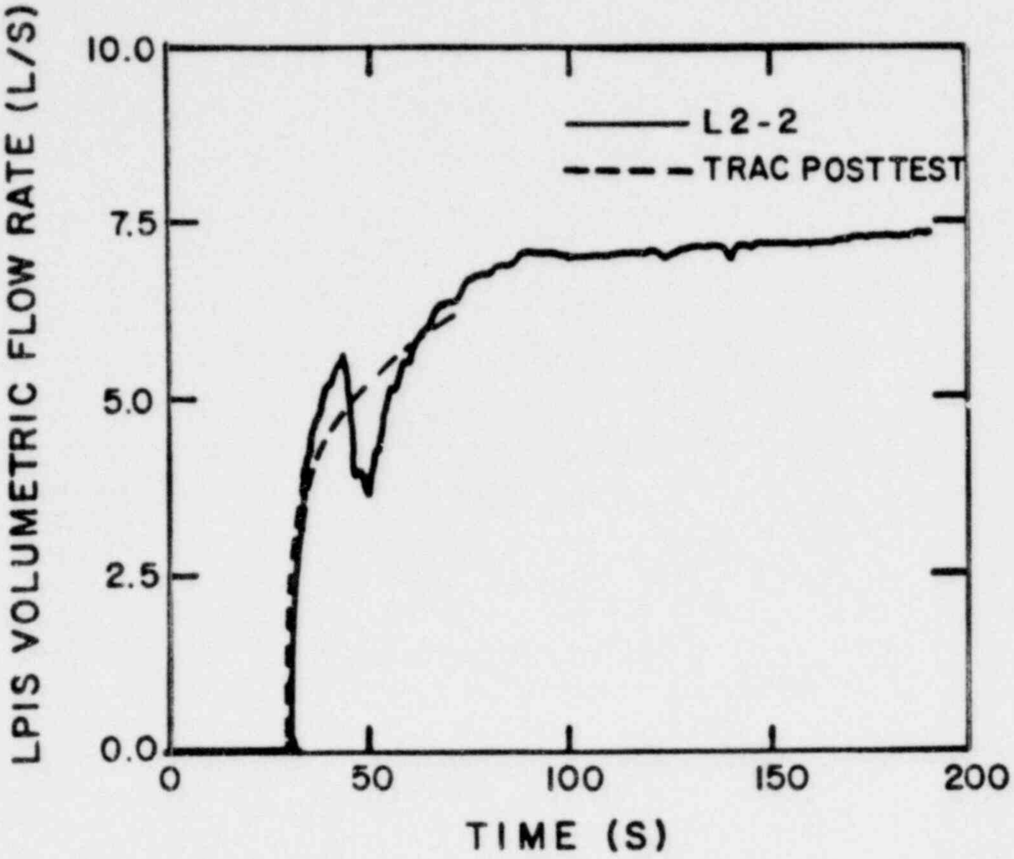
Average coolant temperature in intact hot leg.

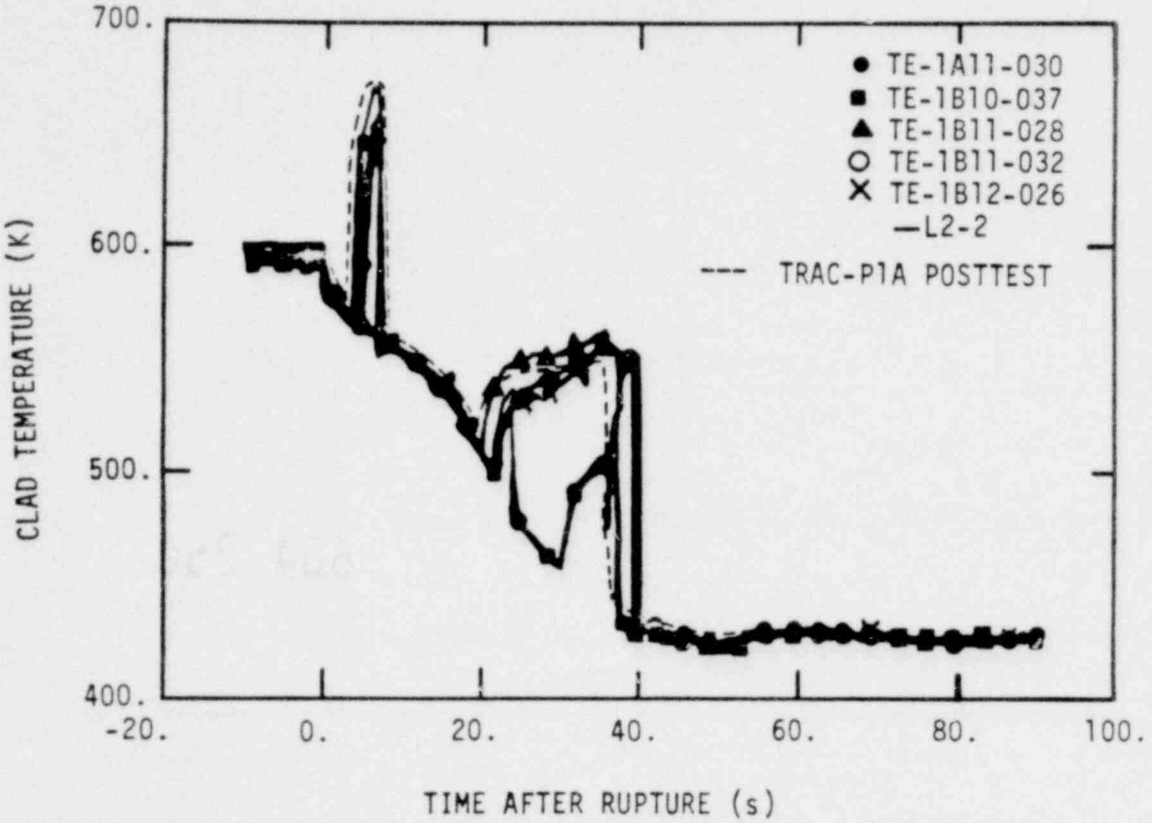


Average coolant temperature in intact cold leg.


ACCUMULATOR
VOLUMETRIC FLOW RATE (L/S)
75.
50.
25.
0.
-25.
0.
25.
50.
75.
100.
TIME (S)
L2-2
TRAC POSTTEST

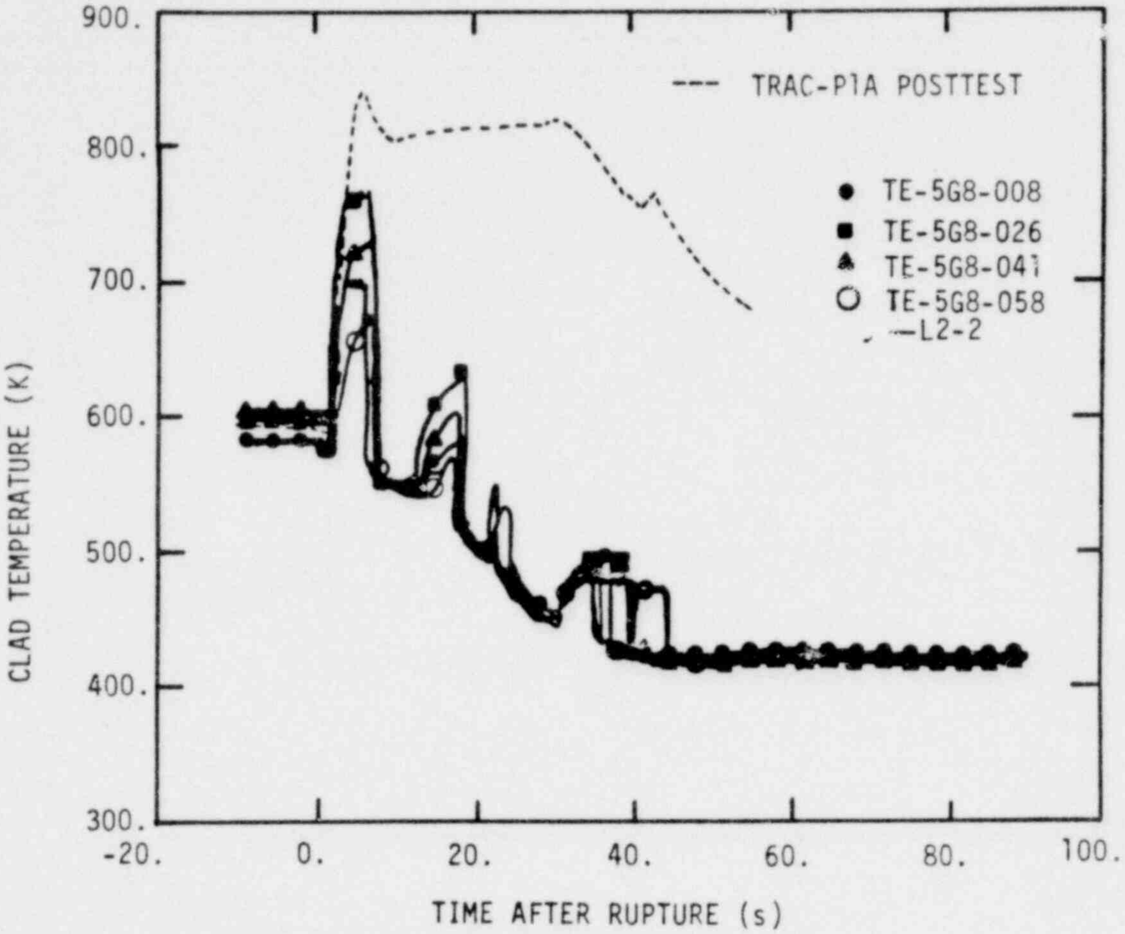

HPIS FLOW RATE (L/S)
2.0
1.5
1.0
0.5
0.0
0.
50.
100.
150.
200.
TIME (S)
L2-2
TRAC POSTTEST


LPIS VOLUMETRIC FLOW RATE (L/S)
10.0
7.5
5.0
2.5
0.0
0
50
100
150
200
TIME (S)
L2-2
TRAC POSTTEST



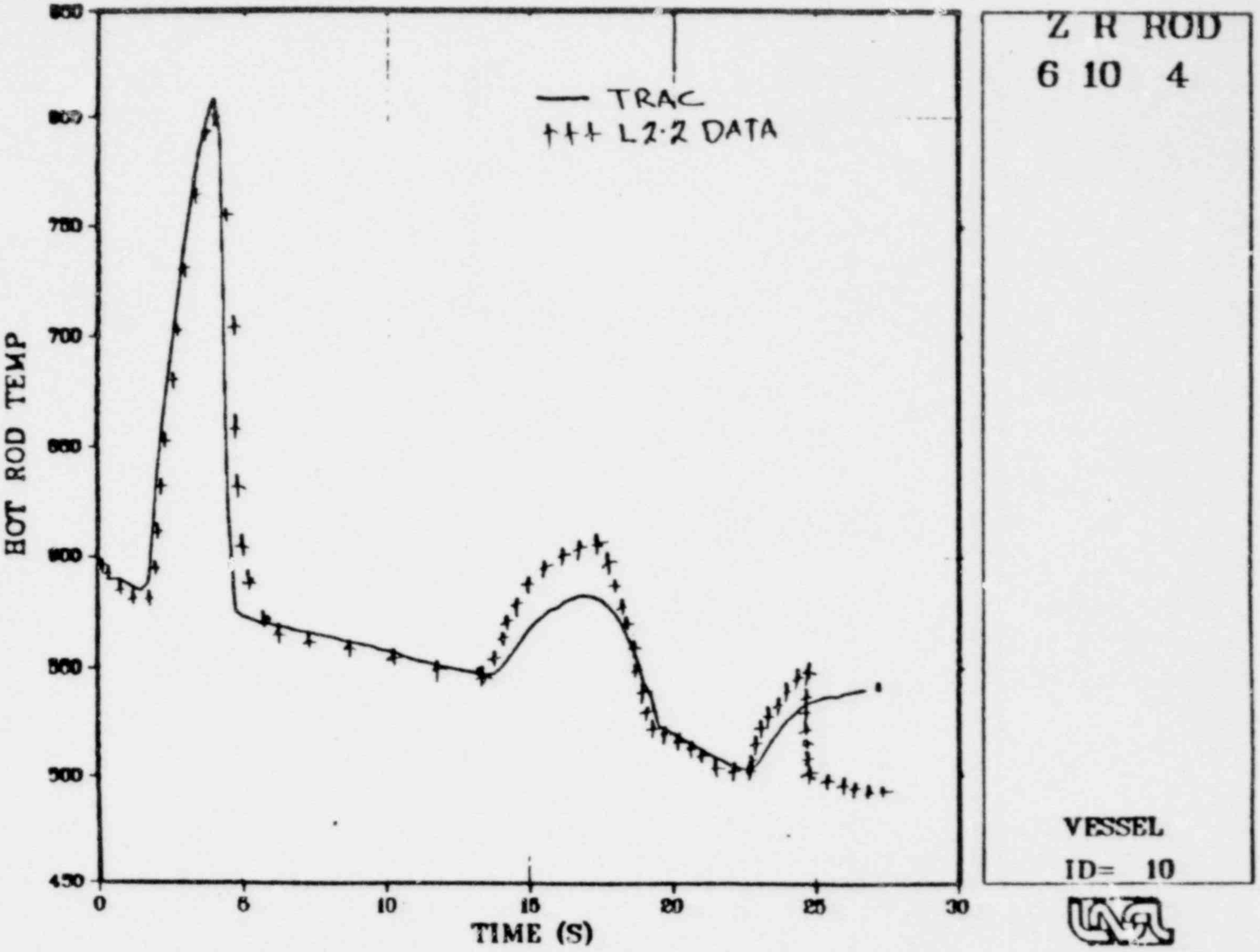
Temperature of cladding of low power rods on Assembly 1.

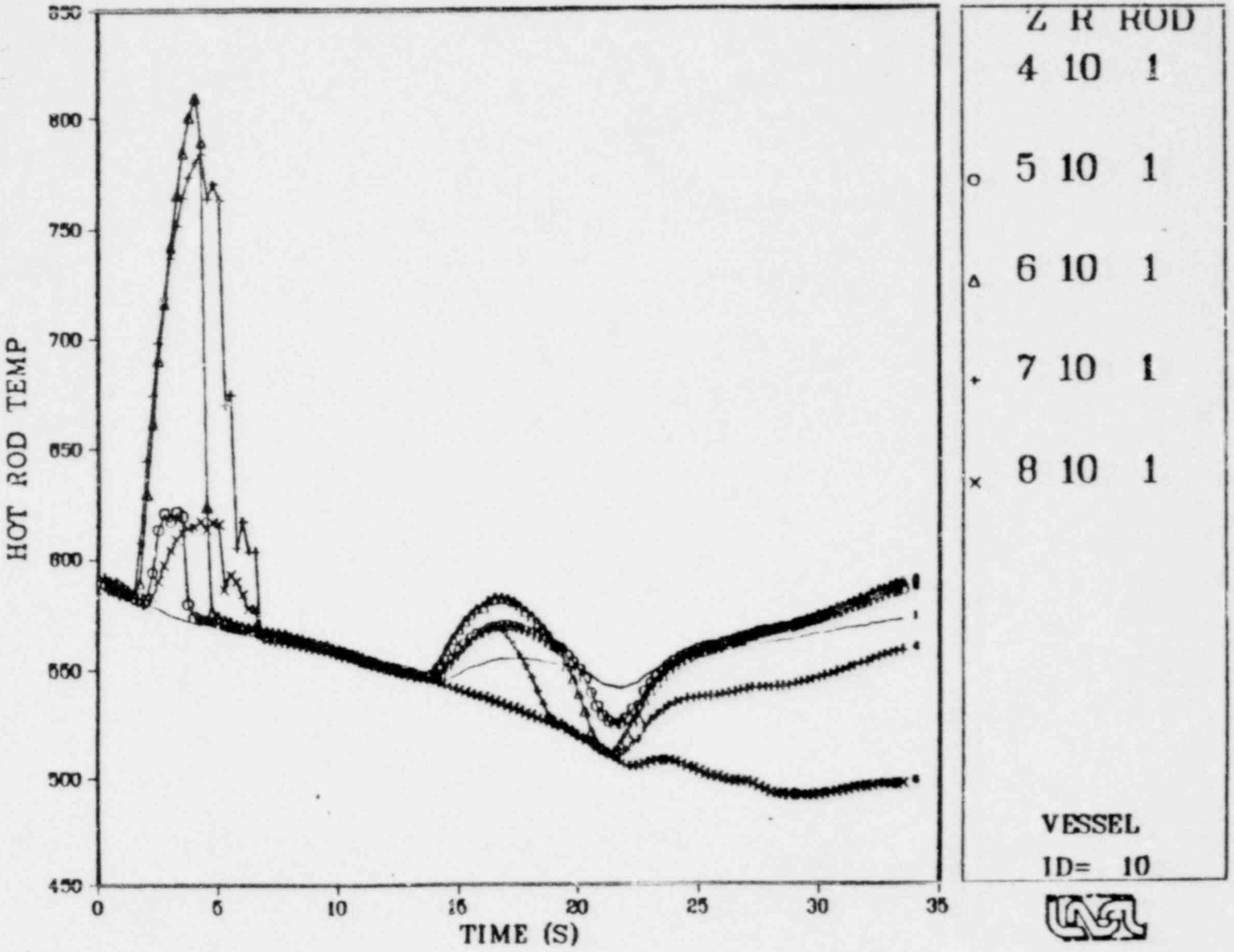
1604 251



Temperature of cladding of high power rods in center assembly.

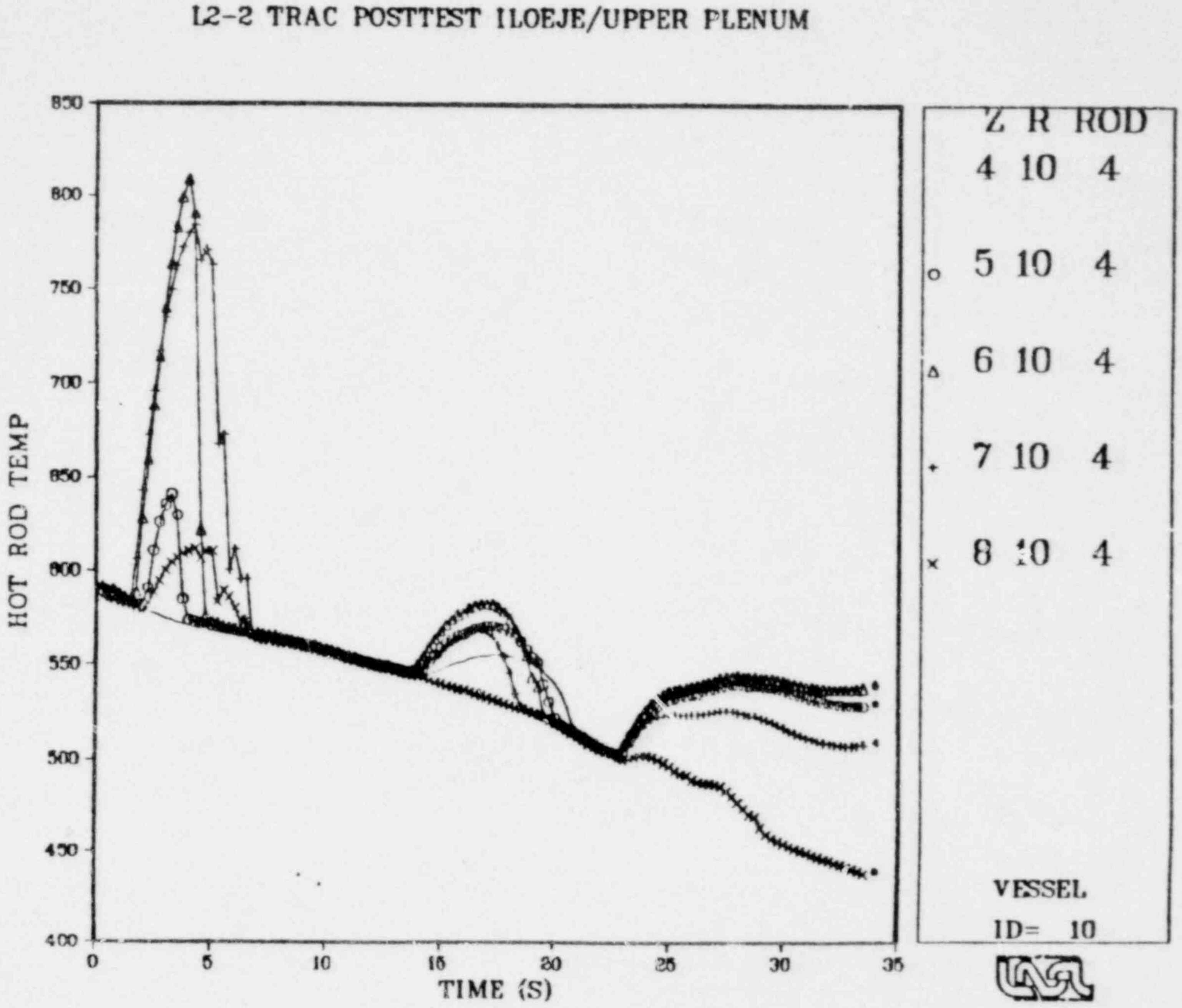
L2-2 TRAC POSTTEST ILOEJE/UPPER PLENUM





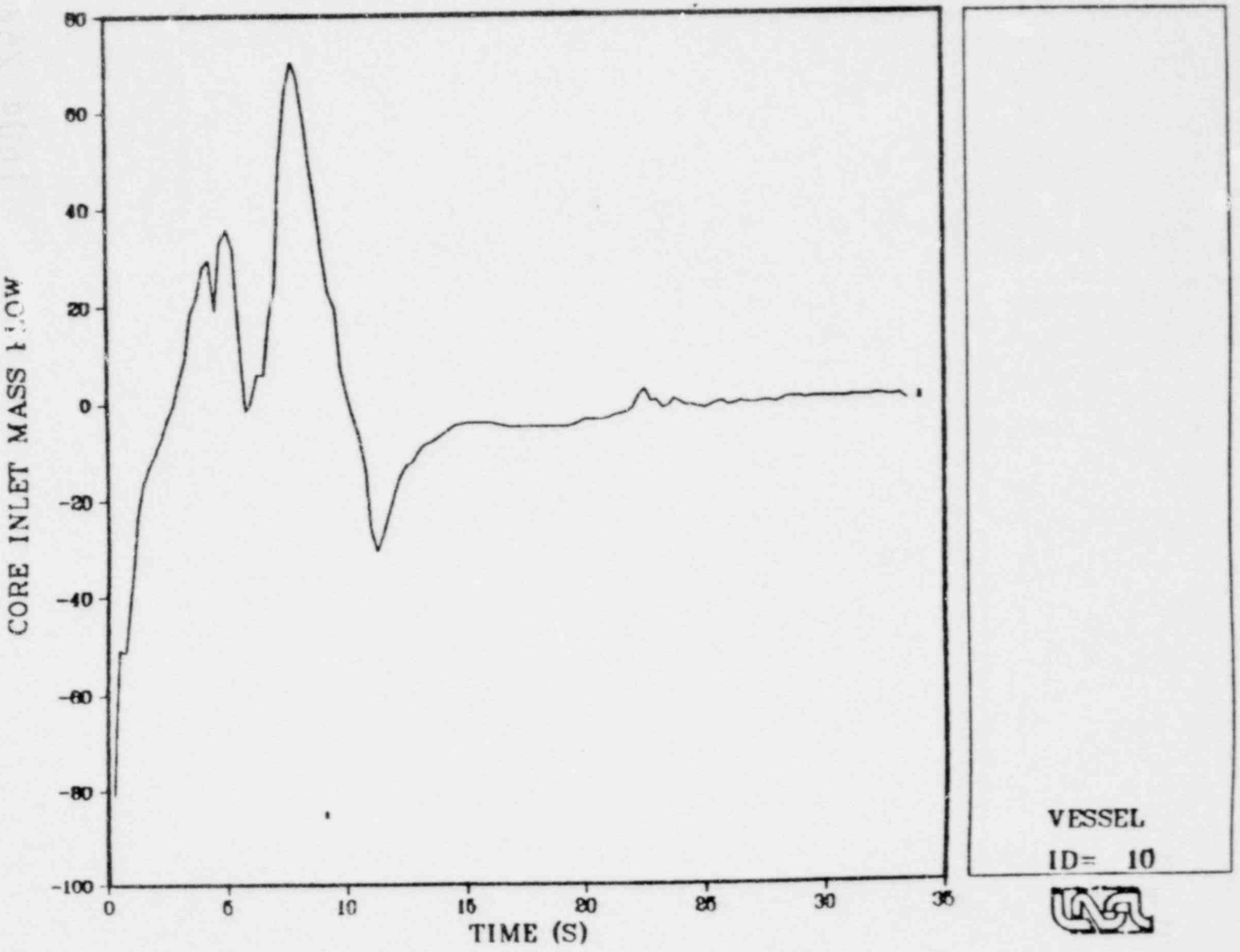
L2-2 TRAC POSTTEST ILOEJE/UPPER PLENUM

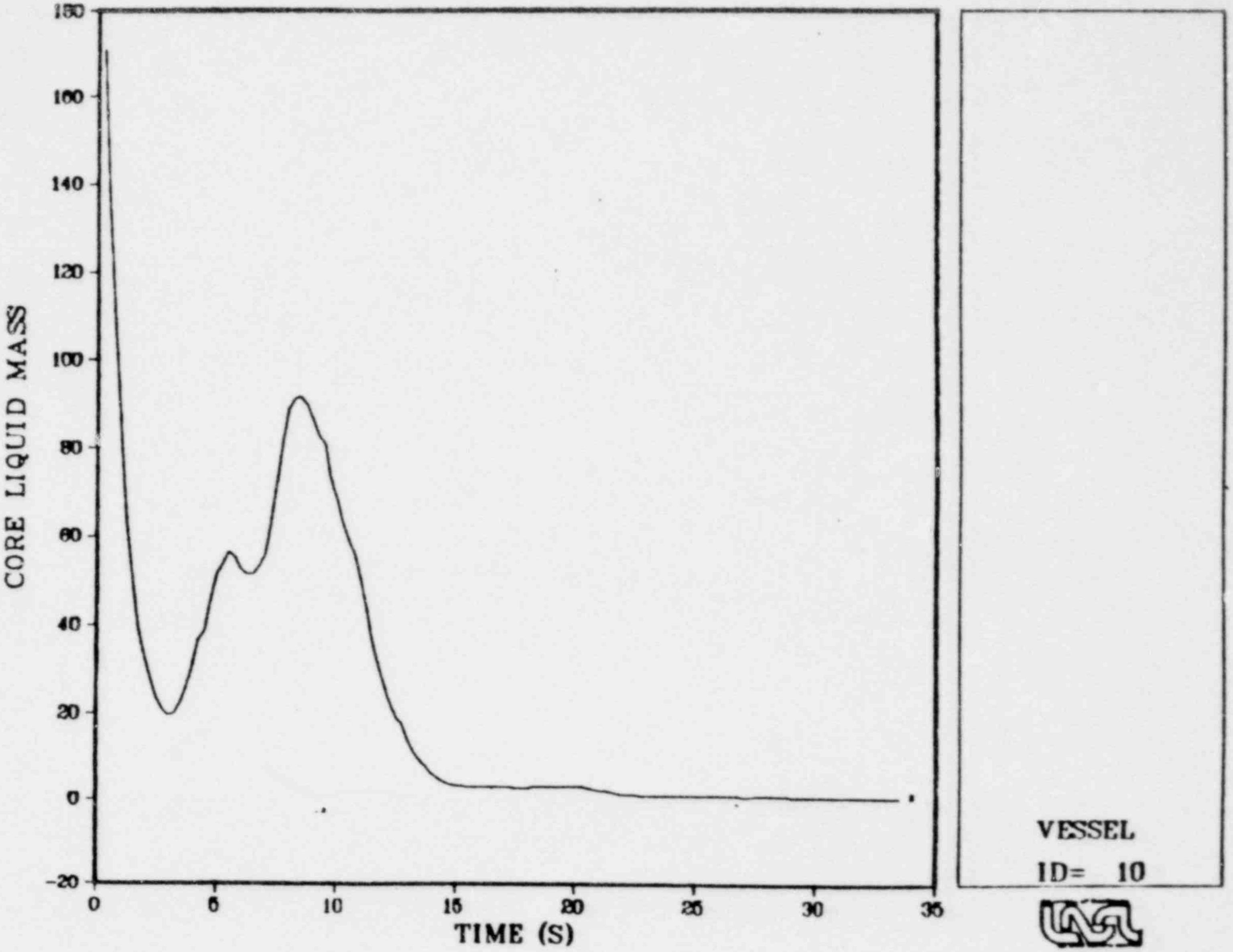
1604 254


L2-2 TRAC POSTTEST ILOEJE/UPPER PLENUM
HOT ROD TEMP
850
800
750
700
650
600
550
500
450
400
0
5
10
15
20
25
30
35
TIME (S)
Z R ROD
4 10 4
○ 5 10 4
△ 6 10 4
+ 7 10 4
× 8 10 4
VESSEL
ID= 10

1604 255

L2-2 TRAC POSTTEST ILOEJE/UPPER PLENUM





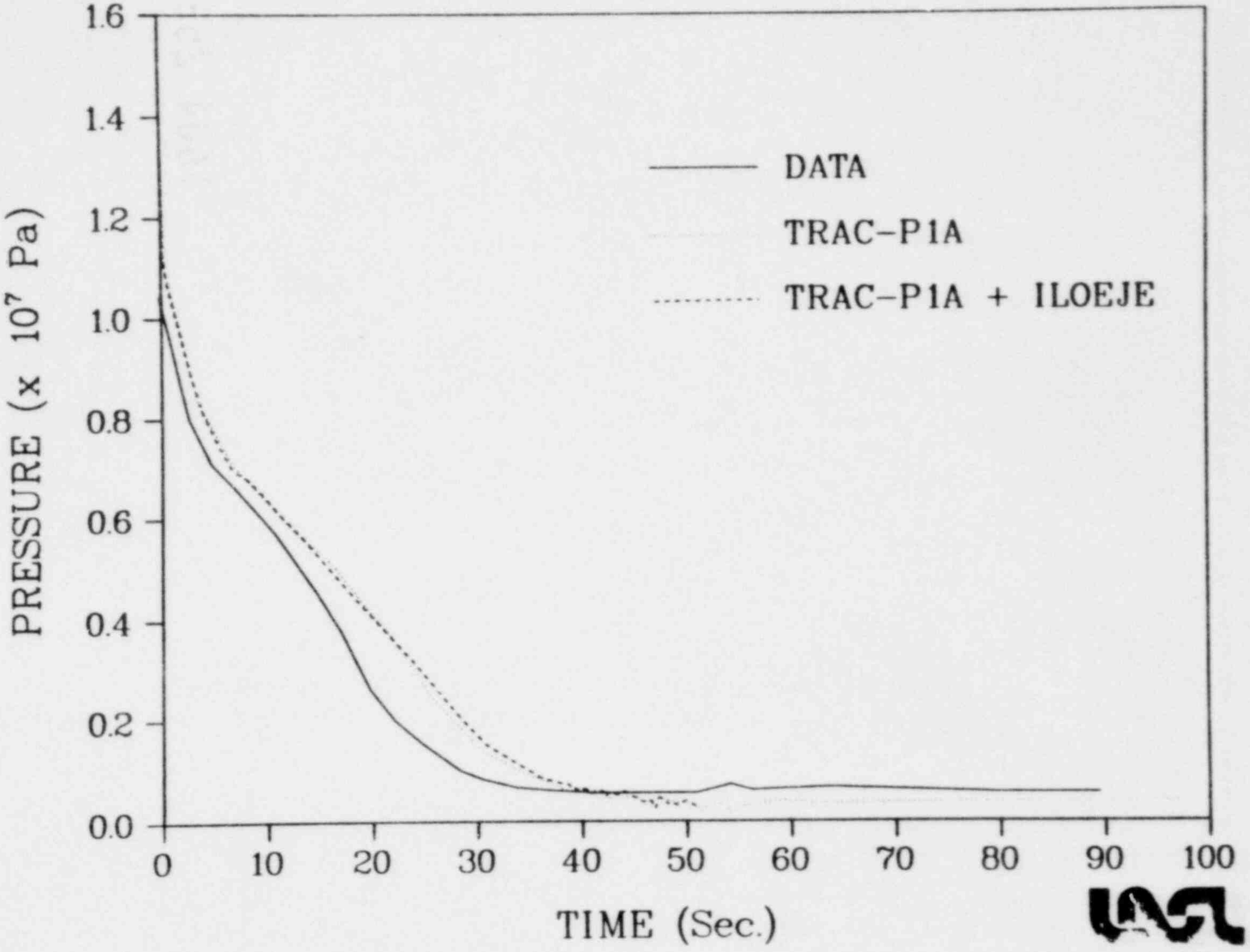
L2-2 TRAC POSTTEST ILOEJE/UPPER PLENUM

TRAC CALCULATIONS OF LOFT NUCLEAR TEST L2-3

1604 258

University of California
LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663, Los Alamos, New Mexico 87545
An affirmative action / equal opportunity employer

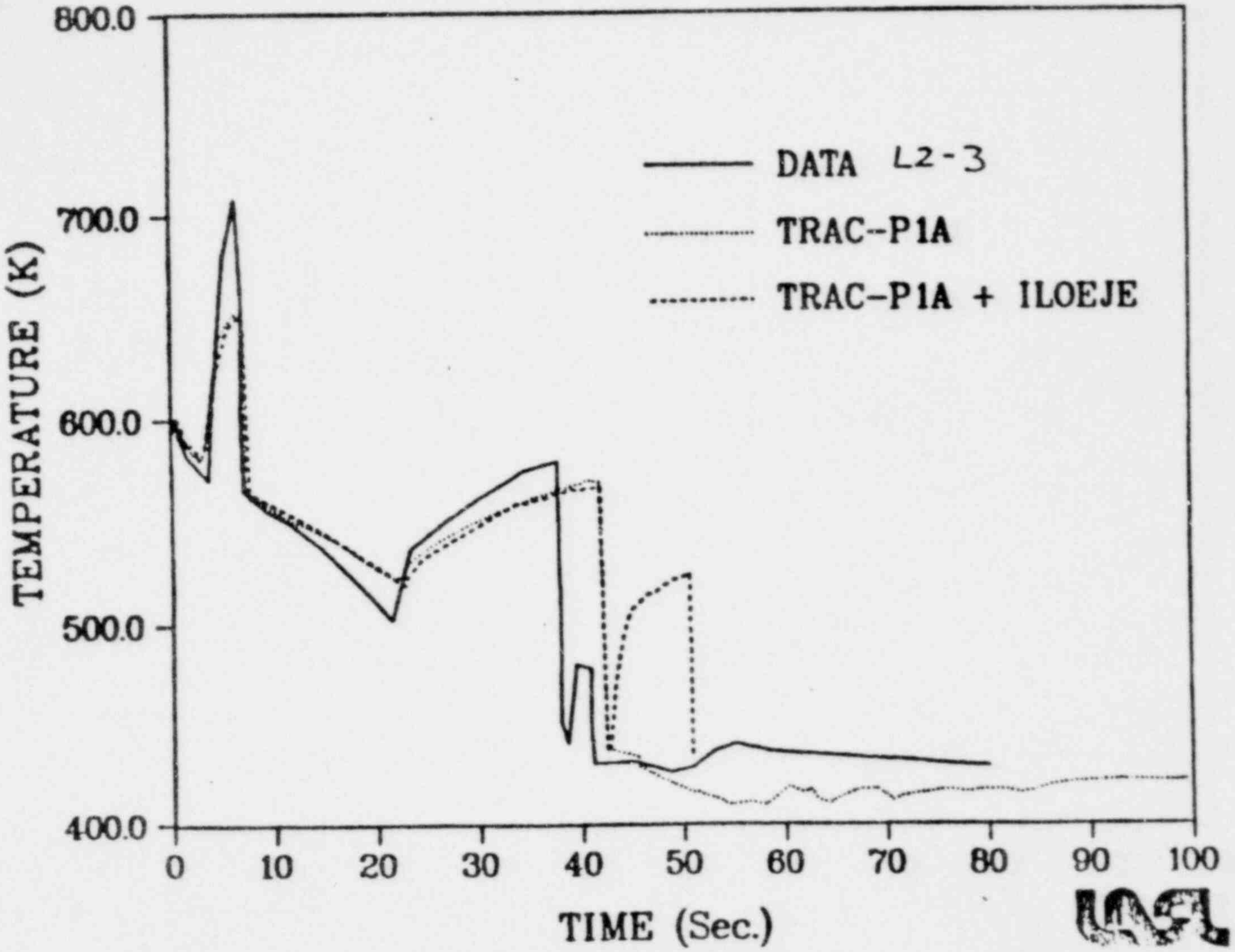
PRESSURE IN THE INTACT LOOP COLD LEG



1604 259

FUEL MODULE 1 ROD B11

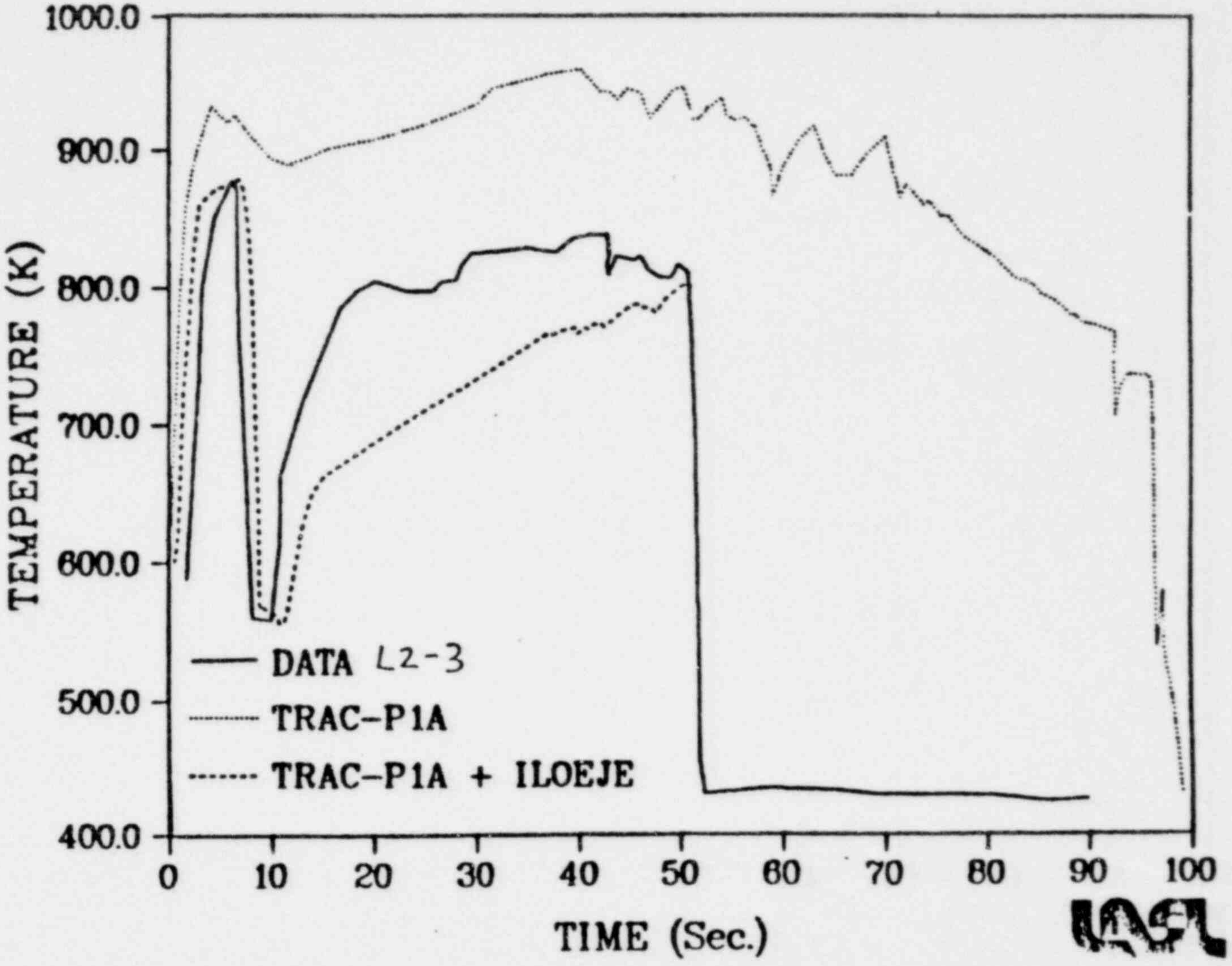
CLAD TEMPERATURE



1604 260

FUEL MODULE 5 ROD D6

CLAD TEMPERATURE



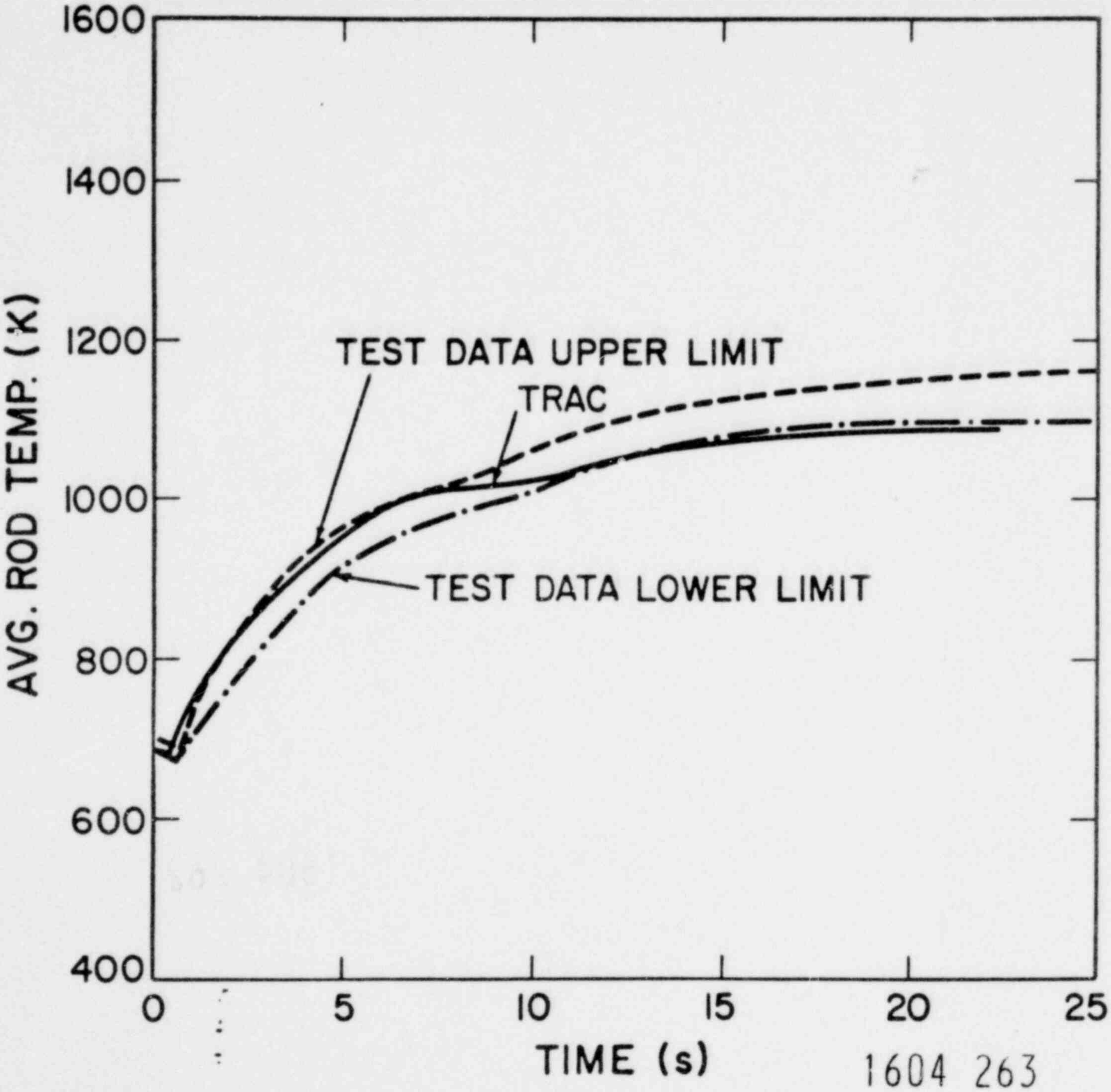
1604 261

TRAC CALCULATIONS OF STANDARD PROBLEM NO. 5

University of California
LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663, Los Alamos, New Mexico 87545

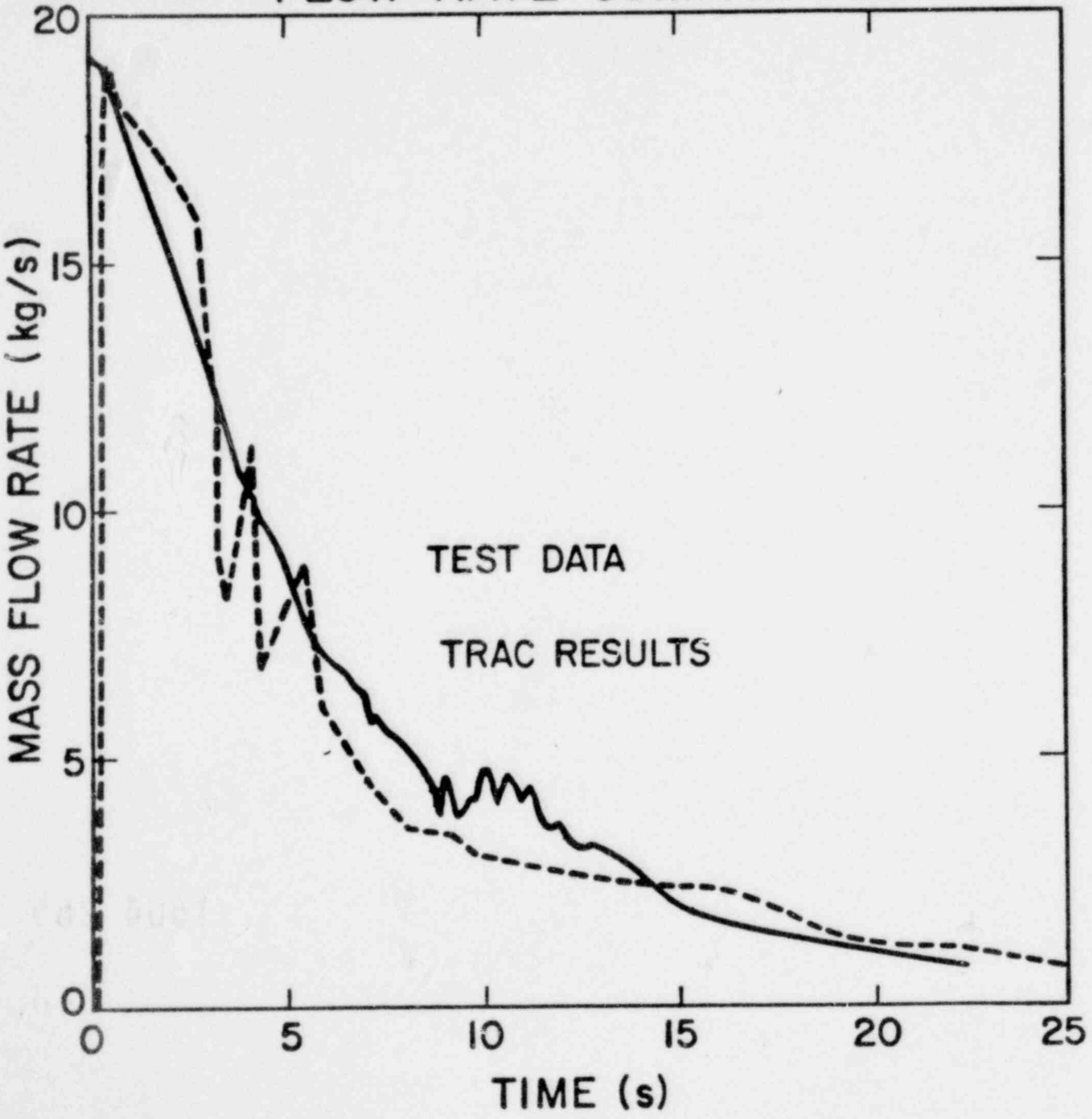
An affirmative action/equal opportunity employer

SP5 HIGH POWER LEVEL CLADDING TEMPERATURE COMPARISON



1604 263

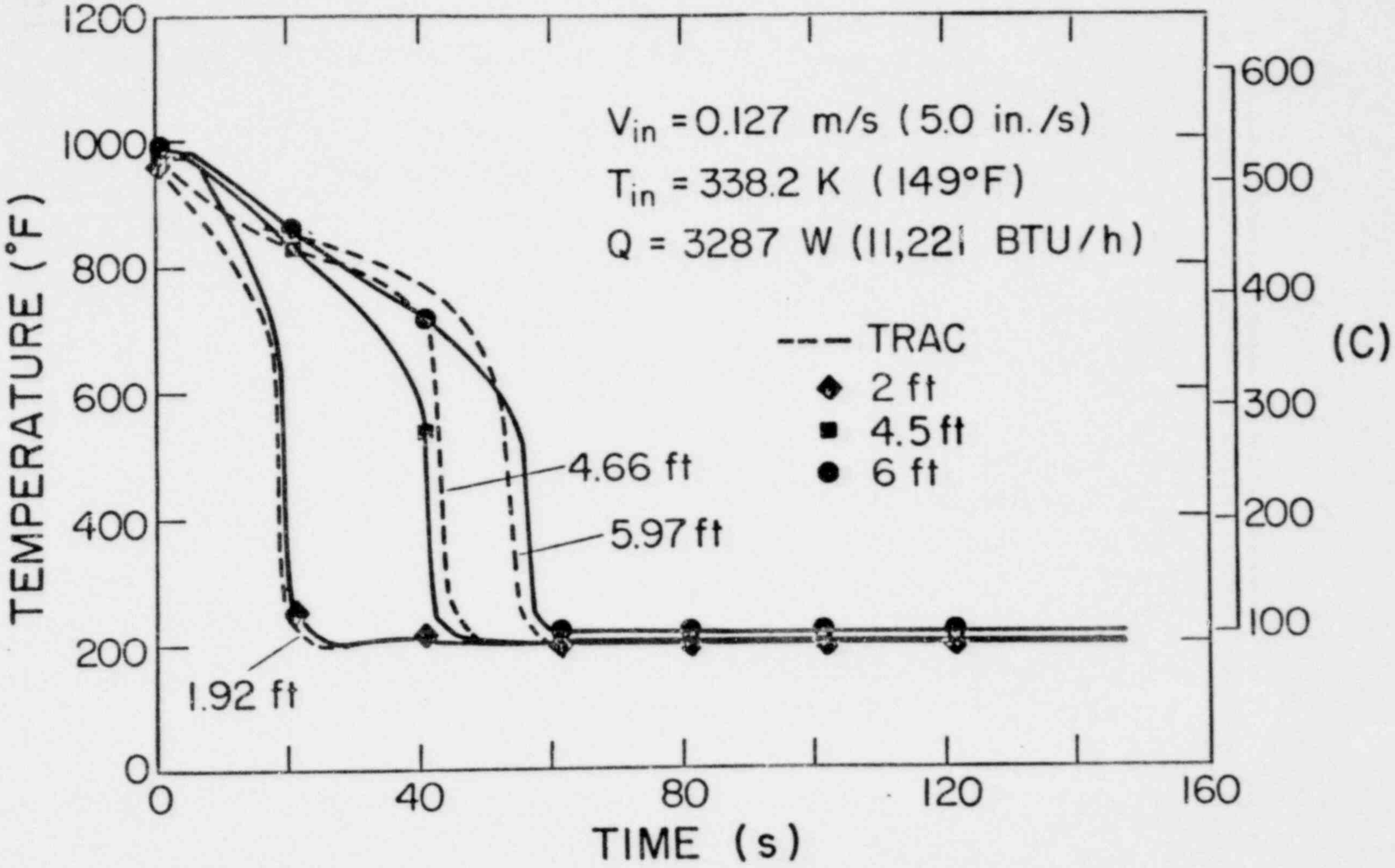
SP5 COLD LEG INLET FLOW RATE COMPARISON



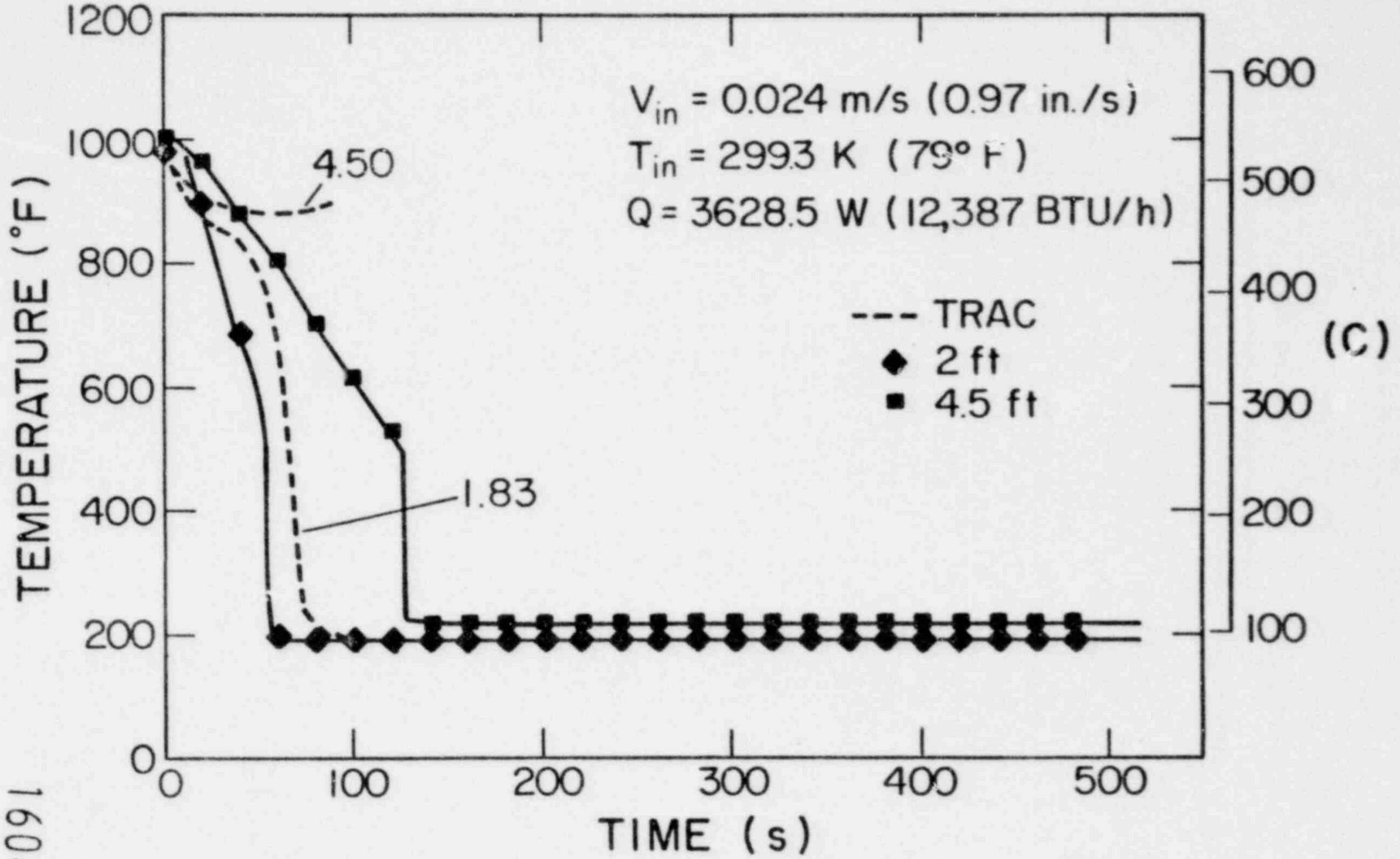
1604 264

TRAC REFLOOD CALCULATIONS

University of California
LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663, Los Alamos, New Mexico 87545



COMPARISONS OF WALL TEMPERATURE PROFILES FOR UC-BERKELEY TEST 114



COMPARISON OF WALL TEMPERATURE PORFILES FOR UC-BERKELEY TEST 187

1604 267

ORNL THTF Analyses

A model of Test 177 conducted at the Oak Ridge National Laboratory (ORNL) Thermal-Hydraulic Test Facility (THTF) is being developed as part of the effort to assess the minimum film boiling correlations in TRAC. A detailed 32 node model is developed for the vessel. Boundary conditions for the inlet and the exit of the vessel are provided with the reminder of THTF not modeled. The single-channel test section uses 28 nodes at 14 axial levels.

BLOWDOWN HEAT TRANSFER TEST NO. 177

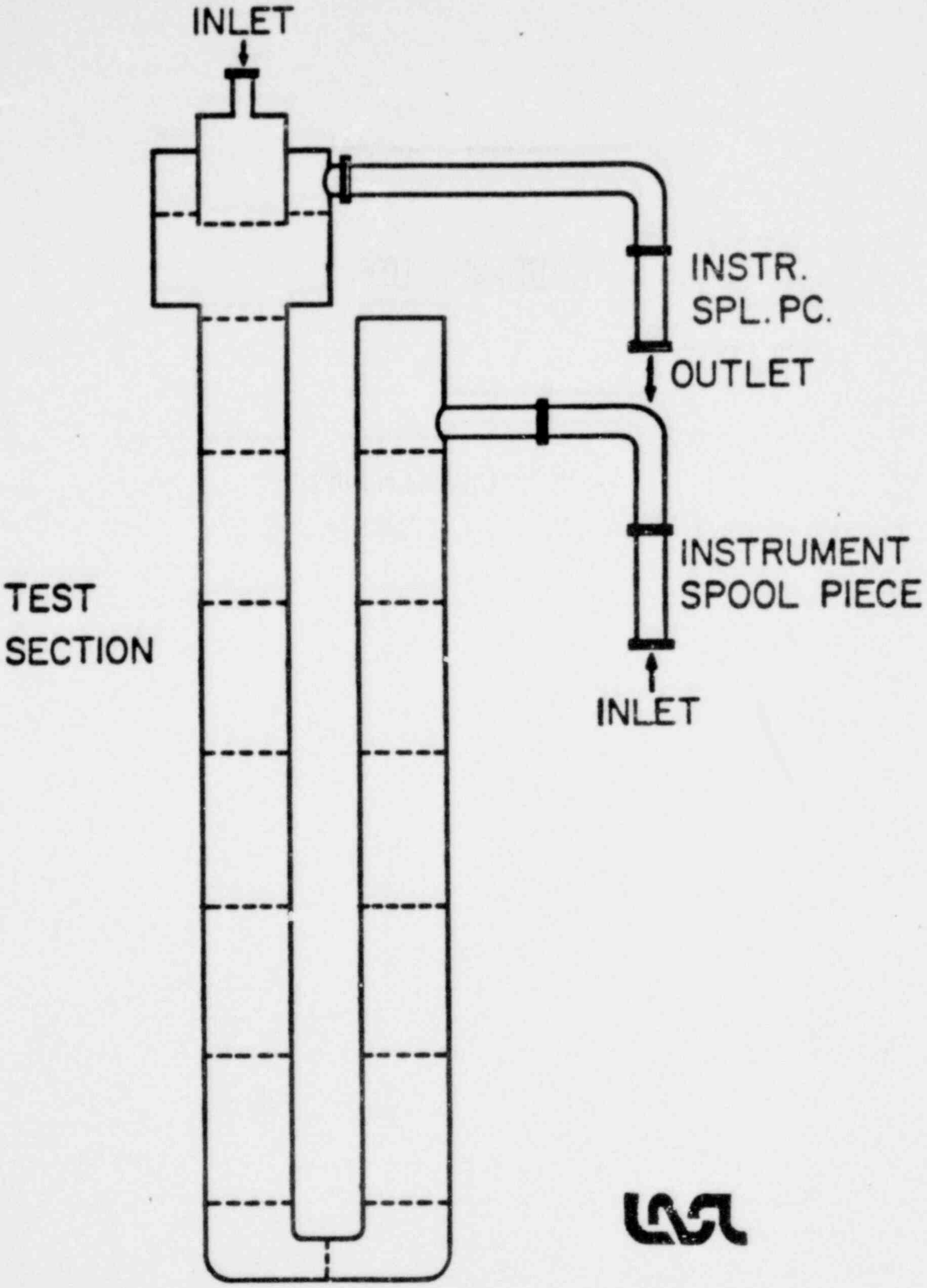
DEPRESSURIZATION AND HEAT TRANSFER OF INITIALLY FLOWING COOLANT IN A NON-NUCLEAR PRESSURIZED-WATER LOOP

ELECTRICALLY HEATED RODS

7 X 7 BUNDLE
0.01122 M DIAMETER
3.66 M LENGTH
82 KW/ROD

COOLANT

12.7×10^6 KG/M^2·HR	MASS FLUX
550 K	INLET TEMPERATURE
581 K	OUTLET TEMPERATURE
15.5 MPA	PRESSURE



SINGLE-CHANNEL TEST SECTION MODEL
(32 VESSEL NODES)