dCS MS-016

AUG 27 1982

Docket No. 50-309

MEMORANDUM FOR: Robert A. Clark, Chief
Operating Reactors Branch #3
Division of Licensing

FROM: Chris C. Nelson, Project Manager
Operating Reactors Branch #3
Division of Licensing

SUBJECT: SUMMARY OF MEETING WITH YANKEE ATOMIC ELECTRIC COMPANY

Attendees at this meeting are listed in Enclosure 1.

Enclosure 2 summarizes presentations made by the Yankee Atomic Electric Company to the NRC staff.

Specific comments made by the NRC staff in reply to the YAEC presentation are as follows:

1. Better documentation should be made on the existing and approved models from which RELAP5YA was developed. Charts summarizing these changes from earlier models would help the NRC reviewers.
2. Indicate how RELAP5YA addresses the specific staff concerns summarized in the Bulletins and Orders Task Force Reports.
3. Emphasize comparisons with experimental data.
4. Develop a summary indicating in detail how RELAPS5YA will be used. This should include a tabulation of what ancillary codes are used as part of these calculations. Indicate which ancillary codes have received NRC review and approval.
5. Relevant sample calculations should be submitted as soon as practical indicating how the codes would be used in the specific licensing actions discussed in item 4.

8209230003 820827
PDR ADOCK 05000309
P PDR

OFFICE ▶							
SURNAME ▶							
DATE ▶							

6. All submittals should be extremely clear about the specific licensing actions and related schedules for which NRC review and approval is requested. Careful consideration should be given to critical path scheduling for reviewe affecting multiple licensing actions for several plants.

Original signed by
Robert A. Clark for
Chris C. Nelson, Project Manager
Operating Reactors Branch #3
Division of Licensing

cc: See next page

OFFICE ▸	ORB #3	ORB #3	ORB #3	ORB #3			
SURNAME ▸	Kreutzer	Heitner/tcm	Nelson	RAClark			
DATE ▸	8/[illegible]/82	8/20/82	8/[illegible]/82	8/[illegible]/82			

MEETING SUMMARY DISTRIBUTION

Licensee: Maine Yankee Atomic Power Company

*Copies also sent to those people on service (cc) list for subject plant(s).

✓Docket File
NRC PDR
L PDR
NSIC
TERA
ORB#3 Rdg
JHeltemes
BGrimes
RAClark
Project Manager
PMKreutzer
OELD
I&E
ACRS-10
ORB#3 Summary File
NRC Participants

Maine Yankee Atomic Power Company

cc: E. W. Thurlow, President
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U. S. Environmental Protection Agency
Region I Office
ATTN: Reg. Radiation Representative
JFK Federal Building
Boston, Massachusetts 02203

State Planning Officer
Executive Department
189 State Street
Augusta, Maine 04330

ATTENDANCE MEETING FOR

MAINE YANKEE MEETING WITH NRC

August 19, 1982

NAME	ORGANIZATION
C. Nelson	NRC-PM
W. Lyon	NRR/RSB
Kenneth L. Heitner	NRC-PM
Edward D. Throm	NRC/RSB
Jack Guttmann	NRC/RSB
Gordon Willcutt	LANL
Tom Fernandez	YAEC
Bob Groce	YAEC
Ramu Sundaram	YAEC
Jamal Ghaus	YAEC
Bob Harvey	YAEC
Jim Loomis	YAEC
Ming-Shig Lu	BNL
Melvin Levine	BNL
N. Lauben	NRR/RSB
A. Husain	YAEC

Enclosure 2 — Meeting Record Copy —

YANKEE ATOMIC ELECTRIC COMPANY

YANKEE ATOMIC ELECTRIC COMPANY
RELAP5YA
PRESENTATION TO NRC
AUGUST 19, 1982

YNSD Participants:

A. Husain
R. T. Fernandez
R. K. Sundaram
R. C. Harvey
J. M. Ghaus
J. N. Loomis

MEETING OBJECTIVES

1. To Inform NRC of the TECHNICAL CONTENTS of RELAP5YA Methods Development & Assessment Project.

   Submittal slated for Oct. 15, 1982.

2. To Elicit NRC comments on the tech. contents.

3. To obtain NRC Review schedule and a preliminary estimate on the date of SER issuance.

LOCA METHODS DEVELOPMENT & ASSESSMENT PROGRAM

GOALS

- DEVELOP BWR LOCA ANALYSIS CAPABILITY AT YAEC TO SUPPORT VERMONT YANKEE
  - COMPLETE BREAK SIZE AND LOCATION SPECTRA
  - BEST ESTIMATE (BE) AND EVALUATION MODEL (EM) CAPABILITY
- UPGRADE PWR Small Break Methods to Support Yankee, Maine Yankee and Seabrook
  - Meet NUREG-0737 Requirement II.K.3.30

MAJOR TASKS

- METHODS DEVELOPMENT
  - Enhancement
  - Evaluation Model

- METHODS QUALIFICATION
  - Separate Effects
  - Integral Tests

- DOCUMENTATION & Quality Assurance

- NRC Review & Approval

- Sample Problems (BWR & PWR)

- Plant Applications

AGENDA

9:00- 9:10	INTRODUCTION	Ausaf Husain
9:10-11:30	MODEL DEVELOPMENT AND ASSESSMENT	
9:10-10:30	HYDRODYNAMIC MODELS	
9:10- 9:40	Interfacial Shear	Ramu K. Sundaram
9:40- 9:55	Two Phase Critical Flow	R. Thomas Fernandez
9:55-10:00	Accumulator	R. Thomas Fernandez
10:00-10:30	Jet Pump	Jamal Ghaus
10:30-11:15	HEAT TRANSFER MODELS	
10:30-10:35	Forced Convective Boiling	Robert C. Harvey
10:35-10:45	Critical Heat Flux	James N. Loomis
10:45-10:55	Radiation Heat Transfer	R. Thomas Fernandez
10:55-11:05	Rewet and Quench	R. Thomas Fernandez
11:05-11:15	Heat Transfer Lockouts	R. Thomas Fernandez
11:15-11:35	FUEL BEHAVIOR MODELS	
	Assumptions	James N. Loomis
	Model Features	James N. Loomis
	Benchmarks	James N. Loomis

CODE ASSESSMENT AGAINST SYSTEM TESTS

11:35-12:05	THTF	R. Thomas Fernandez
	Steady State Film Boiling	
	Transient Film Boiling	
	Quasi Steady Boiloff	
	Reflood	
12:05-1:00	LUNCH	
1:00-2:30	TLTA	Ramu K. Sundaram
1:00-1:15	Transient Boiloff	
1:15-1:30	Small Break	
	Large Break w/ ECC	
1:30-2:00	Best Estimate	
2:00-2:15	Evaluation Model	
2:15-2:30	Large Break w/o ECC	
2:30-2:45	LOFT	Robert C. Harvey
	Small Break Test L3-6	
2:45-2:50	SUMMARY	Ausaf Husain/ R. Thomas Fernandez
3:00-3:30	DISCUSSION	All
3:30-3:45	PRELIMINARY NRC REVIEW SCHEDULE	NRR

INTERPHASE DRAG

BACKGROUND

- RELAP5 USES 2 MOMENTUM EQUATIONS
- INTERFACIAL DRAG FORCE PER UNIT VOLUME

$$FI_{gf} = -A_{gf}B_{gf}\,(V_g - V_f) = -F_I\,(V_g - V_f)$$

- $F_I = A_{gf}B_{gf}$ -- CONSTITUTIVE RELATIONSHIP
- AT LOW FLOWS,

$$V_r = (V_g - V_f) \sim \frac{1}{F_I}\,\alpha_g(1-\alpha_g)(\rho_f - \rho_g)\frac{g}{g_c}$$

- $A_{gf} = A_{gf}\,(FR, \alpha, V_r)$

$B_{gf} = B_{gf}\,(FR, \alpha, V_r)$

$-F_I$ CALCULATION NOT EXPLICIT

- $F_I = A_{gf} B_{gf} \sim (V_r)^m$

- IF $V_r = V_r^n$, NUMERICAL OSCILLATIONS POSSIBLE AT LOW FLOWS

- RELAP5YA MODEL FOR F_I
  - SIMPLE FLOW REGIME MAP BASED ON G AND α

  - AT HIGH FLOWS, $V_r = V_r^n$

  - AT LOW FLOWS, V_r → INDEPENDENT MODEL

3. <u>SLUG FLOW</u>

$$F_I = 0.5\, C_D\, \rho_f\, |V_r|\, (\alpha / L_s)$$

$$V_r = V_r(\alpha, D_h) \quad ; \quad G \leqslant 100 \text{ kg/m}^2\text{-s}$$

$$V_r = V_r^n \quad ; \quad G \geqslant 150 \text{ kg/m}^2\text{-s}$$

$$L_s = L_s(\alpha, F_{IB}, F_{IA})$$

4. <u>ANNULAR-MIST REGION</u>

$$F_I = (1 - \epsilon) F_{IA} + \epsilon F_{IM}$$

$\epsilon = \epsilon(\alpha)$ = ENTRAINMENT

<u>NOTE</u>: $F_I(\alpha)$ IS A CONTINUOUS FUNCTION

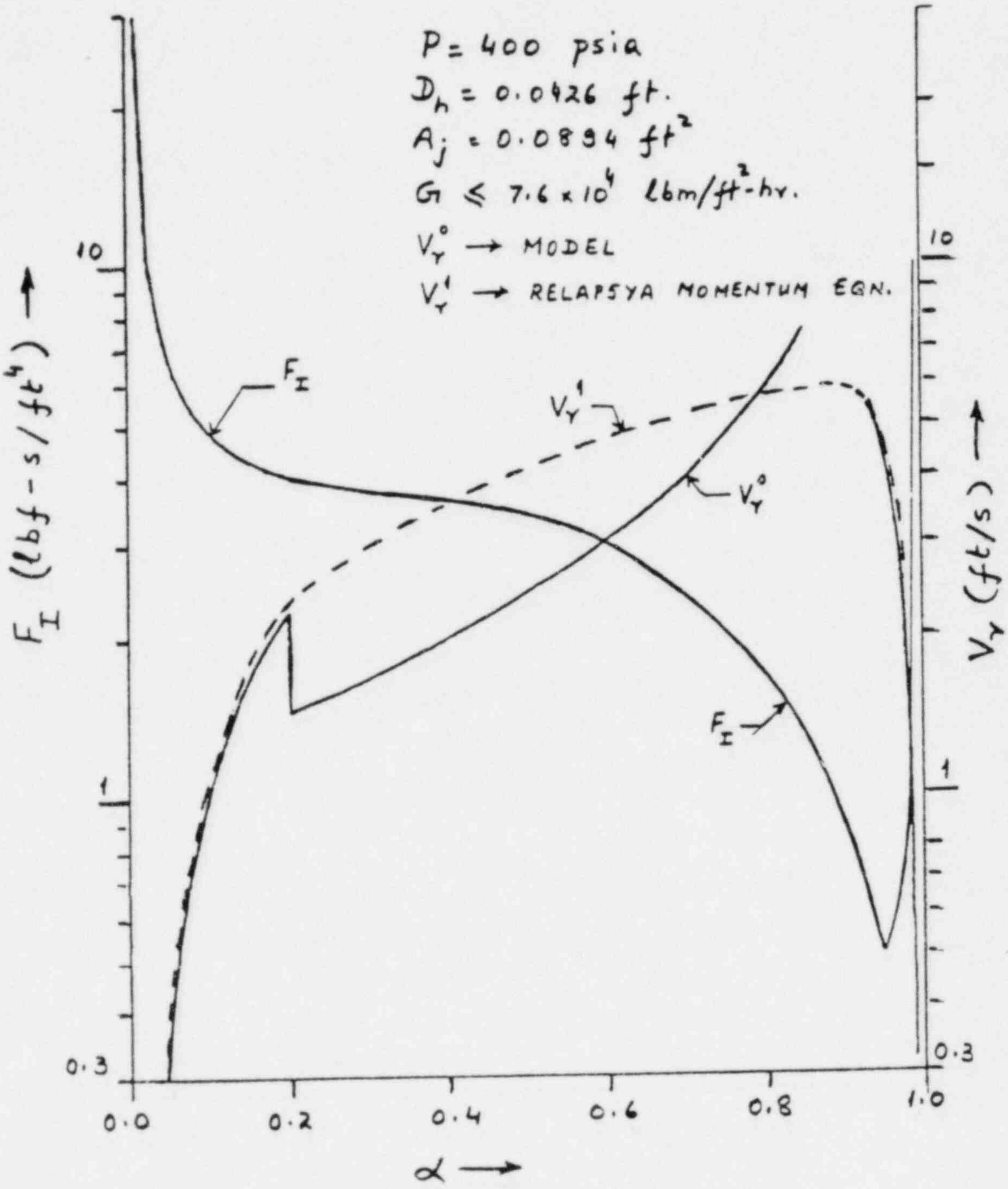


FIG. SAMPLE CALCULATION OF V_r, F_I

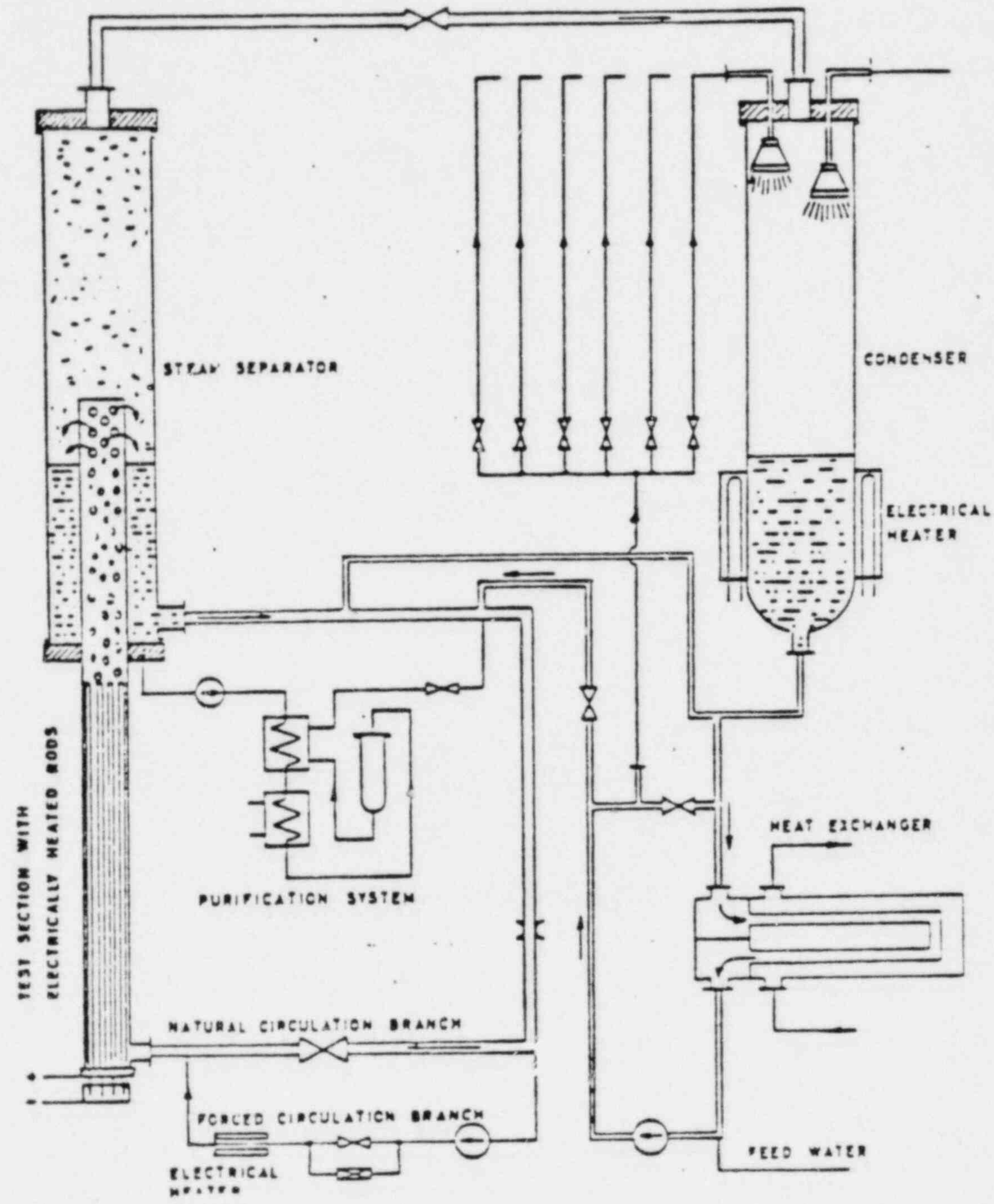
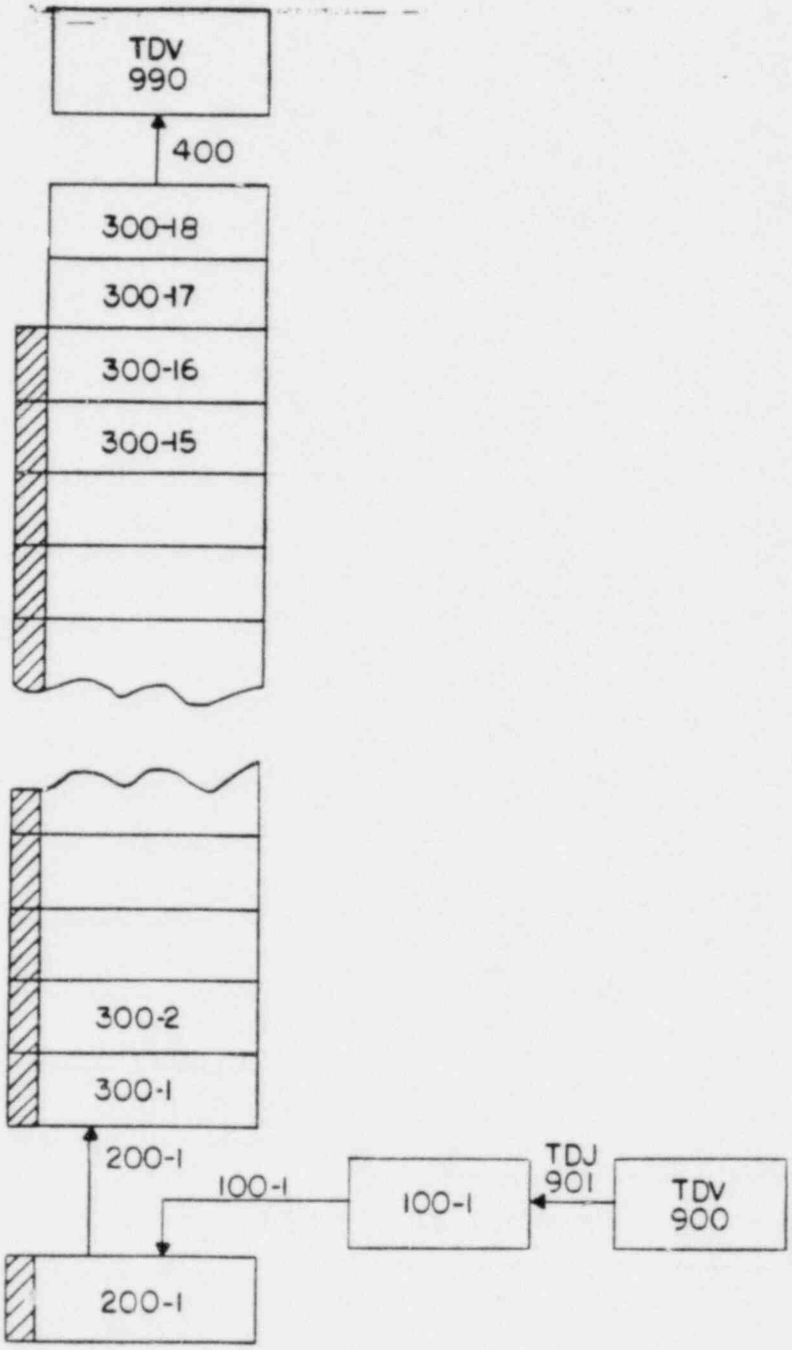
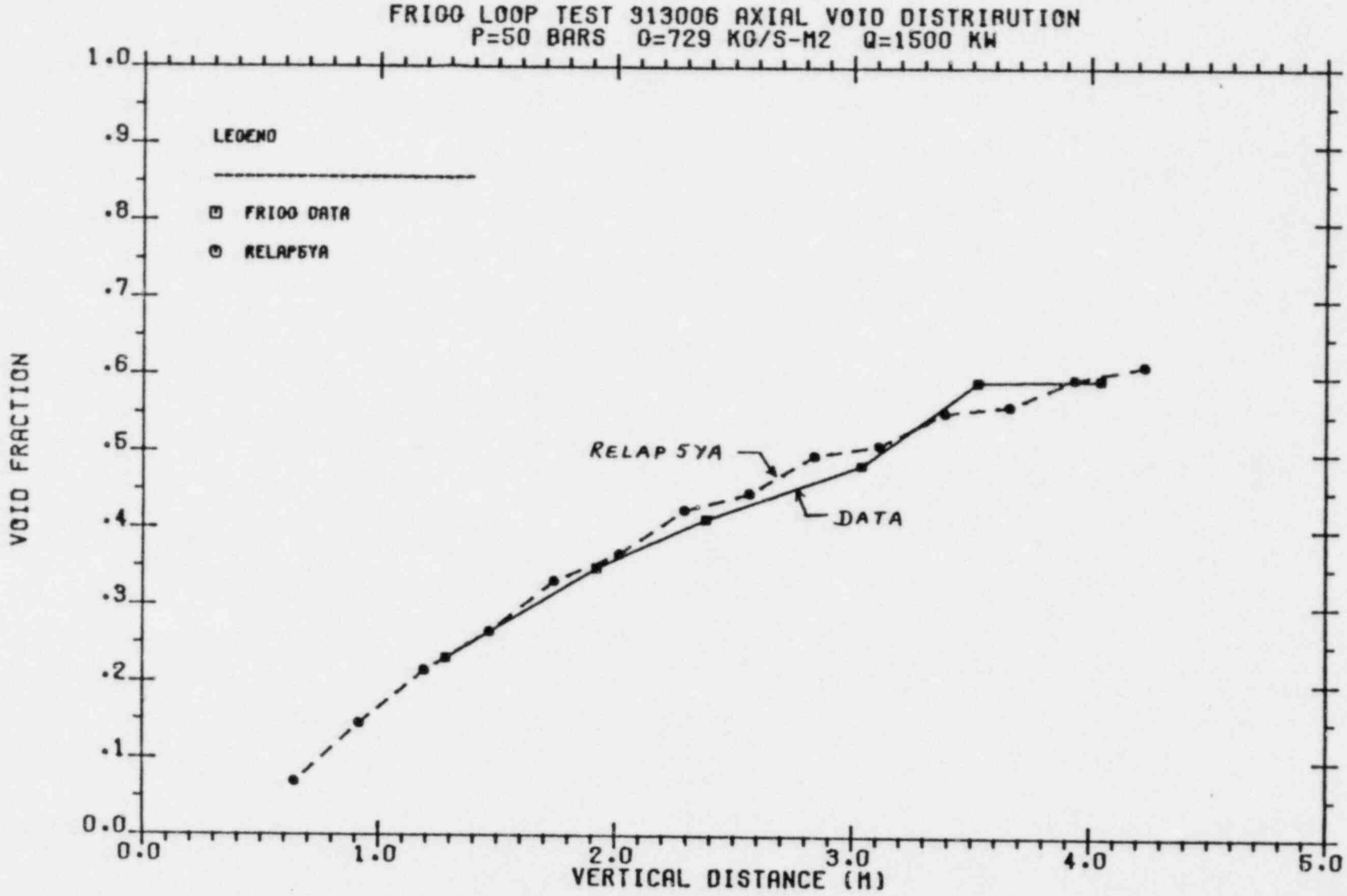
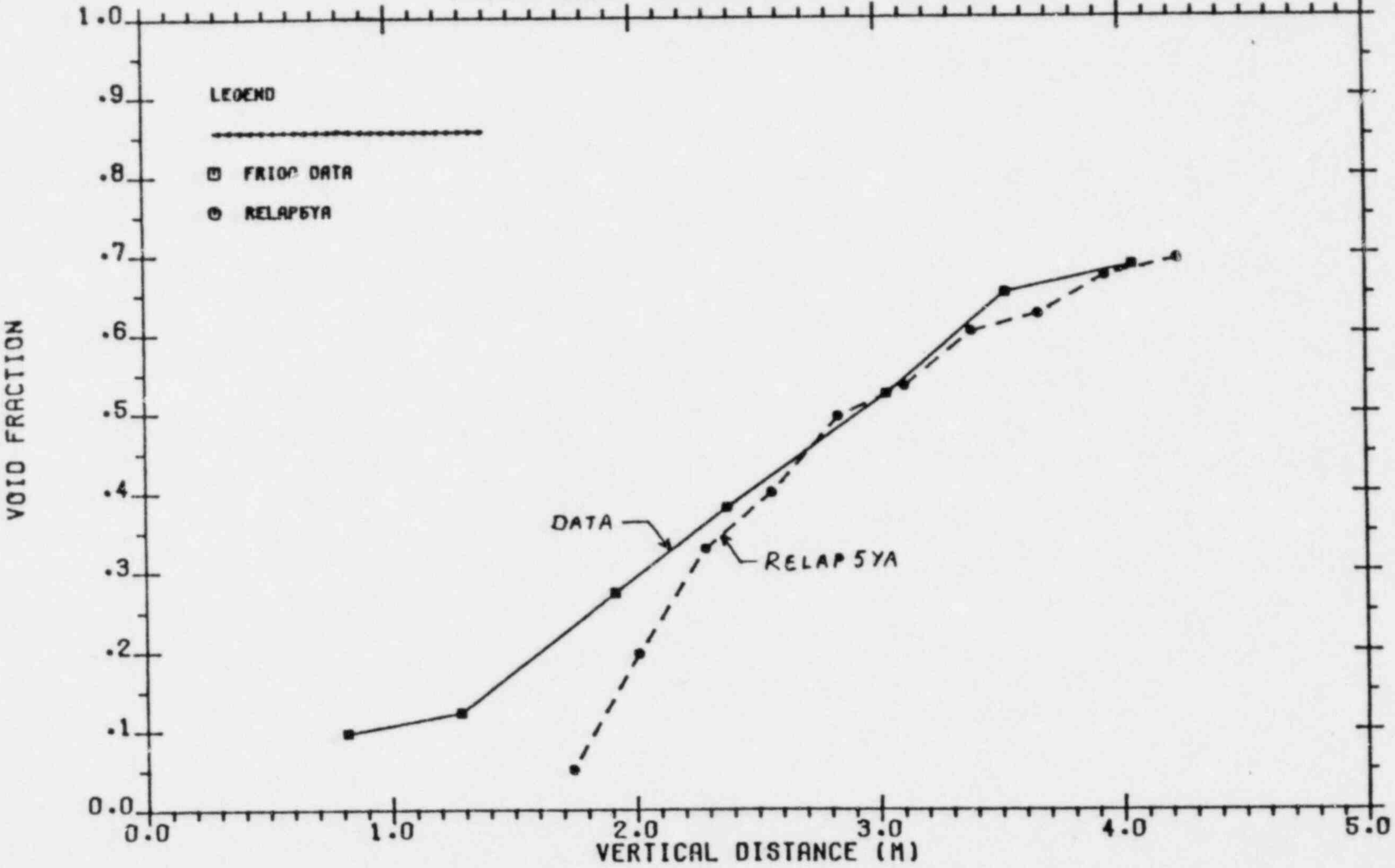


FIG. 1 - SIMPLIFIED FLOW DIAGRAM FOR THE FRIGG LOOP

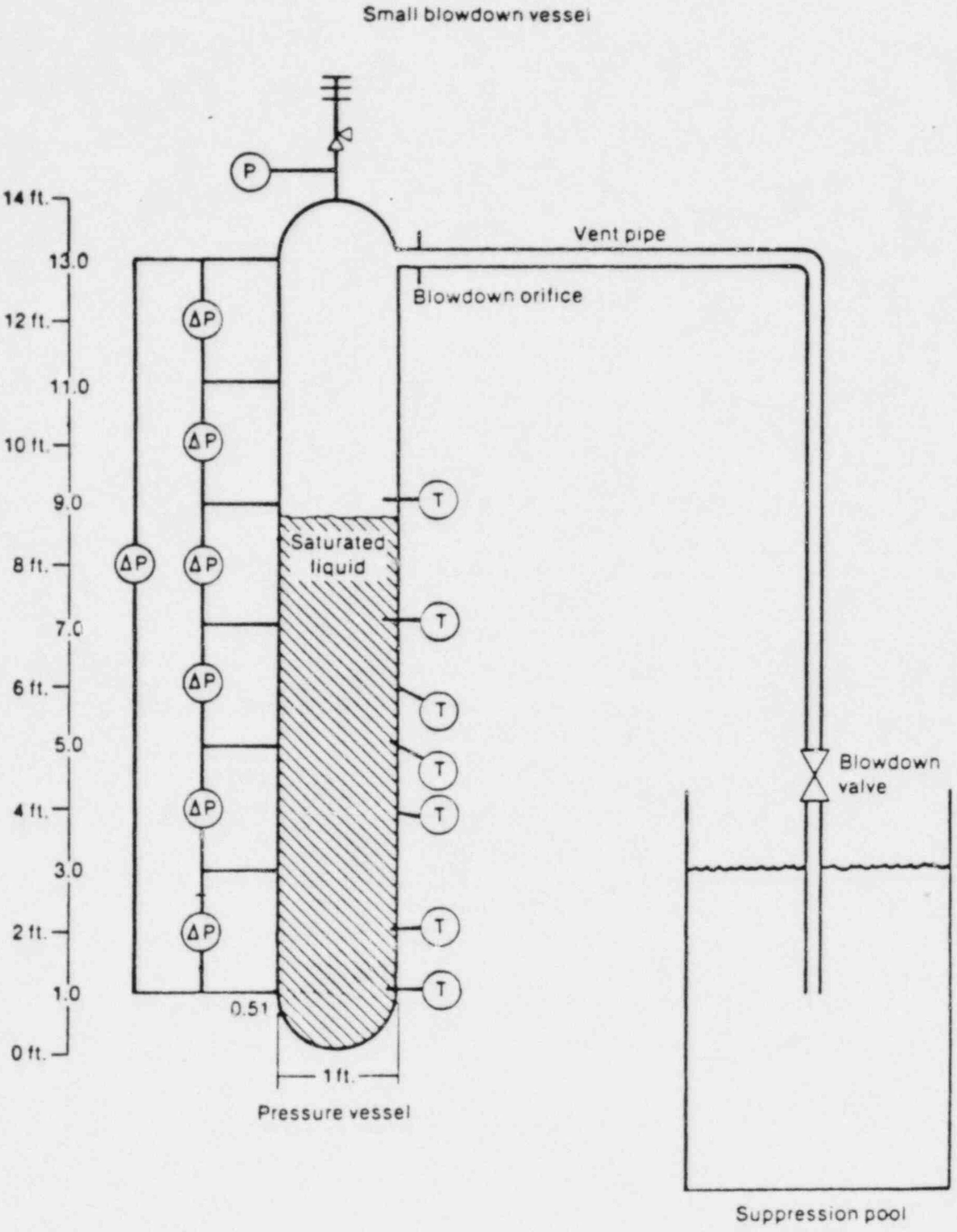


RELAP 5YA MODEL OF FRIGG BUNDLE

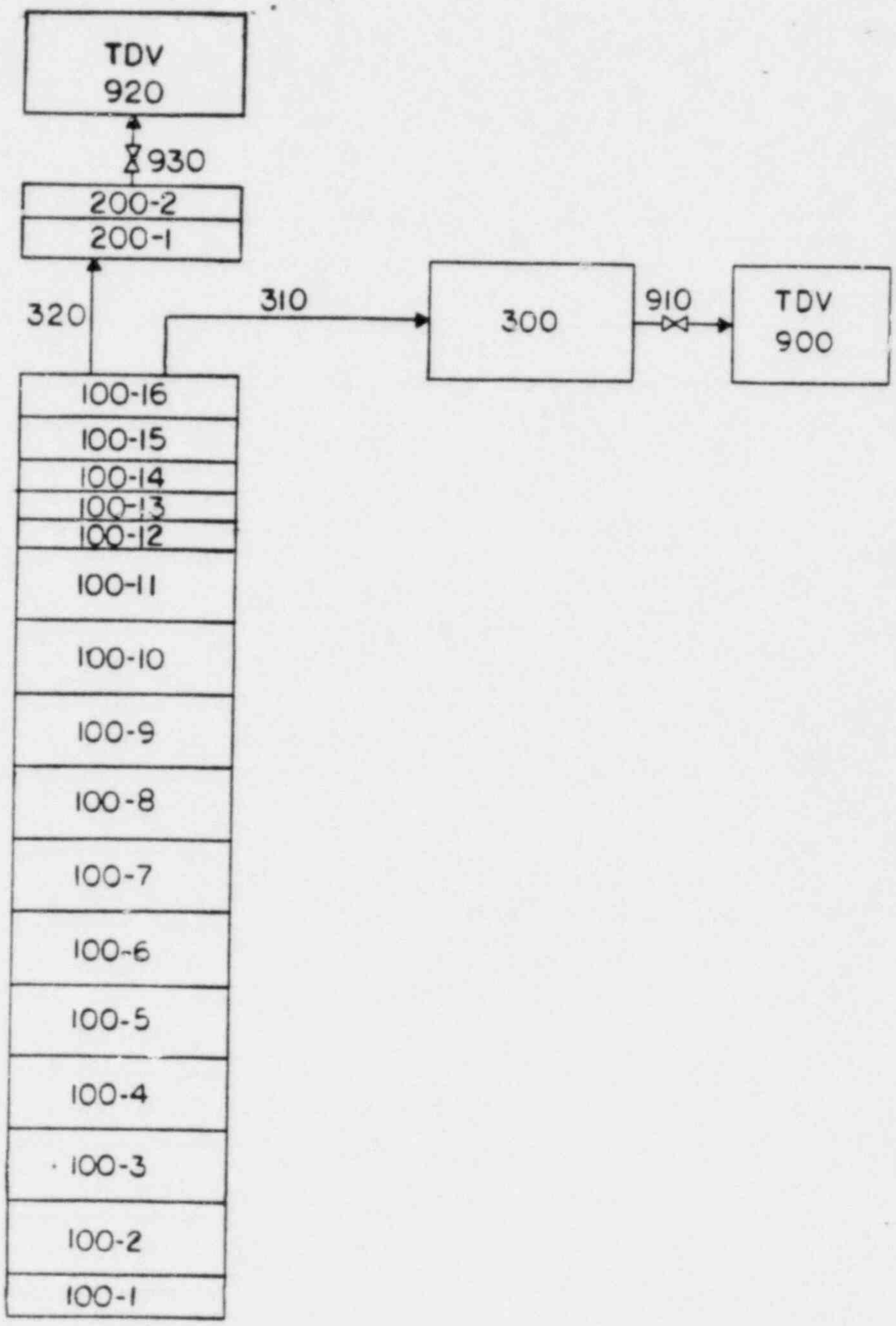

FRIGG LOOP TEST 313006 AXIAL VOID DISTRIBUTION
P=50 BARS G=729 KG/S-M2 Q=1500 KW
LEGEND
FRIGG DATA
RELAP5YA
RELAP 5YA
DATA
VOID FRACTION
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
0.0
1.0
2.0
3.0
4.0
5.0
VERTICAL DISTANCE (M)



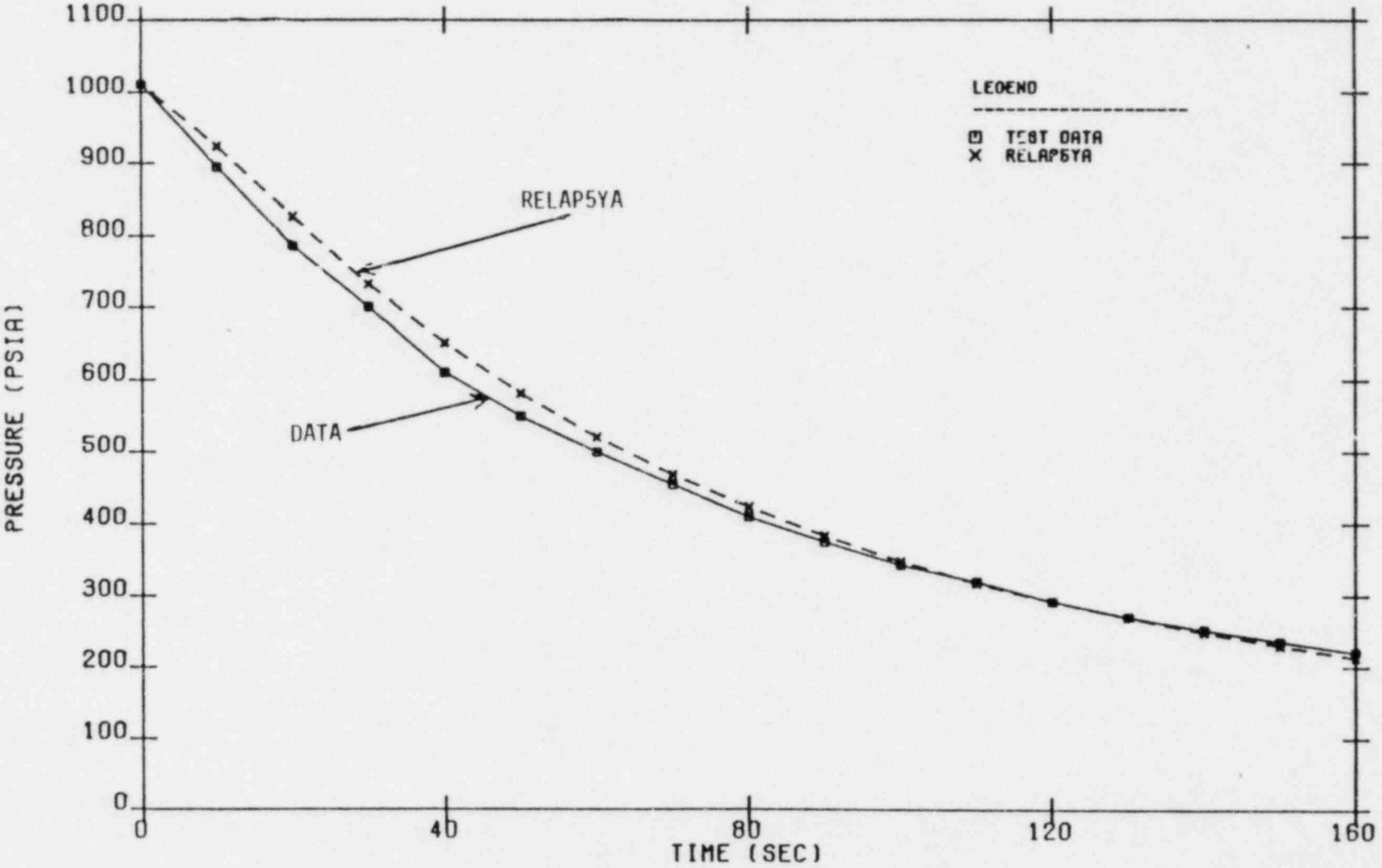
FRIGG LOOP TEST 313020 AXIAL VOID DISTRIBUTION
P=49.7 BARS G=1159 KG/S-M2 Q=4415 KW



GE Level swell test configuration

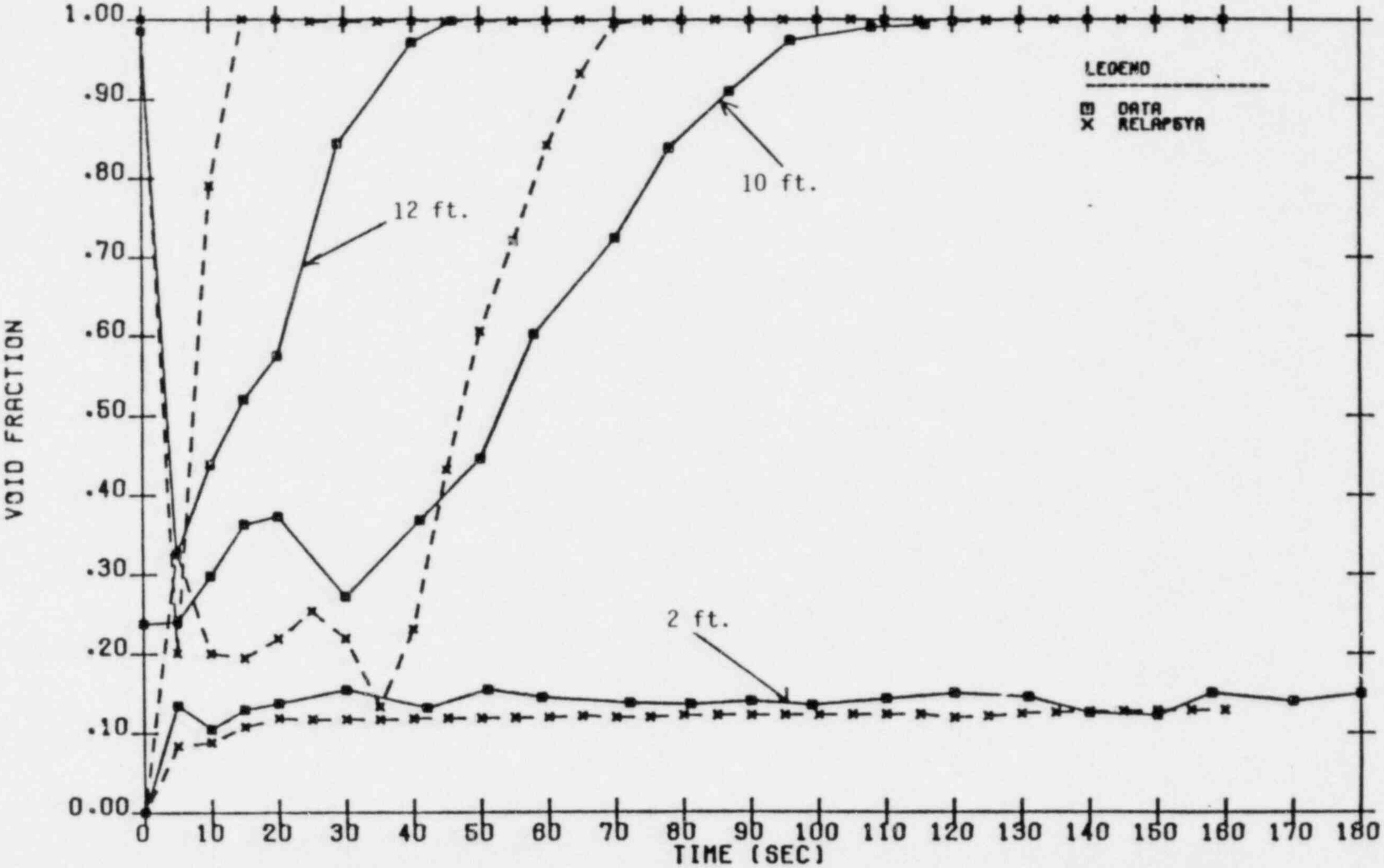


RELAP 5YA MODEL OF GE LEVEL SWELL TEST

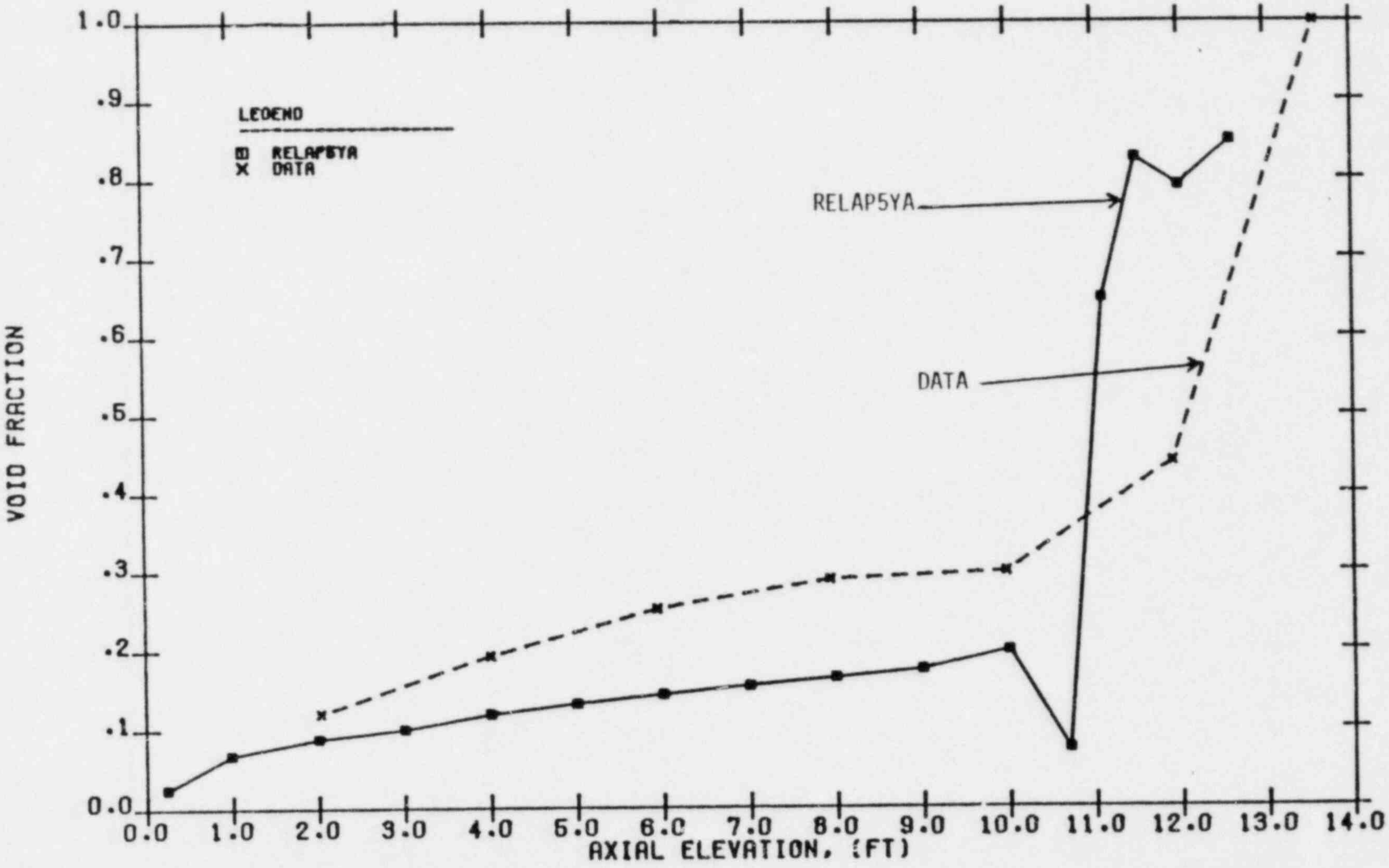


VESSEL PRESSURE
1004-3

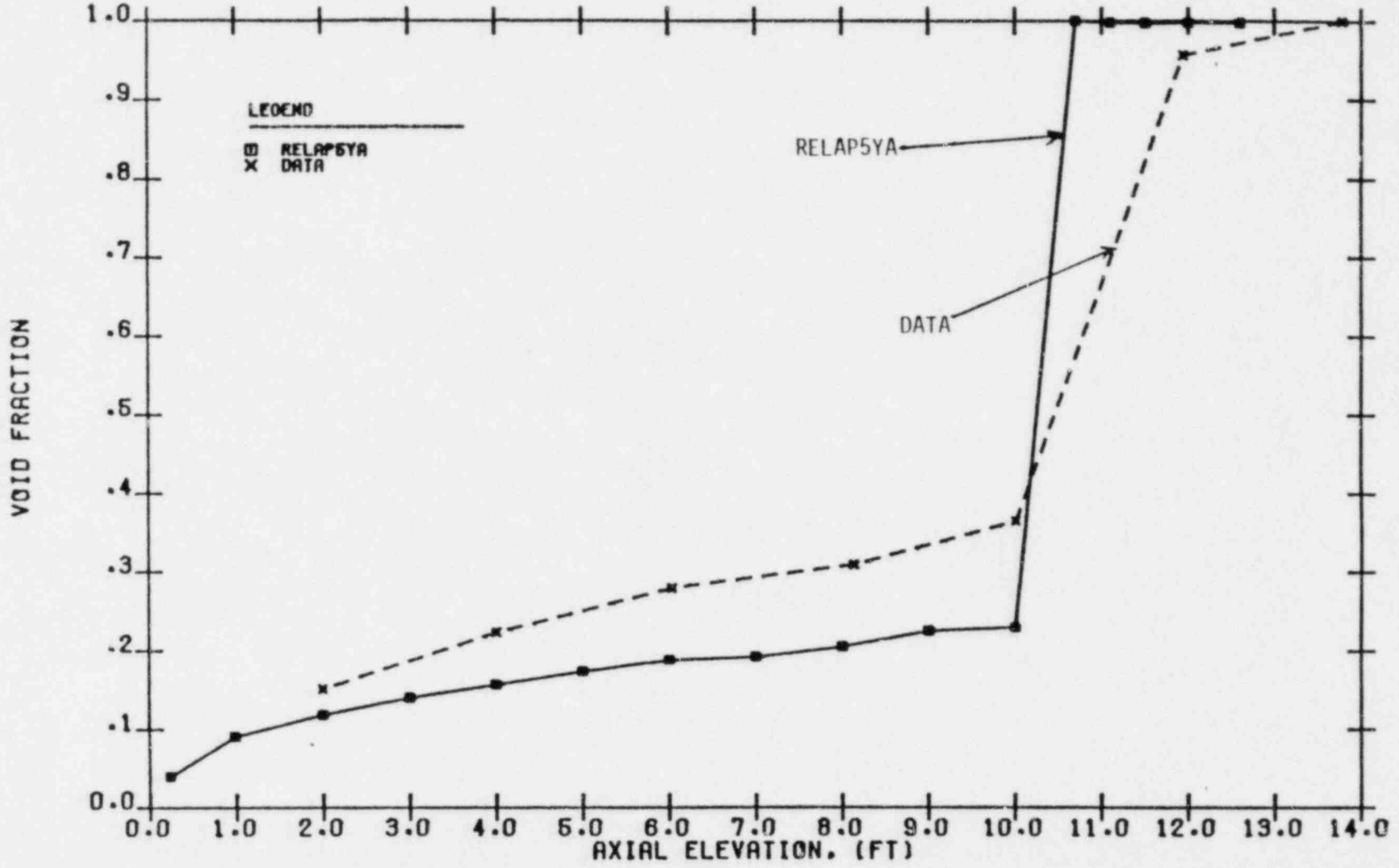
NODAL VOID FRACTION
1004-3

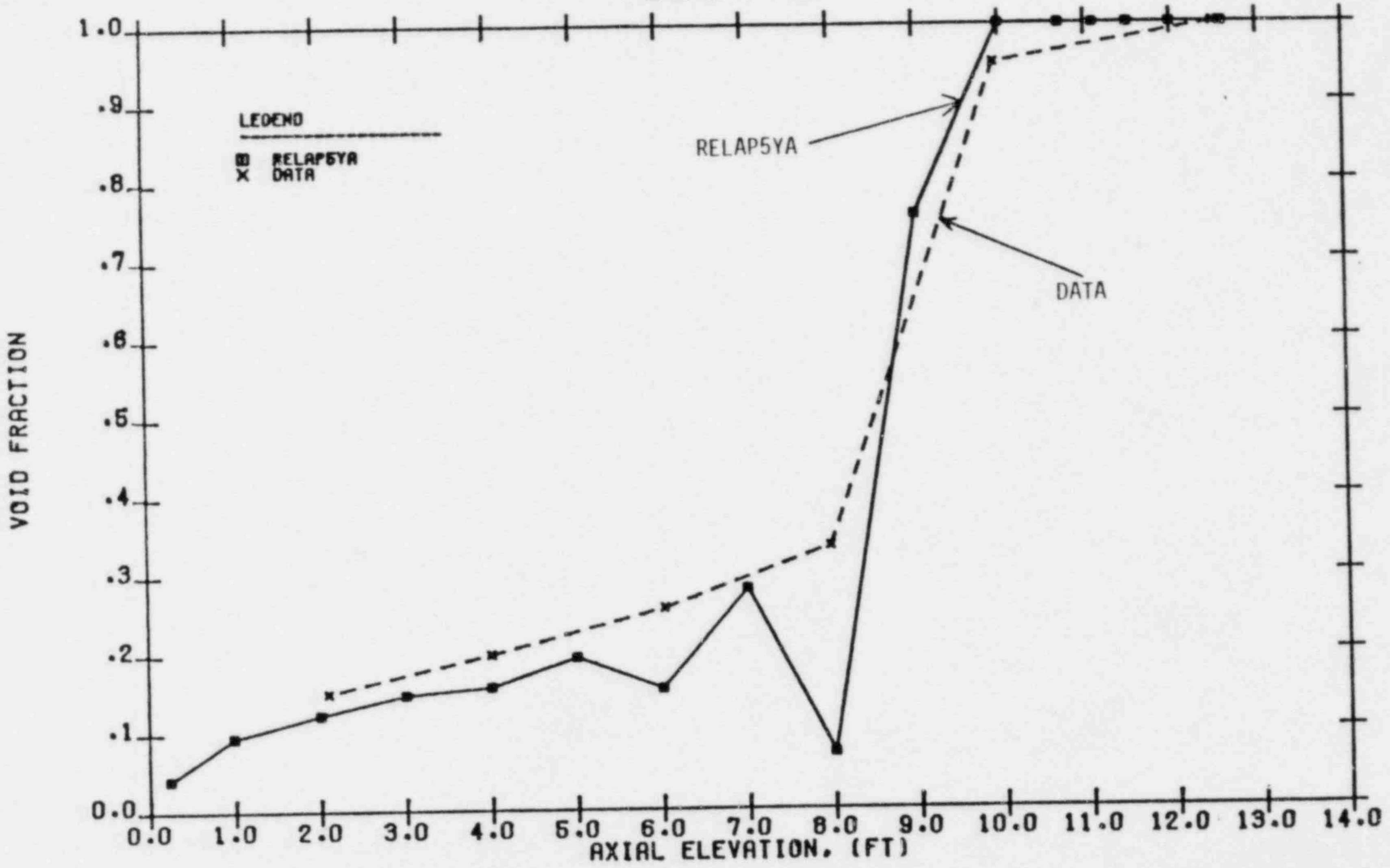


LEVEL SWELL COMPARISON, T = 10 SEC.
1004-3



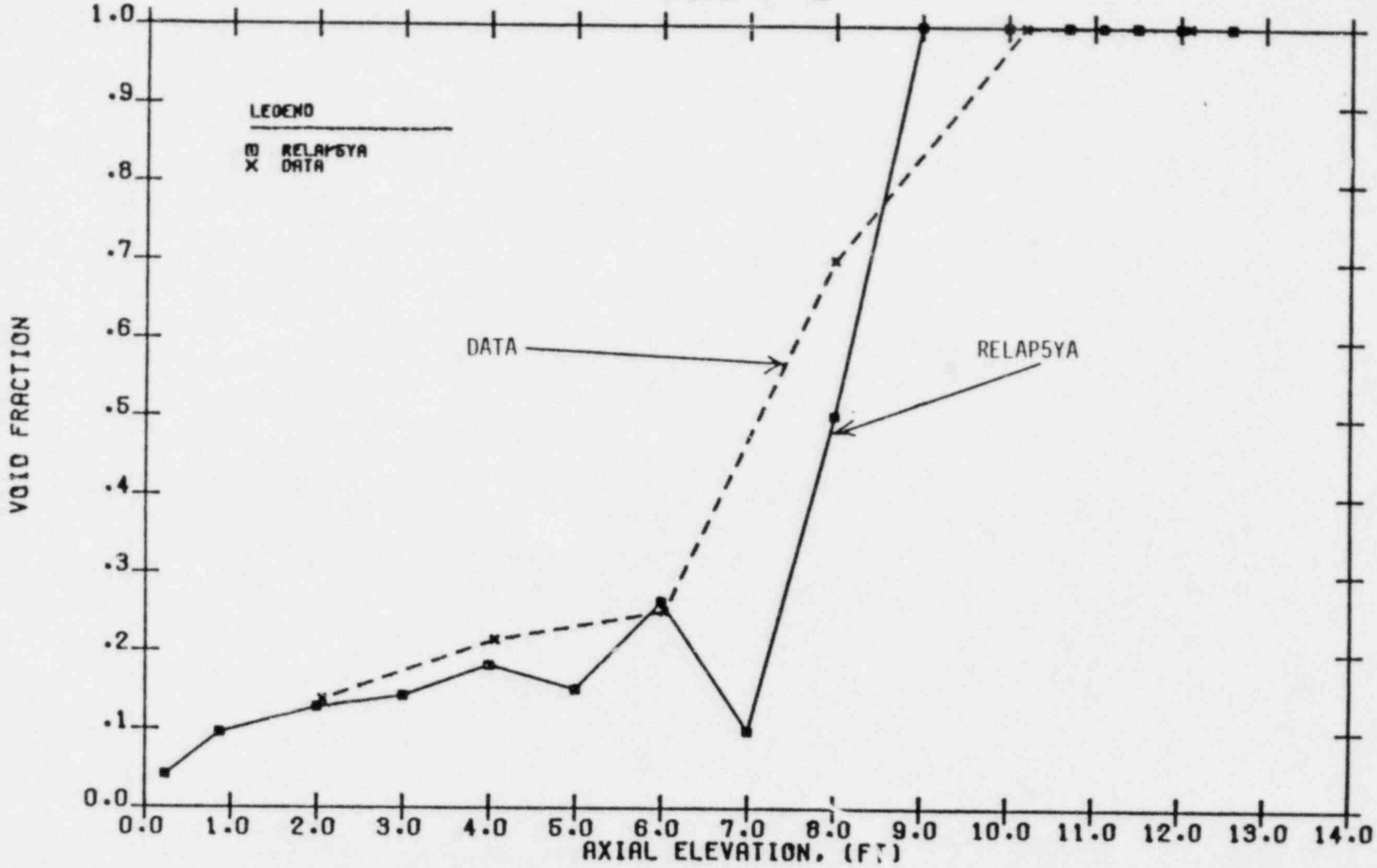
LEVEL SWELL COMPARISON, T = 40 SEC.
1004-3





LEVEL SWELL COMPARISON, T = 100 SEC.
1004-3

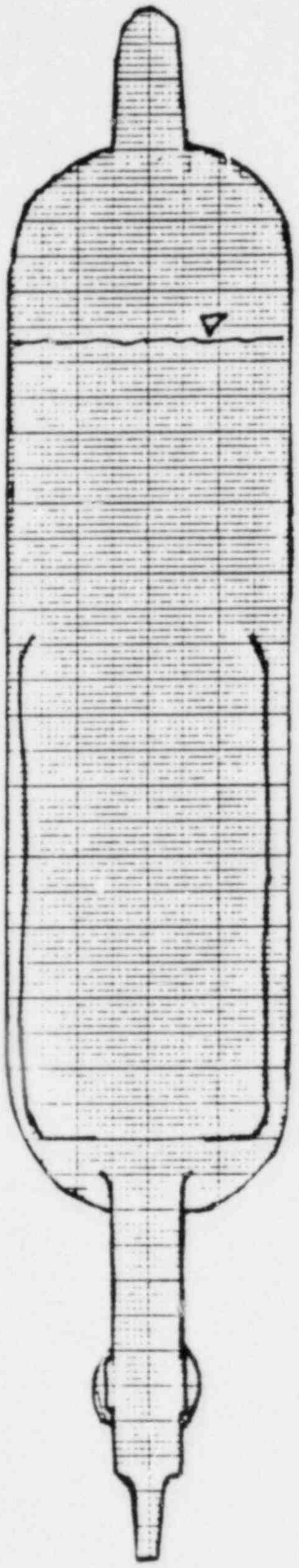
LEVEL SWELL COMPARSON, T = 150 SEC.
1004-3



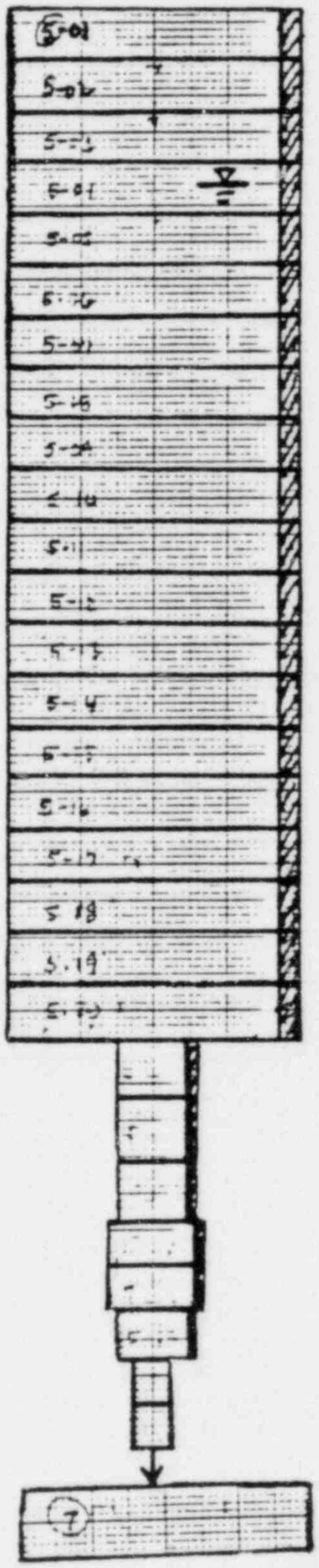
MOODY TWO PHASE CRITICAL FLOW

- $\alpha_g \geqslant 0.05$ FOR TWO PHASE CRITICAL FLOW
- $G_{R5} = (\alpha\rho)_g^n V_g^{n+1/2} + (\alpha\rho)_f^n V_f^{n+1/2}$
- $G_{CRIT} = C_D \cdot G_M(P, h)$
- CHOKING CRITERIA
  - * INITIAL : $G_{R5} \geqslant C_D \cdot G_M$
  - * UNCHOKING : $G_{R5} < 0.95\, C_D \cdot G_M$
    ONE TIME STEP LAG
- PHASIC VELOCITIES $(V_g, V_f)^{n+1}$
  - * CONT. $(\alpha\rho)_g^n V_g^{n+1} + (\alpha_f\rho)_f^{n+1} = G_{CRIT}$
  - * SUM AND DIFF. MOMENTA EQNS.
- FEATURES
  - – C_D RETAINED
  - – FIJ = 1.0 E15 ⇒ $S \approx 1$
  - – STATIC (P_s, h_s) OR STAGNATION (P_o, h_o) OPTION
  - – MOODY TABLE $G_M(P_o, h_o)$

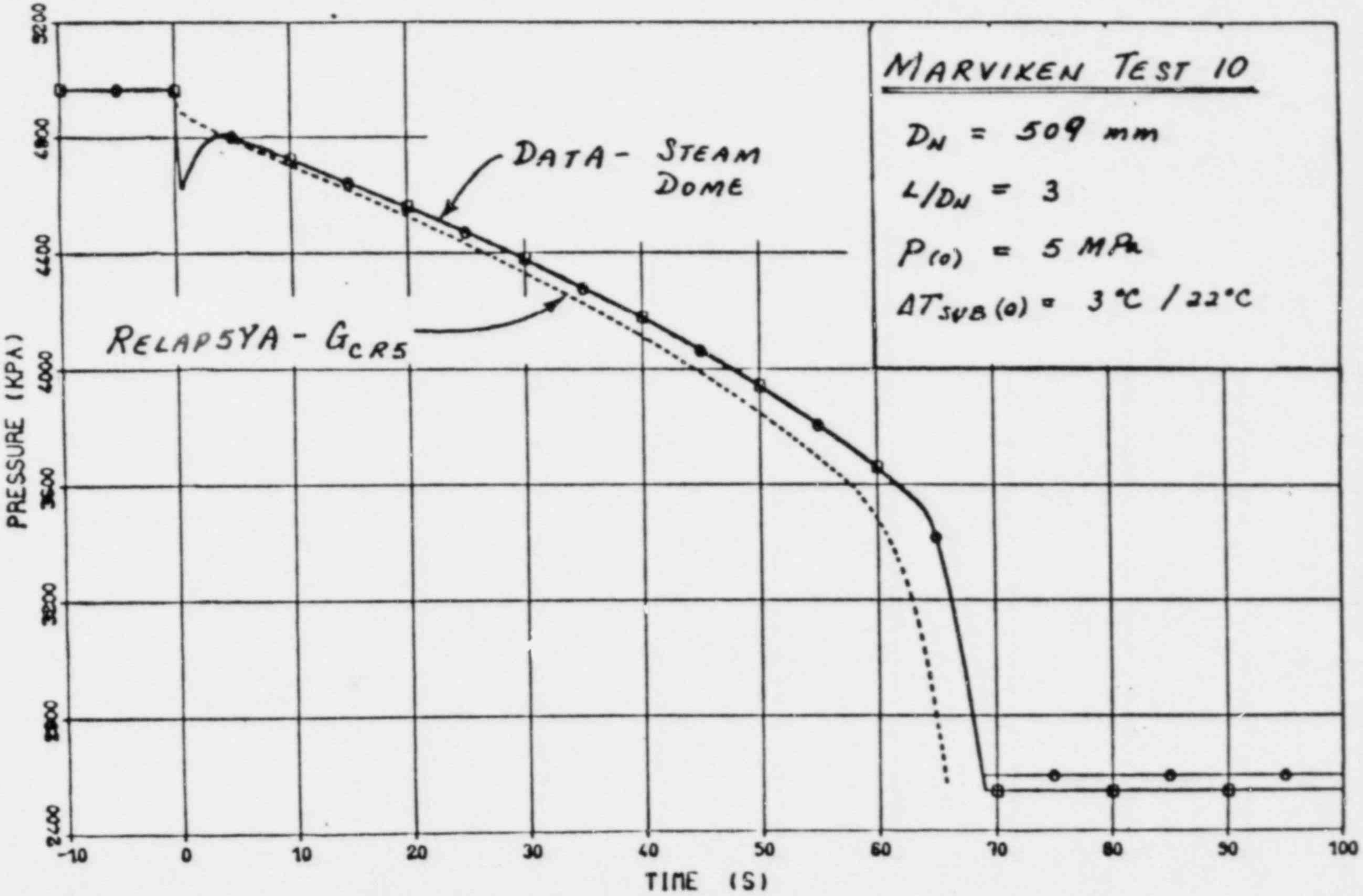
FACILITY



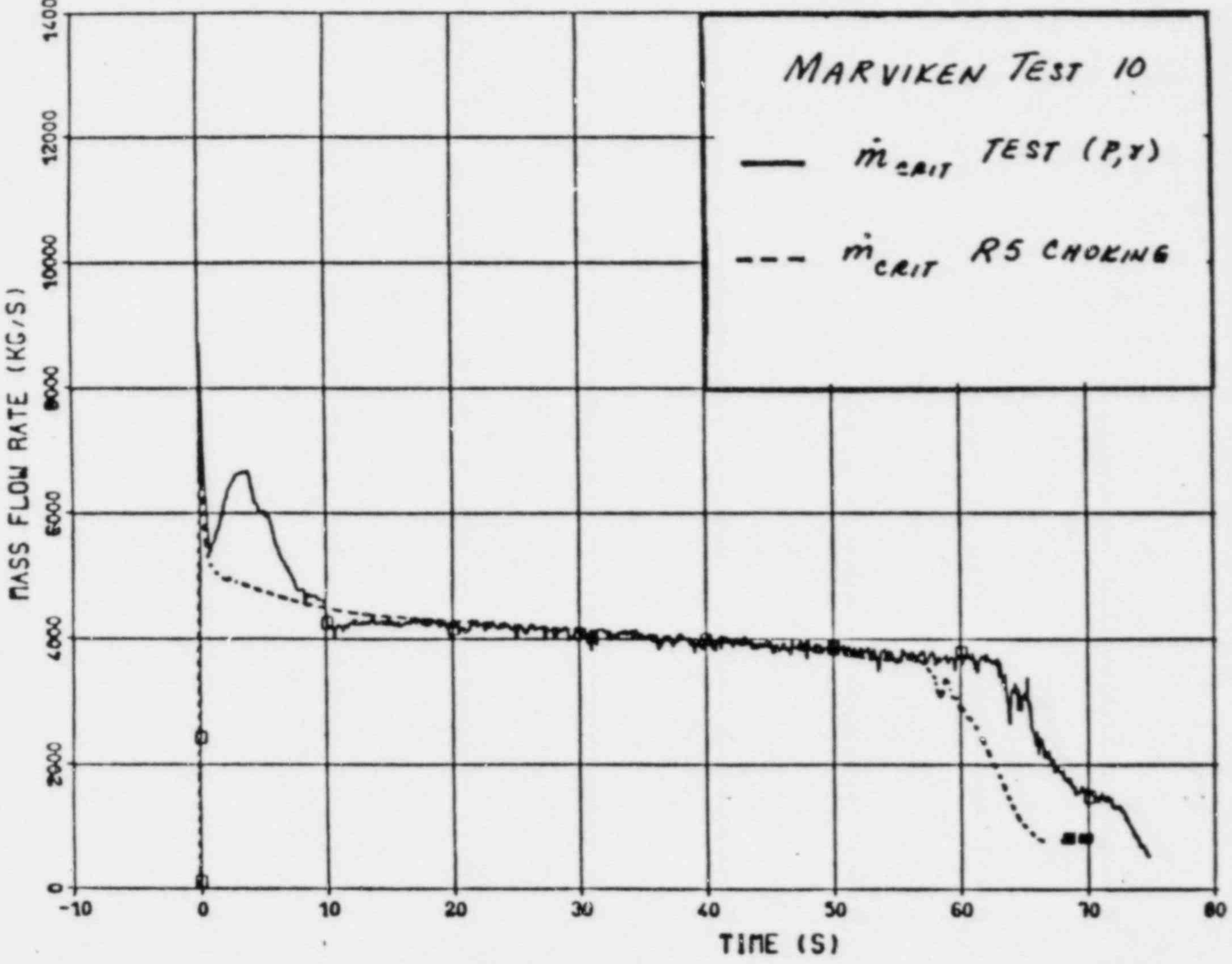
RELAP5YA MODEL



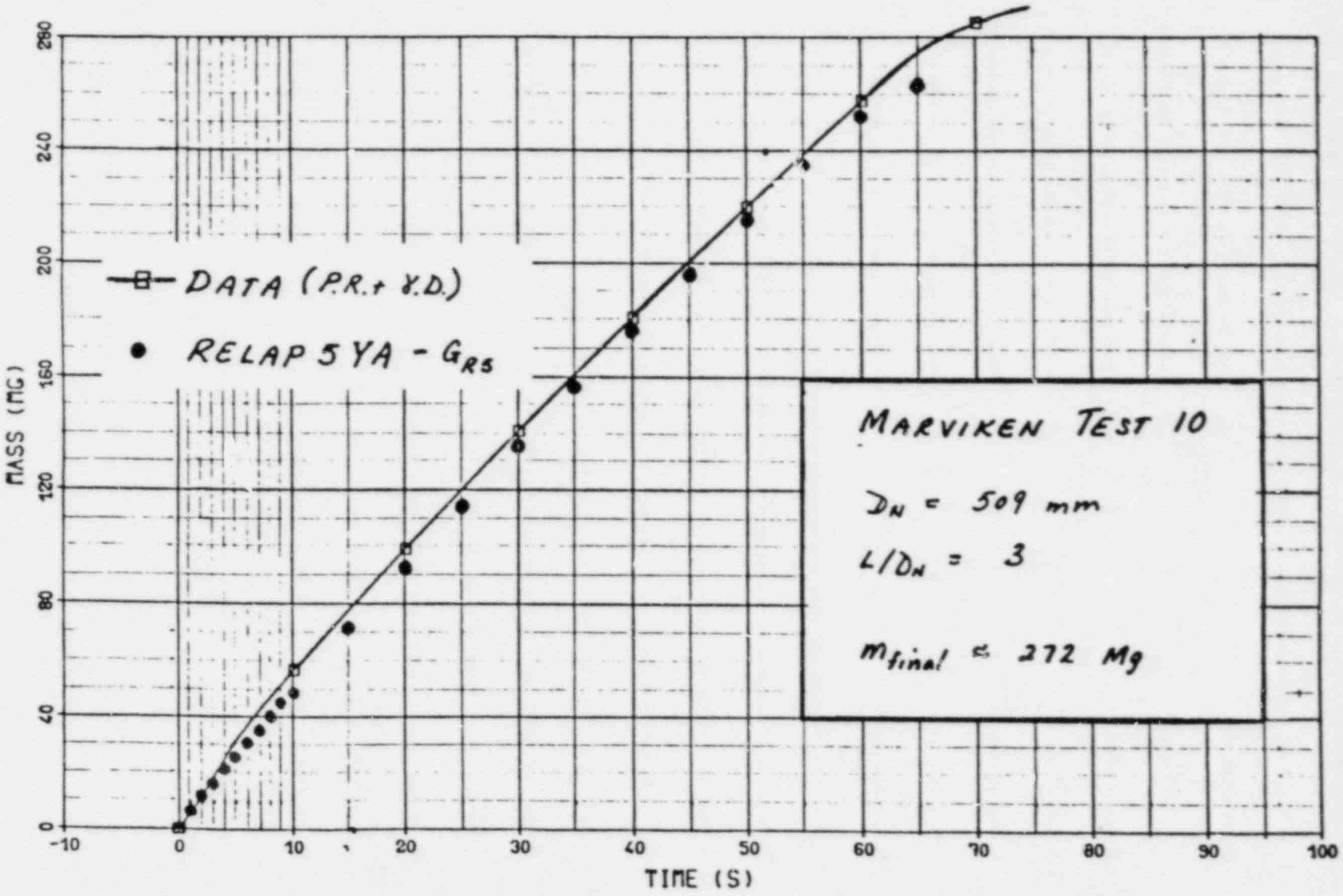
PRESSURE HISTORY - RELAP5YA



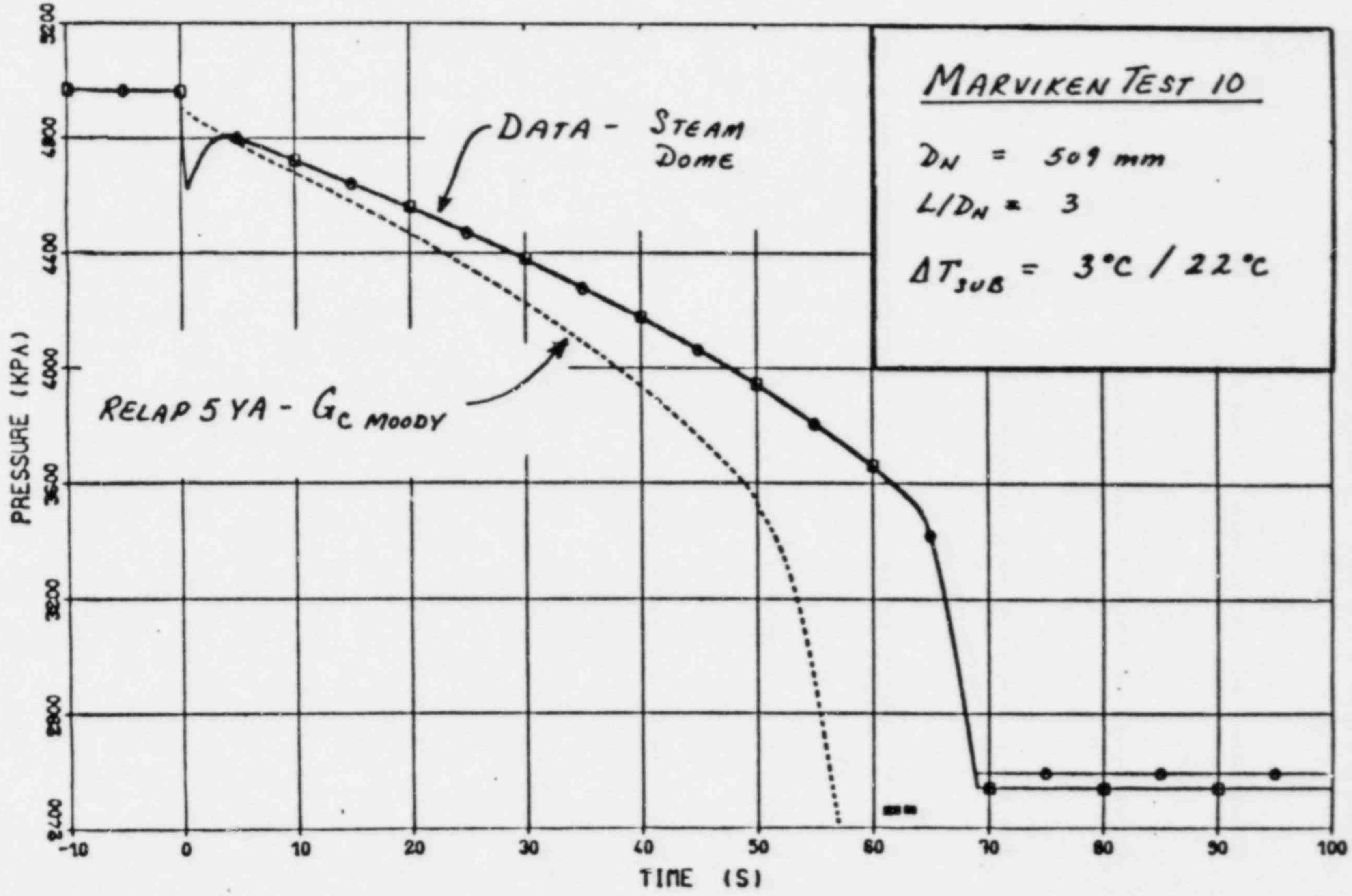
MASS FLOW RATE - RELAP 5YA



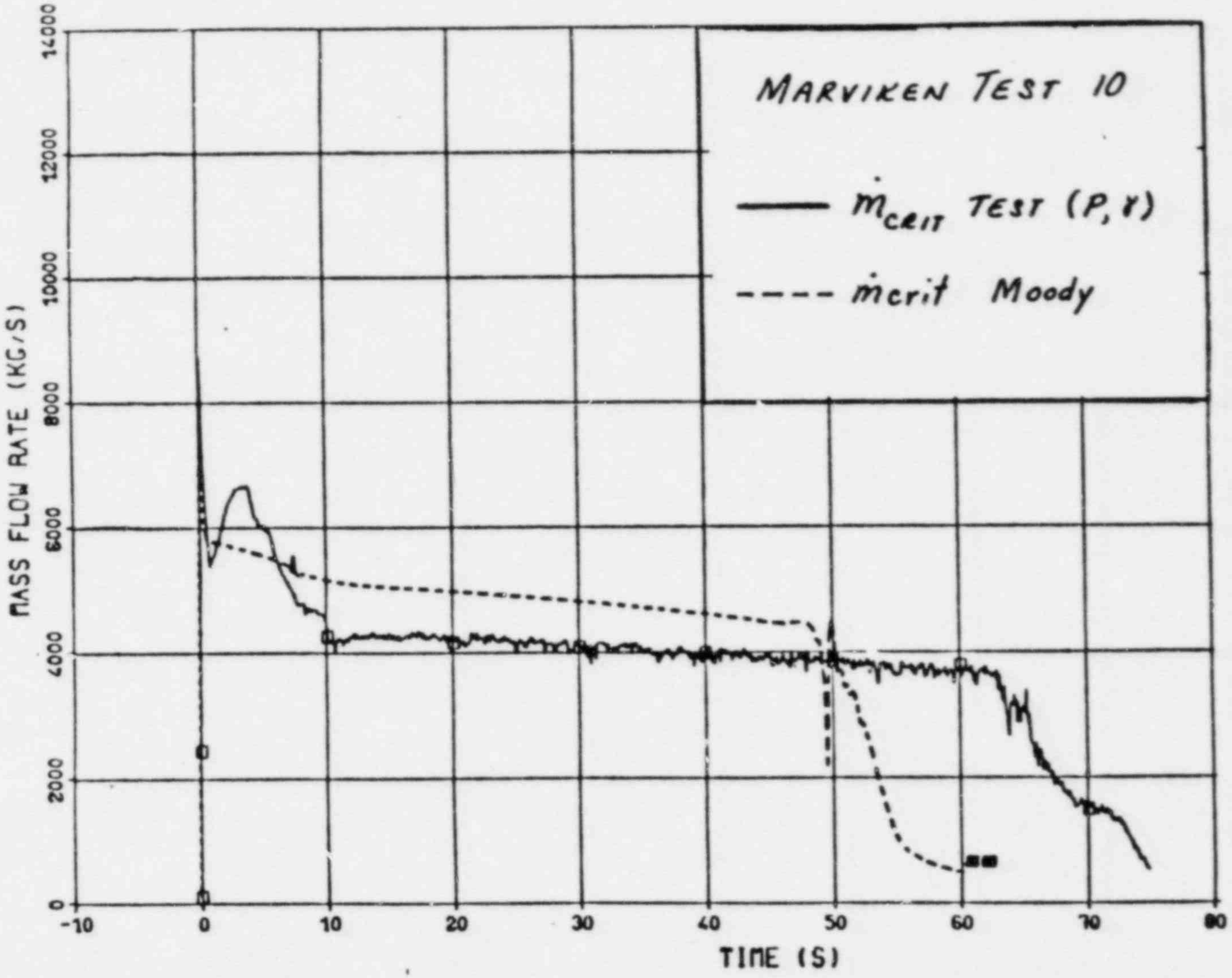
ESCAPED MASS HISTORY - RELAP 5YA



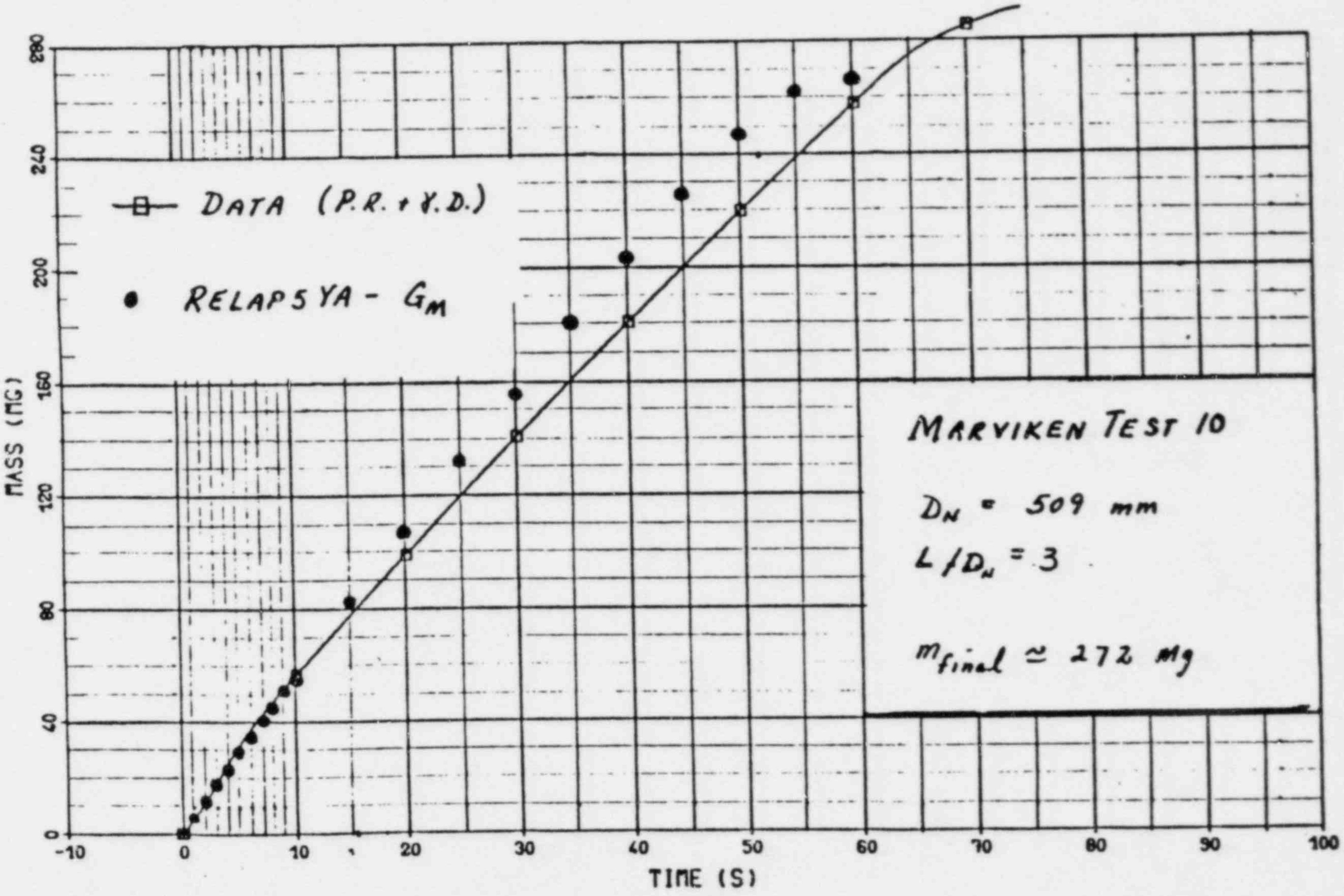
PRESSURE HISTORY - MOODY



MASS FLOW RATE - MOODY



ESCAPED MASS HISTORY - MOODY



ACCUMULATOR MODEL

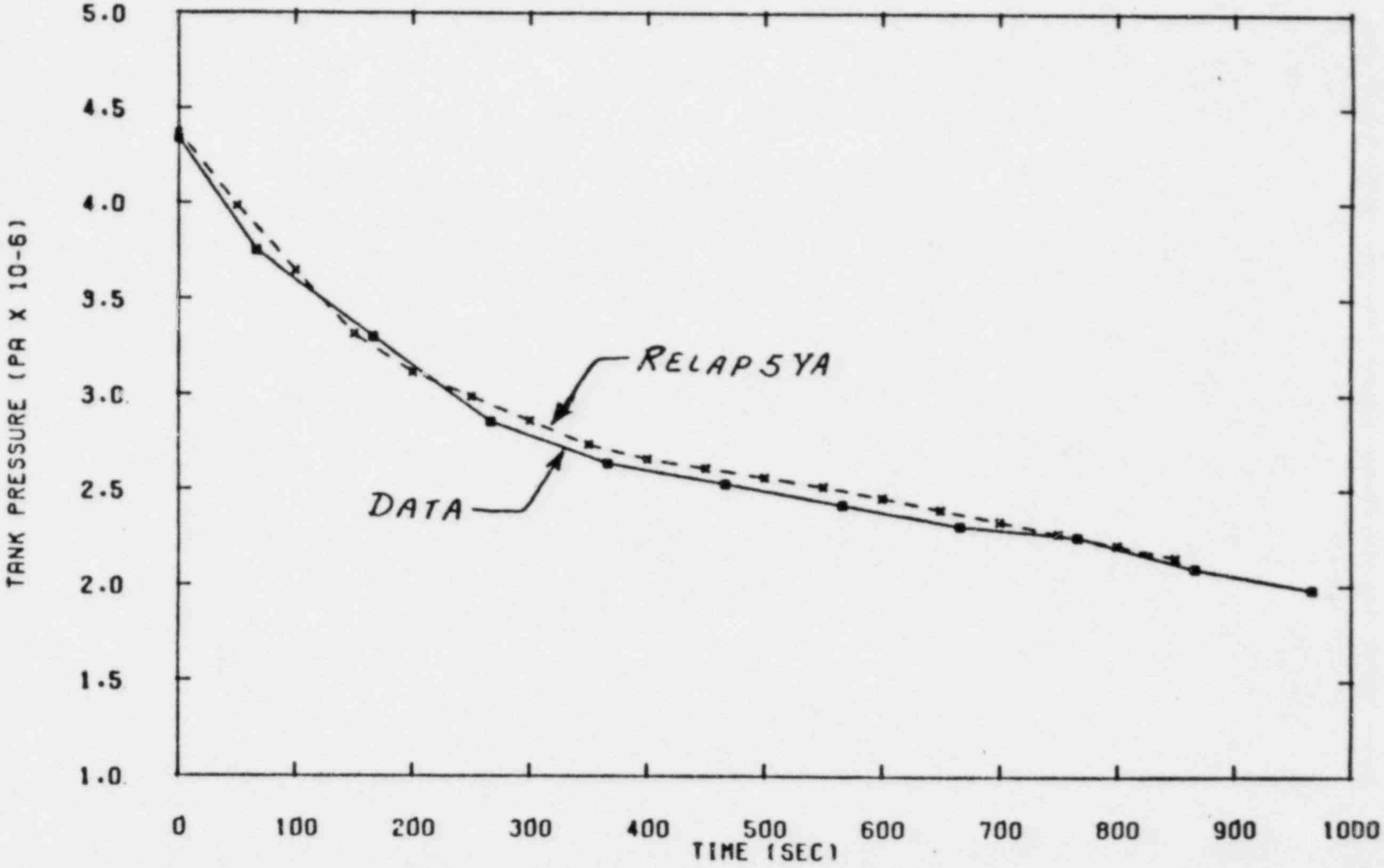
ASSESSMENT - FIRST PASS

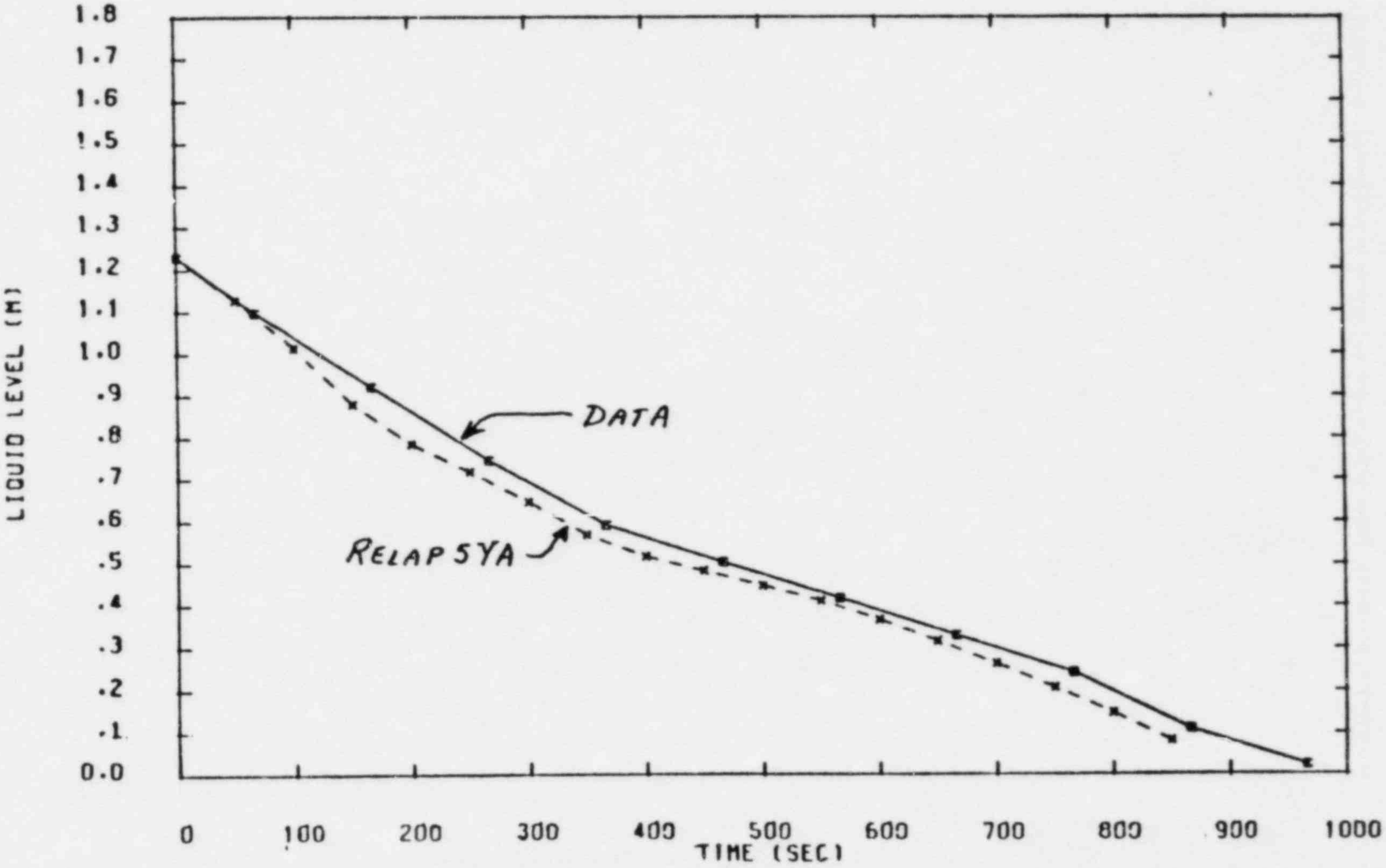
- MOMENTUM EQUATION ERROR
- HEAT TRANFER
  - GRASHOF NUMBER
  - AIR - WATER DIFFUSIVITY
  - TOTAL TANK WALL TO NITROGEN
- REDERIVED AND REPROGRAMMED MODEL

MODEL DIFFERENCES

- MOMENTUM EQUATION GENERALIZED
  - FRICTION FACTOR USER SUPPLIED
  - FORM LOSS FROM TANK TO SURGE LINE
- HEAT TRANFER CORRECTED
  - UNCOVERED TANK WALL TO NITROGEN
  - GR, $\mathcal{D}_{w-a}$
- FOURTH ORDER RUNGE KUTTA INTEGRATION

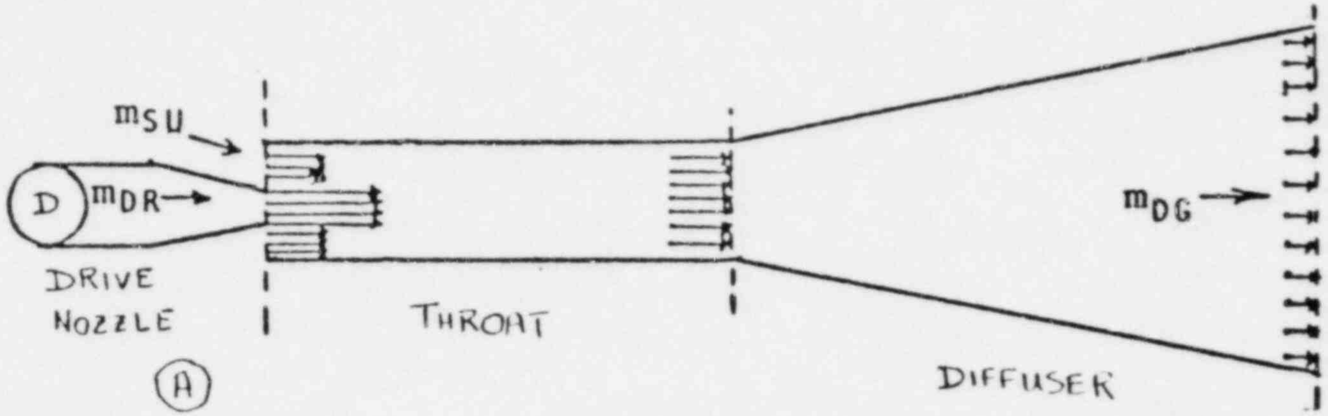
LOFT3-1
TANK PRESSURE VERSUS TIME

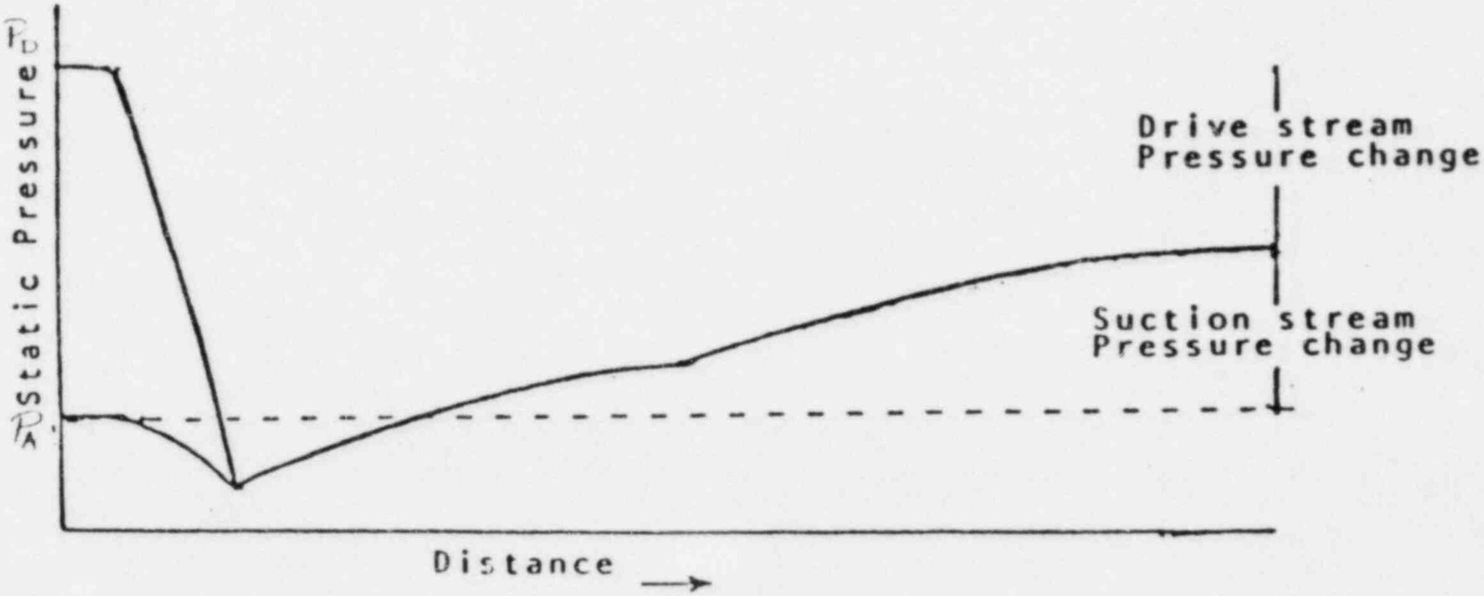




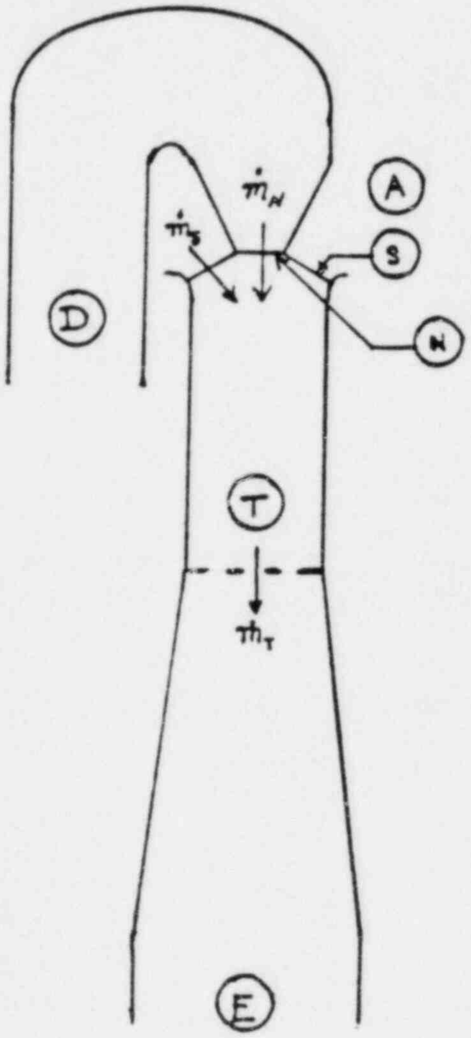
LOFT3-1
LIQUID LEVEL VERSUS TIME

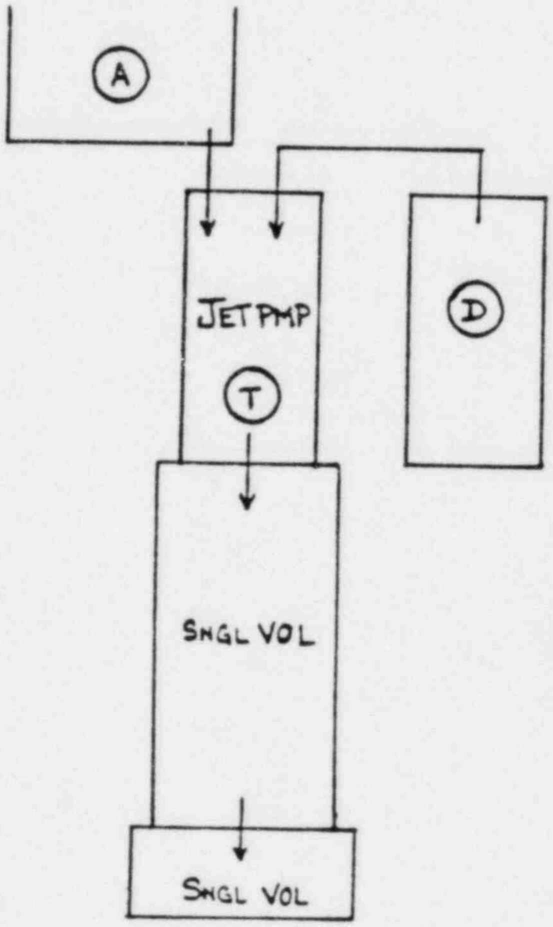
JET PUMP
MODEL

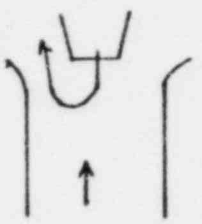
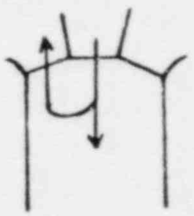
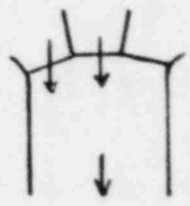
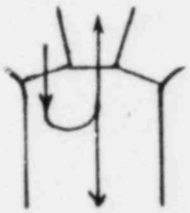
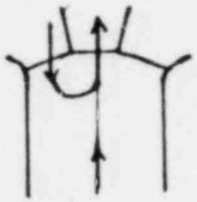
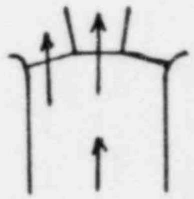

m_SU
D
m_DR
DRIVE
NOZZLE
Ⓐ
THROAT
DIFFUSER
m_DG


P_D
Static Pressure
P_A
Drive stream
Pressure change
Suction stream
Pressure change
Distance →

JET PUMP MODEL





	$-\infty \leq M < -1$	$-1 \leq M \leq 0$	$0 \leq M \leq +\infty$
POSITIVE DRIVE			
CONTINUITY	$\dot{Q}_N - \dot{Q}_S = -\dot{Q}_T$	$\dot{Q}_N - \dot{Q}_S = \dot{Q}_T$	$\dot{Q}_N + \dot{Q}_S = \dot{Q}_T$
MECH. ENERGY	$\overline{P}_T - \overline{P}_N = EL_{TN}$ $\overline{P}_T - \overline{P}_S = EL_{TS}$	$\overline{P}_T - \overline{P}_S = EL_{TS}$ $\overline{P}_N - \overline{P}_S = EL_{NS}$	$\overline{P}_N - \overline{P}_T = EL_{NT}$ $\overline{P}_S - \overline{P}_T = EL_{ST}$
	$-\infty \leq M \leq -1$	$-1 \leq M \leq 0$	$0 \leq M \leq +\infty$
REVERSE DRIVE			
CONTINUITY	$-\dot{Q}_N + \dot{Q}_S = \dot{Q}_T$	$-\dot{Q}_N + \dot{Q}_S = -\dot{Q}_T$	$-\dot{Q}_N - \dot{Q}_S = -\dot{Q}_T$
MECH ENERGY	$\overline{P}_S - \overline{P}_N = EL_{SN}$ $\overline{P}_S - \overline{P}_T = EL_{ST}$	$\overline{P}_T - \overline{P}_N = EL_{TN}$ $\overline{P}_S - \overline{P}_T = EL_{TS}$	$\overline{P}_T - \overline{P}_N = EL_{TN}$ $\overline{P}_T - \overline{P}_S = EL_{TS}$

MODEL DEVELOPMENT AND IMPLEMENTATION

(1) FOR STEADY STATE SINGLE PHASE

$$\bar{P}_D - \bar{P}_T = f(K, \mathrm{Geom}, V)$$

$$\bar{P}_A - \bar{P}_T = f(K, \mathrm{Geom}, V)$$

(2) EXTEND TO 2φ CONDITIONS AND IMPLEMENT INTO RELAP5

POSITIVE DRIVE POSITIVE SUCTION FLOW

MSOURCE(DRIVJ) = f(Geom,V)

MSOURCE(SUCTJ) = f(Geom,V)

FLOSS(DRIVJ) = K

FLOSS(SUCTJ) = K

ALL OTHER FLOW CONFIGURATIONS

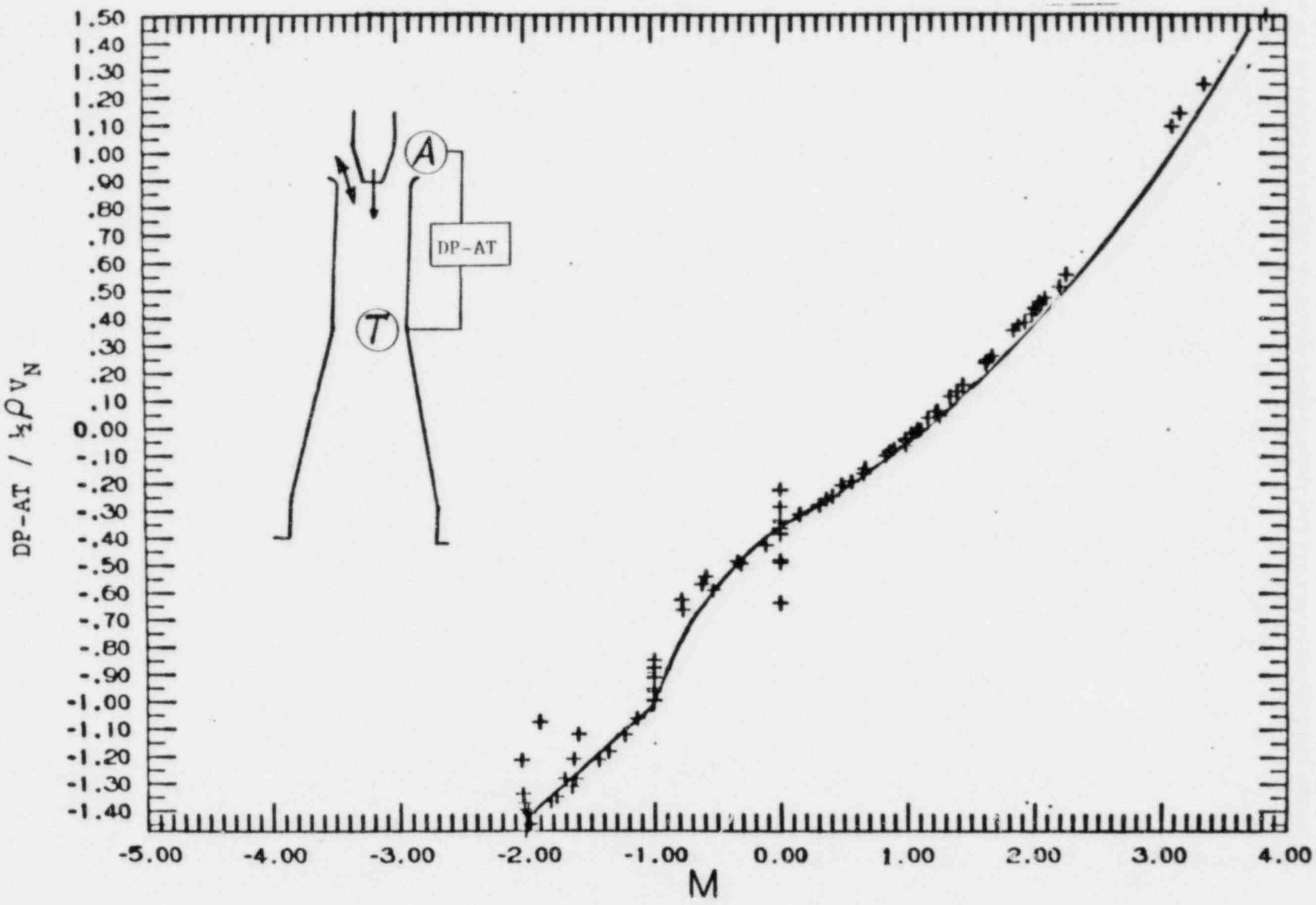
MSOURCE(DRIVJ) = 0.0

MSOURCE(SUCTJ) = 0.0

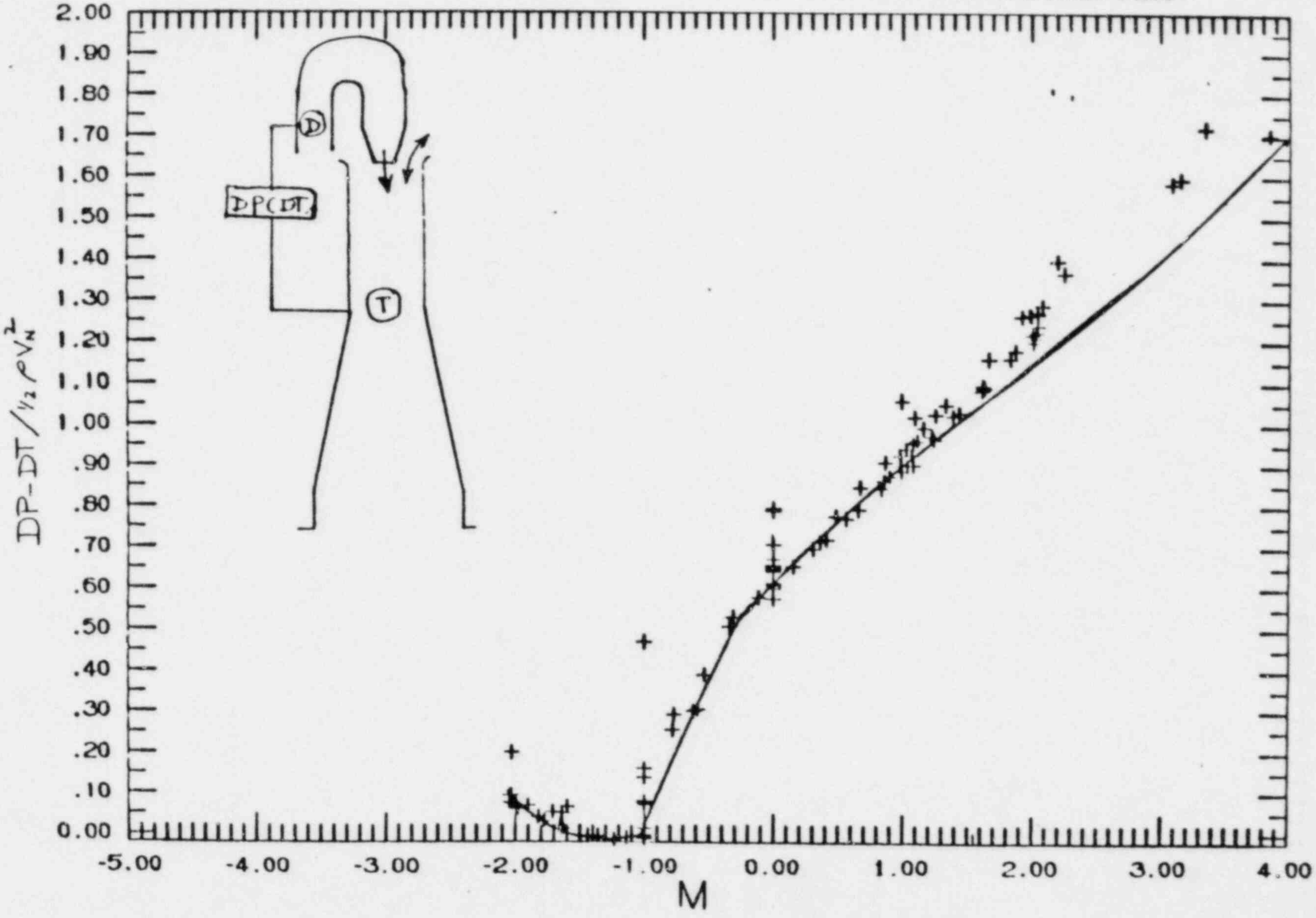
$$\mathrm{FLOSS(DRIVJ)} = \frac{\bar{P}_D - \bar{P}_T}{\frac{1}{2}\rho V_n^2} = f(K, \mathrm{Geom}, M)$$

$$\mathrm{FLOSS(SUCTJ)} = \frac{\bar{P}_A - \bar{P}_T}{\frac{1}{2}\rho V^2} = f(K, \mathrm{Geom}, M)$$

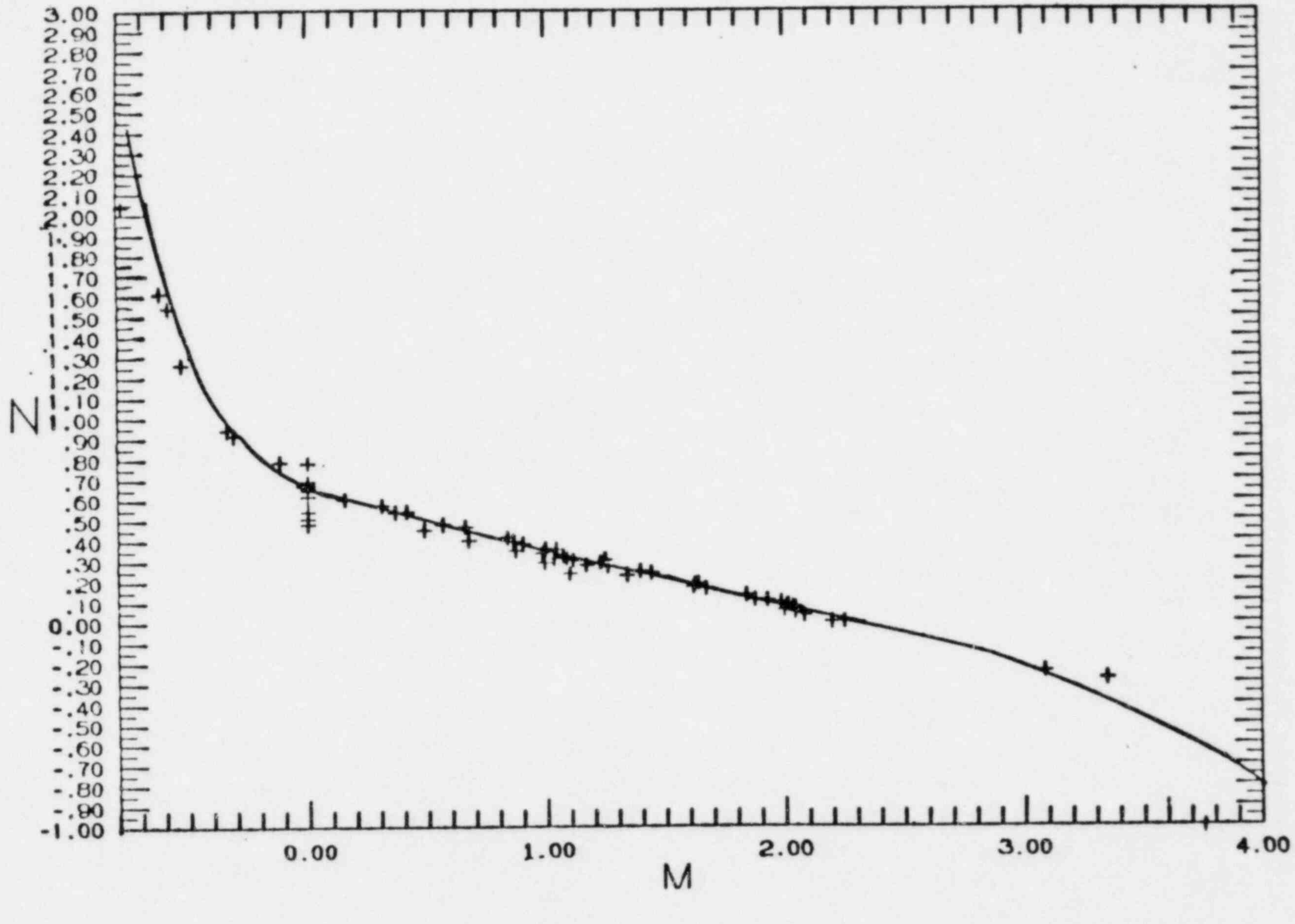
POSITIVE DRIVE; NORMALIZED DOWNCOMMER TO THROAT PRESSURE DROP

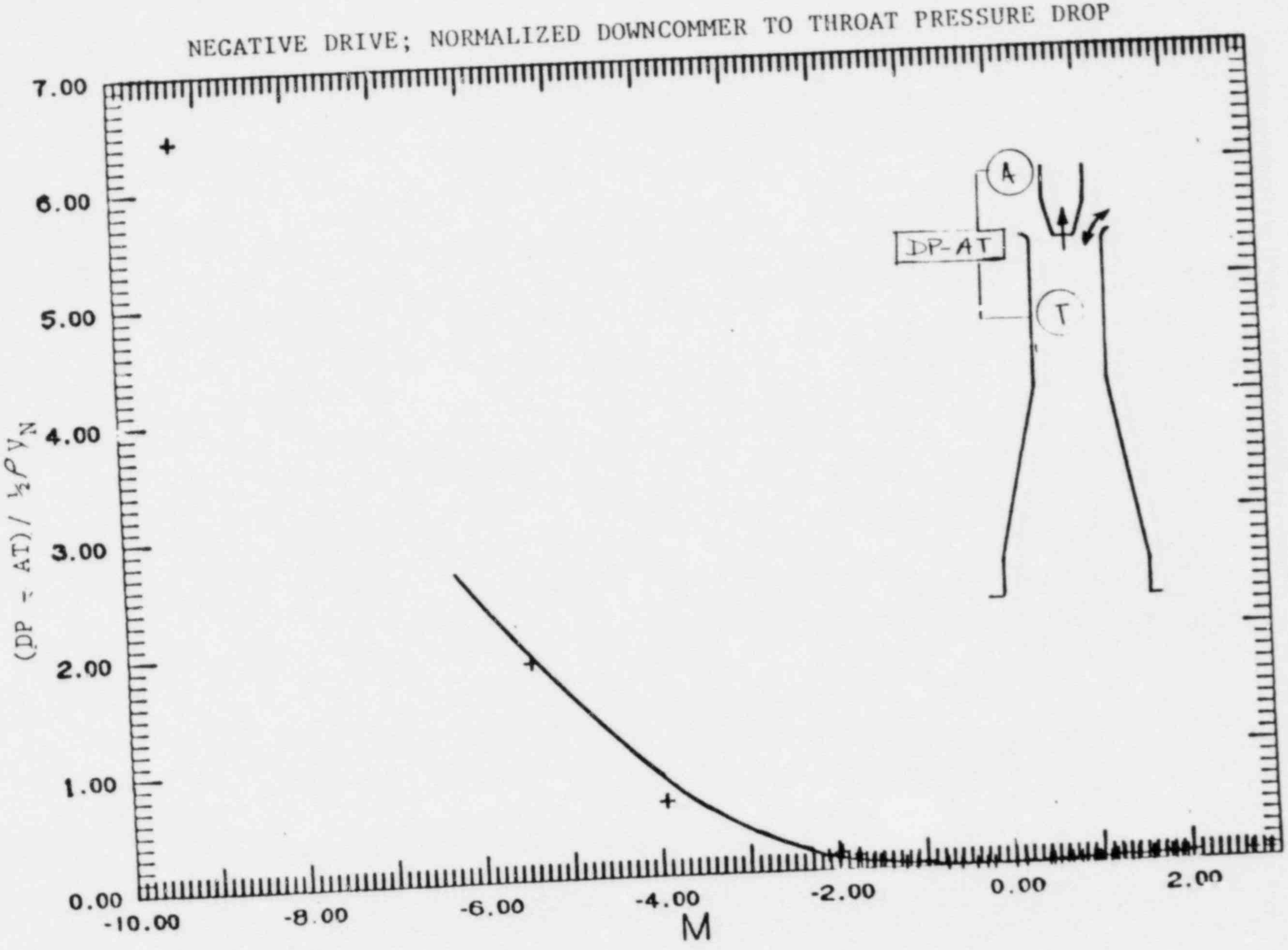


POSITIVE DRIVE; NORMALIZED DRIVE LINE TO THROAT PRESSURE DROP

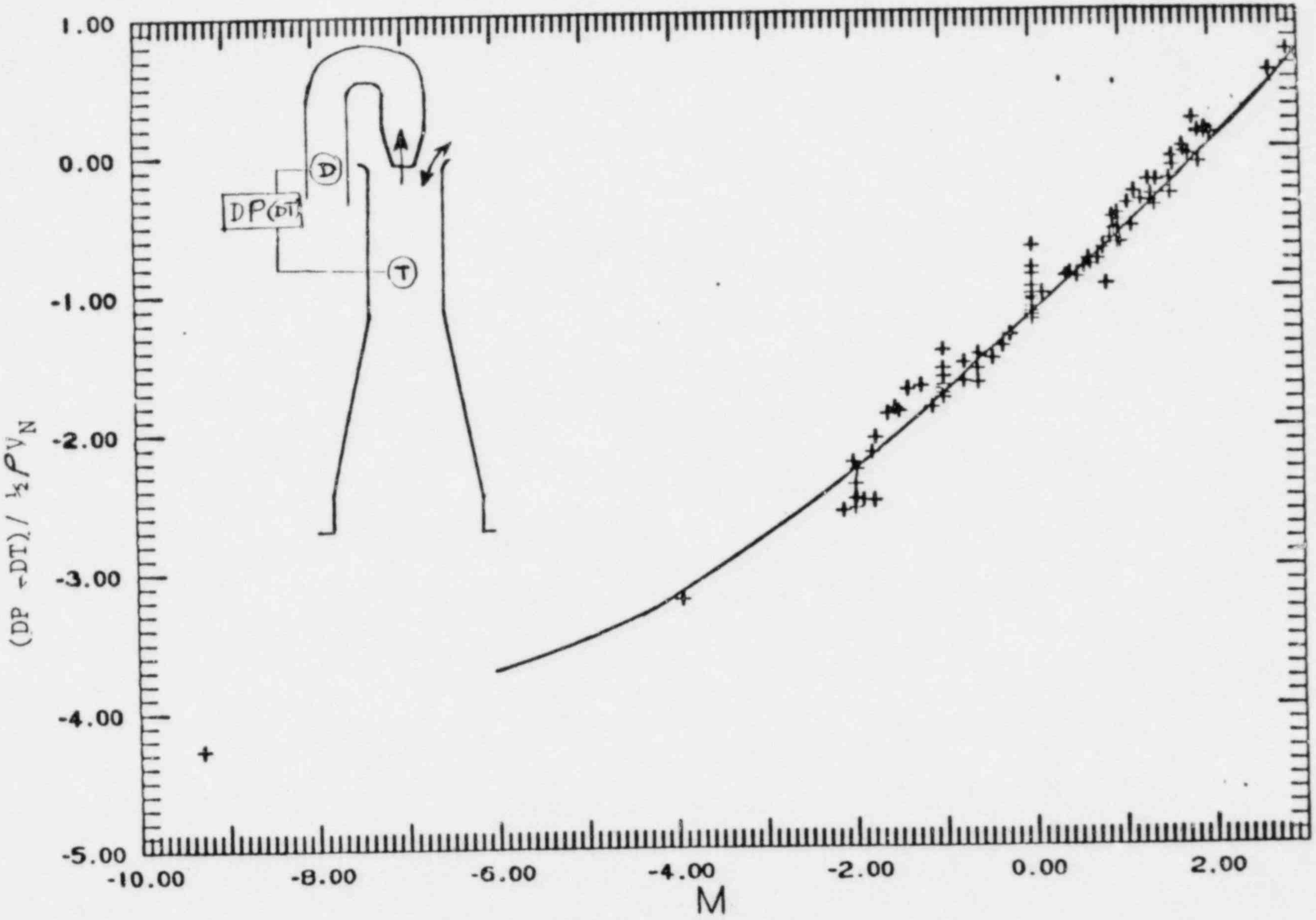


POSITIVE DRIVE; N VERSUS M

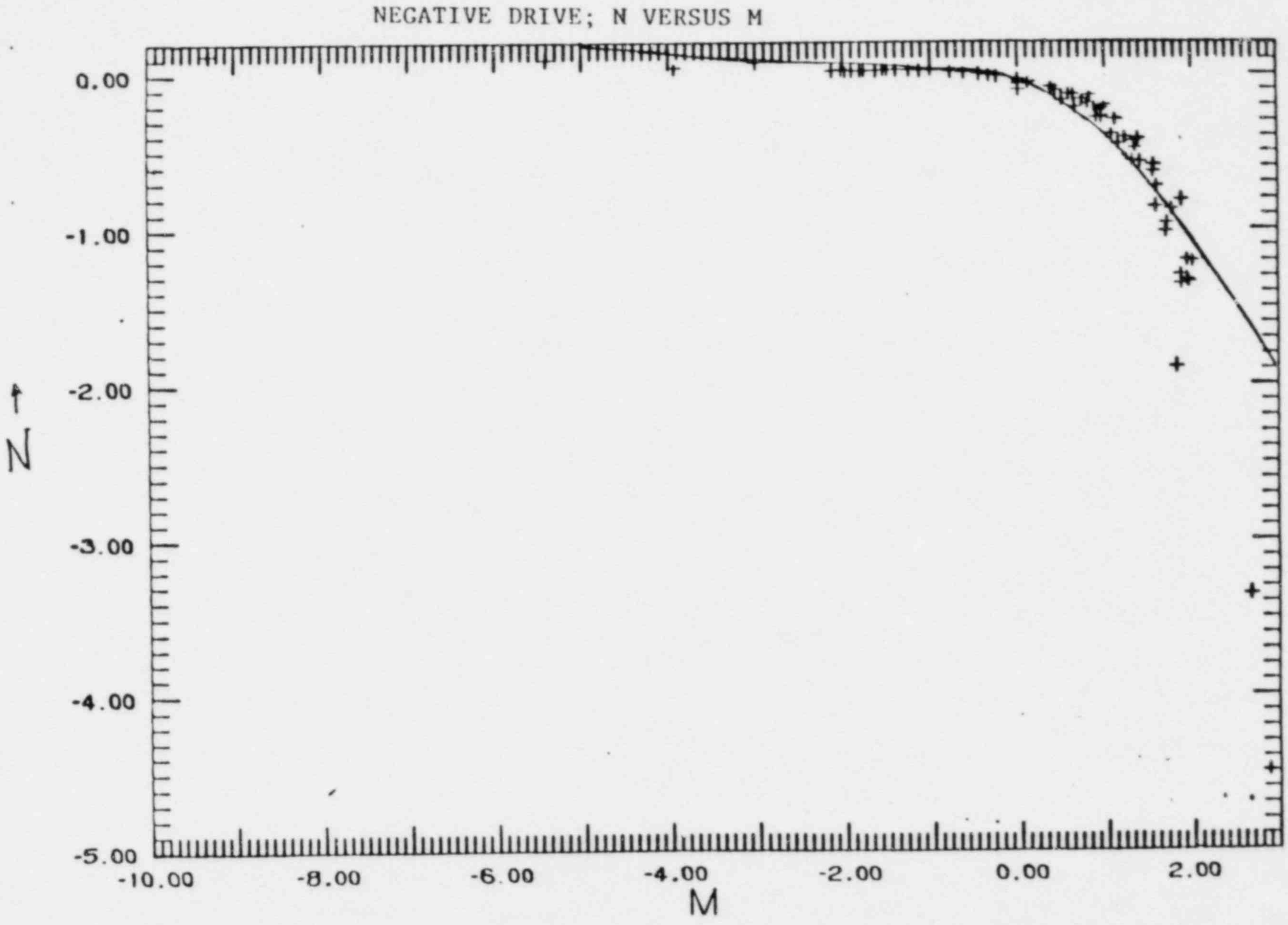




NEGATIVE DRIVE; NORMALIZED DOWNCOMMER TO THROAT PRESSURE DROP



NEGATIVE DRIVE; NORMALIZED DRIVE LINE TO THROAT PRESSURE DROP



NEGATIVE DRIVE; N VERSUS M

FORCED CONVECTIVE BOILING

REASON FOR MODIFICATION

JUSTIFICATION OF CHANGE

NEW MODEL

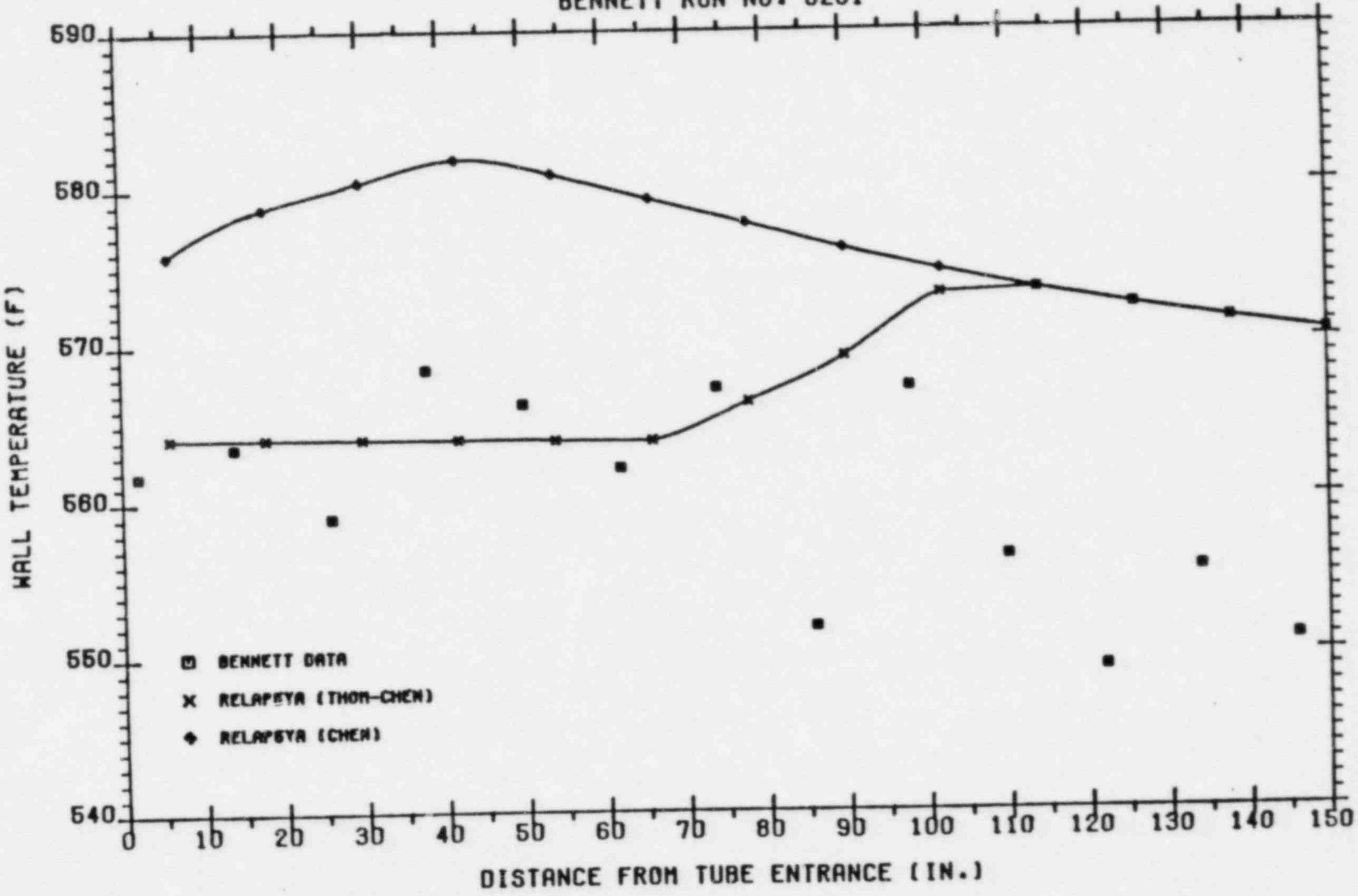
	VOID FRACTION
THOM	0.0 - 0.8
interpolate	0.8 - 0.9
CHEN	0.9 - 1.0

RESULTS

CHEN correlation

THOM-CHEN correlations

COMPARISON OF RELAP5 WALL TEMPERATURE PREDICTIONS WITH DATA
BENNETT RUN NO. 5251



CRITICAL HEAT FLUX MODEL INCORPORATED IN RELAP5YA

THEORY

- Modified Biasi correlation is used for high mass flux
- Griffith-Zuber correlation is used for low mass flux
- Linear interpolation between the two correlations is used for intermediate mass flux
- critical void fraction (used to determine dryout) depends on mass flux

SEPARATE EFFECTS TESTS

- Columbia University
- General Electric Co. Nine-Rod
- ORNL THTF

STEADY STATE CHF TEST CONDITIONS

Experiment	Pressure (psi)	Ave. Mass Flux ($Mlb/hr-ft^2$)	Ave. Heat Flux ($MBtu/hr-ft^2$)	Heated Rod Diameter (in.)	Heated Length (in.)
Columbia	1500 - 2005	1.968 - 2.008	0.282 - 0.436	0.382	150.0
GE 9 Rod	997 - 1005	0.249 - 1.248	0.289 - 0.522	0.570	72.0
ORNL THTF	635 - 1849	0.166 - 0.525	0.14 - 0.29	0.374	144.0

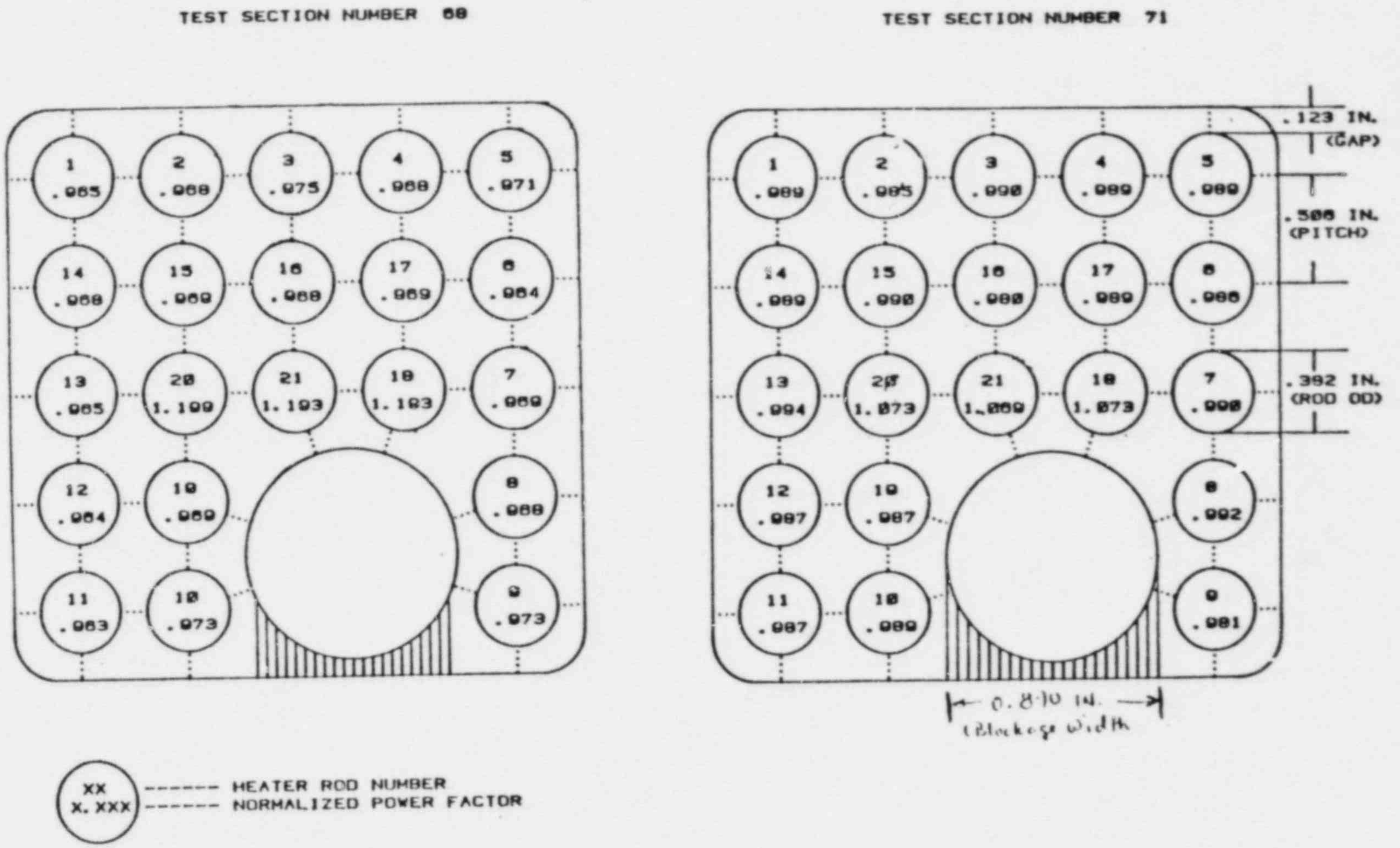
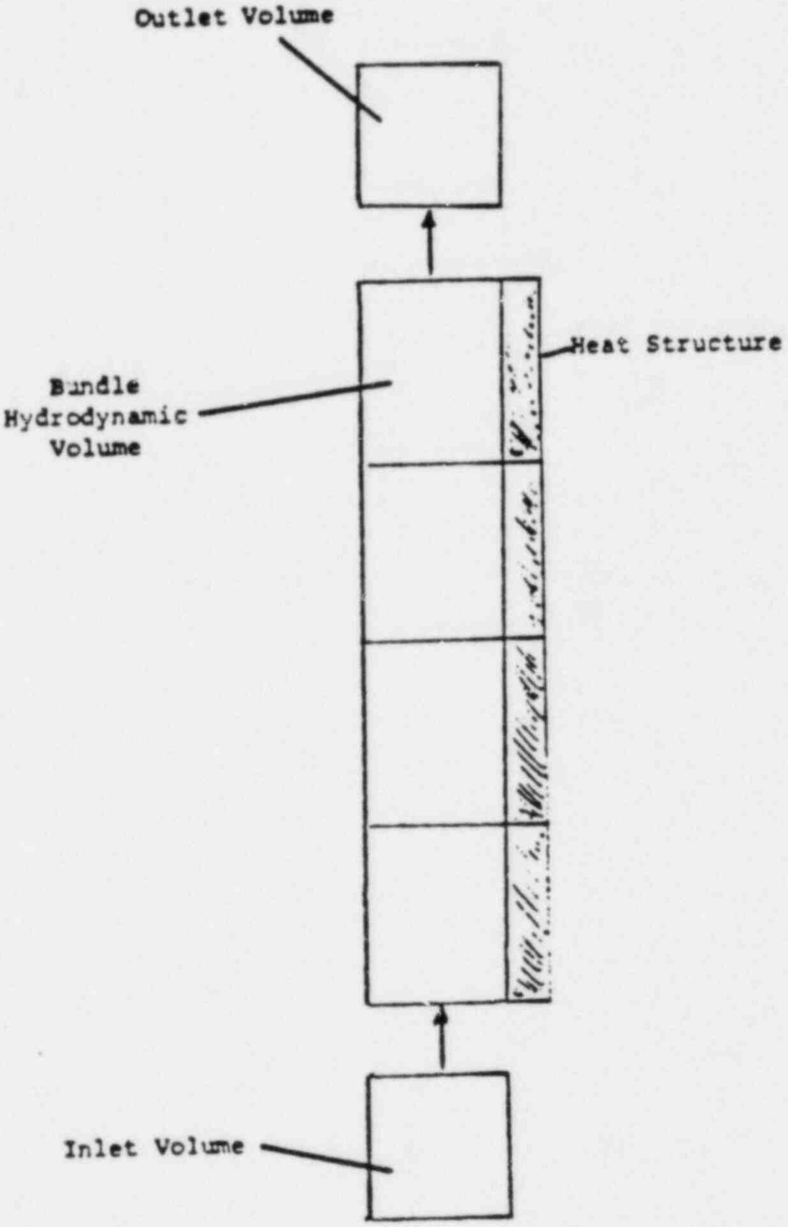


Figure 3.1 -1
Columbia Radial Geometry and Power Distribution



RELAP5 Model For Columbia Test Sections 68 and 71

TEST SECTION 68:

Run Number 18

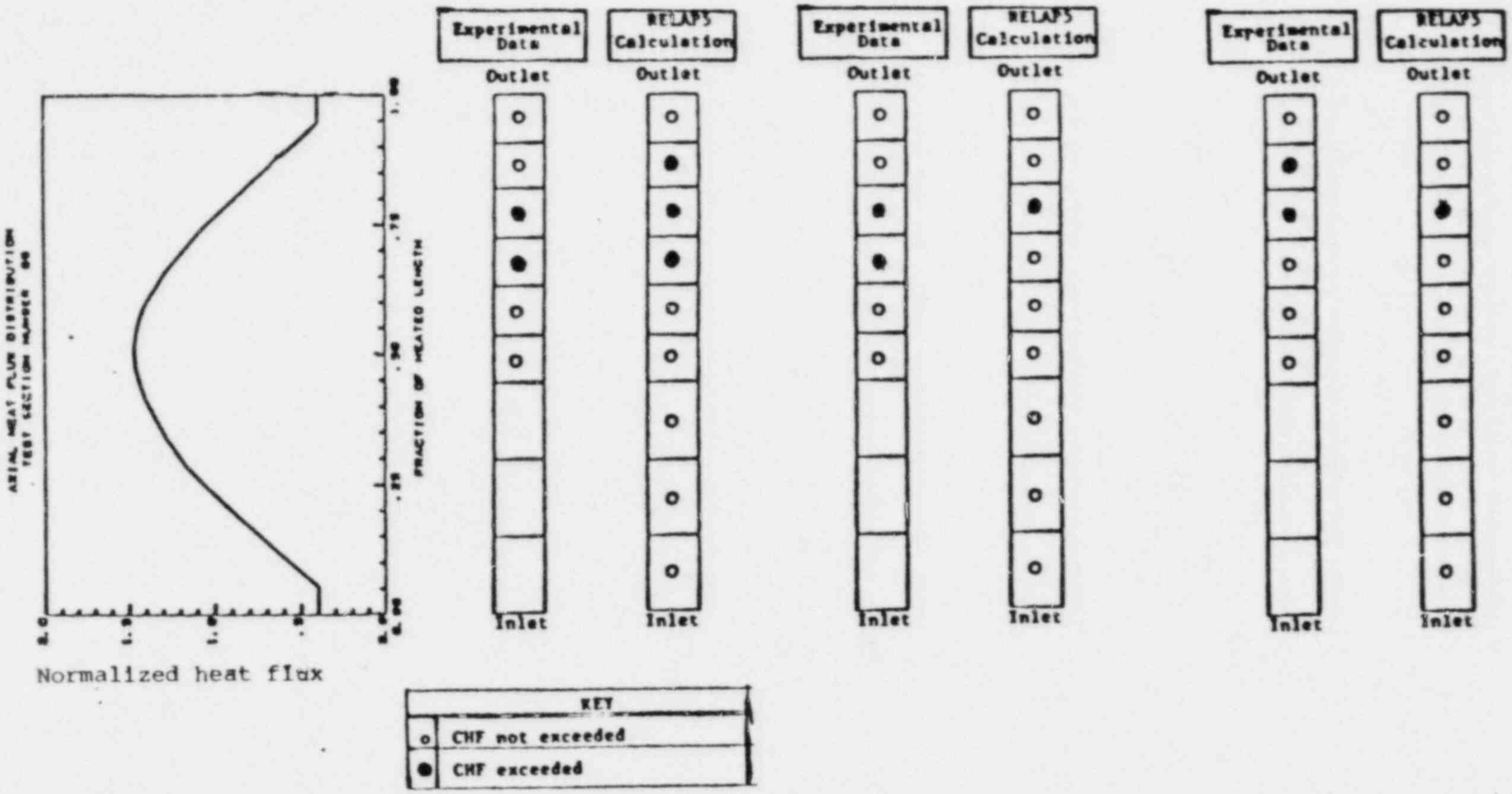
Inlet Temp.= 581.7°F
P = 1755. psia
G = 1.980 Mlb/hr-ft^2

Run Number 22

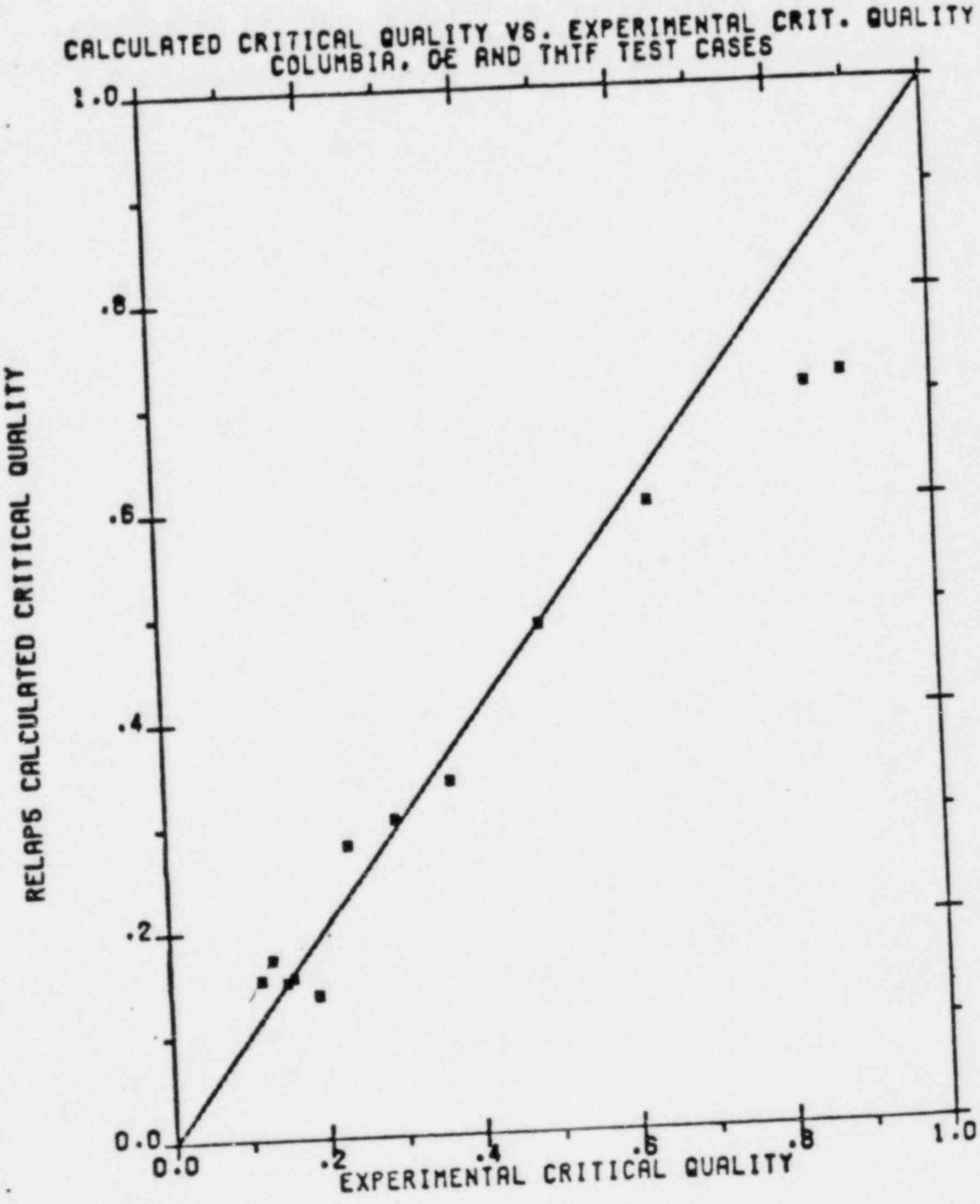
Inlet Temp.=553.4
P = 1755.
G = 2.008

Run Number 27

Inlet Temp.=520.5
P = 1500.
G = 1.995



MEASURED AND CALCULATED AXIAL CHF LOCATIONS


CALCULATED CRITICAL QUALITY VS. EXPERIMENTAL CRIT. QUALITY
COLUMBIA, GE AND THTF TEST CASES

RADIATION HEAT TRANSFER

ASSUMPTIONS

- GRAY, DIFFUSE SURFACES; NON-PART. FLUID
- UNIFORM T_i, ρ_i, R_i ON EACH SURFACE
- $0 \leq \varepsilon_i$, CONSTANT ≤ 1.0

THEORY

- $R_i = [\delta_{ij} - \rho_i F_{ij}]^{-1} [\varepsilon_i \sigma T_i^4]$
- $q''_{RAD,i} = \dfrac{\varepsilon_i}{\rho_i} [\sigma T_i^4 - R_i]$
- $A_i F_{ij} = A_j F_{ji}$ Reciprocity
- $\sum_{j=1}^{n} F_{ij} = 1.0$ Continuity
- $\varepsilon_i = (1 - \rho_i)$

IMPLEMENTATION

- $T_i \geq T_{RAD\ ON}$, $\alpha_i \geq \alpha_{RAD\ ON}$
- $-K \dfrac{\partial T}{\partial r}^{n+1} = h_c^{n+1} [T_i^{n+1} - T_f^{n}] + q^{n}_{RAD,i}$

HEAT TRANSFER LOCKOUT OPTIONS

RETURN TO NUCEATE BOILING LOCKOUT

- USER SELECTED STRUCTURES (JEM1=1)

  IF $q''_{WALL} > q''_{CHF}$, IEM1 = 1

- USER SUPPLIED NUCLEATE BOILING MULTIPLIER

  $$h_{NB-EM} = XMNB \cdot h_{NB-POOL,\ SUB,\ SAT}$$

- UNLOCKED BY

  REWET - QUENCH MODEL AFTER QUENCHING

  RESTART

RETURN TO TRANSITION BOILING LOCKOUT

- USER SELECTED STRUCTURES (JEM2=1)

  IF $\Delta T_{W.\ SUP} \geq 300\,°F$, IEM2 = 1

  $$h_{\substack{RTB-EM \\ RNB-EM}} = h_{FILM\ BOILING,\ HI\ OR\ LO\ FLOW}$$

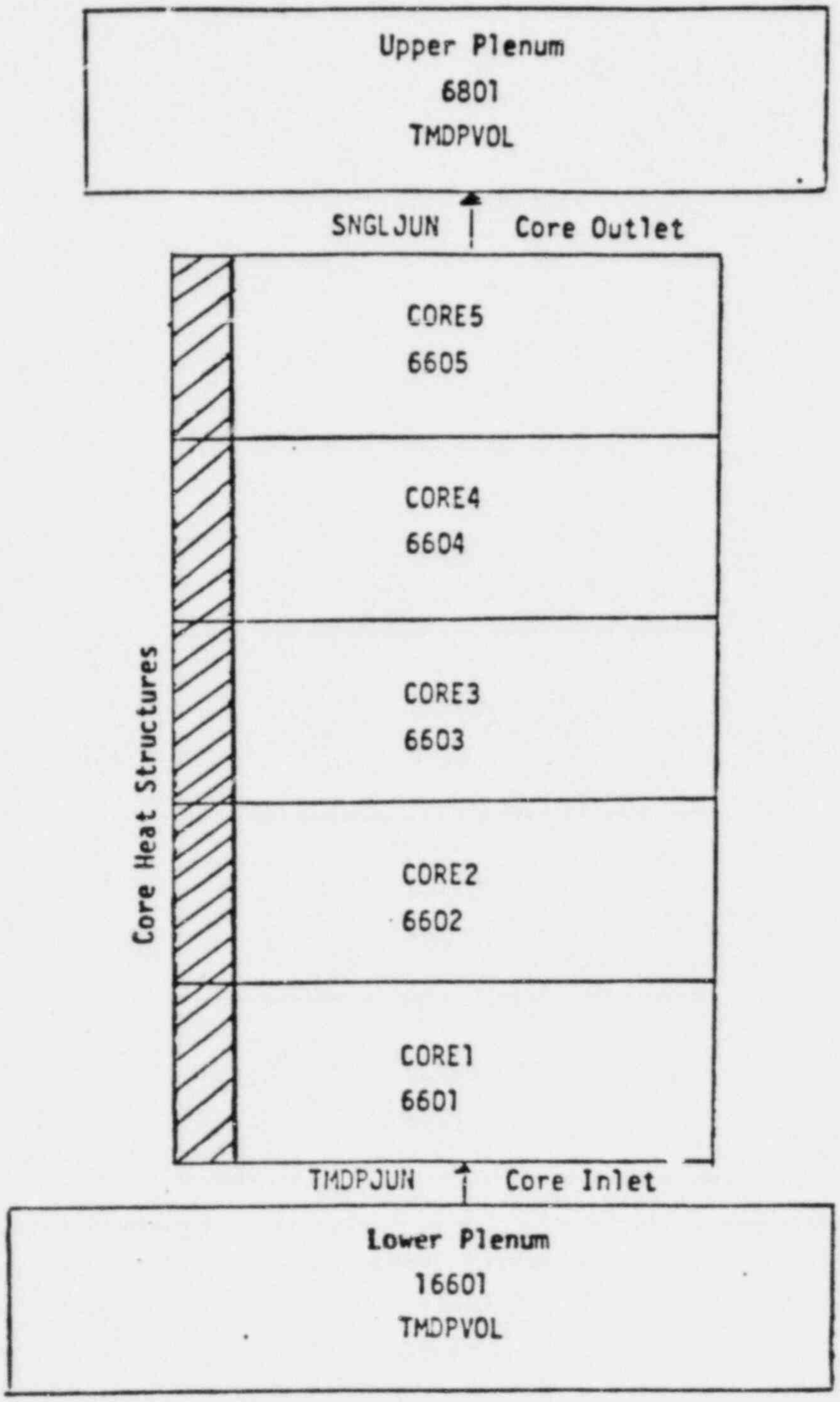
- UNLOCKED BY

  REWET - QUENCH MODEL AFTER QUENCHING

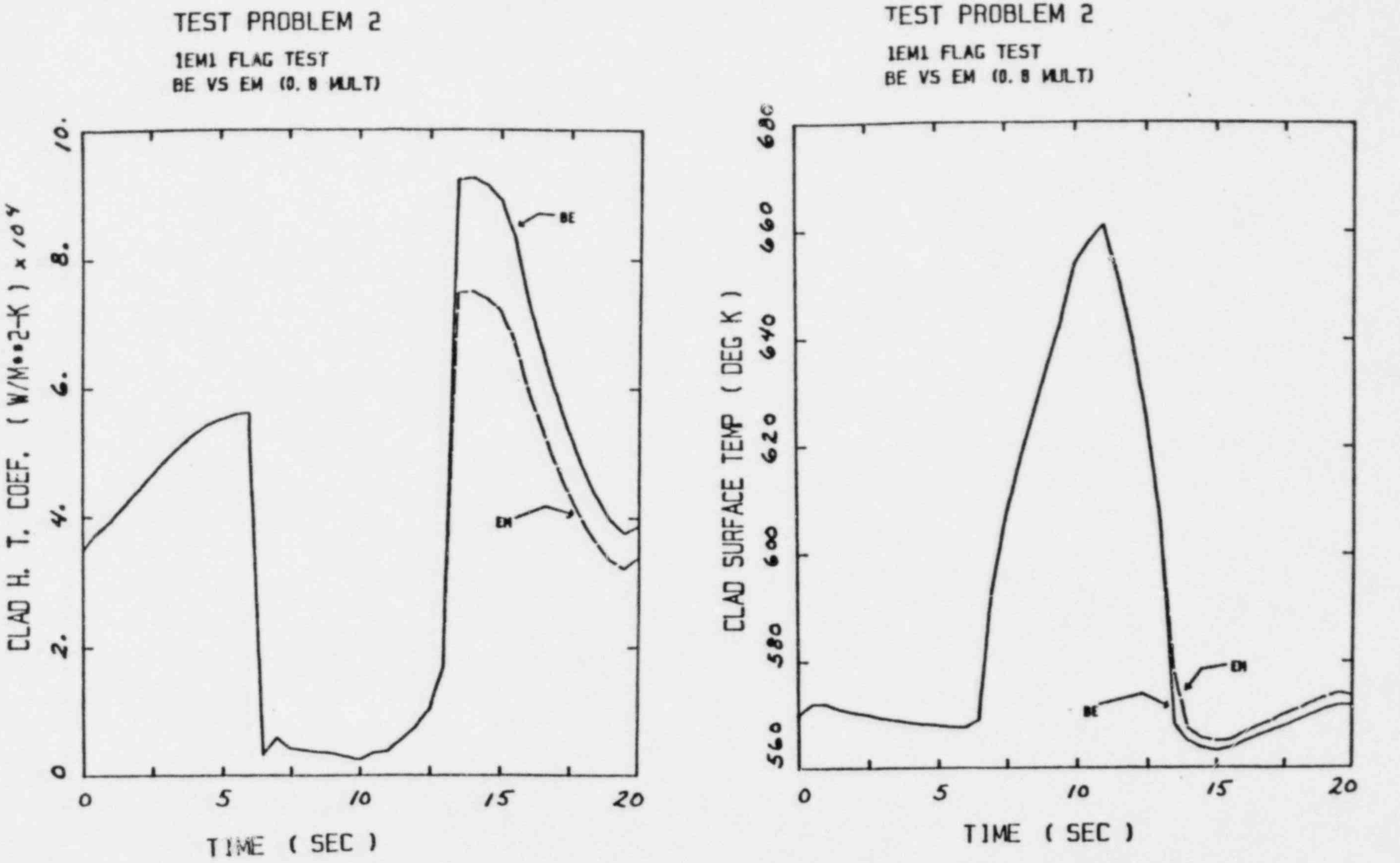
  RESTART

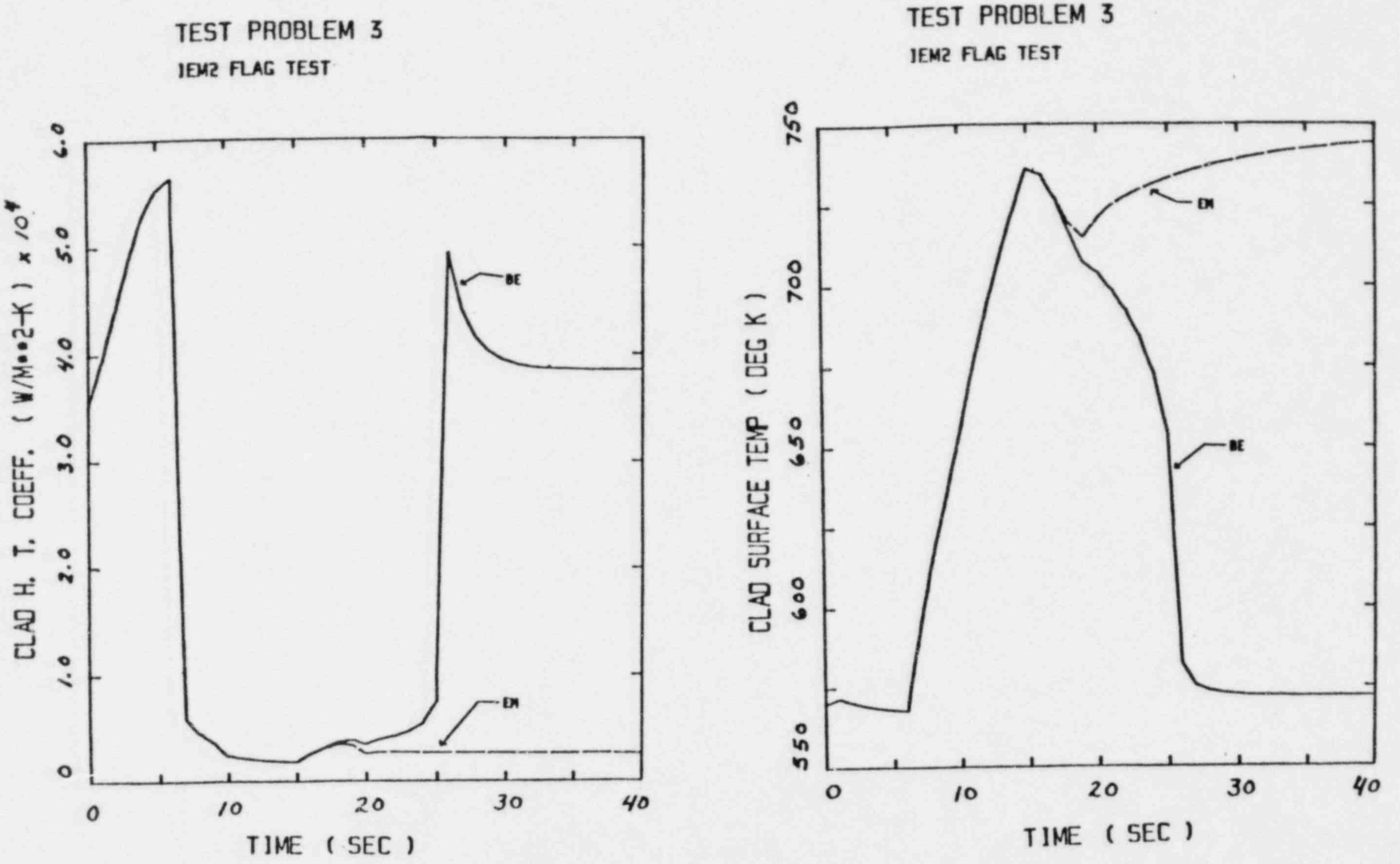
RELAP5YA NODALIZATION DIAGRAM

HEAT TRANSFER LOCKOUT CASES



Comparison of BE and EM clad surface temperature under rewet conditions (IEM1 Flag Activated).





TEST PROBLEM 3

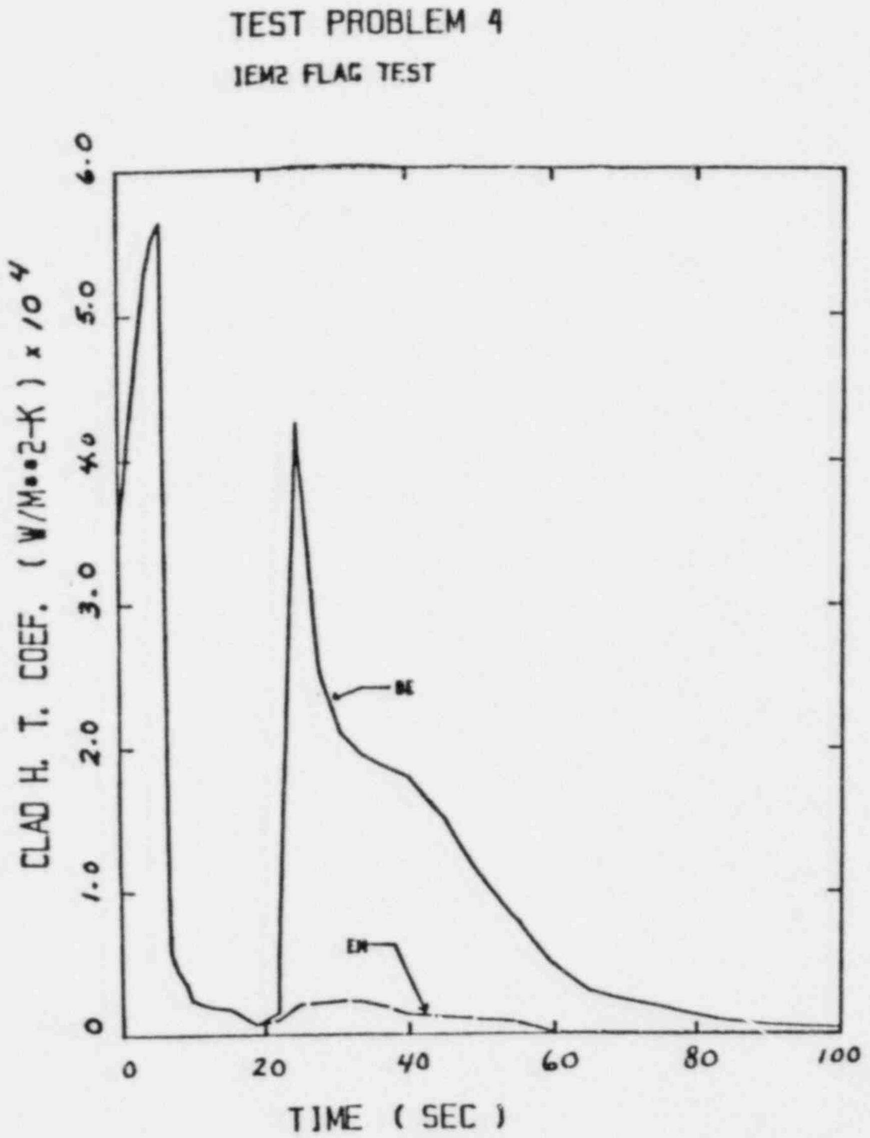
IEM2 FLAG TEST

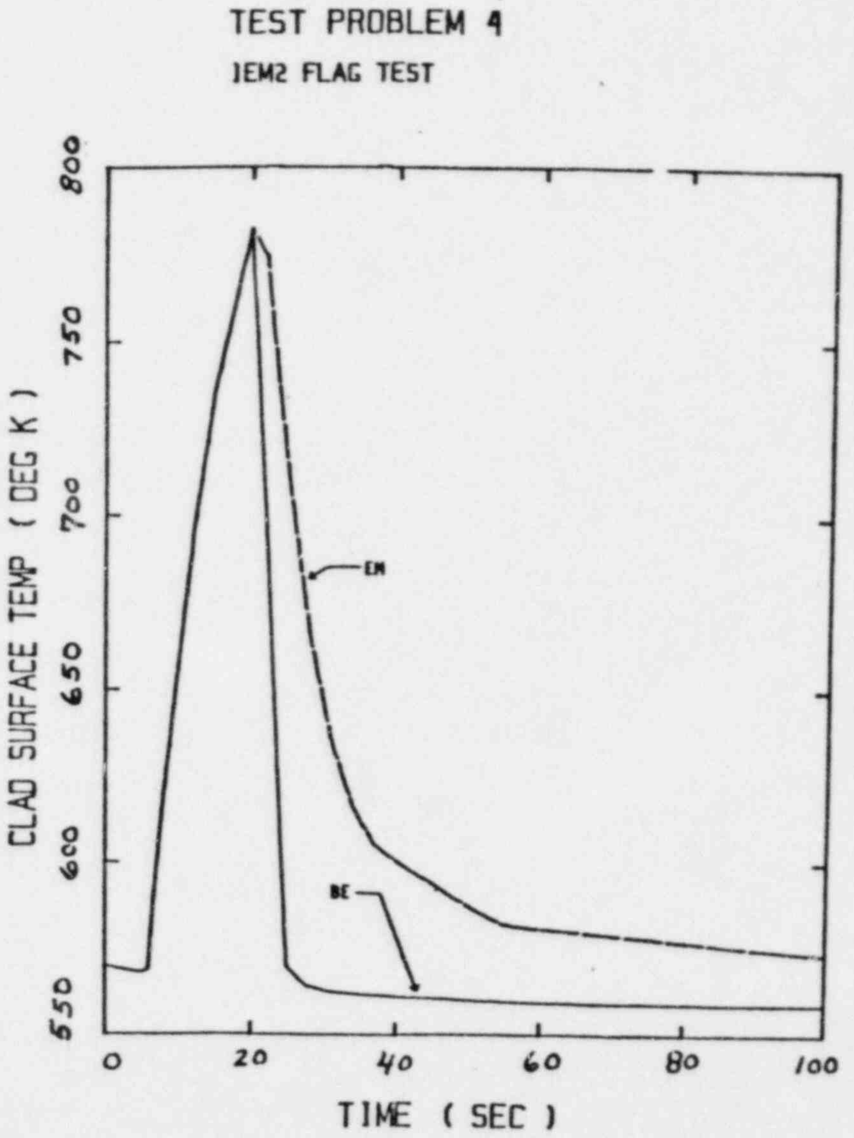
TEST PROBLEM 3

IEM2 FLAG TEST

Comparison of BE and EM clad surface temperature using transition boiling lockout (IEM2 Flag Activated).

Comparison of BE and EM clad heat transfer coefficients under low flow conditions using transition boiling lockout.





FUEL BEHAVIOR MODELS INCORPORATED IN RELAP5YA

- fuel rod internal pressure
- fuel rod deformation
- gap heat transfer
- metal-water reaction

Basis of models is fuel rod evaluation model routines from YAEC's RELAP4/MOD3 licensed code.

Major modifications made in clad deformation and rupture models to comply with new requirements mandated by the NRC.

Fuel rod internal pressure model simplified.

ASSUMPTIONS IN RELAP5YA FUEL BEHAVIOR MODELS

1. Fuel rod deformation is calculated only for the radial direction, no axial deformation is caluclated.

2. Fuel rod clad strain and rupture calculations are based on a single rod rather than a rod bundle.

3. Fuel rod deformation does not affect flow channel geometry.

4. In clad elastic and plastic deformation calculations, cladding is assumed to be divided into nodes of equal thickness and clad strain is applied to clad mid-radius.

5. Fuel and clad thermal expansion calculations assume input radii are specified at 68°F.

6. Emissivity of fuel pellets and cladding are constant.

7. Gap heat transfer coefficient calculation does not consider contact heat transfer.

8. Metal-water reaction is not steam-limited.

9. Fuel pellet melting is assumed not to occur.

10. Ideal gas behavior in fuel rod.

FUEL BEHAVIOR MODELS INCORPORATED IN RELAP5YA

Model	Calculated Quantities
1. Fuel rod internal pressure	1. fuel rod internal pressure
2. Fuel rod deformation	1. fuel pellet thermal expansion 2. clad temperature ramp rate 3. clad hoop stress 4. clad elastic strain 5. clad plastic strain 6. total clad strain(mid-radius of clad) 7. clad rupture temperature 8. clad rupture 9. flow blockage
3. Gap heat transfer	1. gap heat transfer coefficient 2. gap heat capacity
4. Metal-water reaction	1. heat produced by metal-water reaction inside and outside of clad 2. oxide layer thickness at inner and outer clad surfaces

FIGURE 5.3

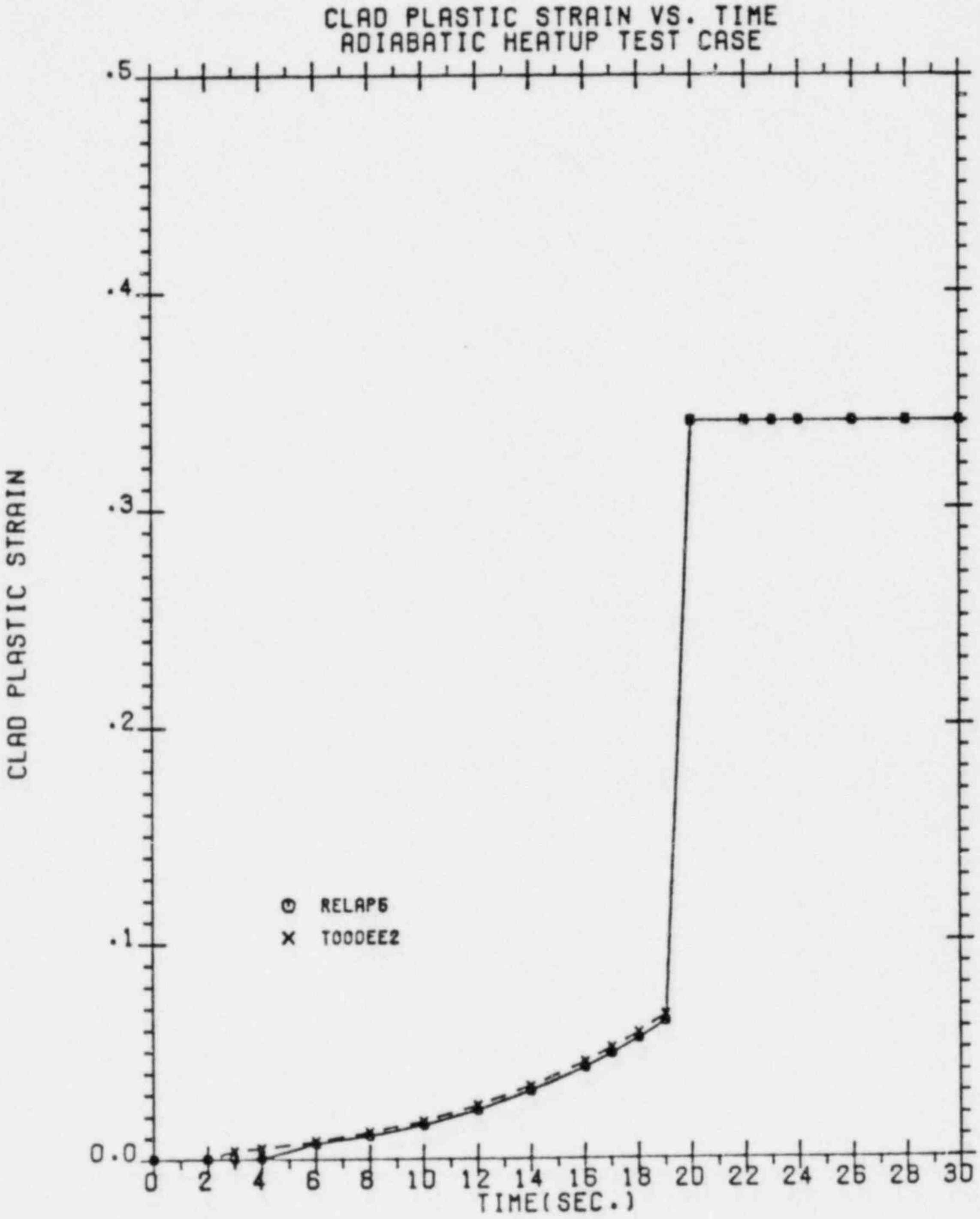

CLAD PLASTIC STRAIN VS. TIME
ADIABATIC HEATUP TEST CASE
CLAD PLASTIC STRAIN
TIME(SEC.)
0.0
.1
.2
.3
.4
.5
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
RELAP5
TOODEE2

FIGURE 5.4

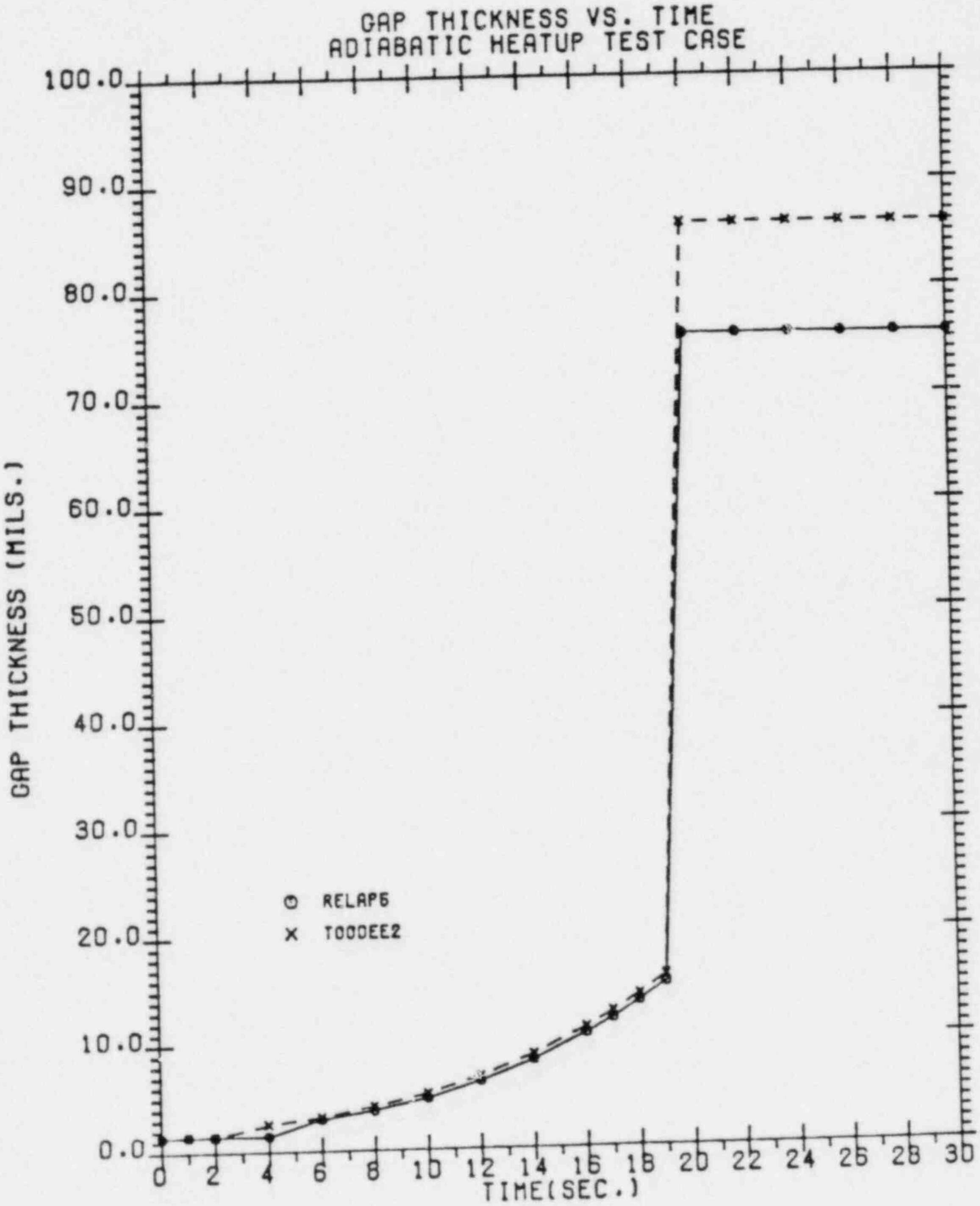

GAP THICKNESS VS. TIME
ADIABATIC HEATUP TEST CASE
GAP THICKNESS (MILS.)
TIME(SEC.)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
RELAP5
TODOEE2

FIGURE 5.5

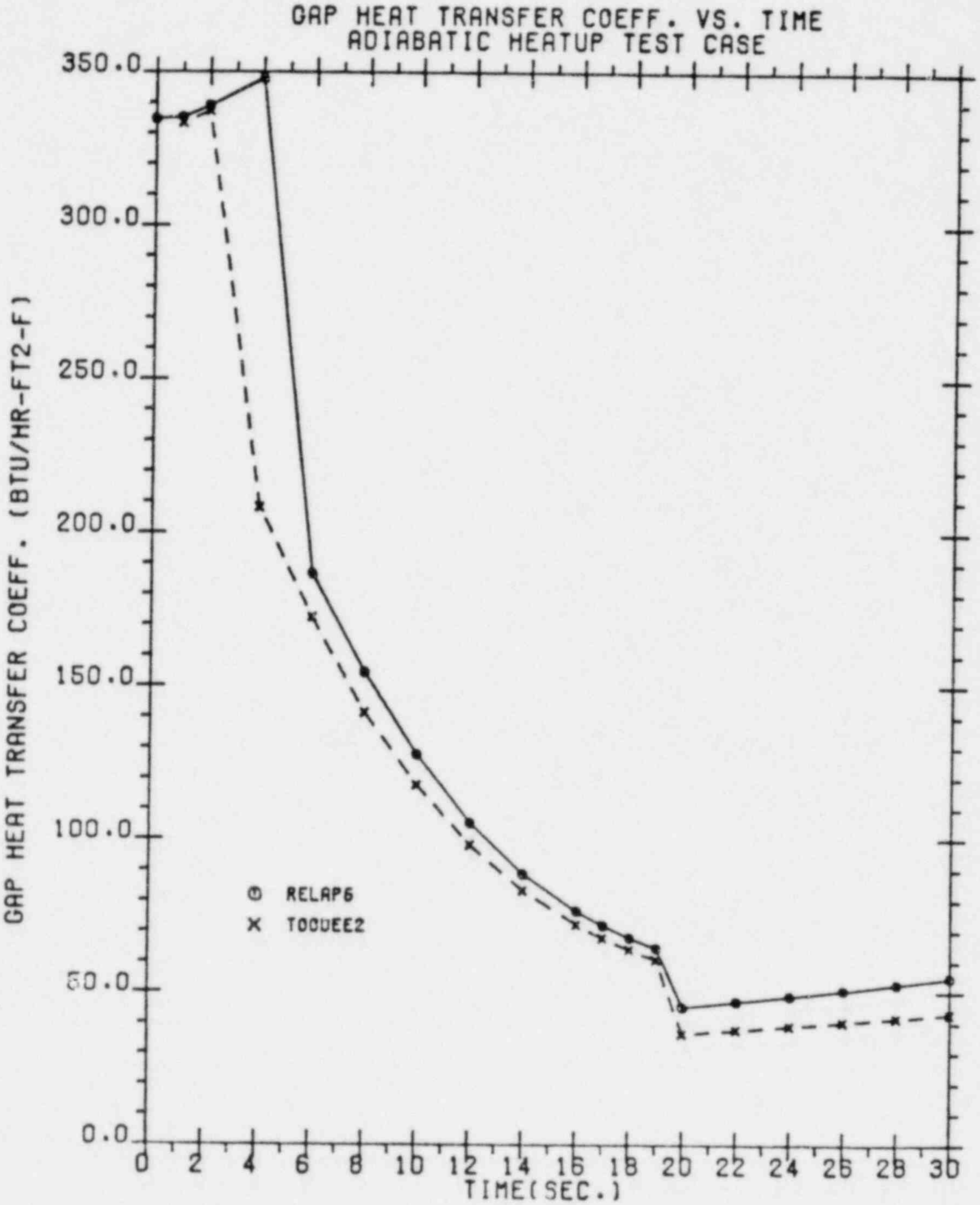

GAP HEAT TRANSFER COEFF. VS. TIME
ADIABATIC HEATUP TEST CASE
GAP HEAT TRANSFER COEFF. (BTU/HR-FT2-F)
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
TIME(SEC.)
⊙ RELAP6
× TOODEE2

FIGURE 5.6

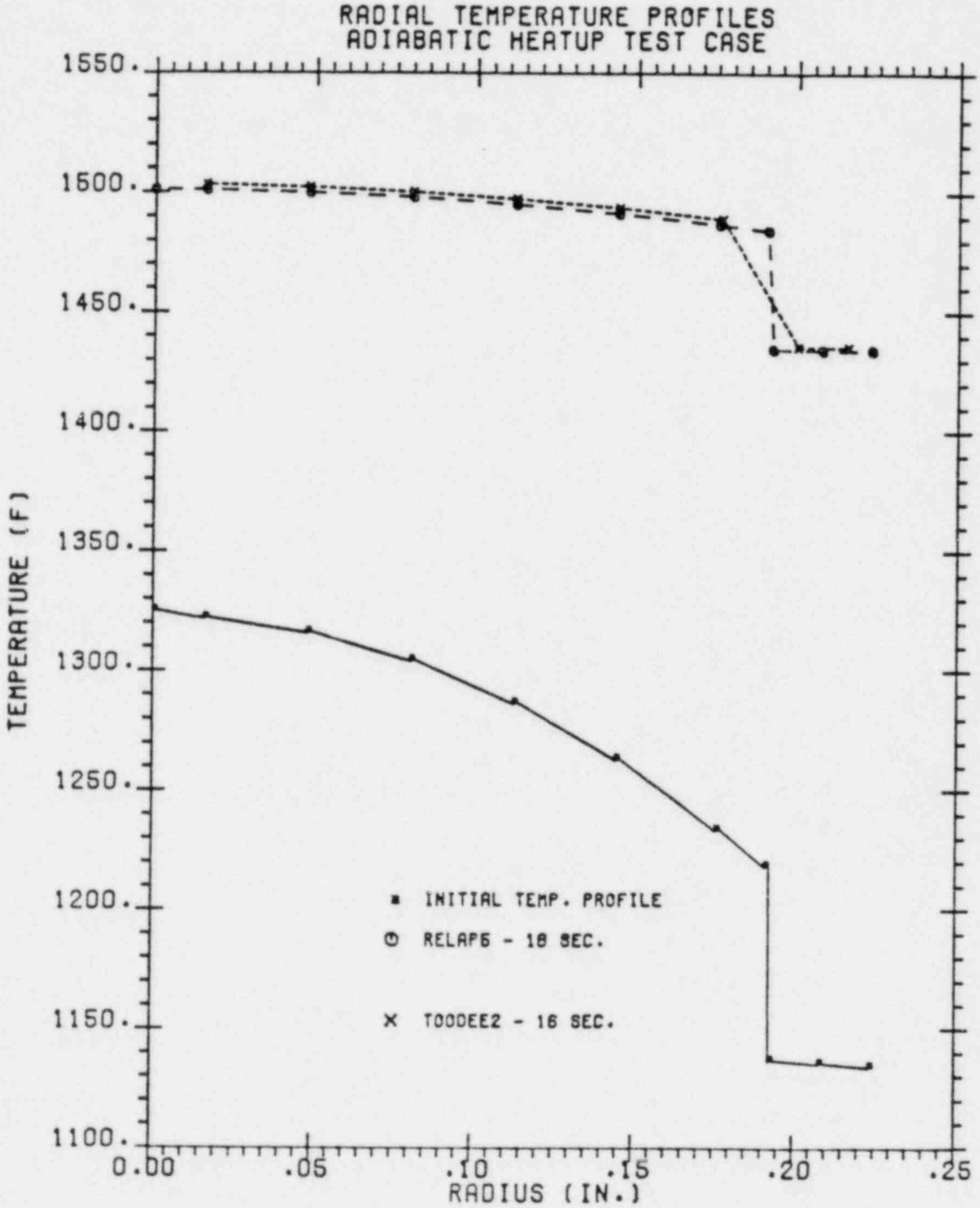

RADIAL TEMPERATURE PROFILES
ADIABATIC HEATUP TEST CASE
1550.
1500.
1450.
1400.
1350.
1300.
1250.
1200.
1150.
1100.
TEMPERATURE (F)
0.00
.05
.10
.15
.20
.25
RADIUS (IN.)
INITIAL TEMP. PROFILE
RELAP5 - 16 SEC.
TOODEE2 - 16 SEC.

FIGURE 5.7

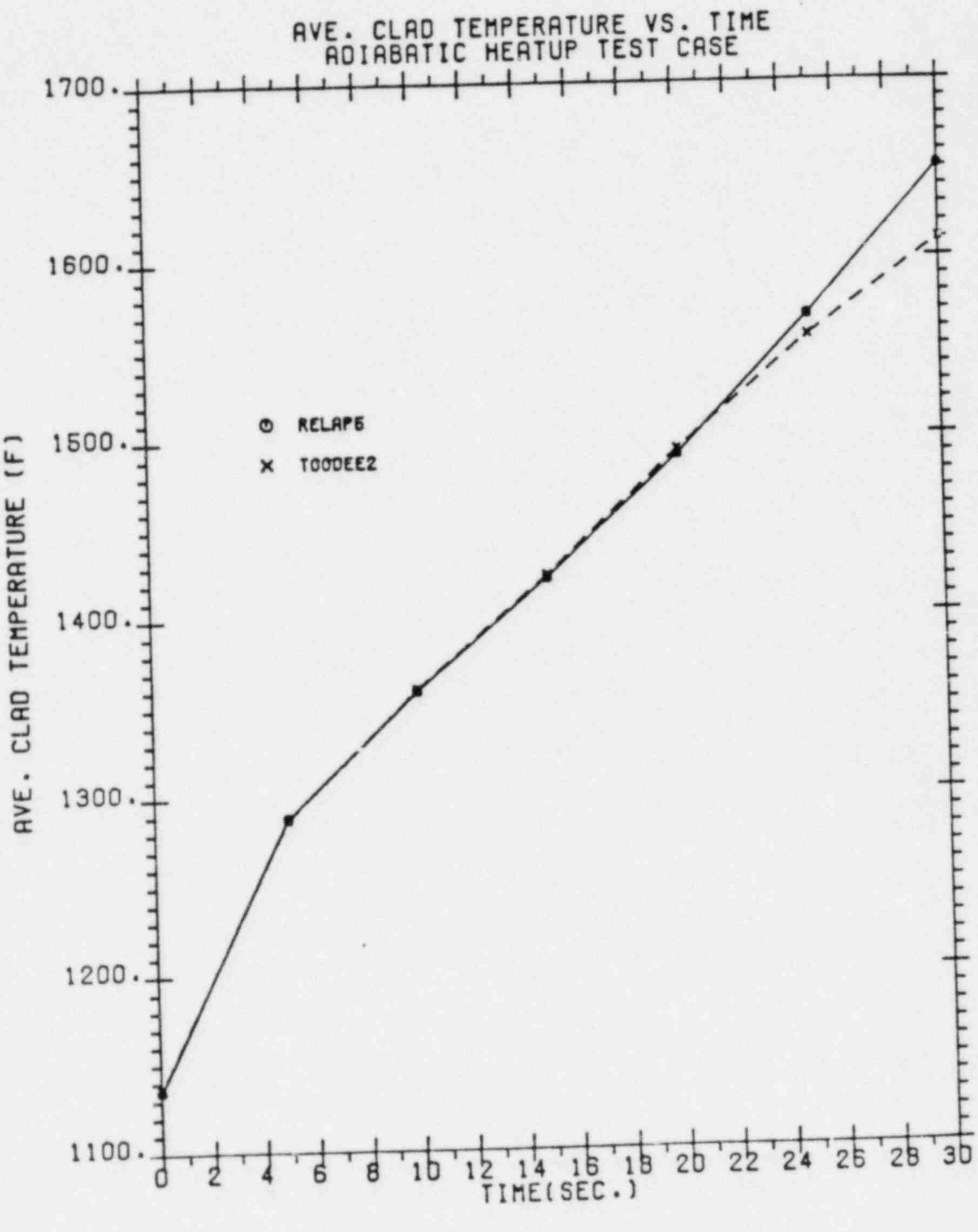
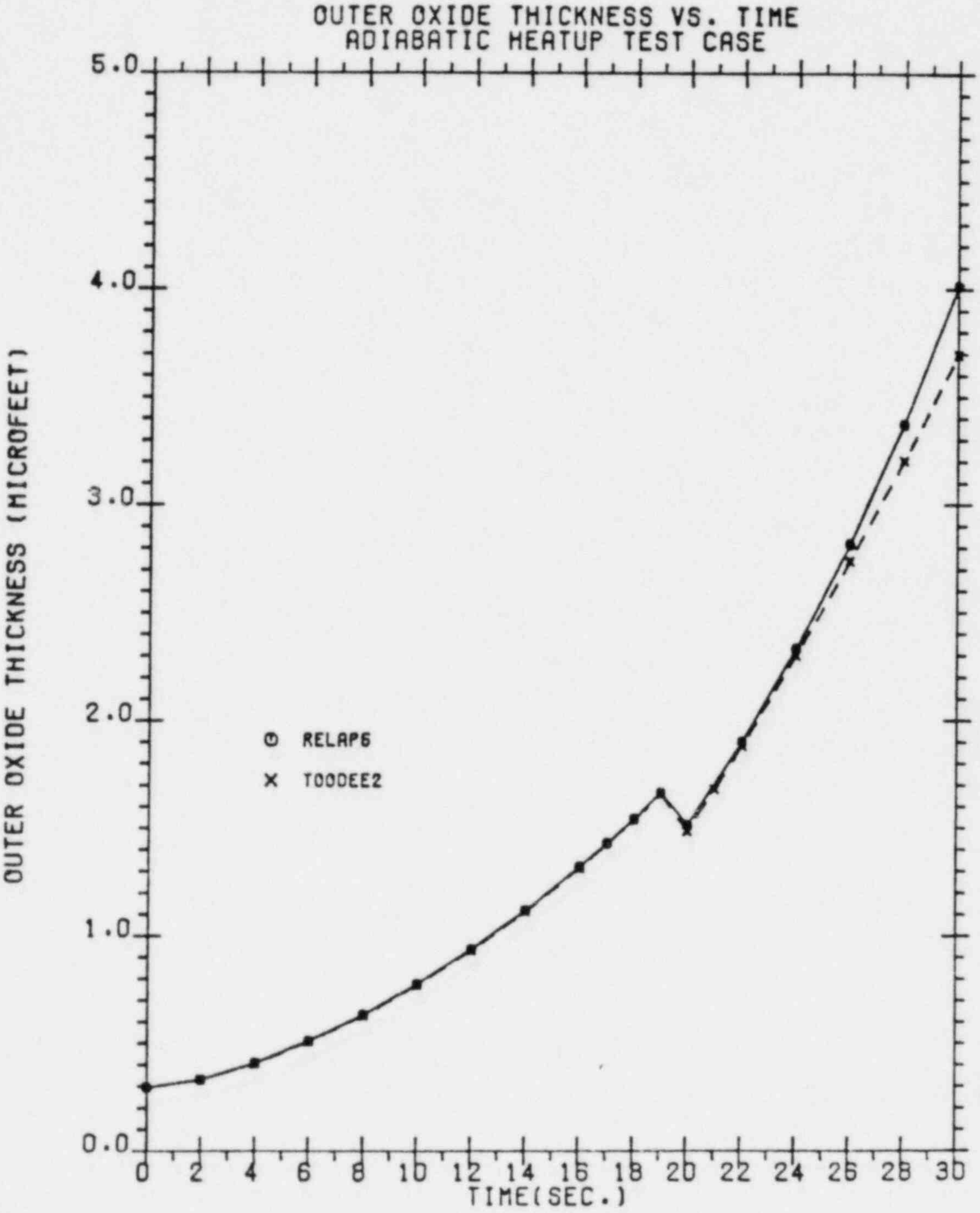

AVE. CLAD TEMPERATURE VS. TIME
ADIABATIC HEATUP TEST CASE
AVE. CLAD TEMPERATURE (F)
TIME(SEC.)
1100.
1200.
1300.
1400.
1500.
1600.
1700.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
⊙ RELAP5
× TOODEE2

FIGURE 5.8



OUTER OXIDE THICKNESS VS. TIME
ADIABATIC HEATUP TEST CASE
OUTER OXIDE THICKNESS (MICROFEET)
TIME(SEC.)
0.0
1.0
2.0
3.0
4.0
5.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
⊙ RELAP5
× TOODEE2

FIGURE 5.9

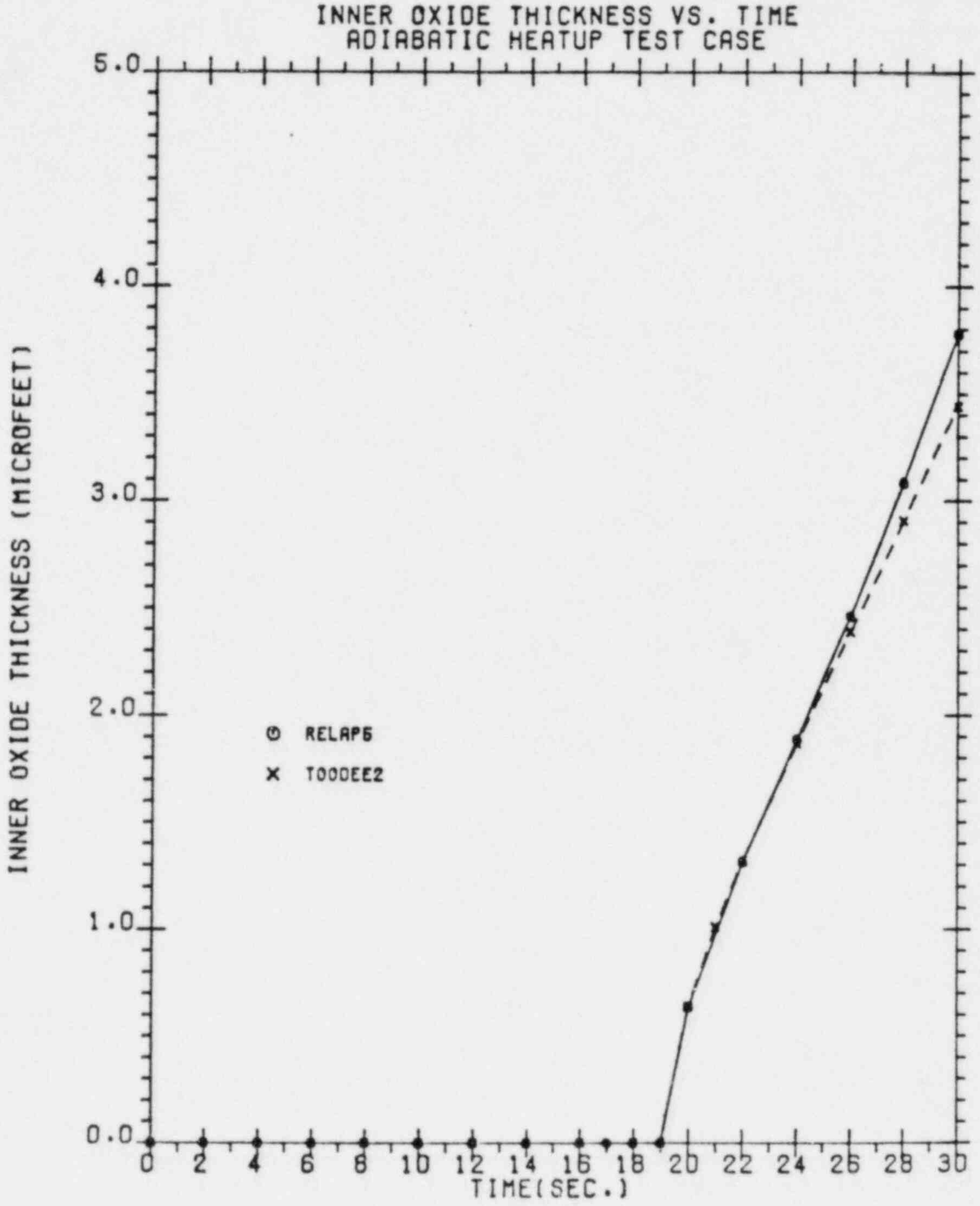
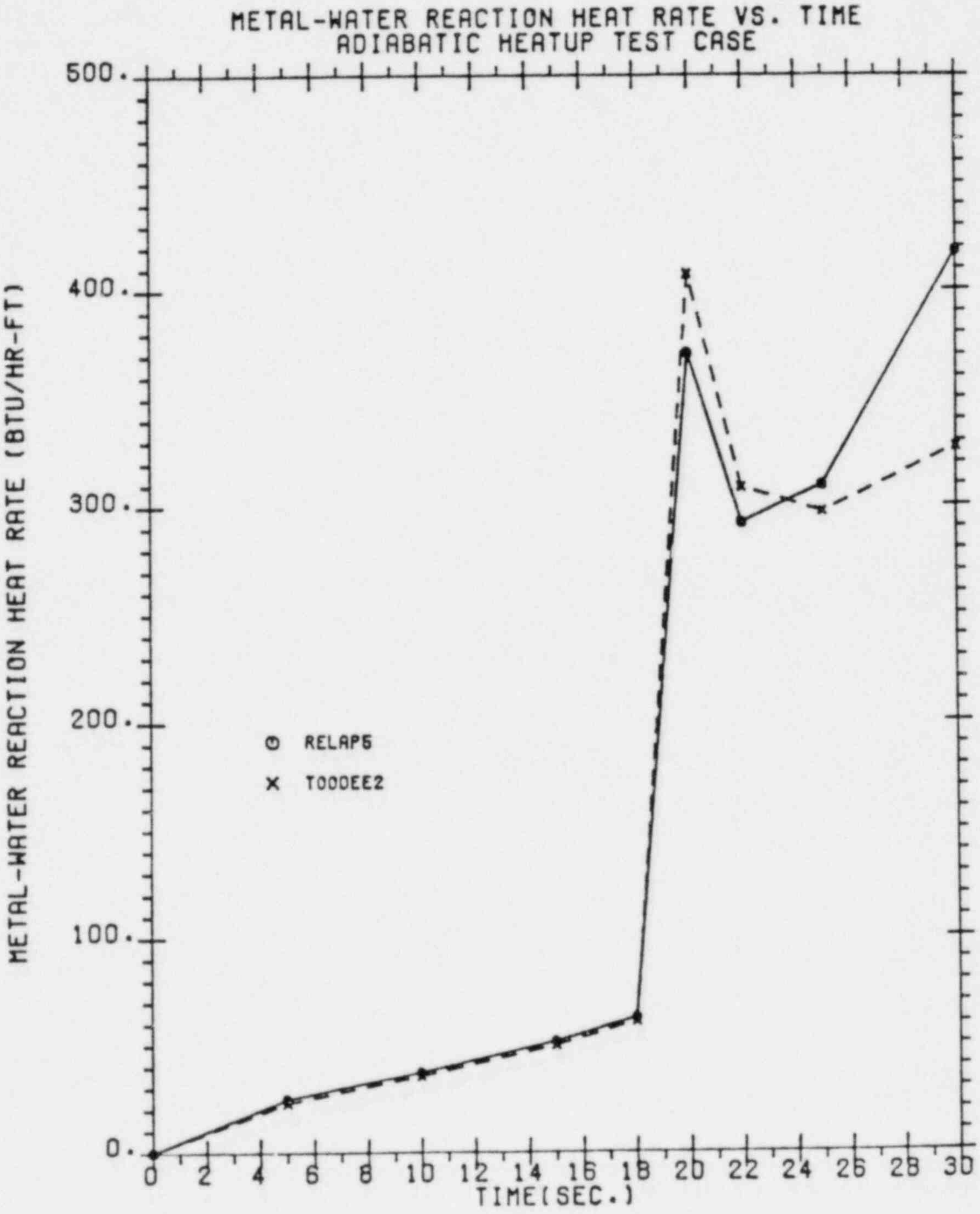

INNER OXIDE THICKNESS VS. TIME
ADIABATIC HEATUP TEST CASE
INNER OXIDE THICKNESS (MICROFEET)
5.0
4.0
3.0
2.0
1.0
0.0
TIME(SEC.)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
⊙ RELAP5
× TOODEE2

FIGURE 5.10


METAL-WATER REACTION HEAT RATE VS. TIME
ADIABATIC HEATUP TEST CASE
METAL-WATER REACTION HEAT RATE (BTU/HR-FT)
500.
400.
300.
200.
100.
0.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
TIME(SEC.)
⊙ RELAP5
× TOODEE2

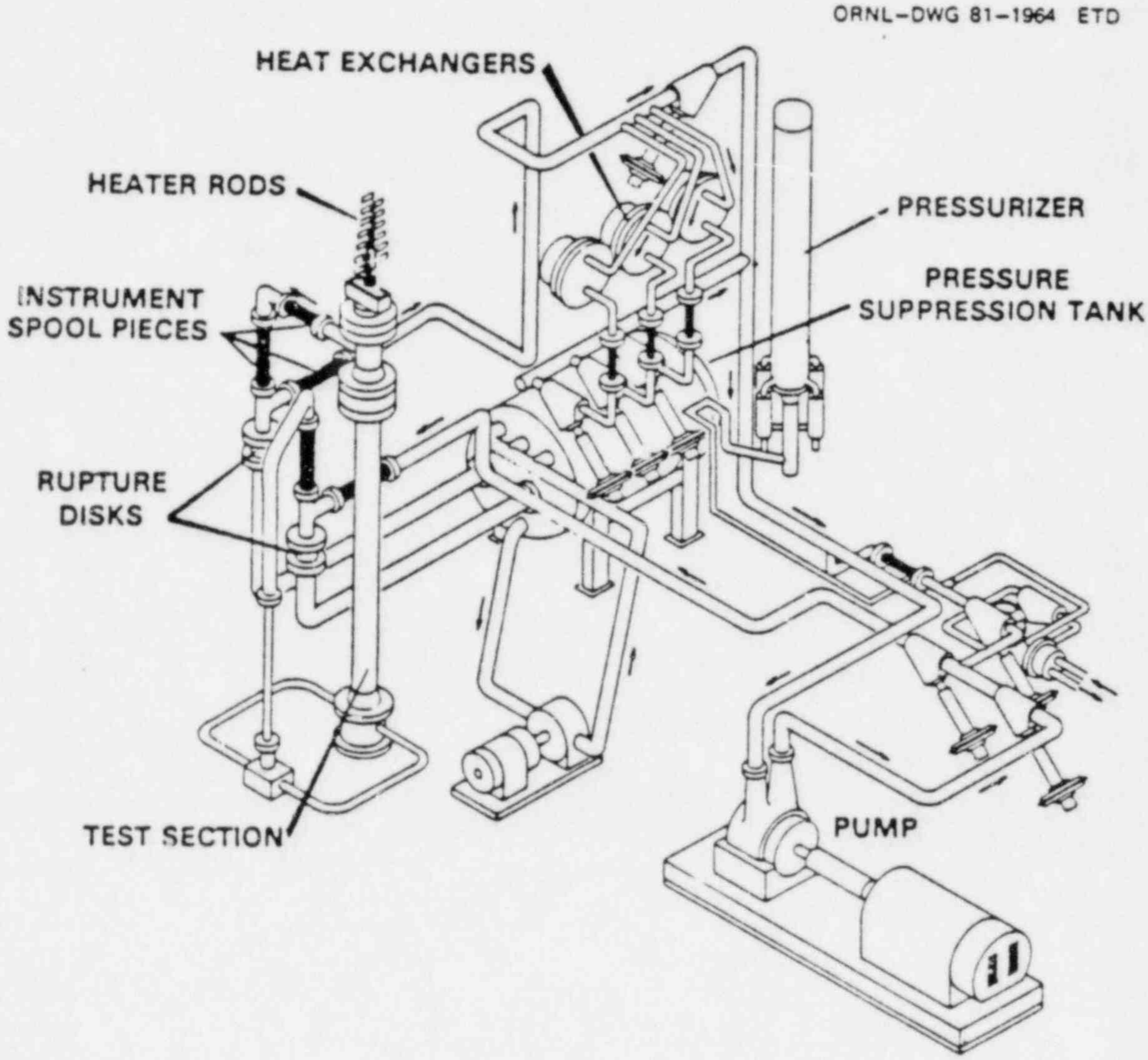
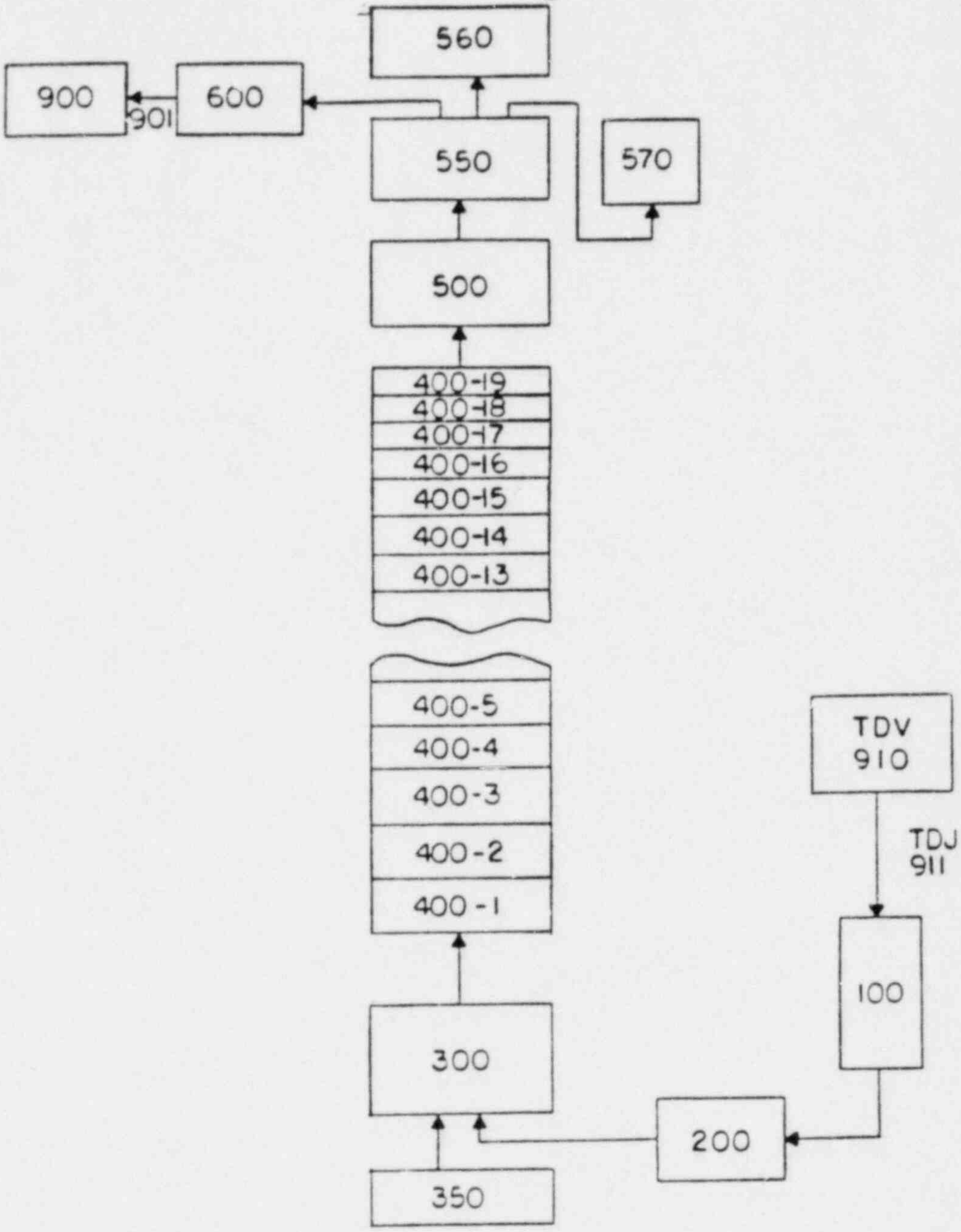


Fig. 2.1. THTF in standard configuration.

THTF-RELAP5YA TEST MATRIX

TEST NO.	TYPE OF TEST
3.07.9B	Steady State Film Boiling
3.07.9K	Steady State Film Boiling
3.07.9X	Steady State Film Boiling
3.08.6C	Transient Film Boiling
3.09.10I	Quasi-Steady State Boiloff Test
3.09.100	Reflood Test
3.09.10Q	Reflood Test

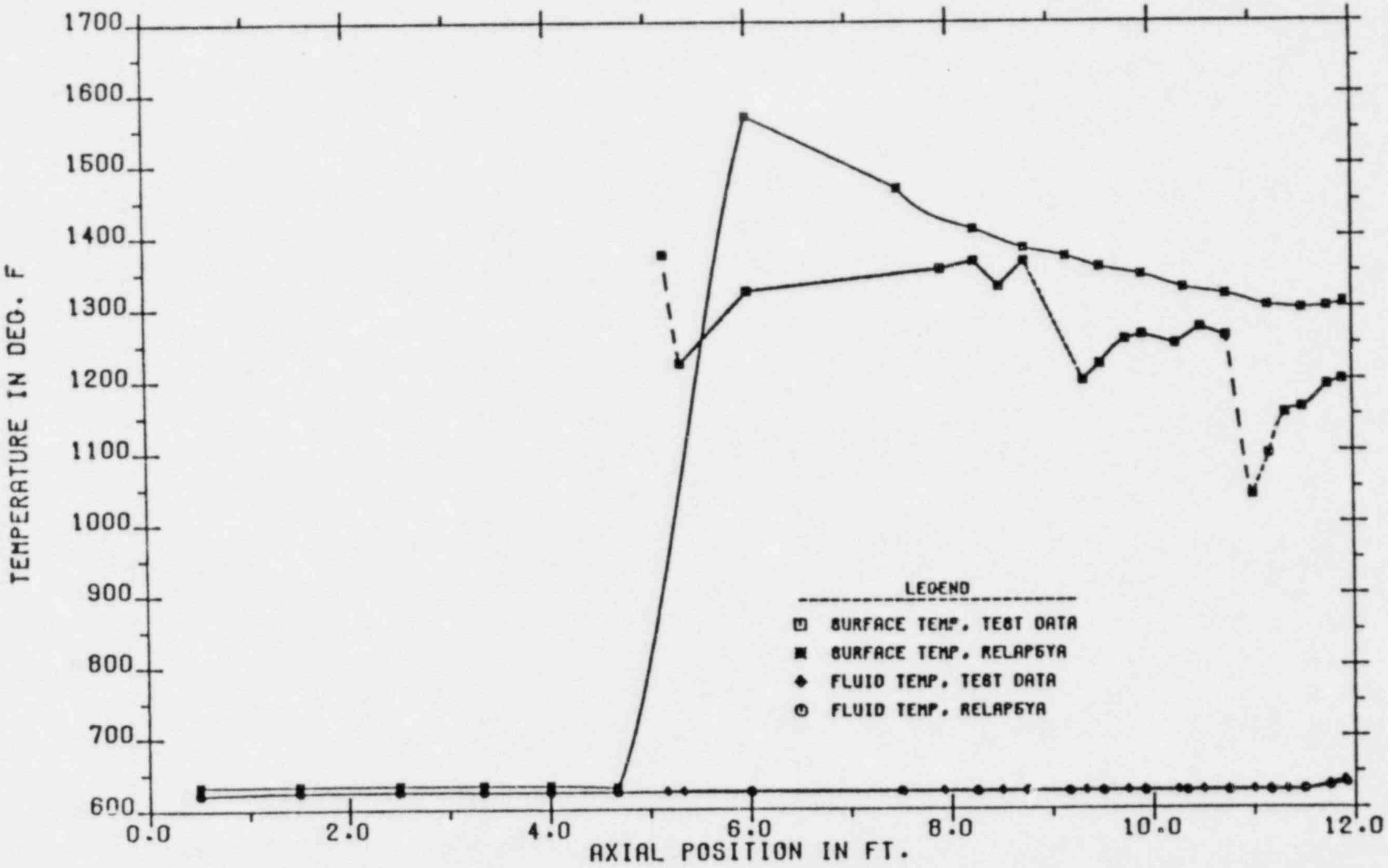


RELAP 5YA MODEL OF THTF TEST SECTION

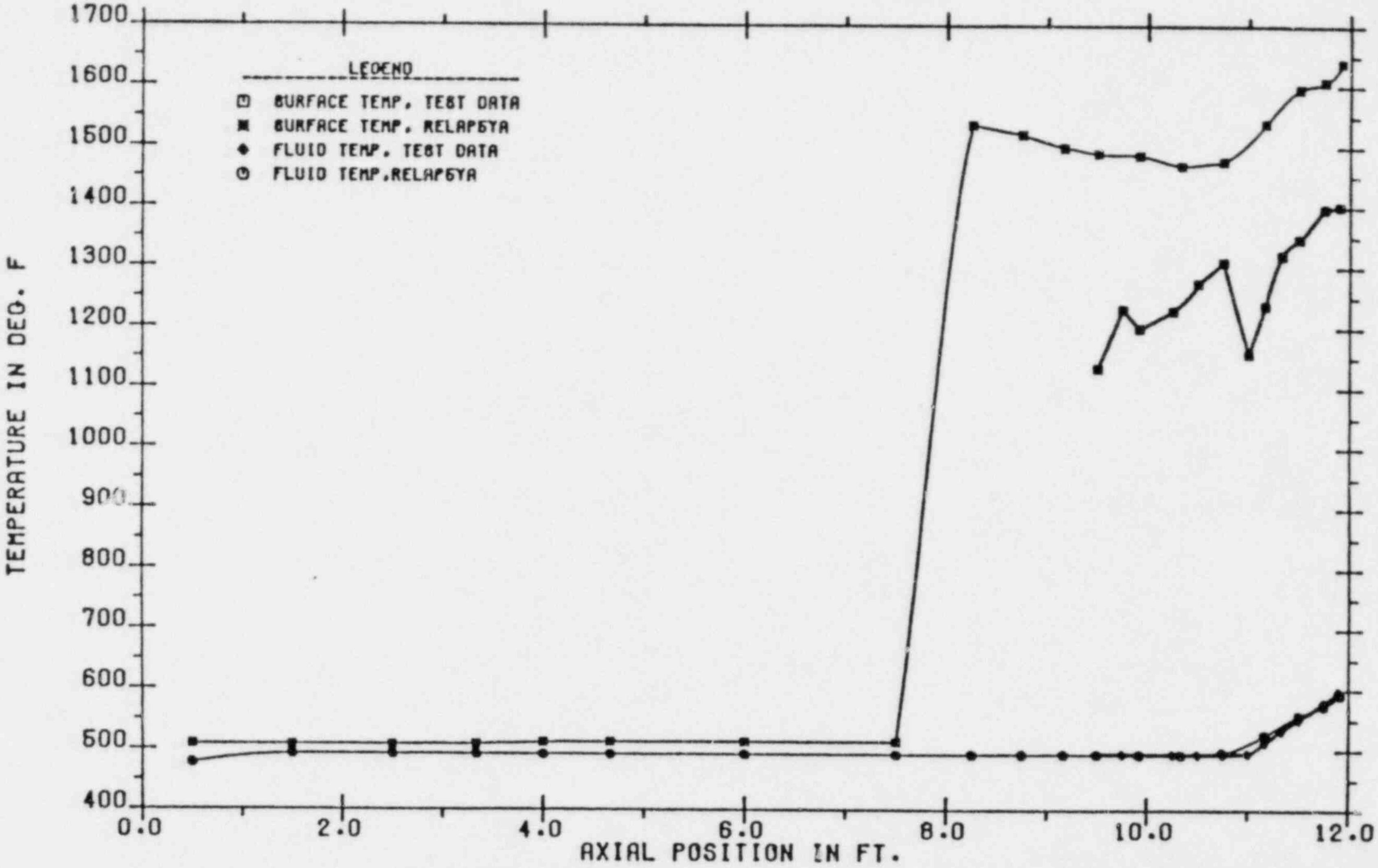
THTF STEADY STATE UP-FLOW
FILM BOILING TESTS

TEST NO.	PRESSURE (psia)	MASS FLUX (lbm/hr-ft^2)	HEAT FLUX (Btu/hr-ft^2)
3.07.9B	1849	$5.25.10^5$	$2.0.10^5$
3.07.9K	635	$1.66.10^5$	$1.4.10^5$
3.07.9 X	872	$2.50.10^5$	$1.9.10^5$

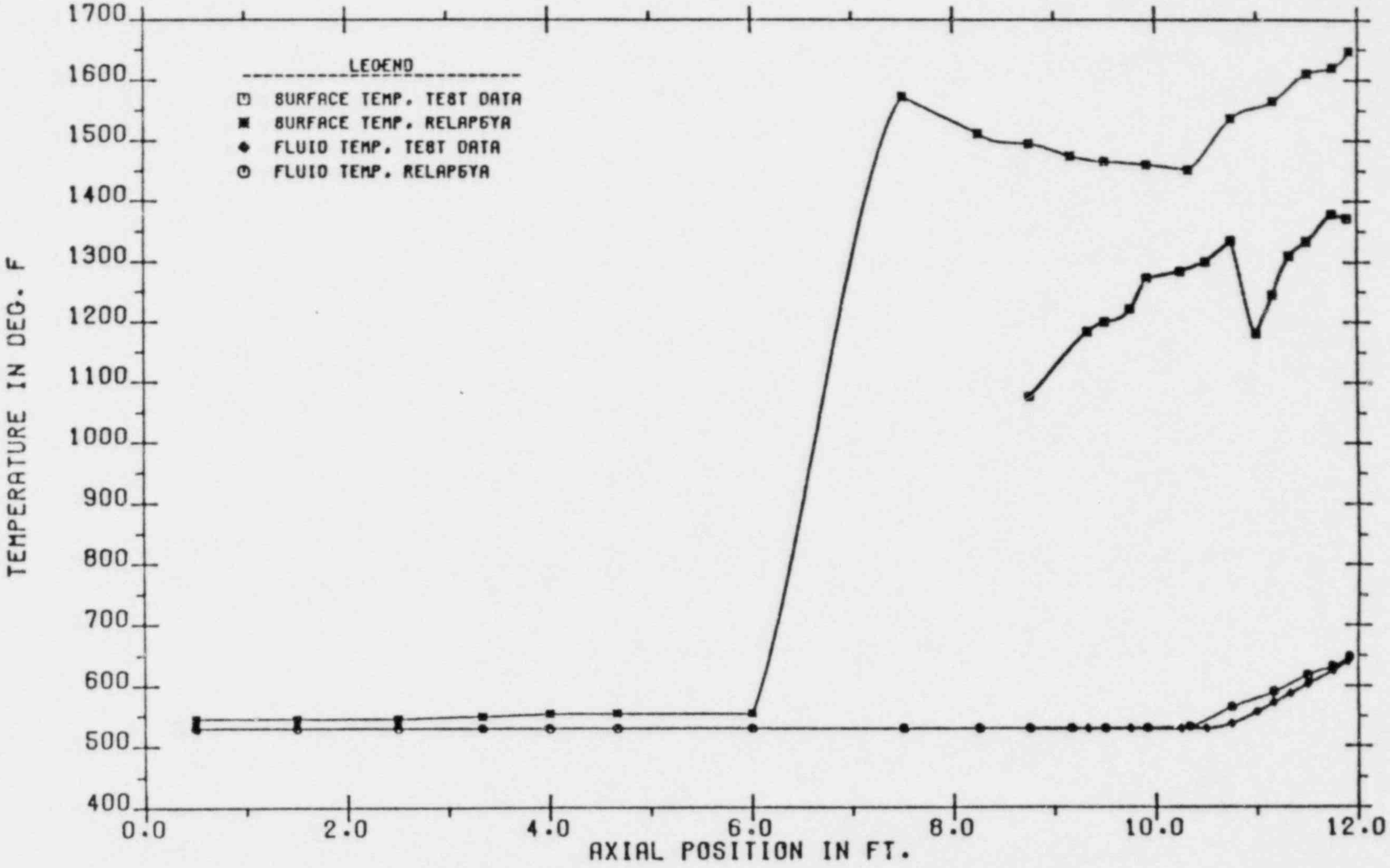
AXIAL TEMPERATURE PROFILE FOR TEST 3.07.9B



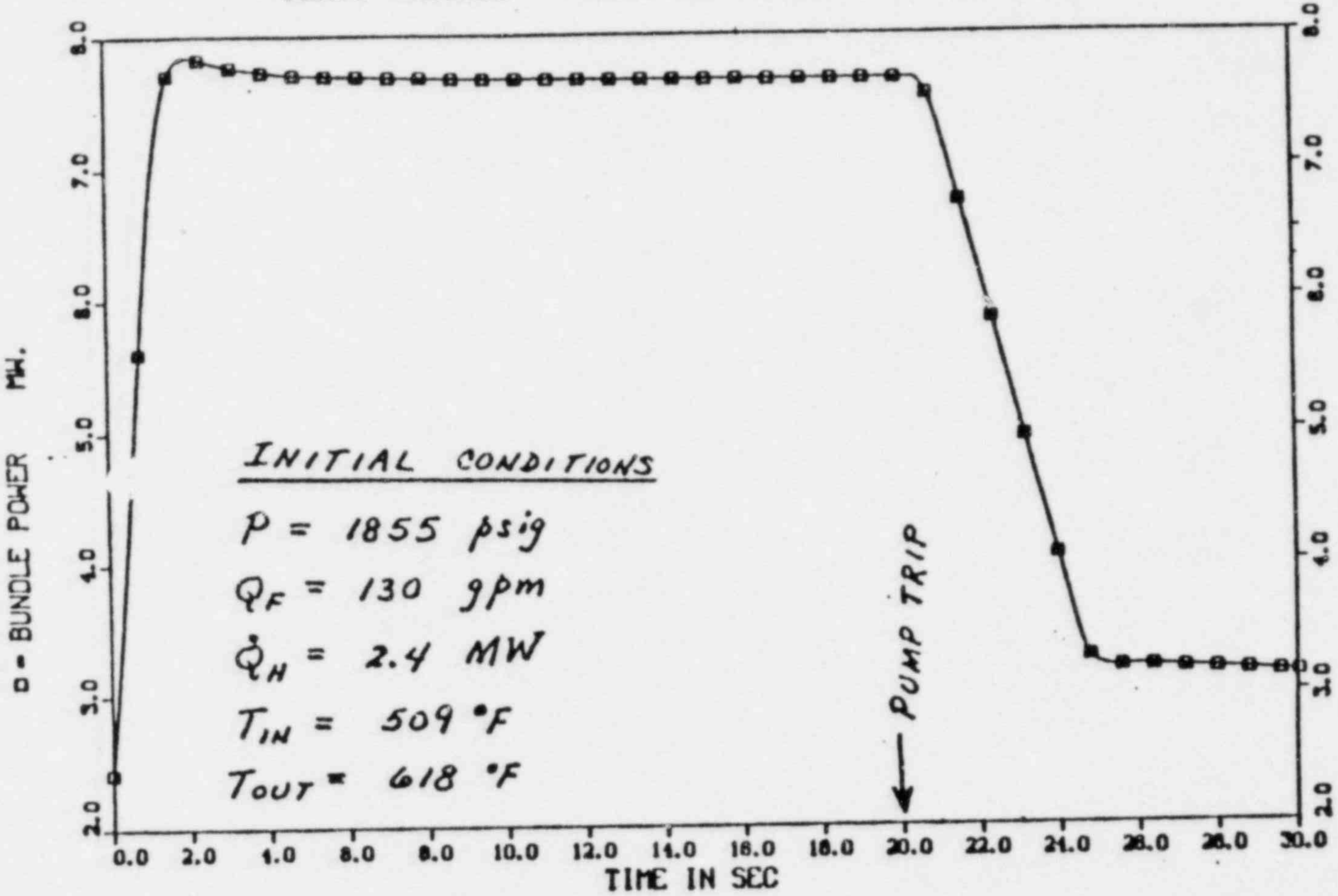
AXIAL TEMPERATURE PROFILE FOR TEST 3.07.9K



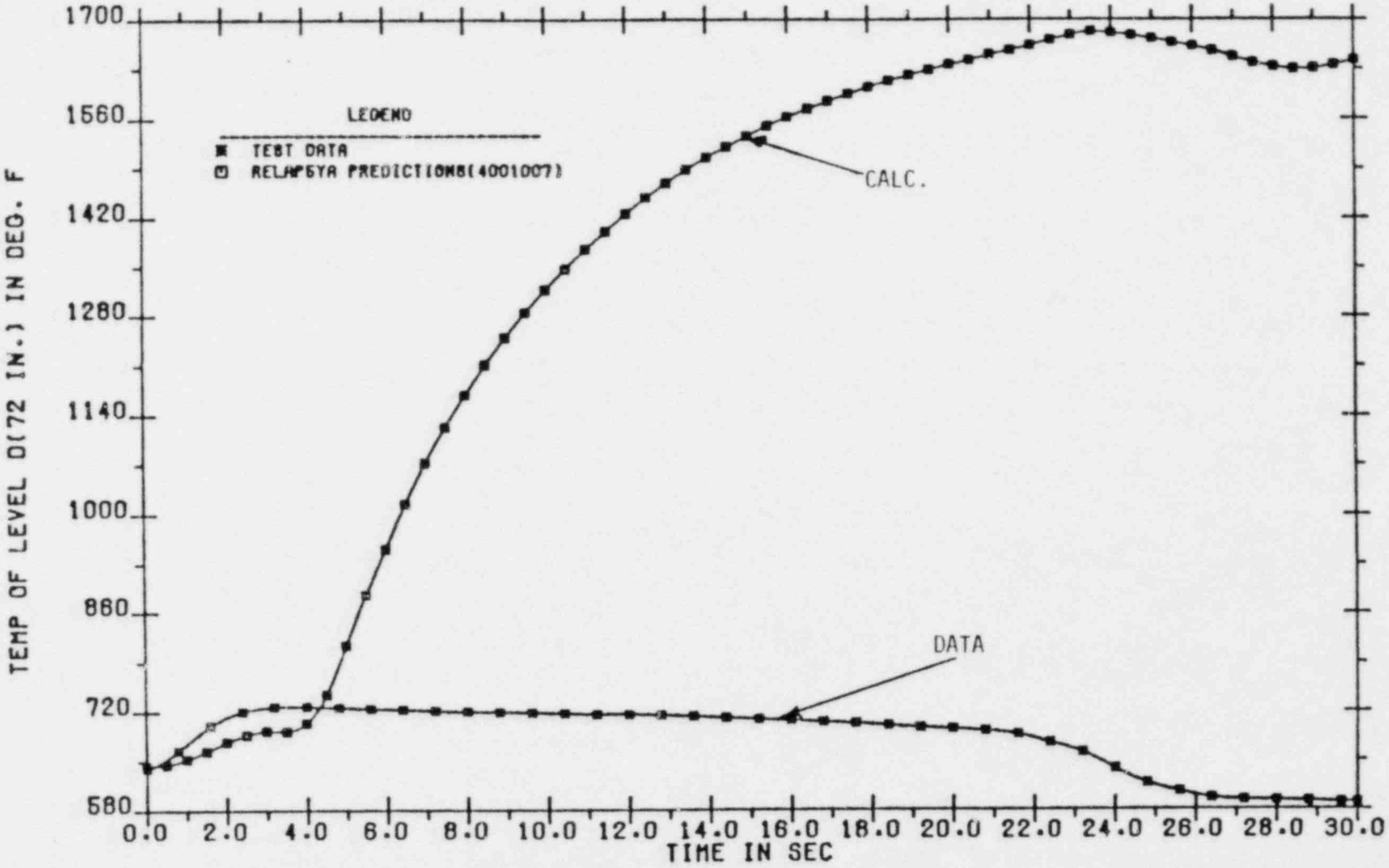
AXIAL TEMPERATURE PROFILE FOR TEST 3.07.9X



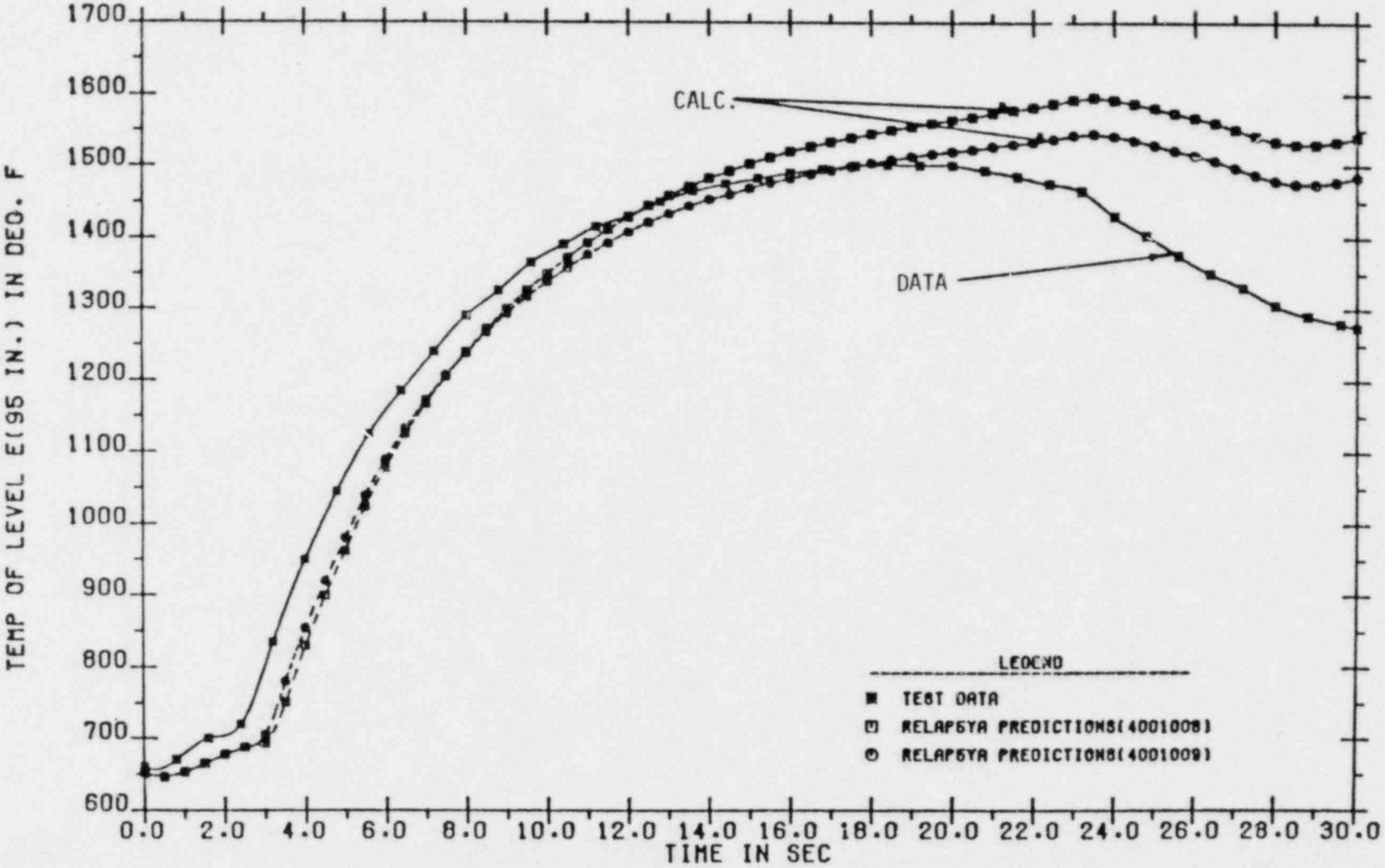
TEST 3086C -FILM BOILING IN UPFLOW



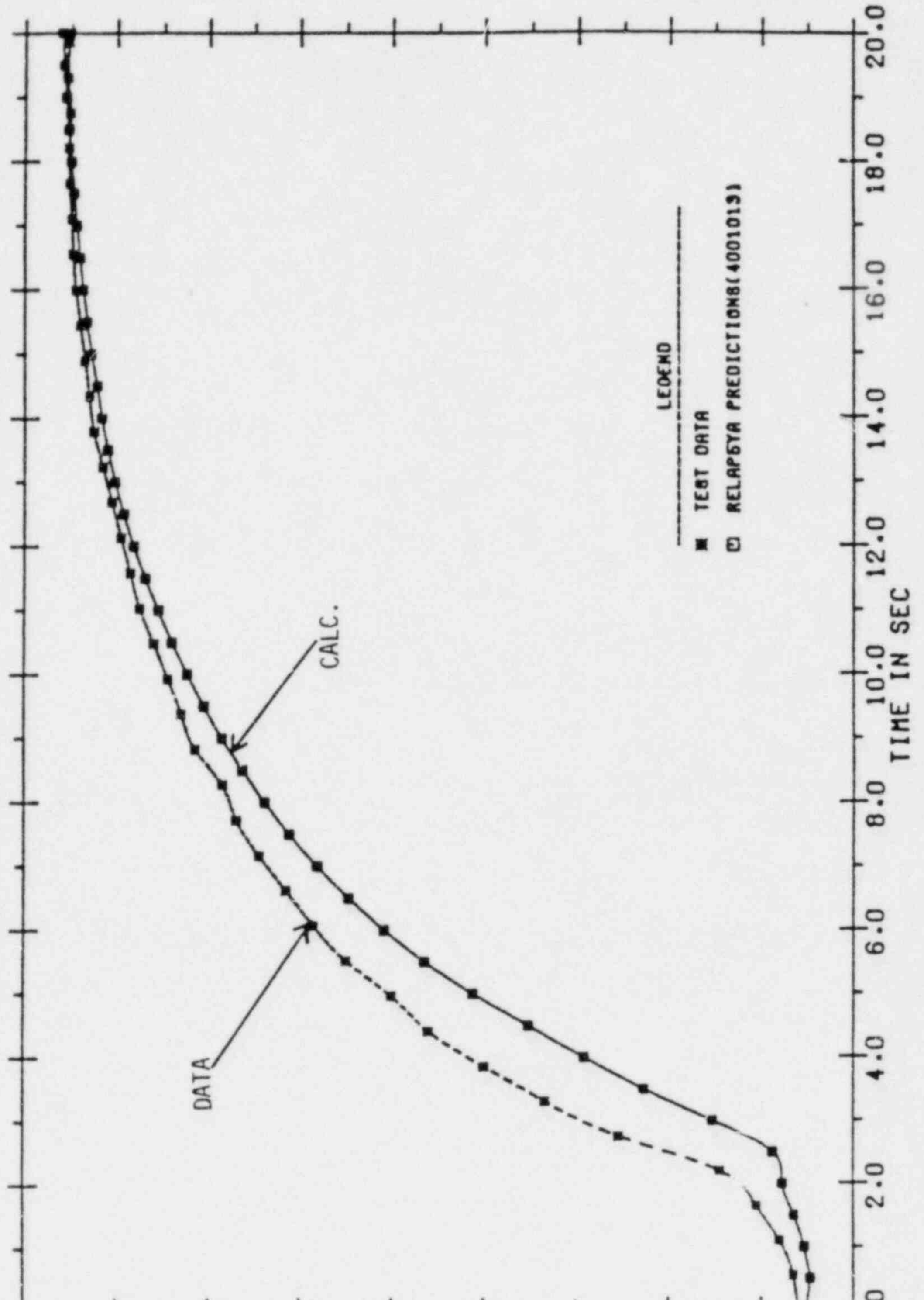
FILM BOILING TEST 3086C
RELAP5YA VS. TEST DATA



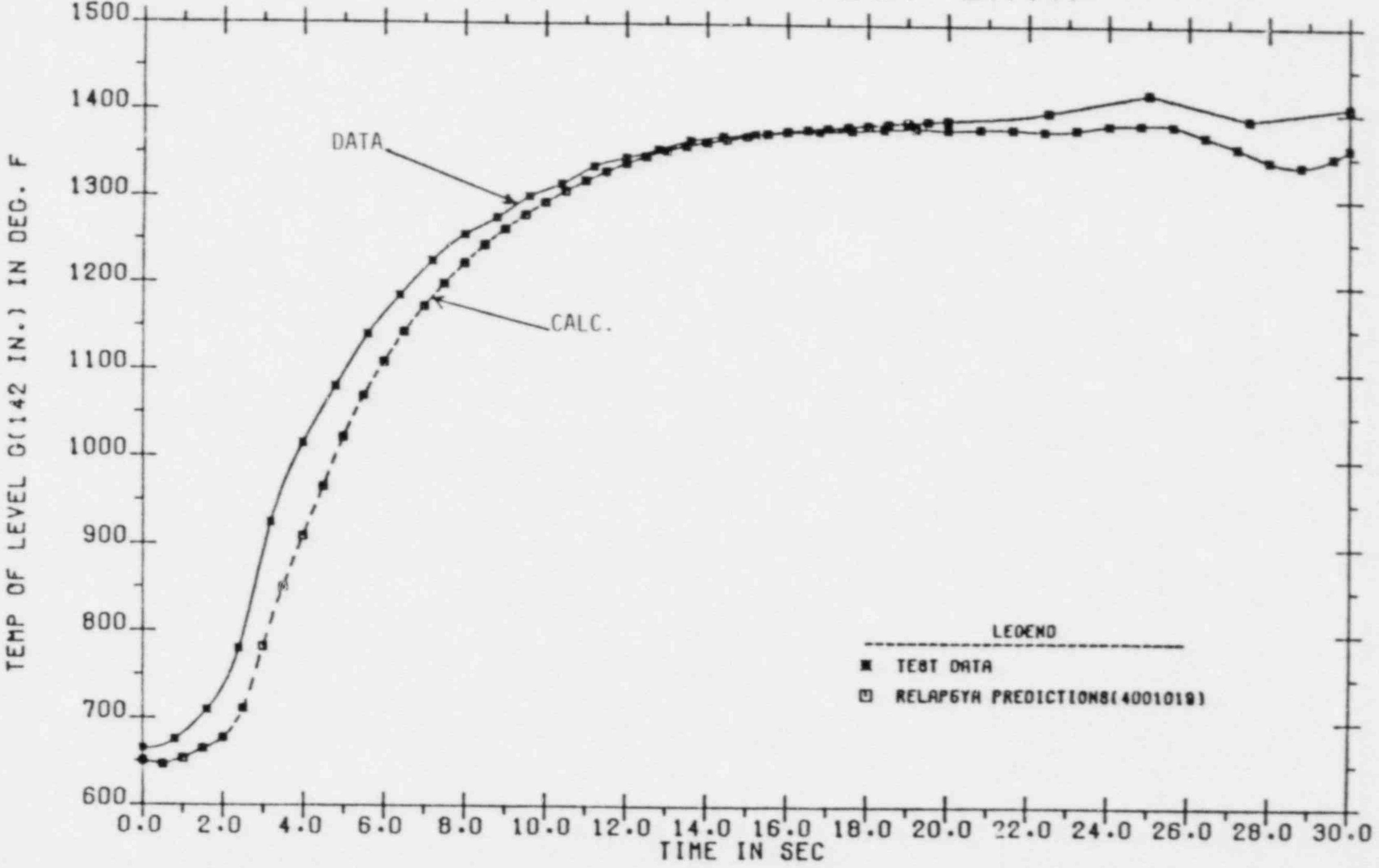
TEST 3086C -FILM BOILING IN UPFLOW
RELAP5YA VS. TEST DATA



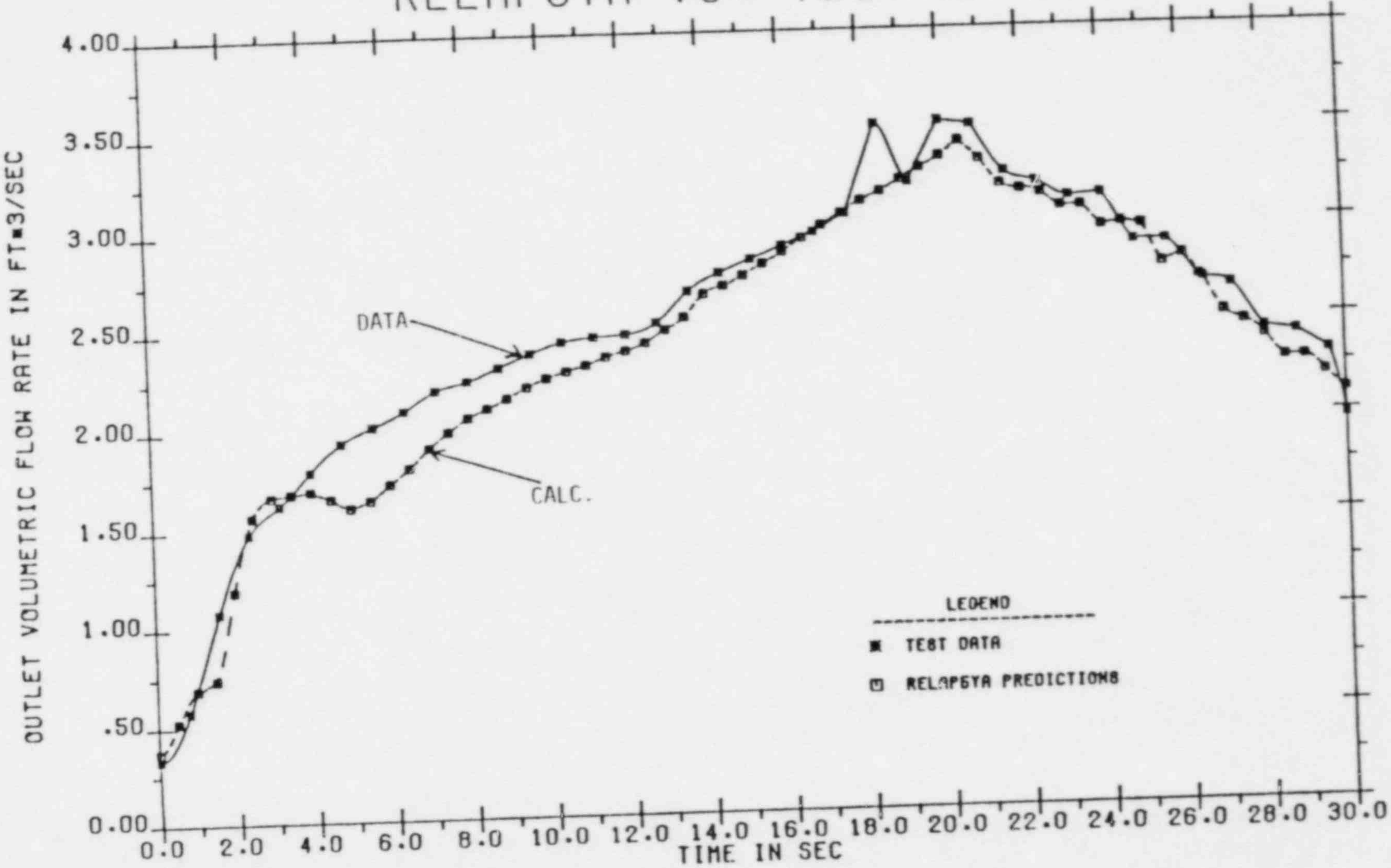
TEST 3086C -FILM BOILING IN UPFLOW
RELAP5YA VS. TEST DATA

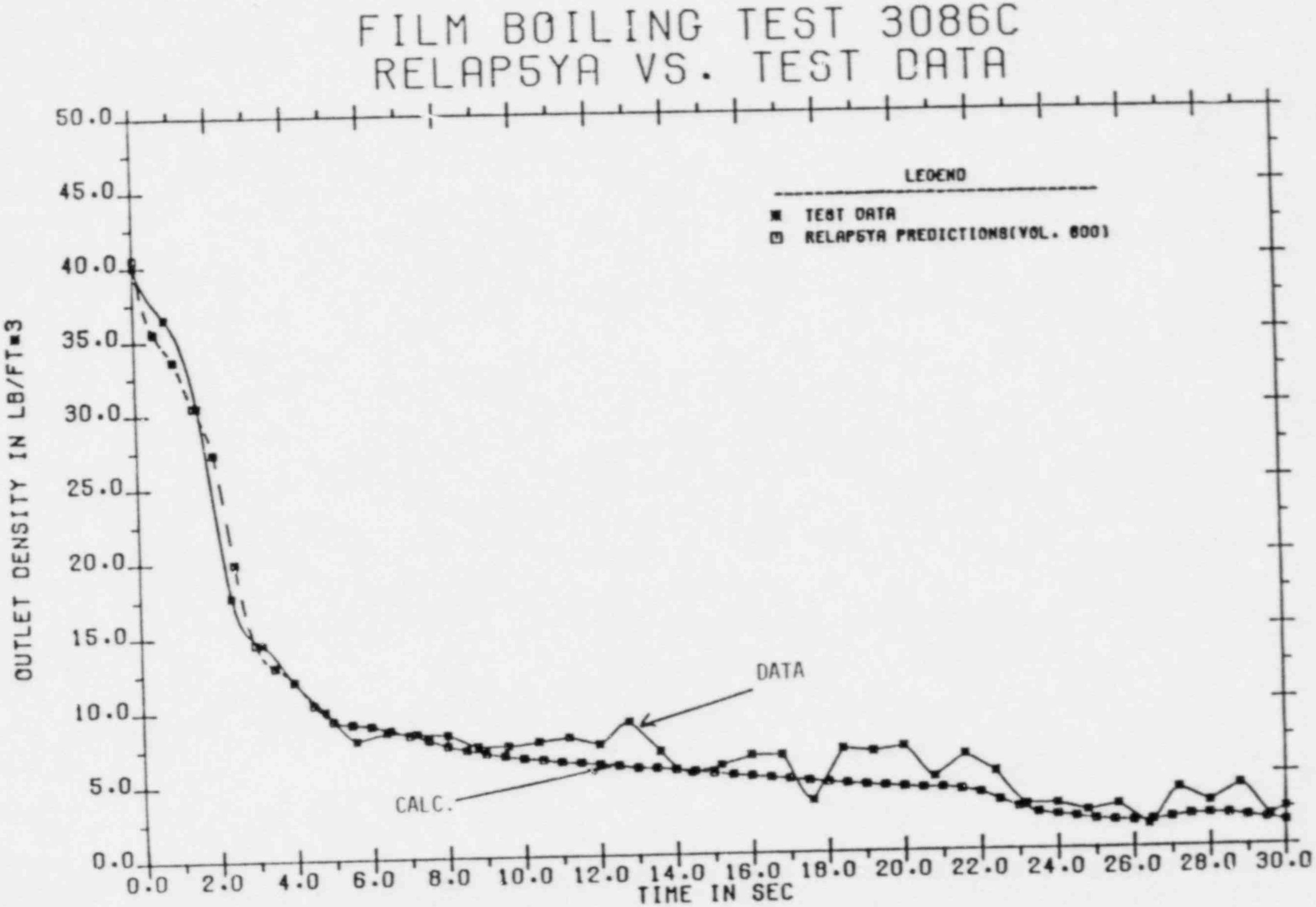


TEST 3086C -FILM BOILING IN UPFLOW
RELAP5YA VS. TEST DATA

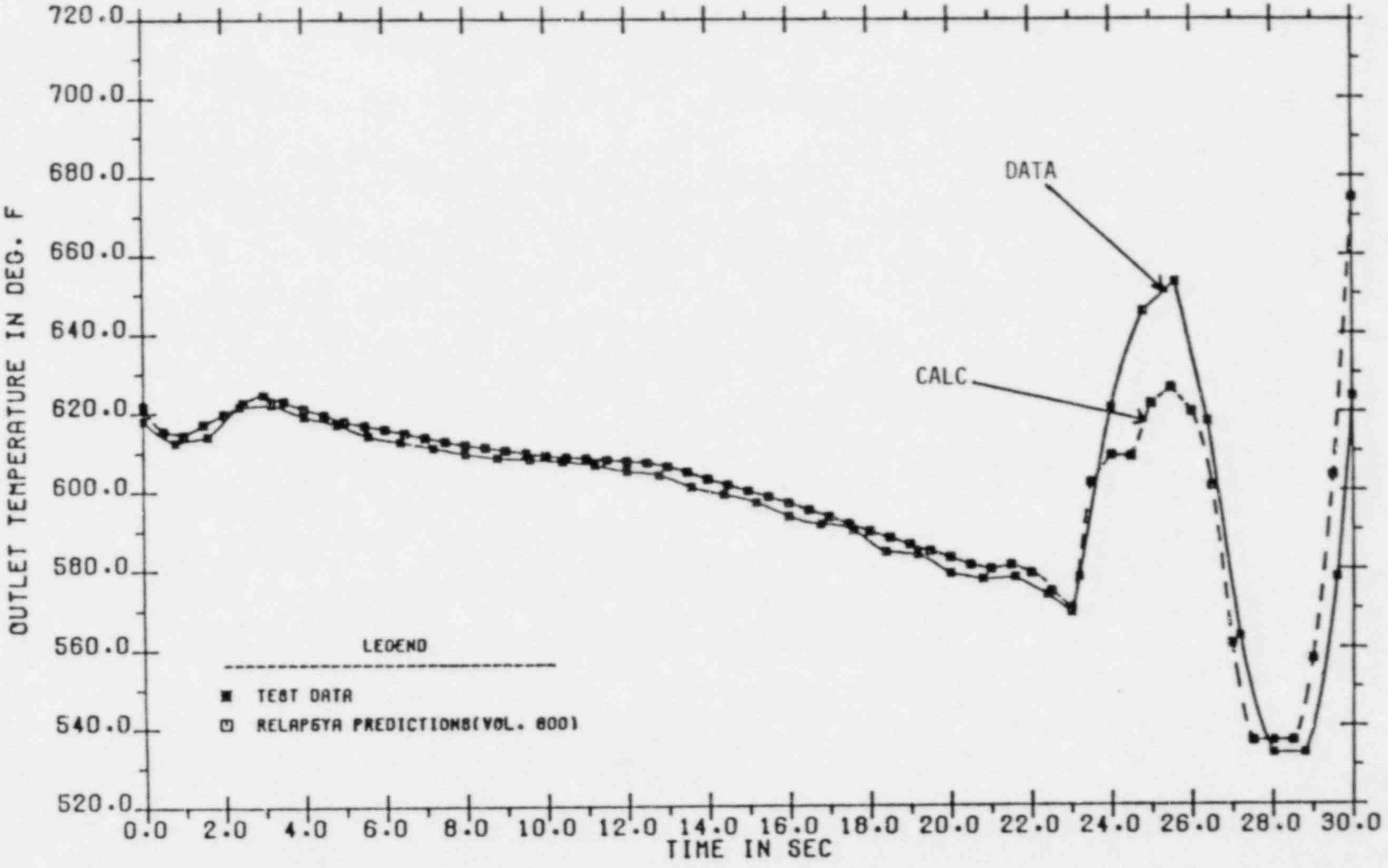


TEST 3086C -FILM BOILING IN UPFLOW
RELAP5YA VS. TEST DATA




FILM BOILING TEST 3086C
RELAP5YA VS. TEST DATA
LEGEND
TEST DATA
RELAP5YA PREDICTIONS(VOL. 800)
DATA
CALC.
OUTLET DENSITY IN LB/FT*3
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
TIME IN SEC

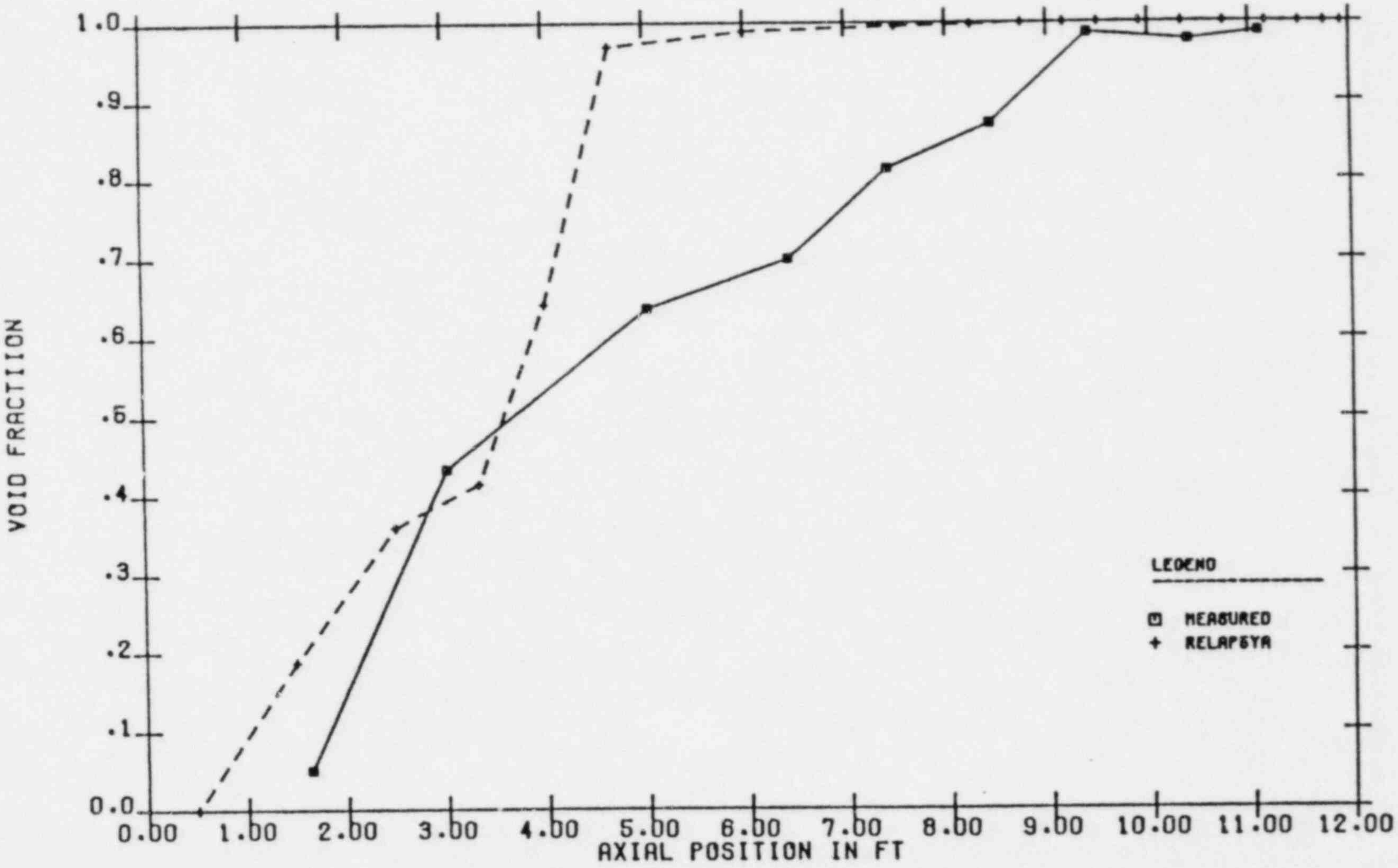
FILM BOILING TEST 3086C
RELAP5YA VS. TEST DATA



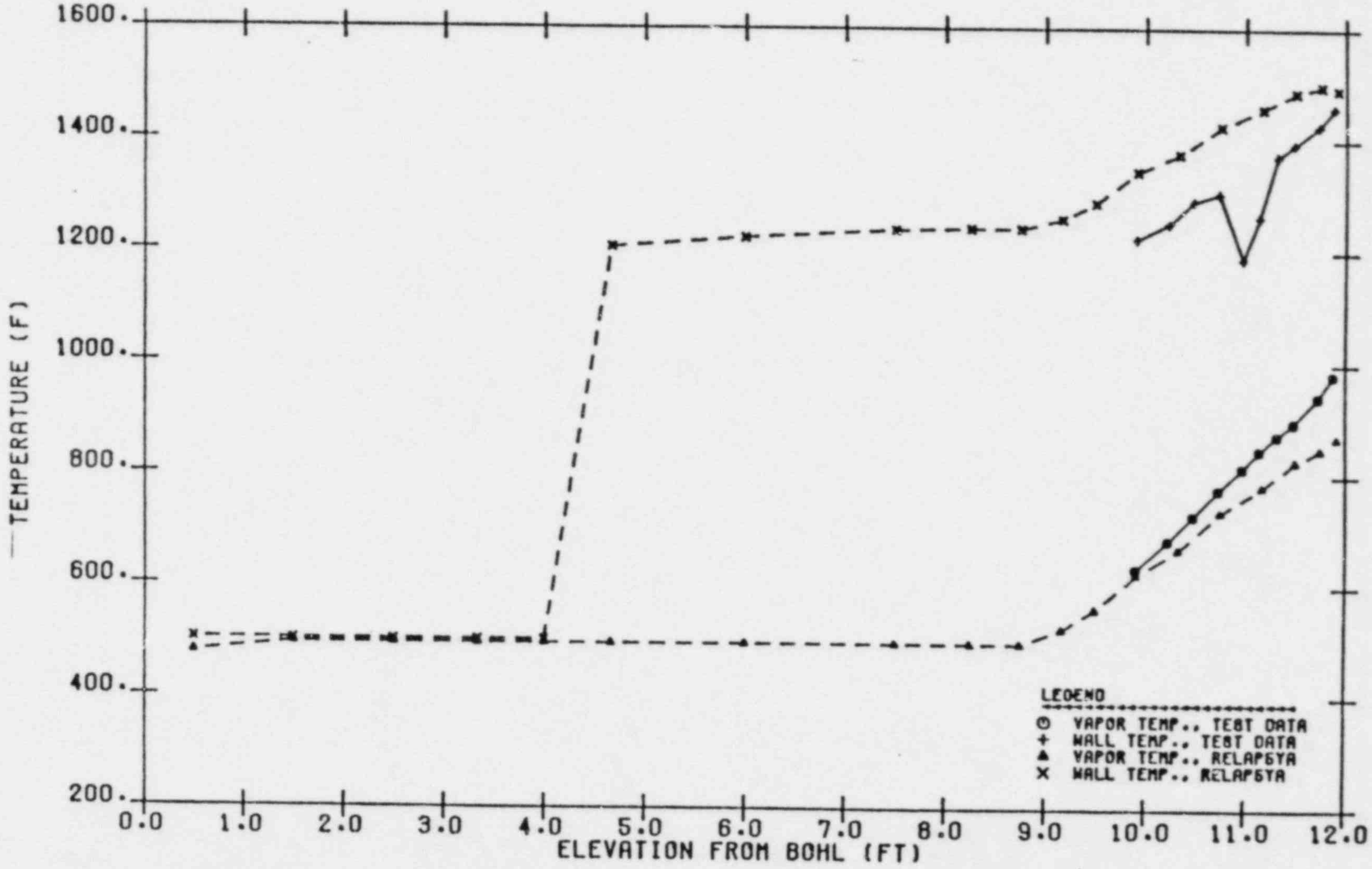
QUASI STEADY STATE BOILOFF TEST

Test No	Pressure (psia)	Mass Flux ($lbm/hr-ft^2$)	Linear Power (kw/ft)
3.09.10I	650	$2.19.10^4$	0.68

VOID FRACTION PROFILE, TEST 3.09.10I



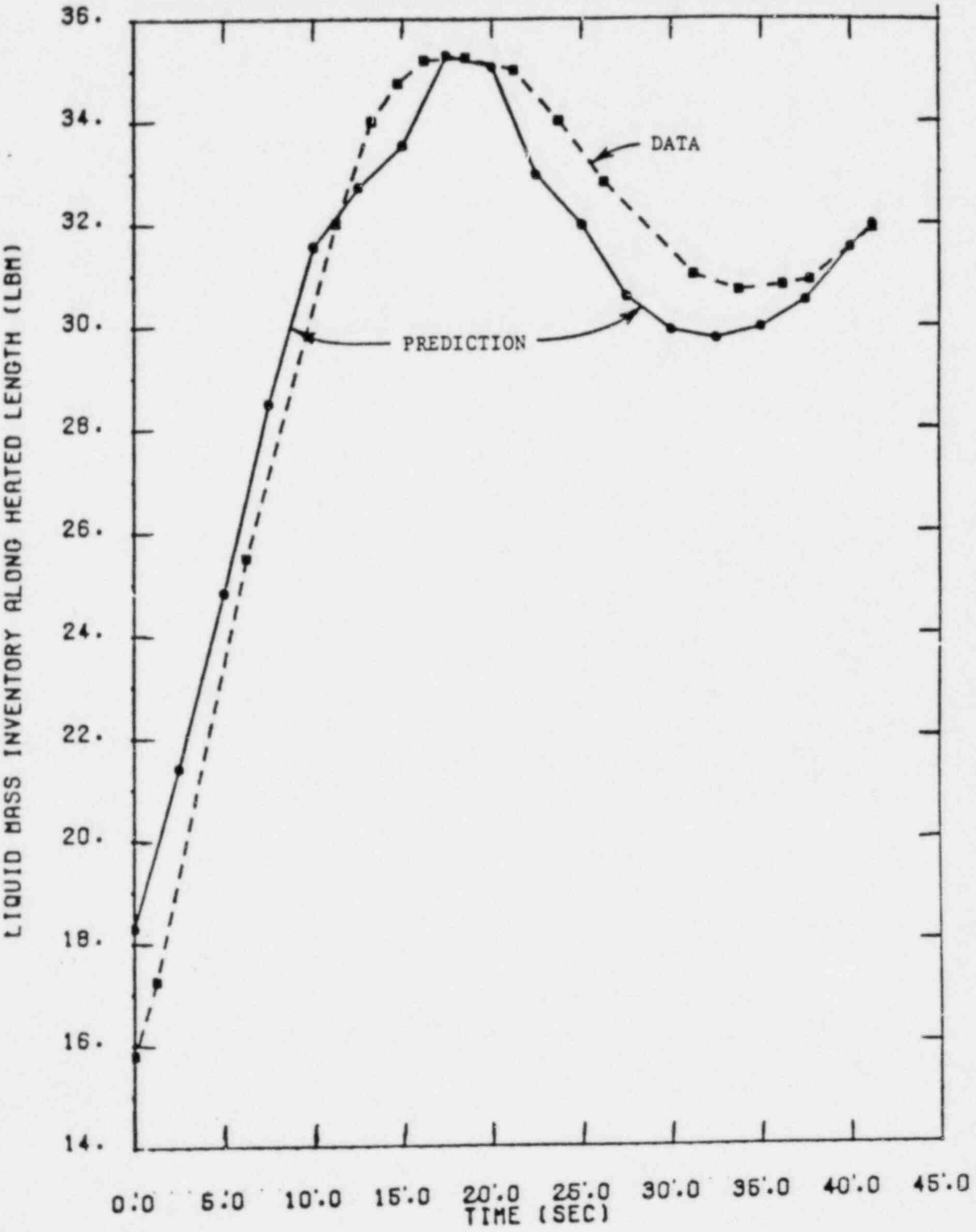
TEMPERATURE PROFILE TEST 3.09.10I



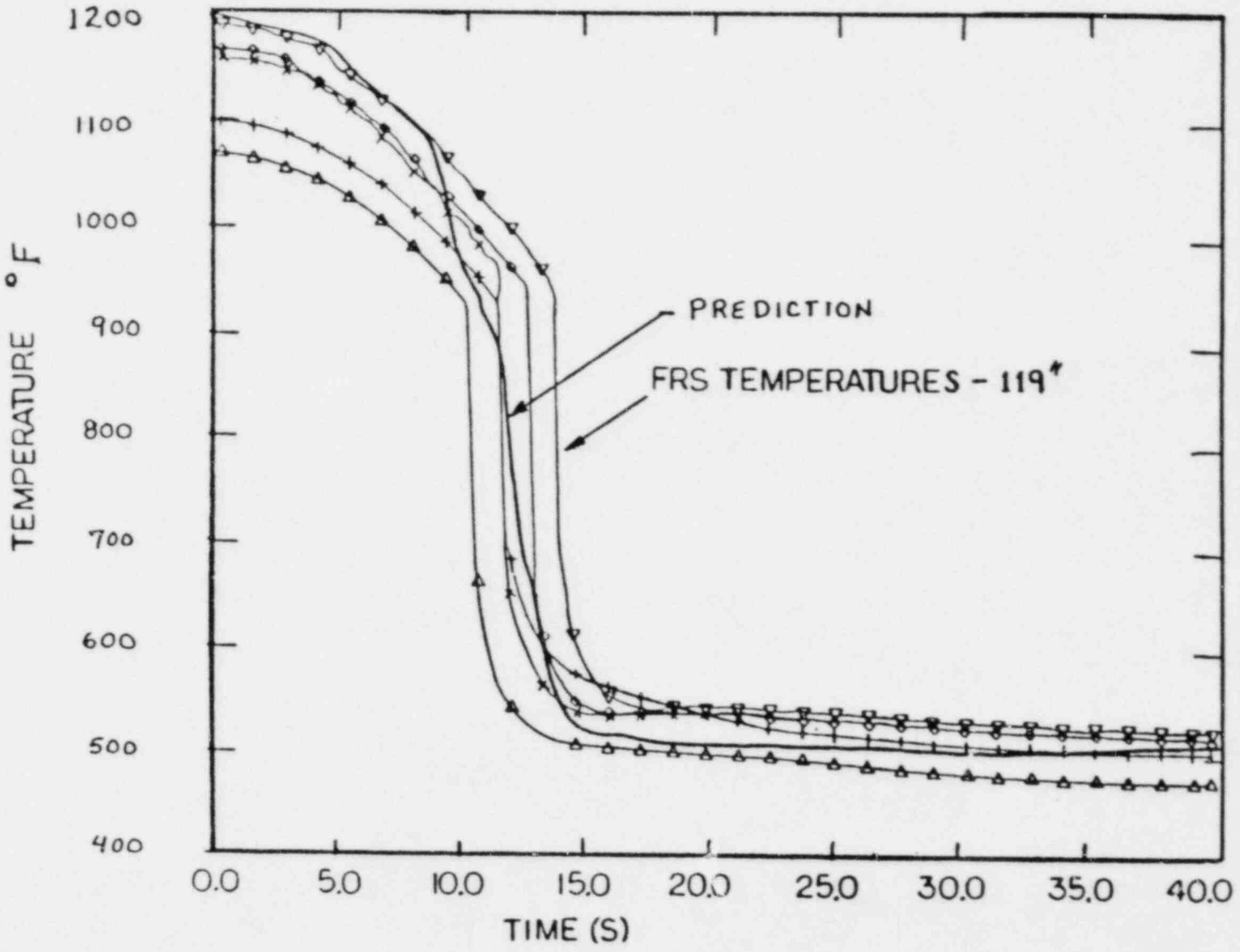
REFLOOD TESTS

TEST NO.	INITIAL PRESSURE (psia)	FLOODING VELOCITY (in/sec)	LINEAR POWER (kw/ft)
3.09.10O	560	4.8	0.62
3.09.10Q	570	2.3	0.31

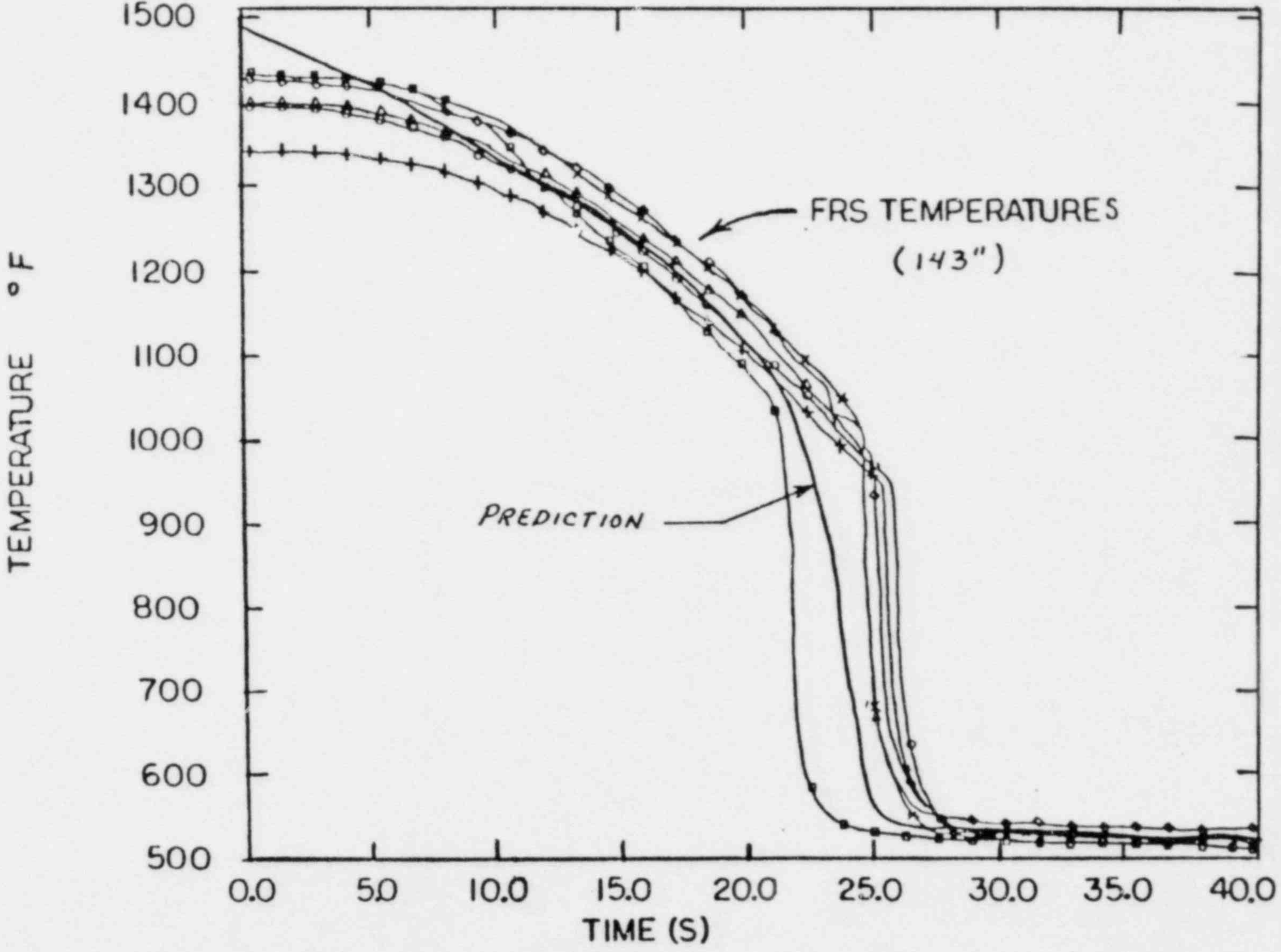
THTF SBLOCA II REFLOOD TEST 3.09.100

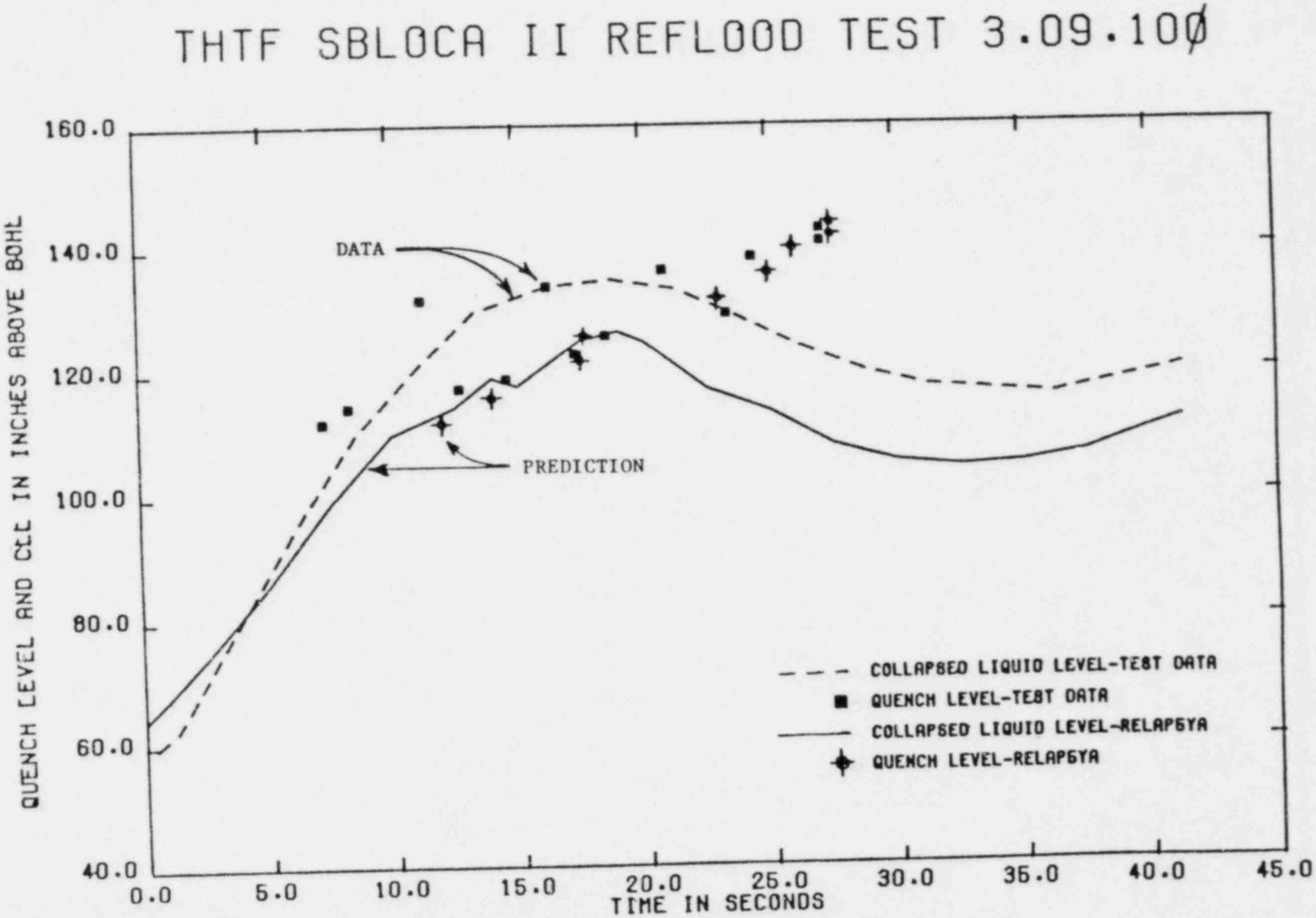


THTF SBLOCA II: REFLOOD TEST 3.09.10Ø

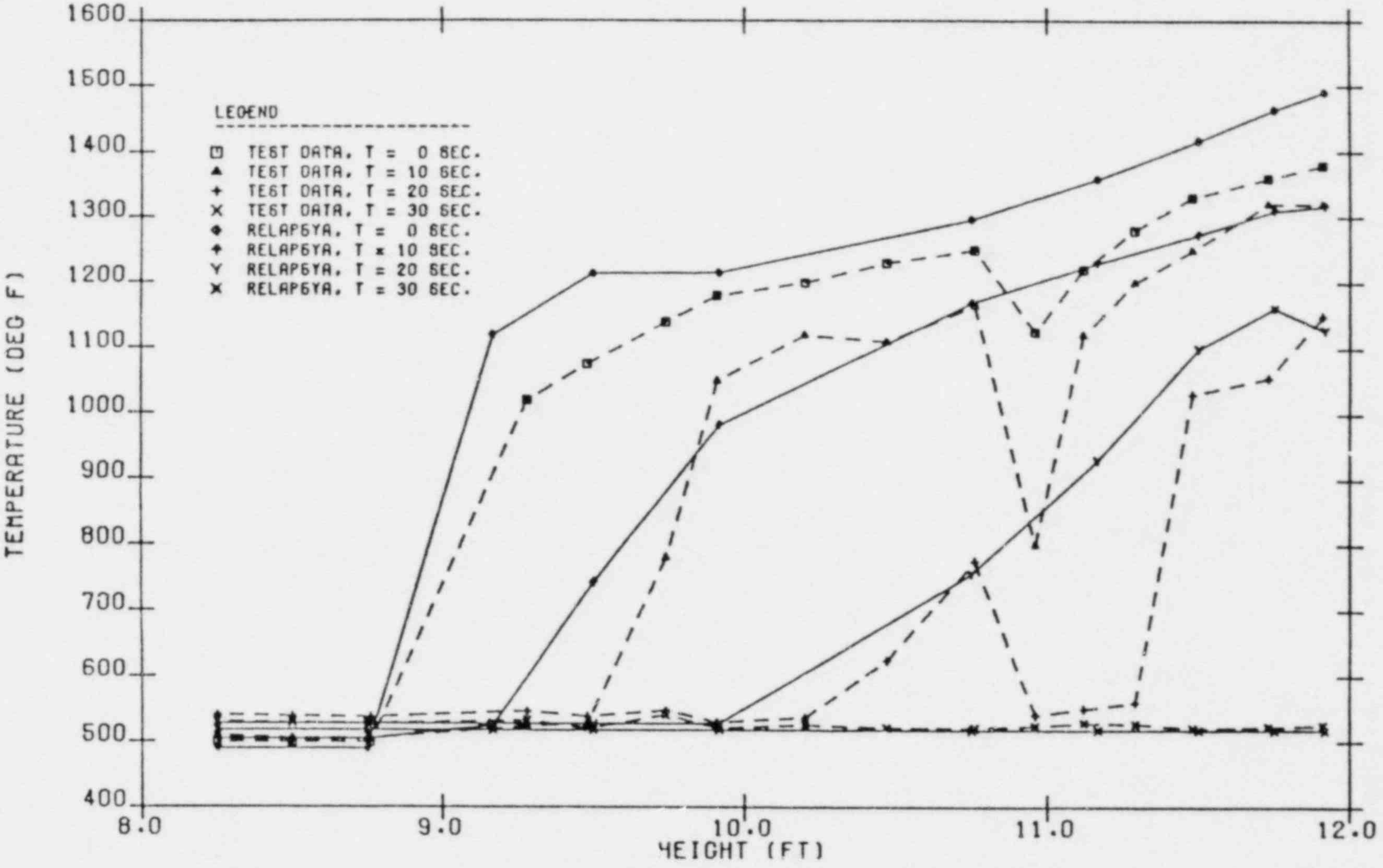


THTF SBLOCA II REFLOOD TEST 3.09.10Ø

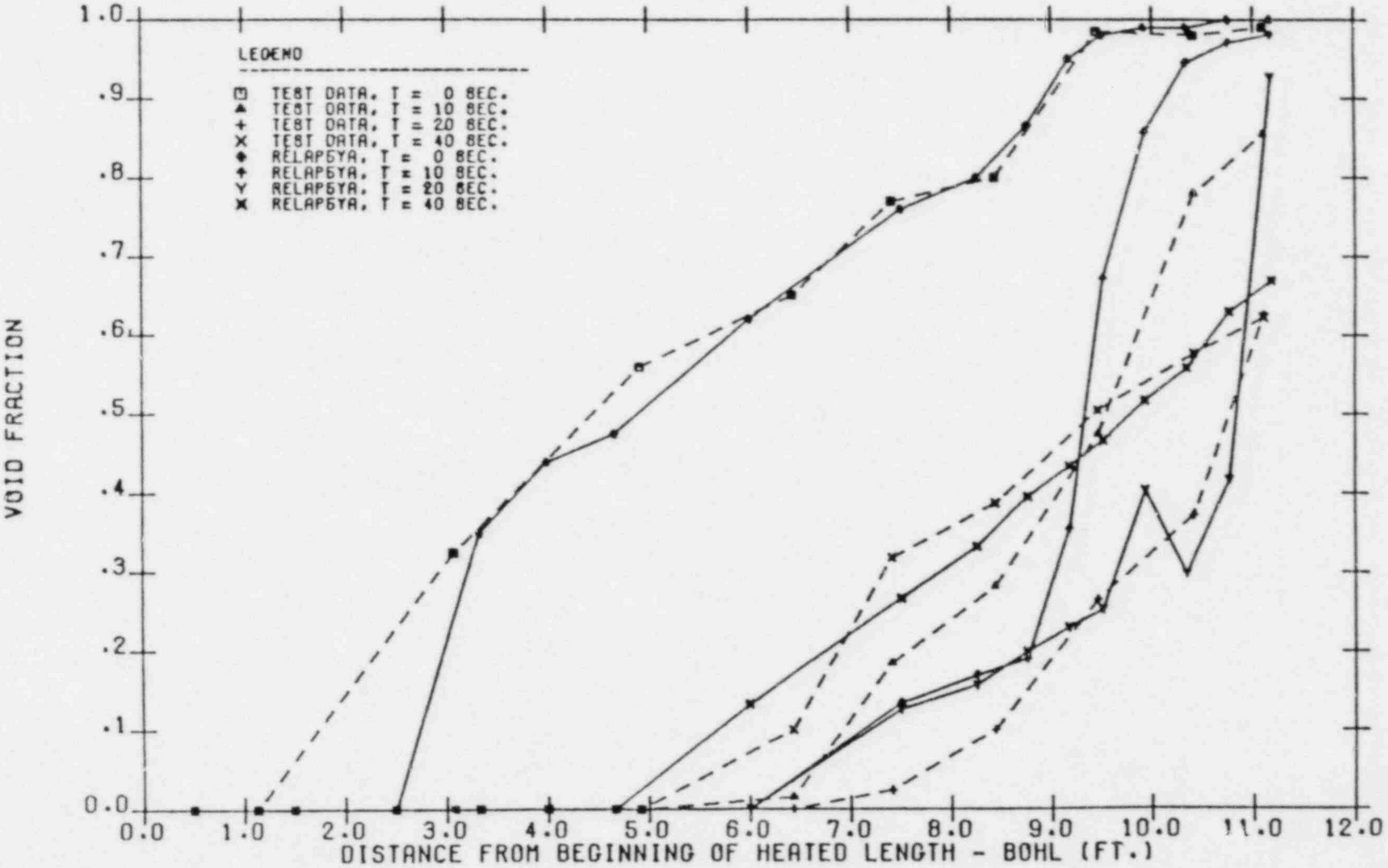



THTF SBLOCA II REFLOOD TEST 3.09.100
QUENCH LEVEL AND CLL IN INCHES ABOVE BOHL
160.0
140.0
120.0
100.0
80.0
60.0
40.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
TIME IN SECONDS
DATA
PREDICTION
COLLAPSED LIQUID LEVEL-TEST DATA
QUENCH LEVEL-TEST DATA
COLLAPSED LIQUID LEVEL-RELAP5YA
QUENCH LEVEL-RELAP5YA

TEMPERATURE PROFILES REFLOOD TEST 3.09.100



VOID FRACTION PROFILES FOR REFLOOD TEST 3.09.100



TLTA LARGE BREAK

TEST 6425/2

BE CALCULATION
(RUN L4-1)

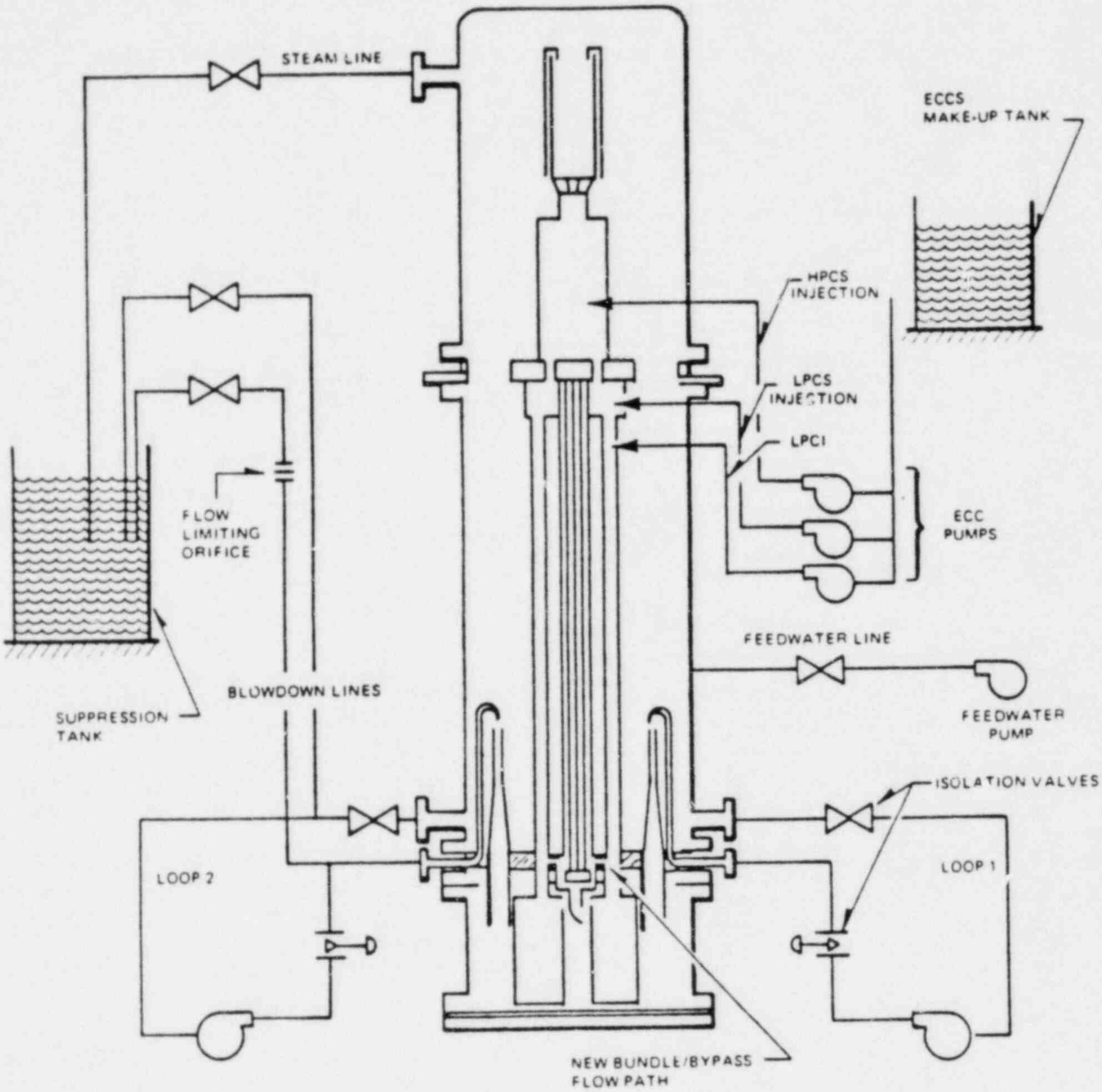


FIG. TLTA-5A CONFIGURATION

INITIAL CONDITIONS OF THE BD/ECC 1A REFERENCE TEST (6425 RUN 2)

Initial Conditions	TLTA	
Bundle power	5.05[a] ± 0.03MW	
Steam dome pressure	1044 ± 5 psia	(7198 Pa)
Lower plenum pressure	1071 ± 5 psia	(7384 Pa)
Lower plenum enthalpy	528 ± 5 Btu/lbm	(1228 Kj/Kg)
Initial water level[b]	73 ± 6 in. El	(1.85m)
Feed water enthalpy	41 ± 2 Btu/lbm	(95 Kj/Kg)
Bundle inlet to outlet DP	17 ± 2 psi	(117 Pa)
Steam flow	6 ± 1 lbm/sec	(2.7 Kg/s)
Feed water flow	1.4 ± 0.3 lbm/sec	(0.5 Kg/s)
Drive Pump 1 flow (INTACT)	9.1 ± 1 lbm/sec	(4.1 Kg/s)
Drive Pump 2 flow (BROKEN)	8.4 ± 1 lbm/sec	(3.8 Kg/s)
Jet Pump 1 flow (INTACT)	22 ± 2 lbm/sec	(10 Kg/s)
Jet Pump 2 flow (BROKEN)	20 ± 2 lbm/sec	(9 Kg/s)
Bundle inlet flow	39 ± 5 lbm/sec	(18 Kg/s)

All uncertainty bands are judged from the maximum of data fluctuation and/or absolute uncertainties of the measurements.

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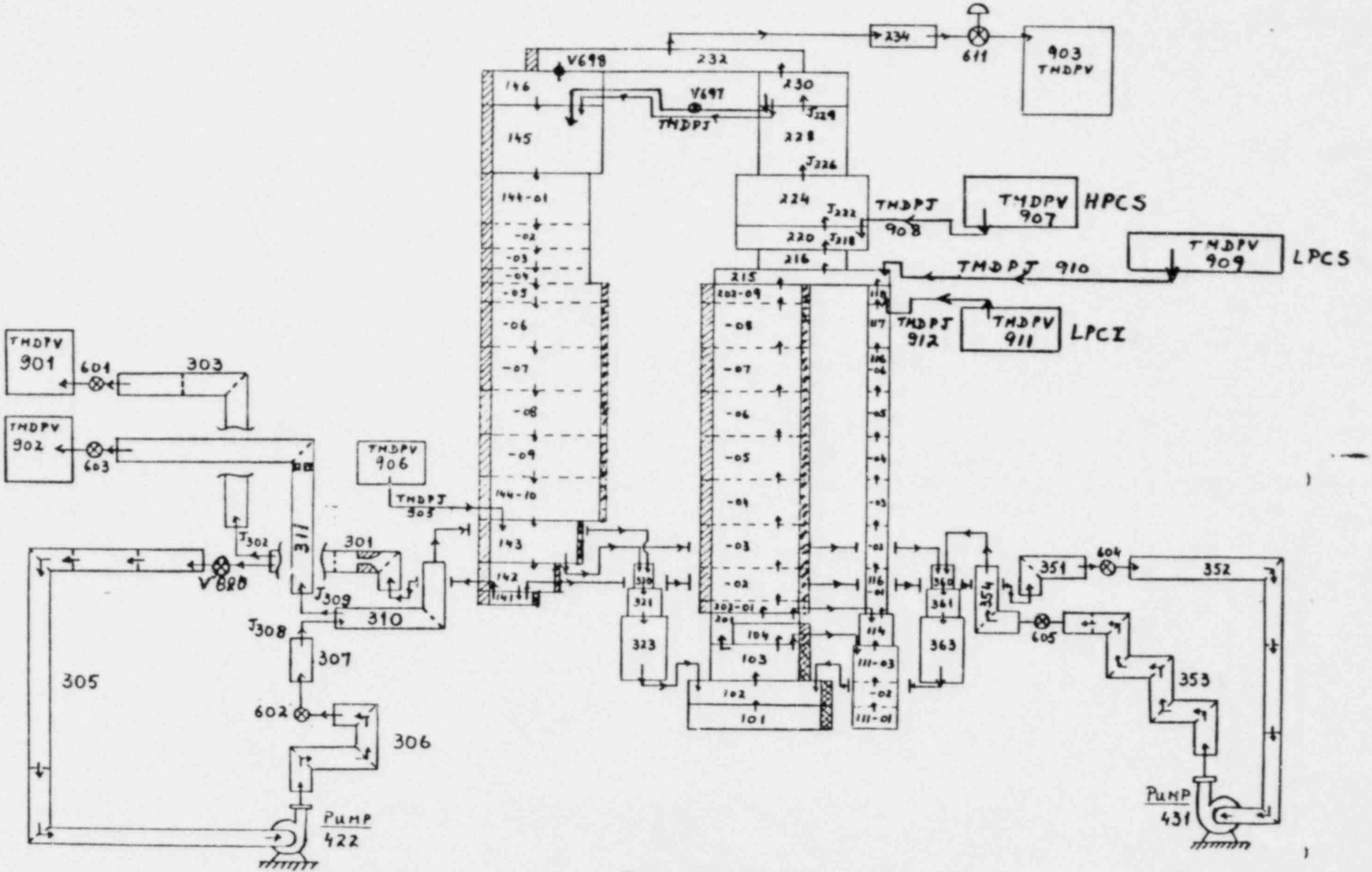
[a] NOTE: 5.05 MW is central average bundle power; core average power is 4.60 MW for BWR/6.

[b] NOTE: Relative to jet pump support plate.



TLTA - 5A NODALIZATION

SEQUENCE OF EVENTS FOR 6425 RUN 2 (AVG. POWER, AVG. ECC)

Events	Time (sec)
Blowdown valves open	0.0
Bundle power decay initiated	0.5
Blowdown loop jet pump flow reverses	0.5
Feedwater flow stops	0.5
Bypass flow reverses	1.7
Jet pump suction uncovers	6.7
Steamline valve completely closed	9.0
Recirc. suction line begins to uncover	9.4
Lower plenum bulk flashing	11
Guide tube flashing	11.2
Core inlet uncovers (SEO center line)	20
Loop 1 isolated	20
HPCS injection begins	27
Lower plenum mixture level reaches jet pump exit plane	35
LPCS, LPCI activated	37
LPCS flow begins	64
LPCI flow begins	75
Bypass/guide tube region begins to refill	85
CCFL breaks down at bypass outlet	95
Bundle begins to refill	114
Bypass region refilled	125
Bundle reflood with two-phase mixture	130
CCFL breaks down at upper tieplate	125
Bundle quenched	150
End of test	400

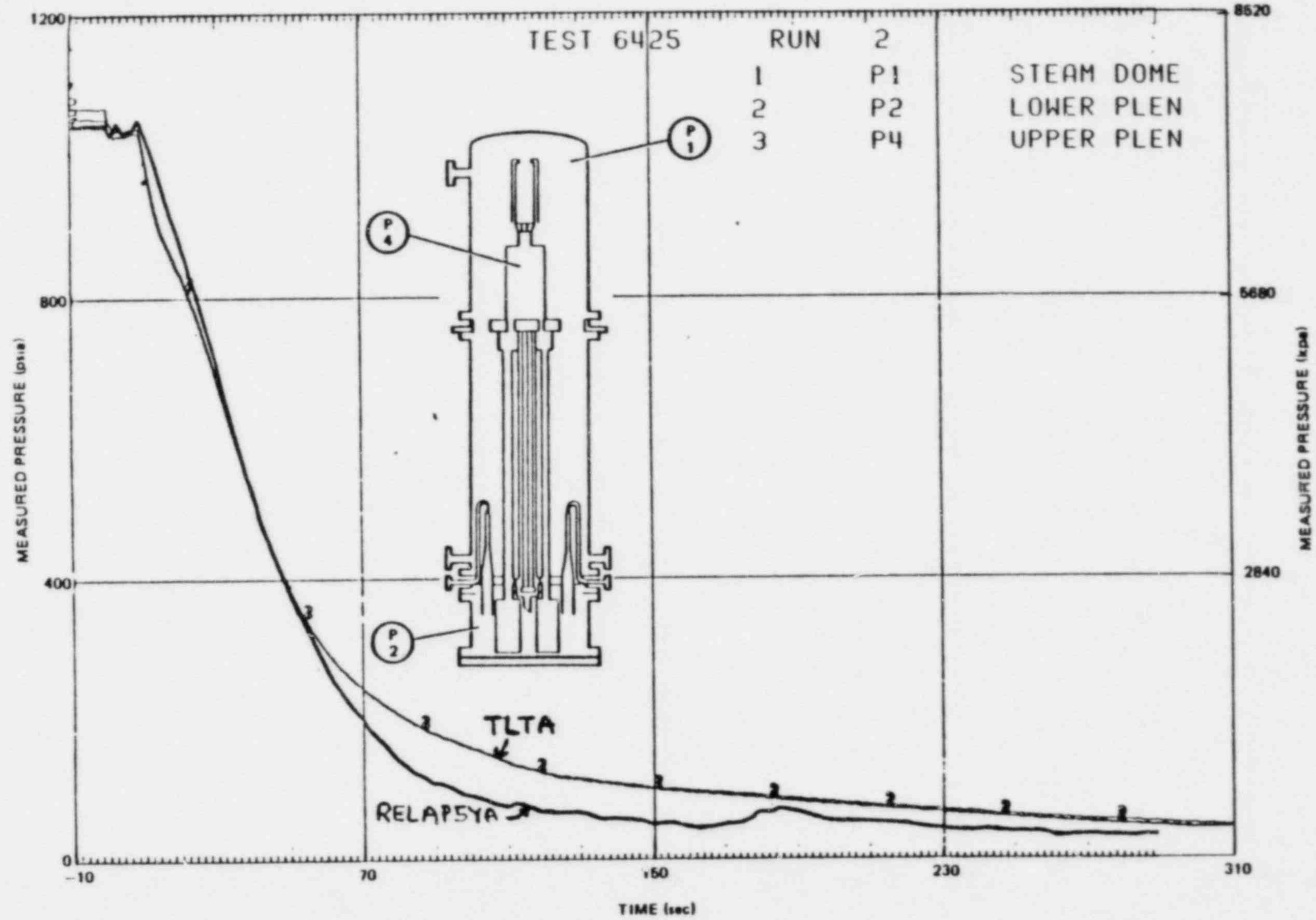


Figure J-5. System Pressures

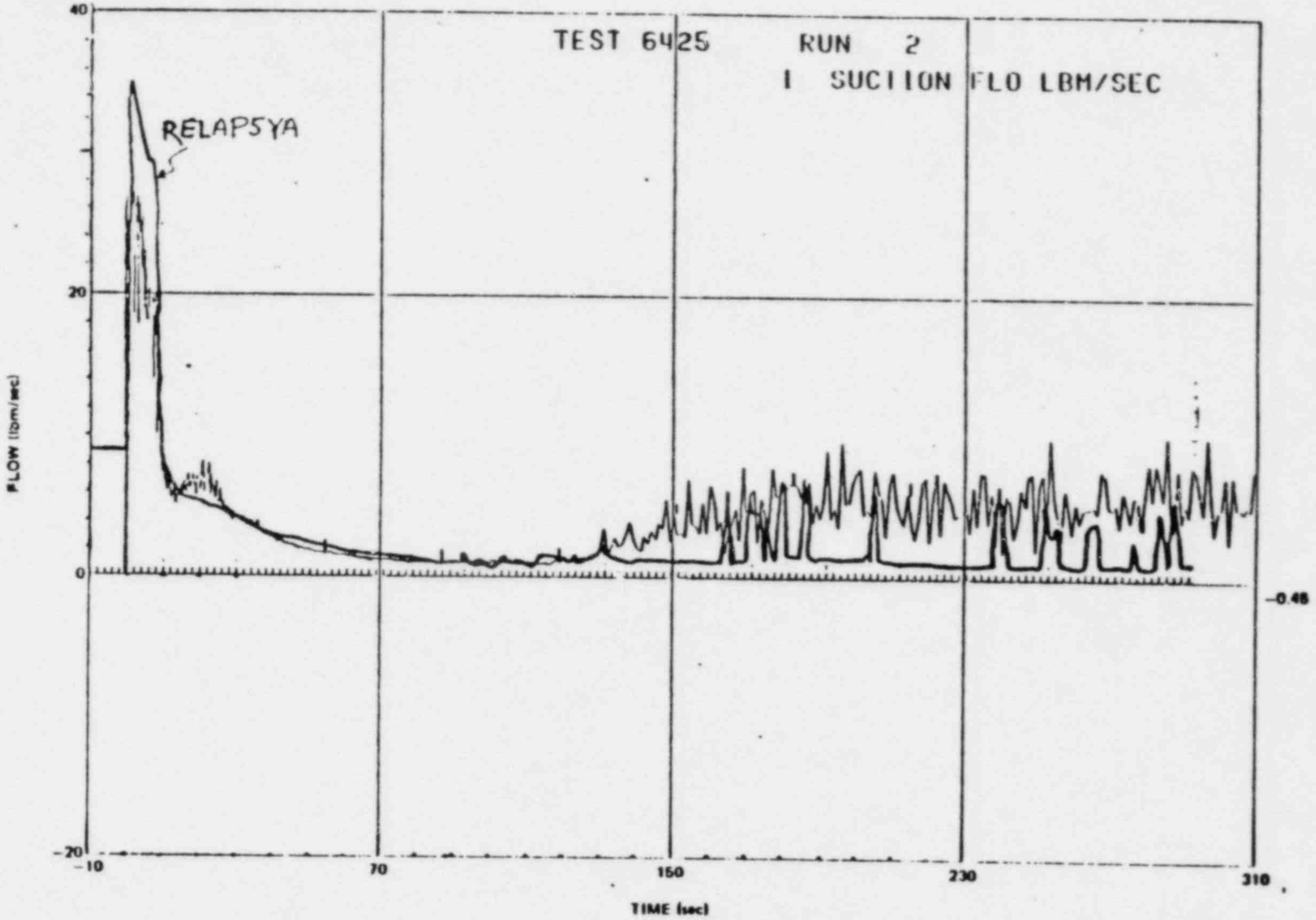


Figure J-65. Suction Line Break Mass Flow Rate

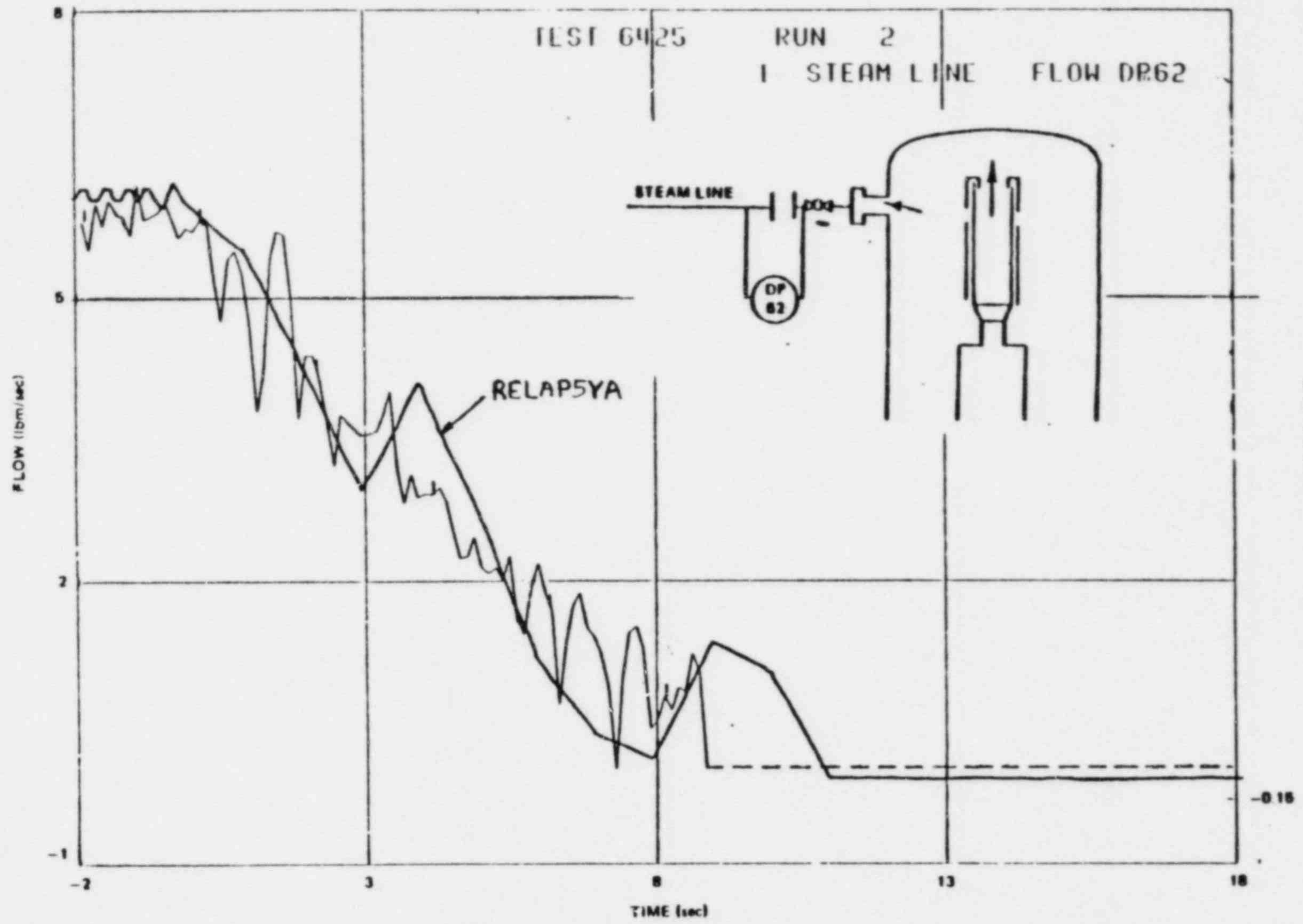


Figure J-72. Steam Line Mass Flow Rate

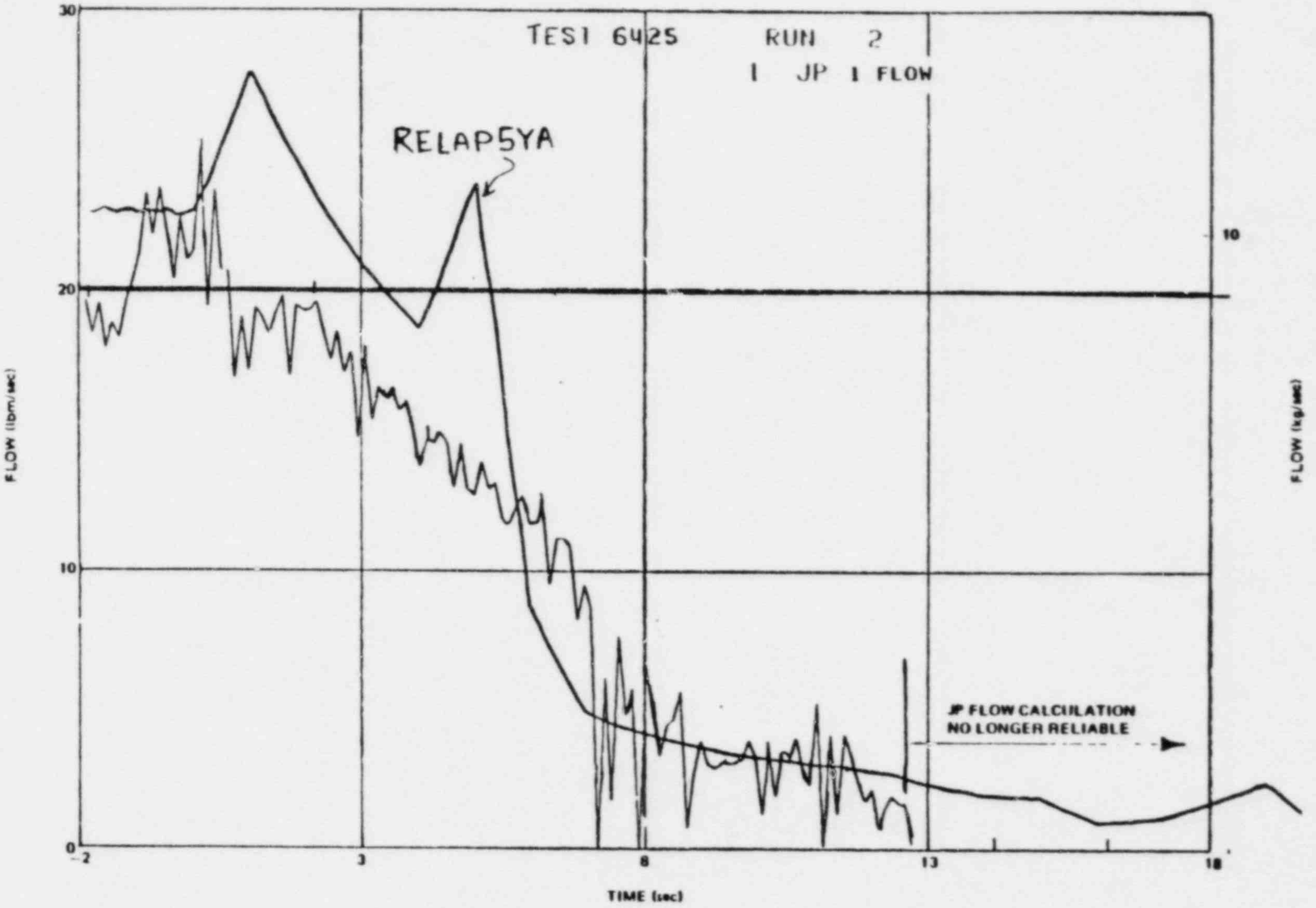


Figure J-75. Intact Loop Jet Pump Mass Flow Rate

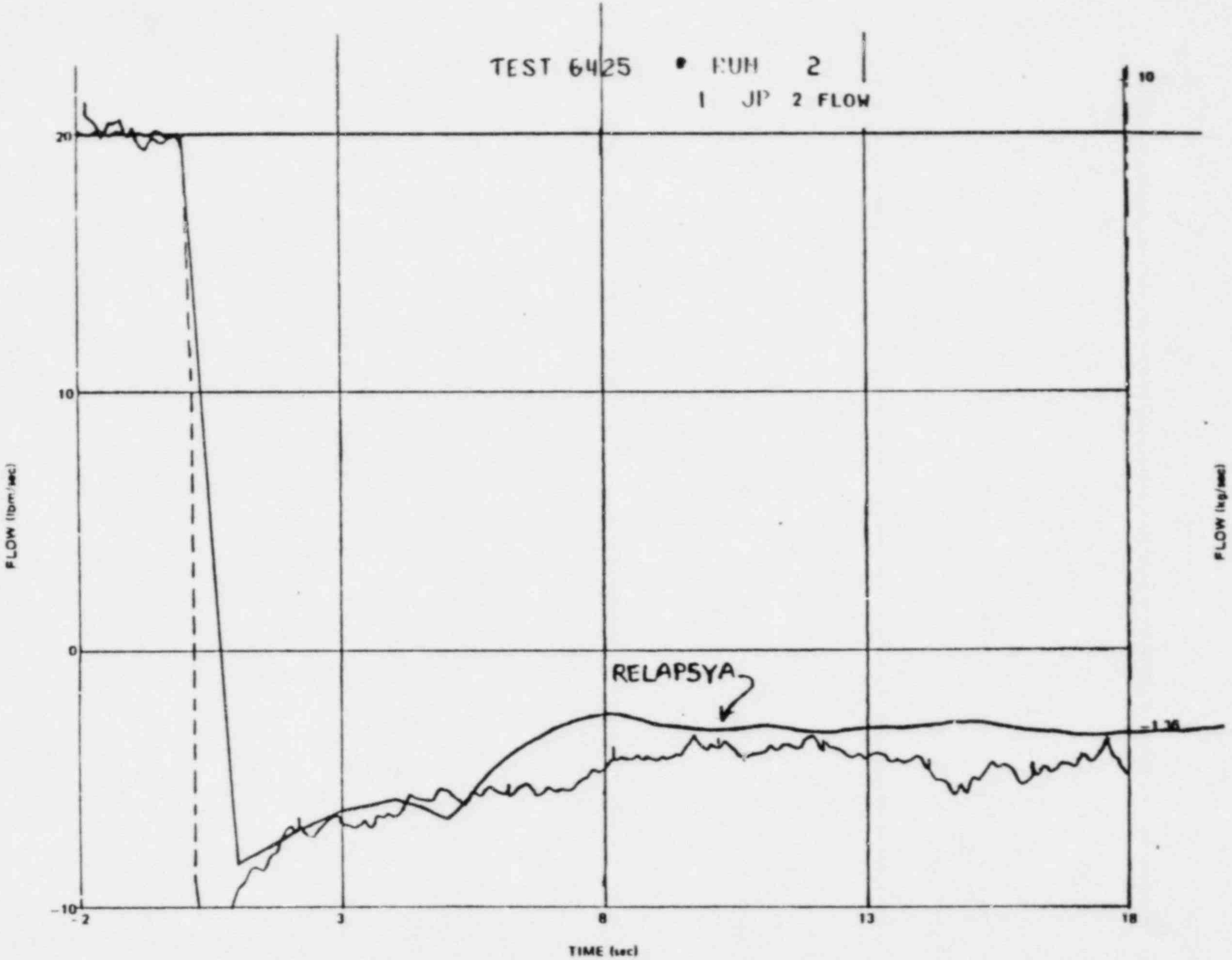


Figure J-76. Broken Loop Jet Pump Mass Flow Rate

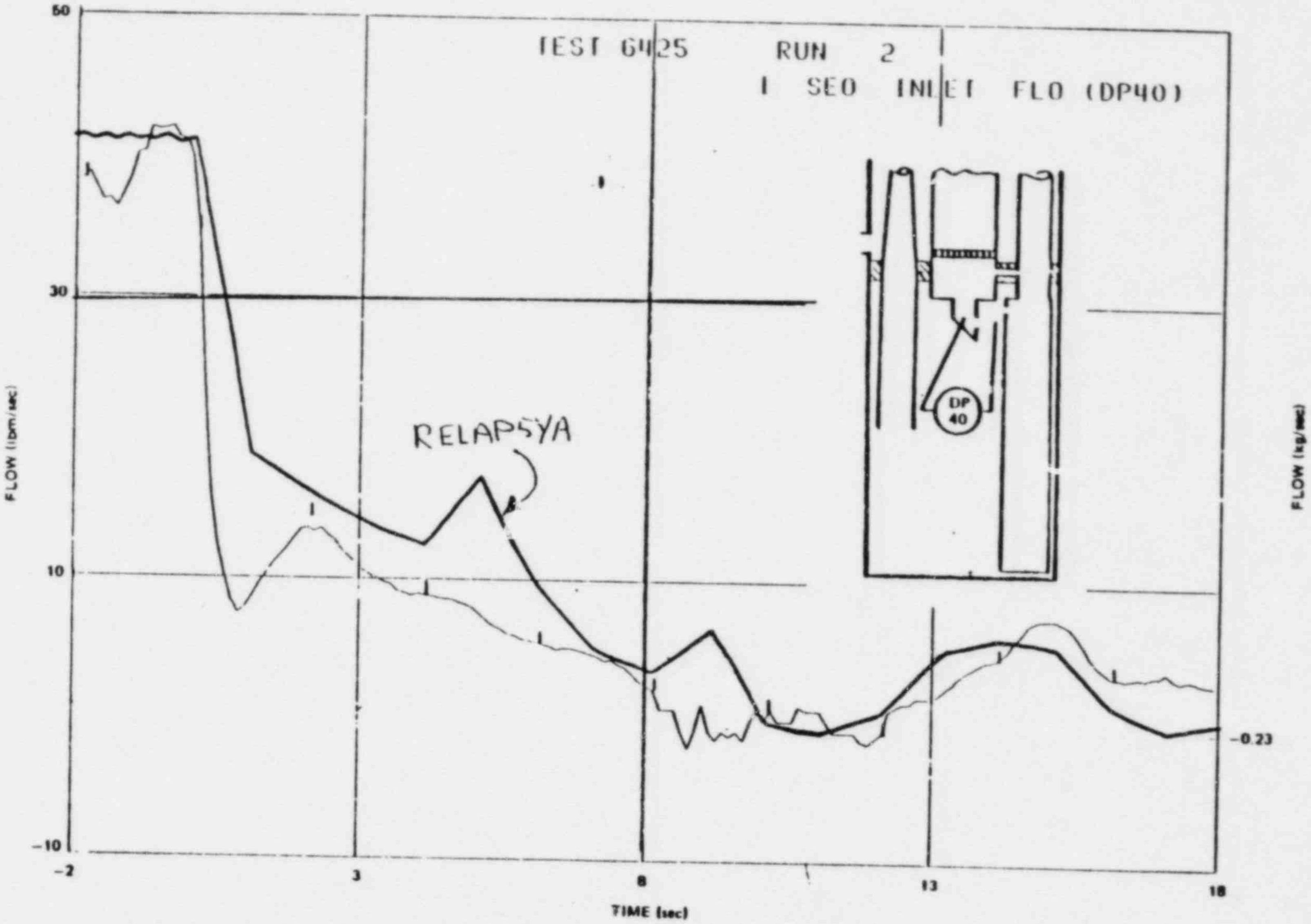


Figure J-68. Bundle Inlet Side Entry Orifice Mass Flow Rate

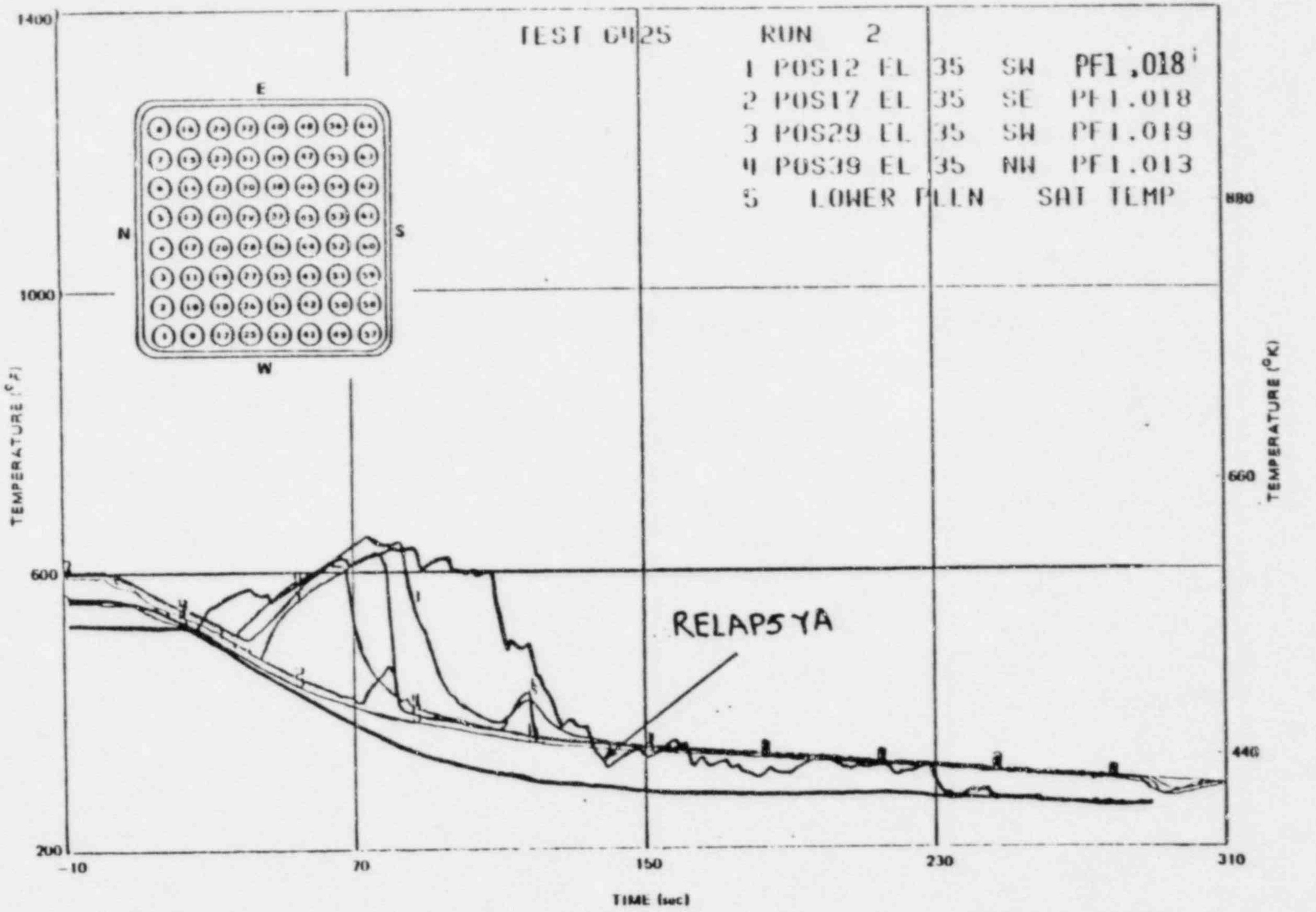


Figure J-95. Inside Clad Temperature-Elevation 35 in.

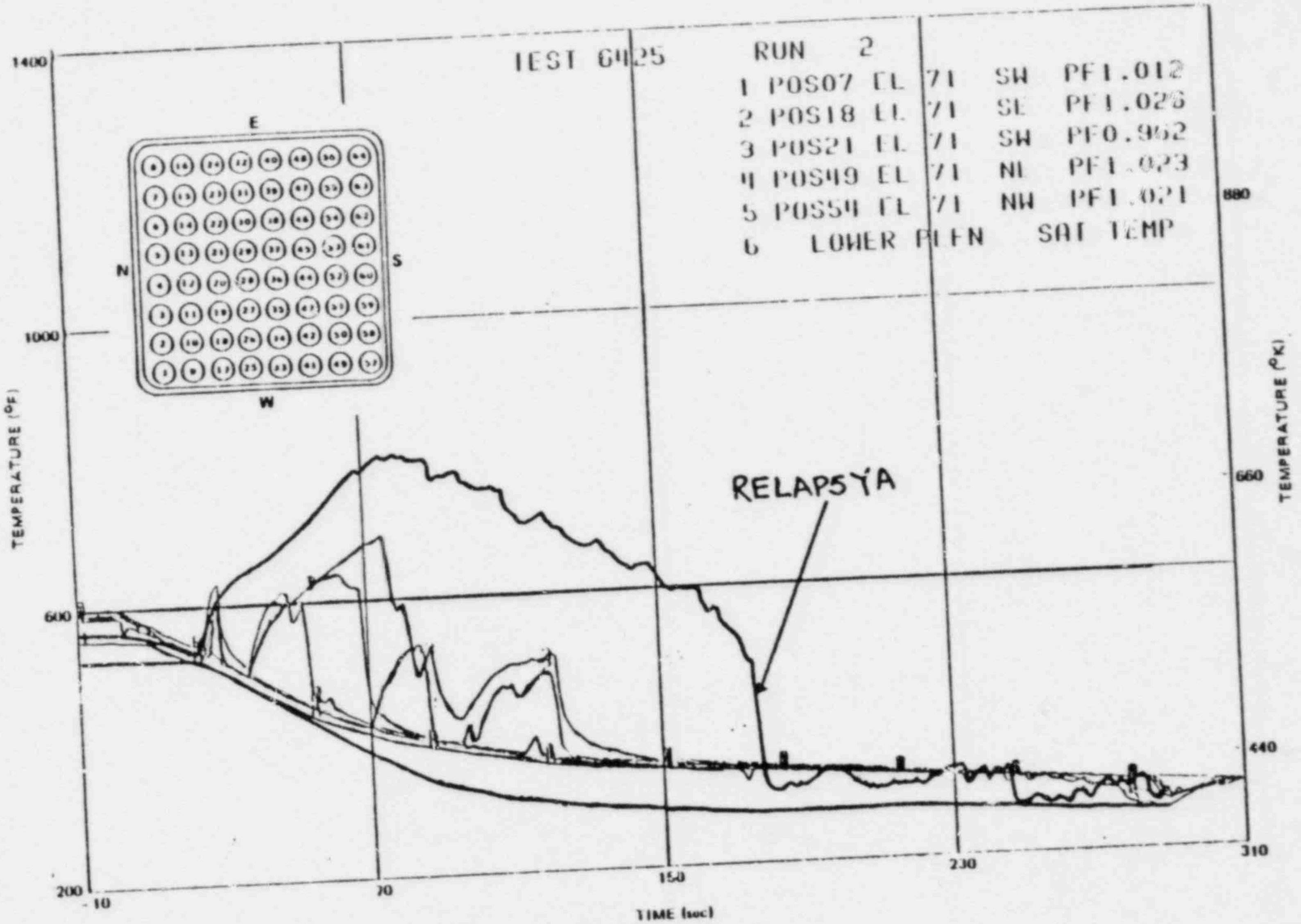


Figure J-91. Inside Clad Temperature-Elevation 71 in.

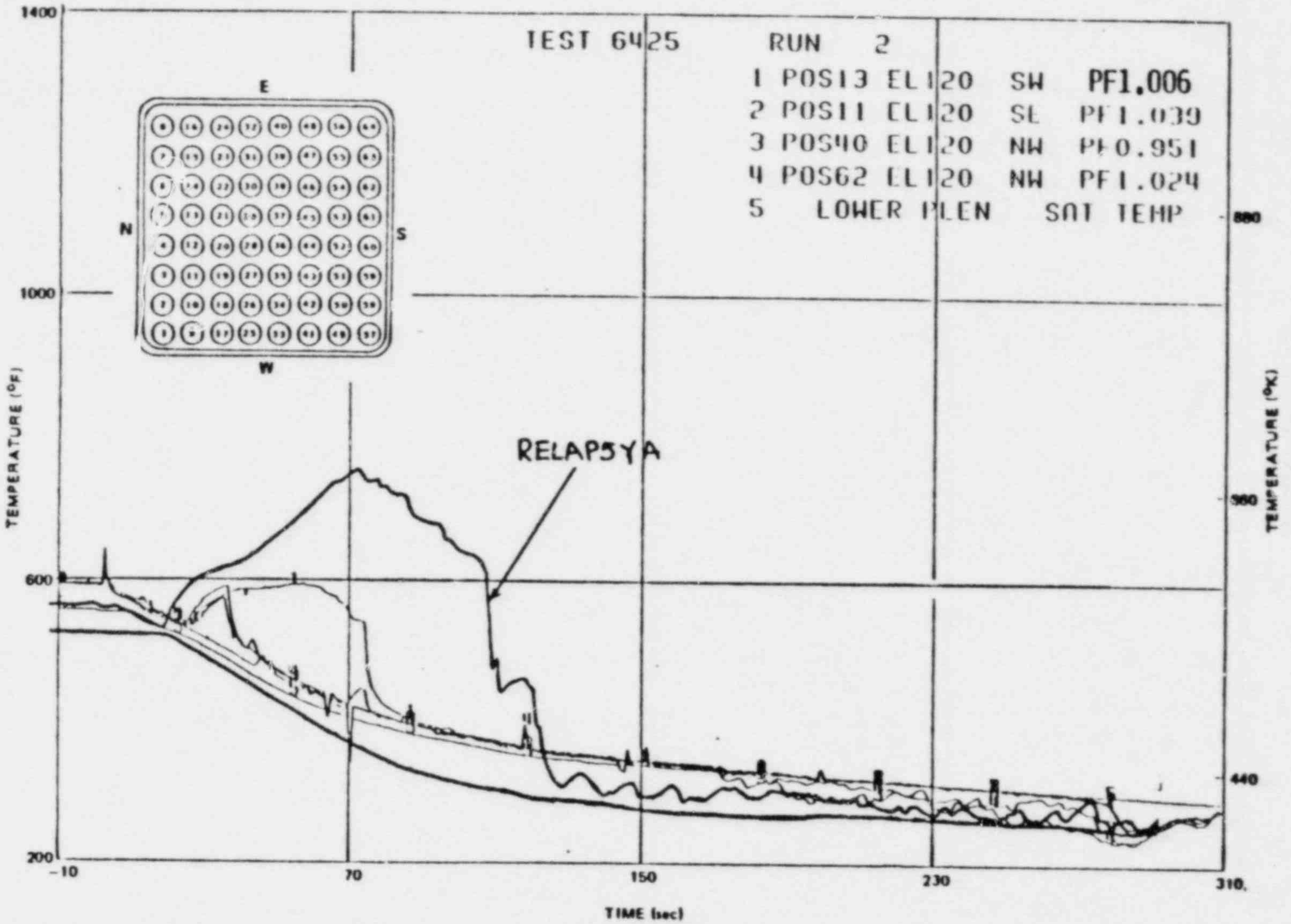


Figure J-83. Inside Clad Temperature-Elevation 120 In.

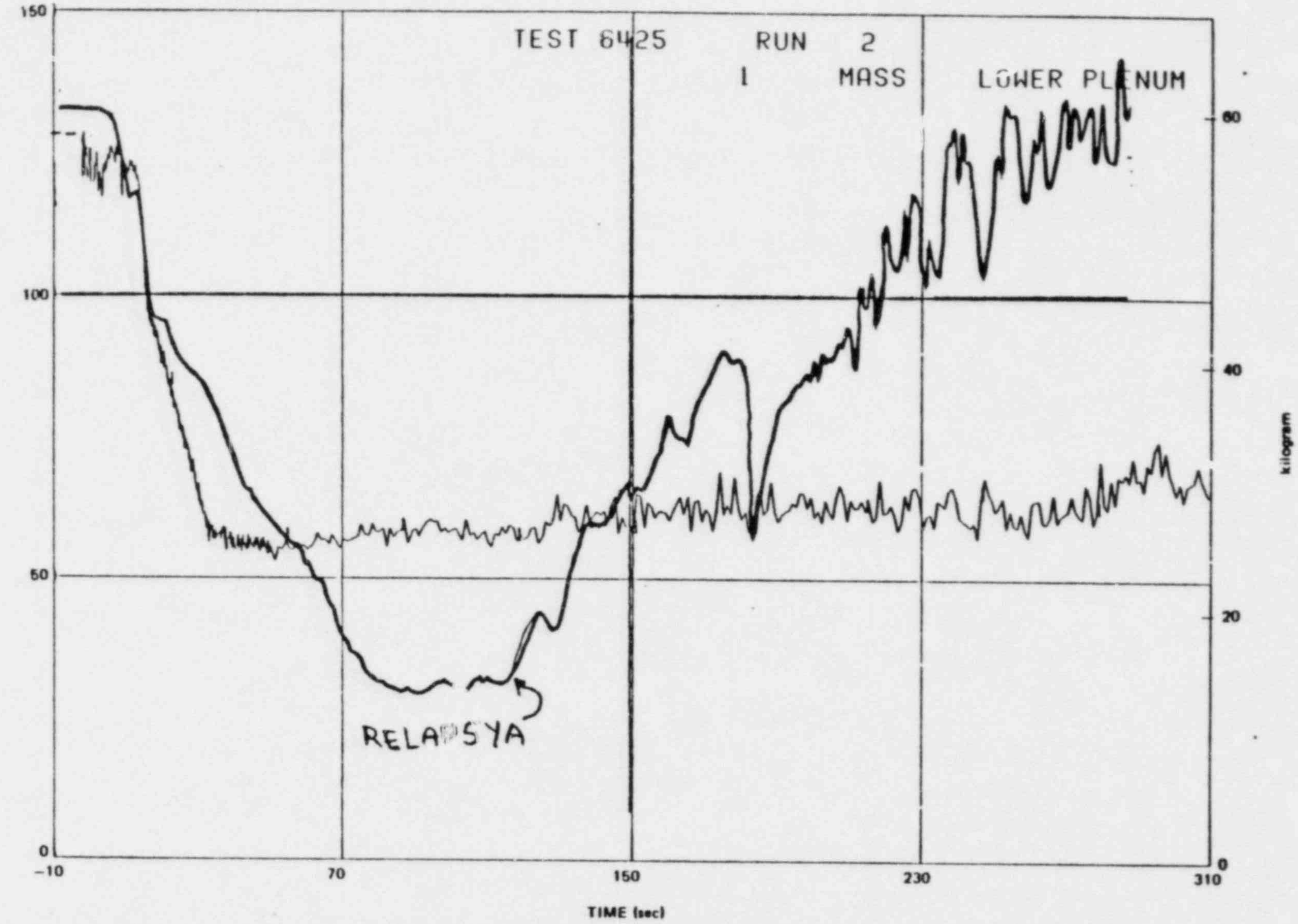


Figure J-49. Lower Plenum Fluid Mass

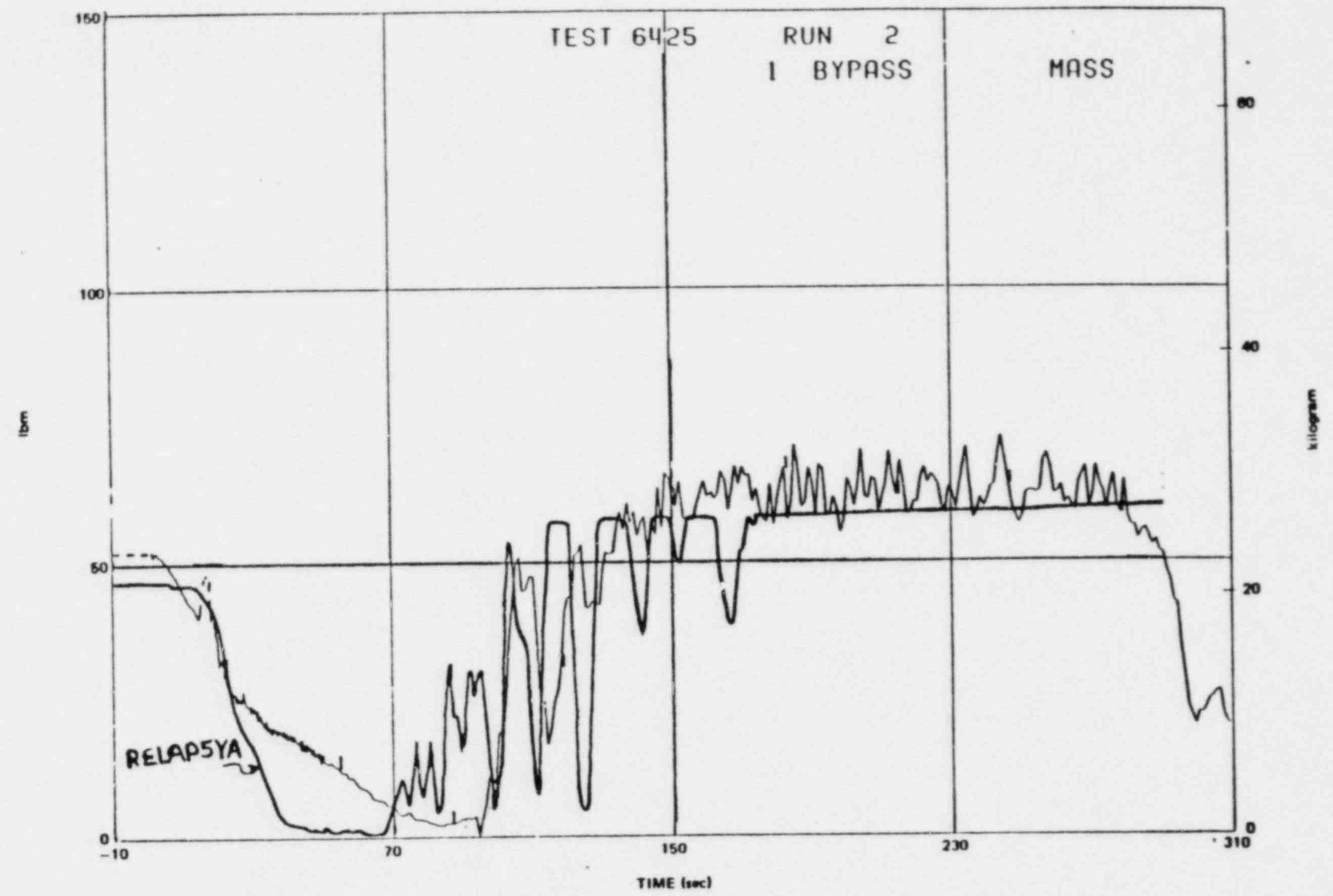


Figure J-53. Bypass Fluid Mass

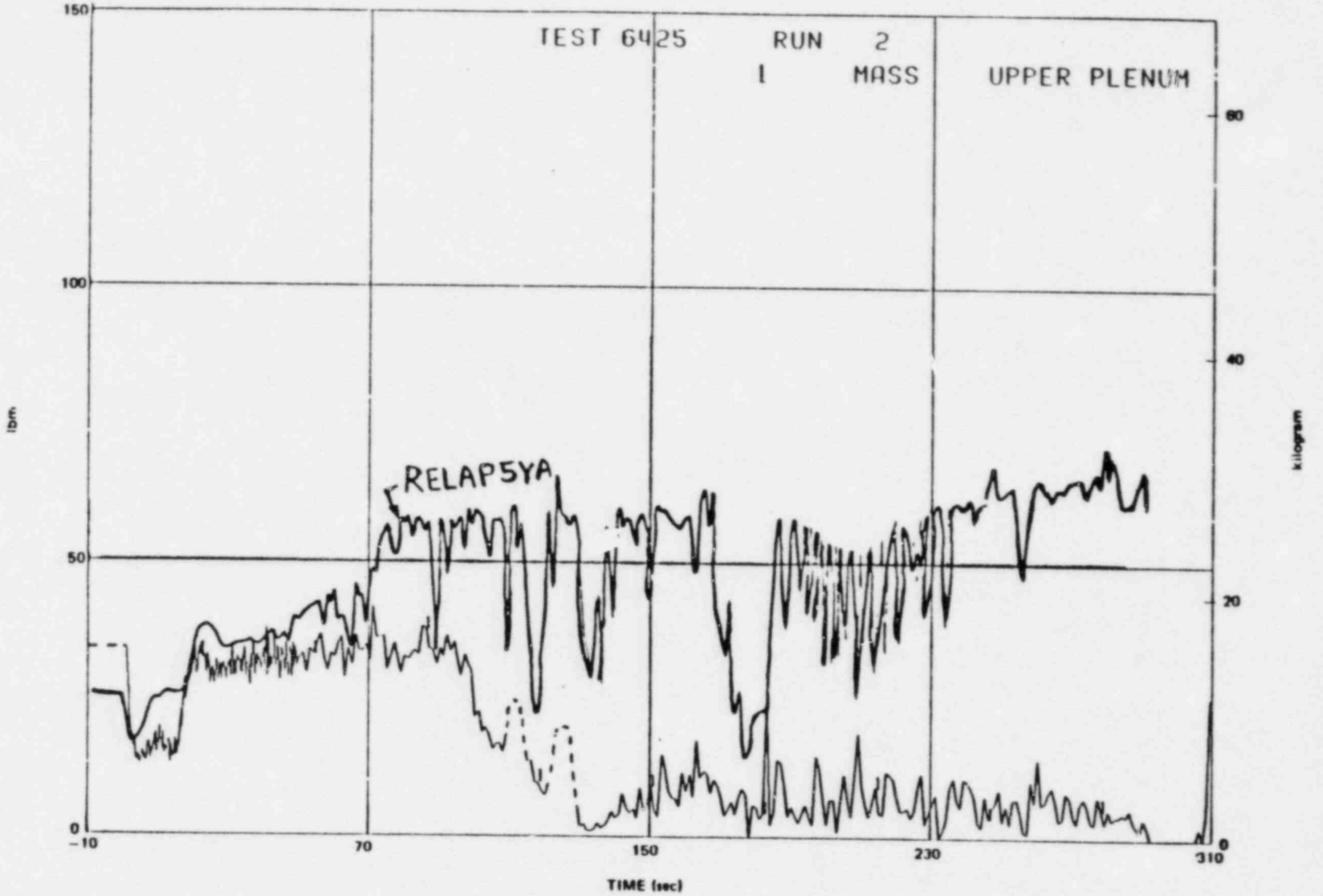


Figure J-54. Upper Plenum Fluid Mass

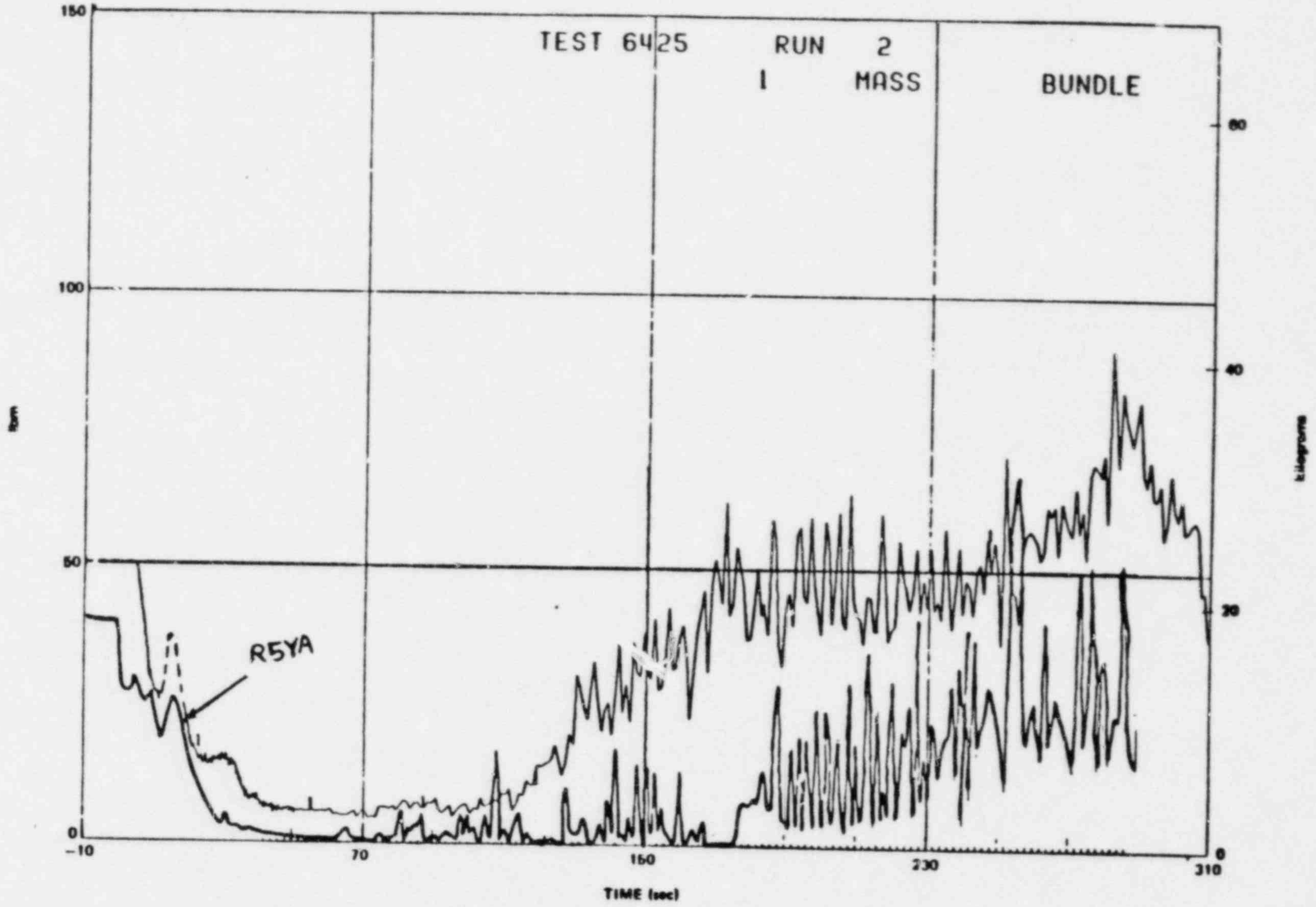


Figure J-50. Bundle Fluid Mass

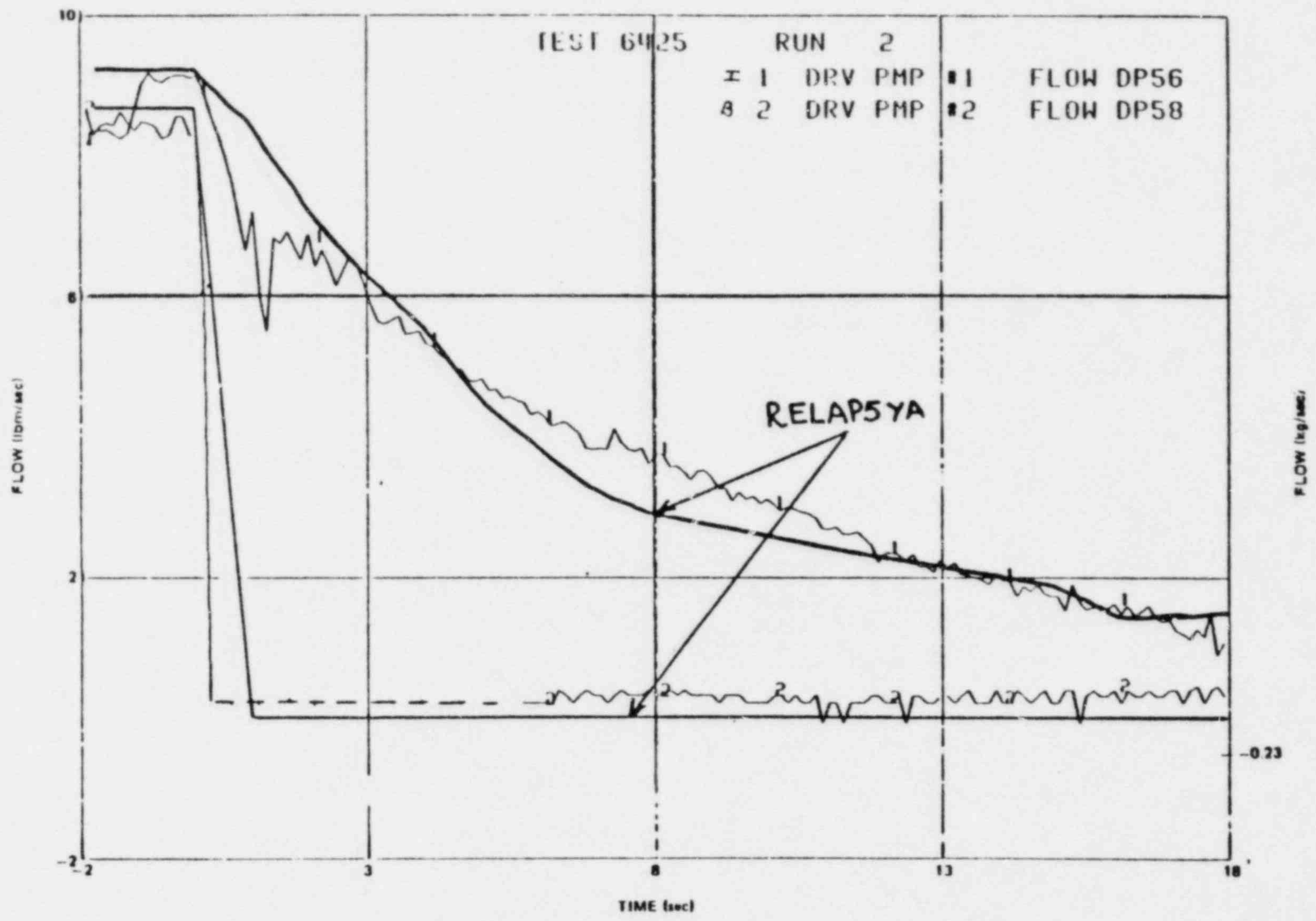


Figure J-74. Recirculation Pump Mass Flow Rates

TLTA LARGE BREAK

TEST 6425/2
(AVERAGE POWER, AVERAGE ECC)
EM CALCULATION
(RUN L3-6)

- EM HEAT TRANSFER FLAGS ON.
- ANS + 20% POWER DECAY
- 2% EXCESS POWER.

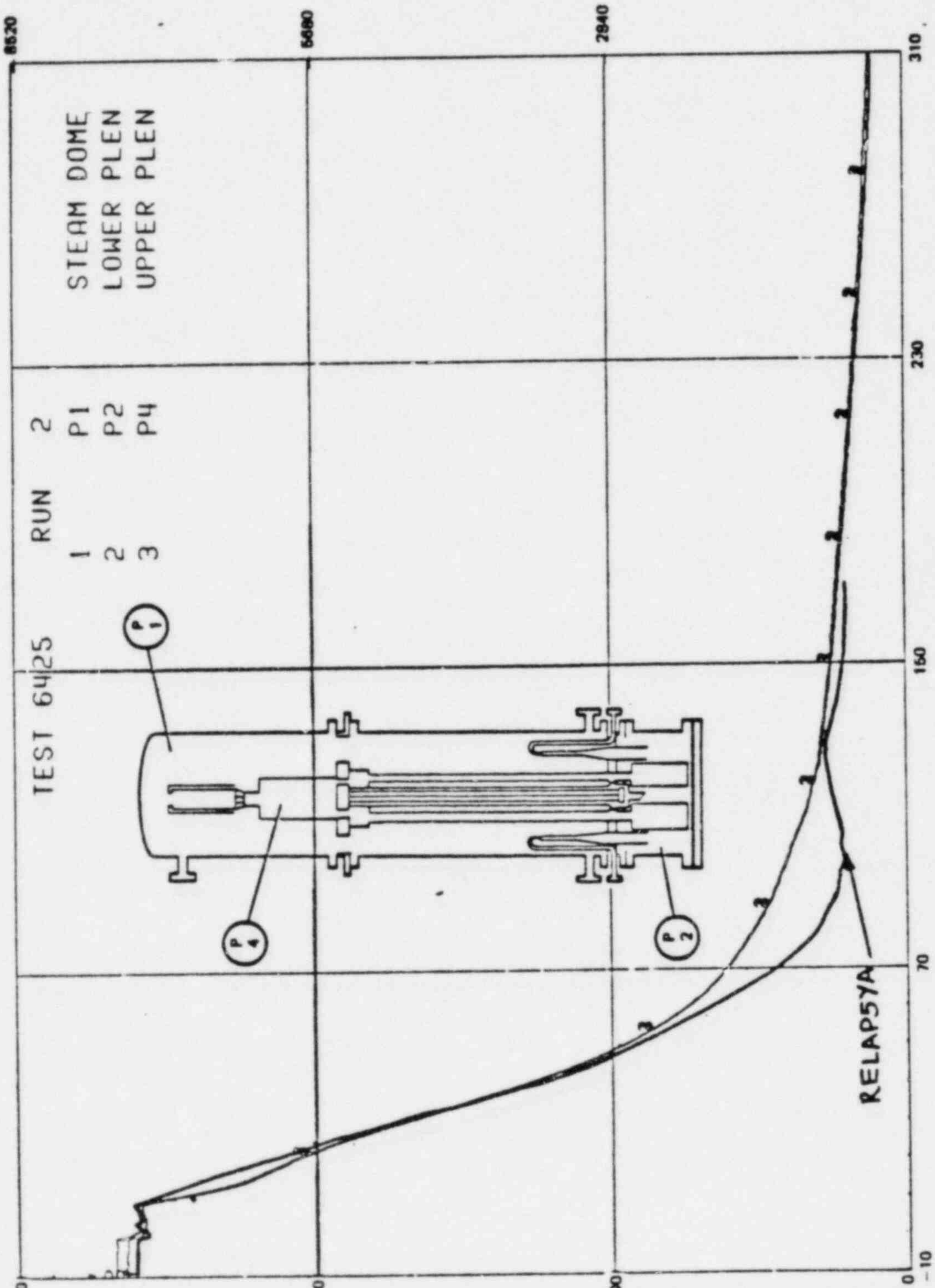


Figure J-5. System Pressures

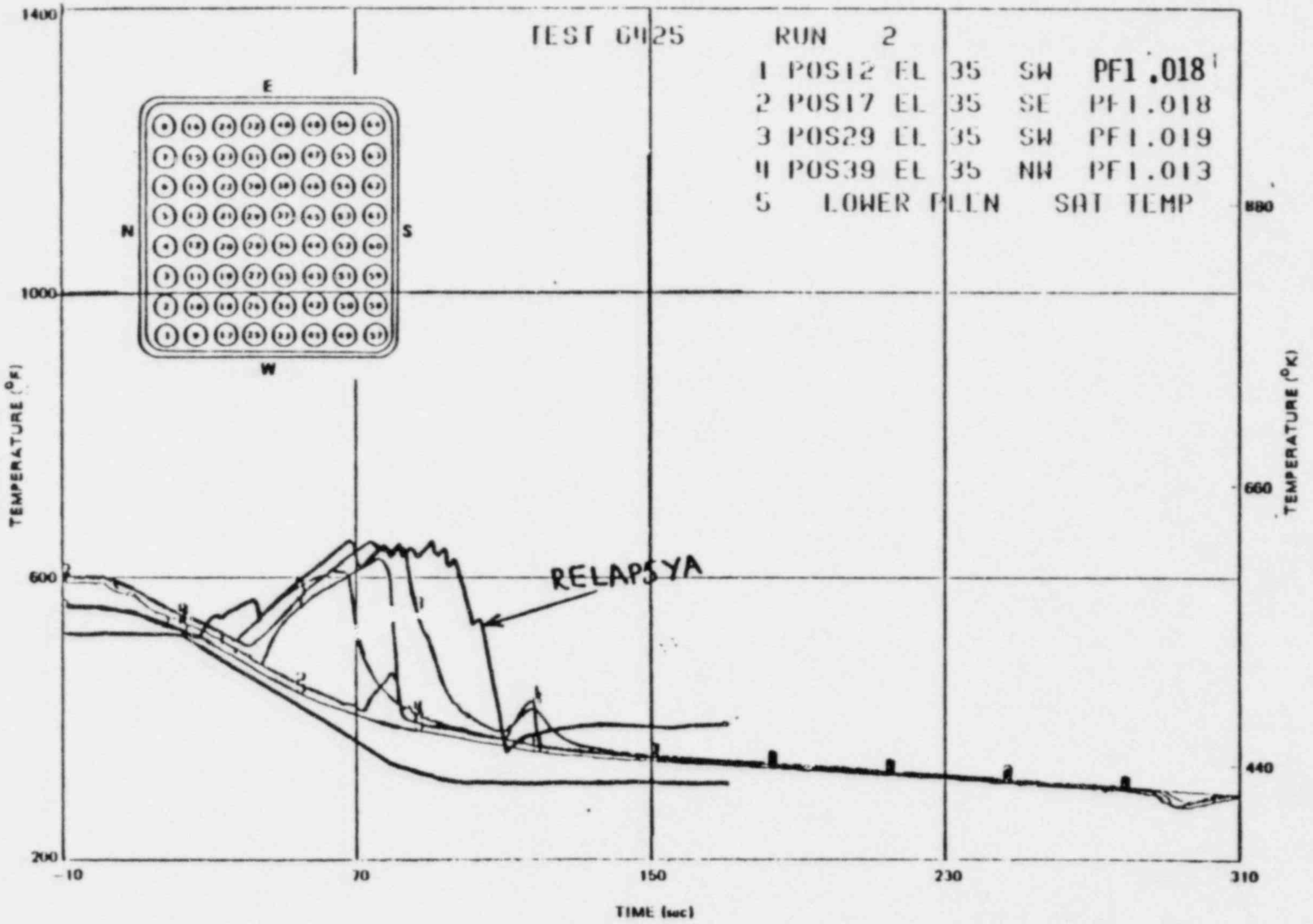


Figure J-95. Inside Clad Temperature-Elevation 35 in.

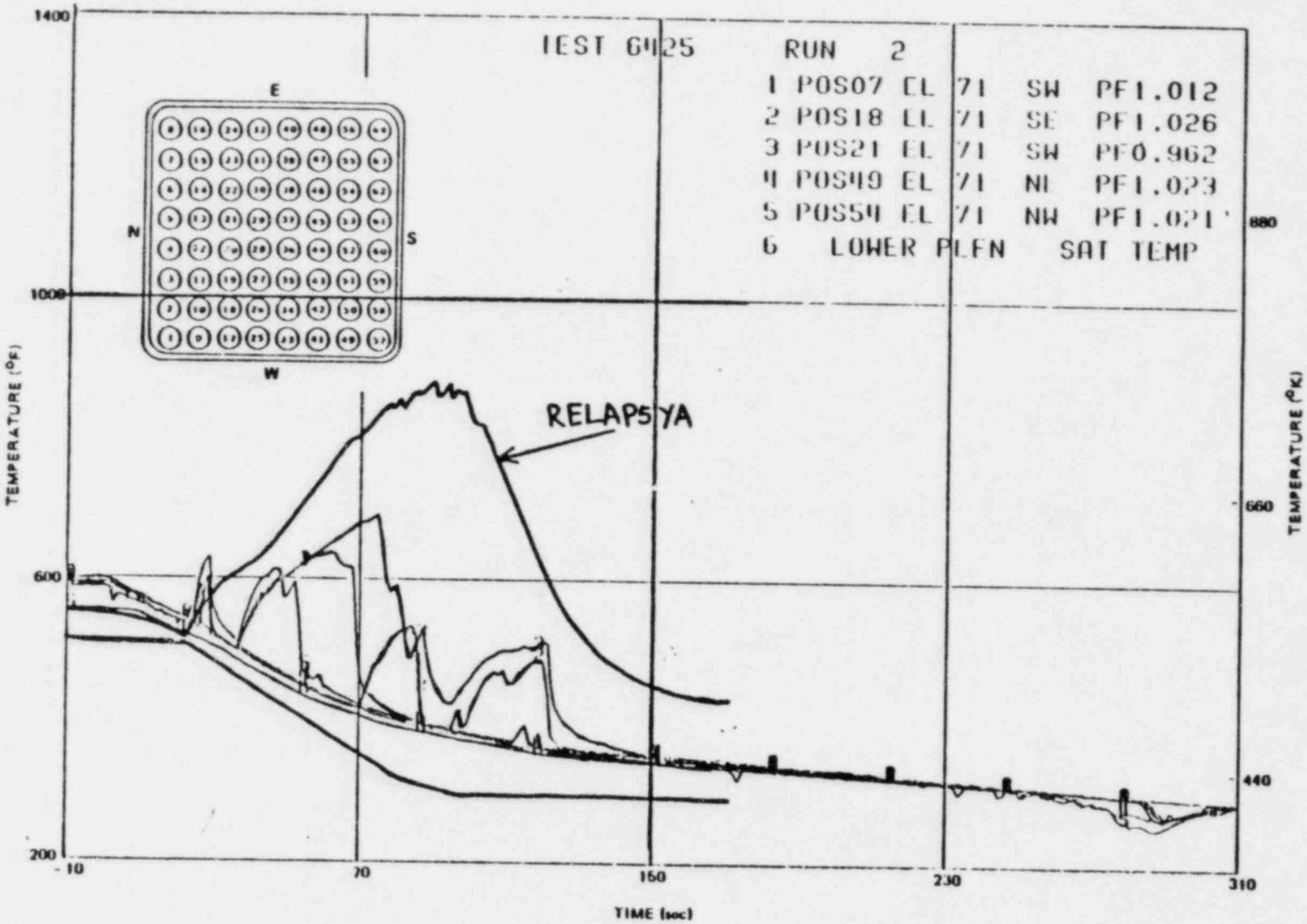


Figure J-91. Inside Clad Temperature-Elevation 71 in.

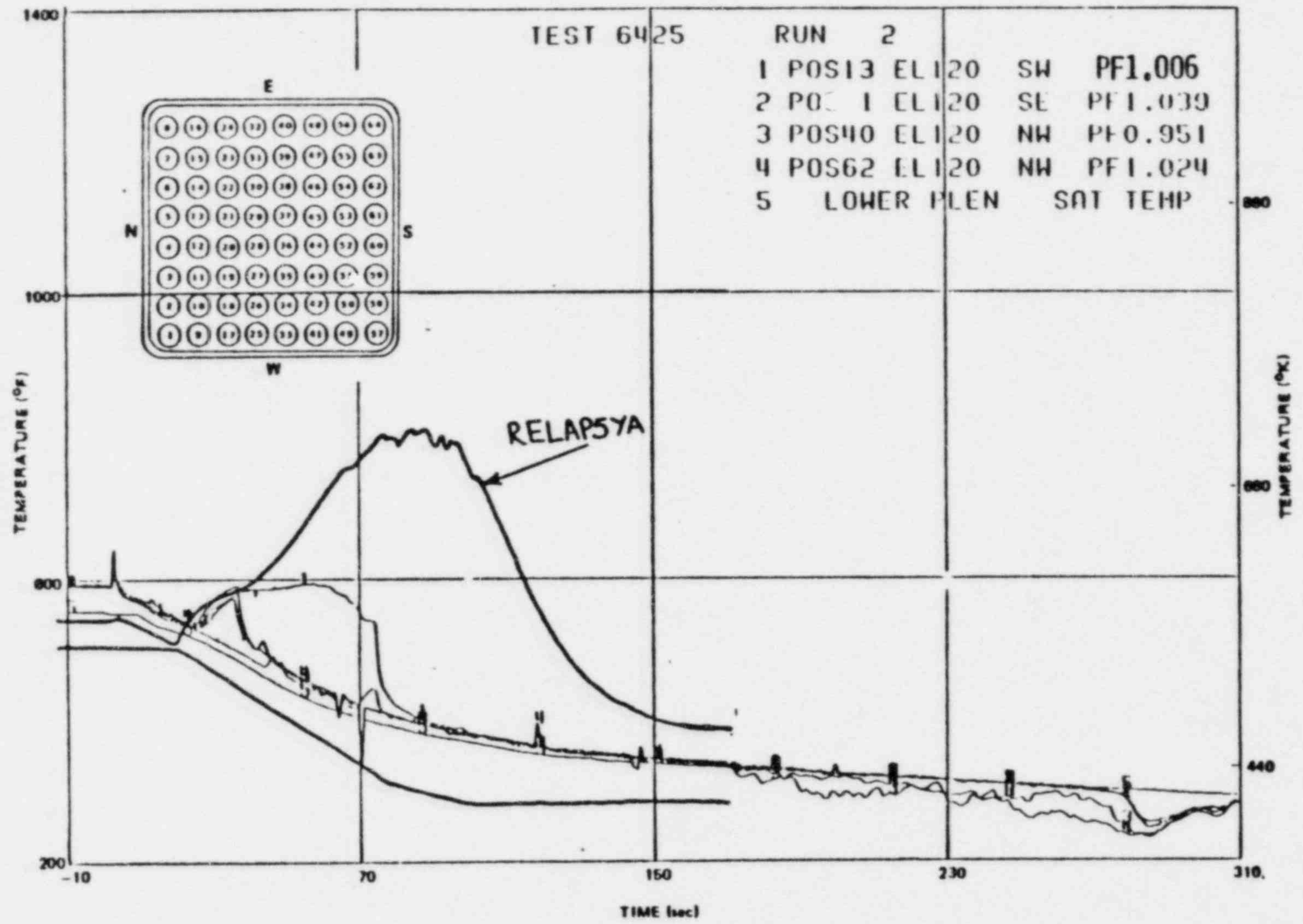


Figure J-83. Inside Clad Temperature-Elevation 120 in.

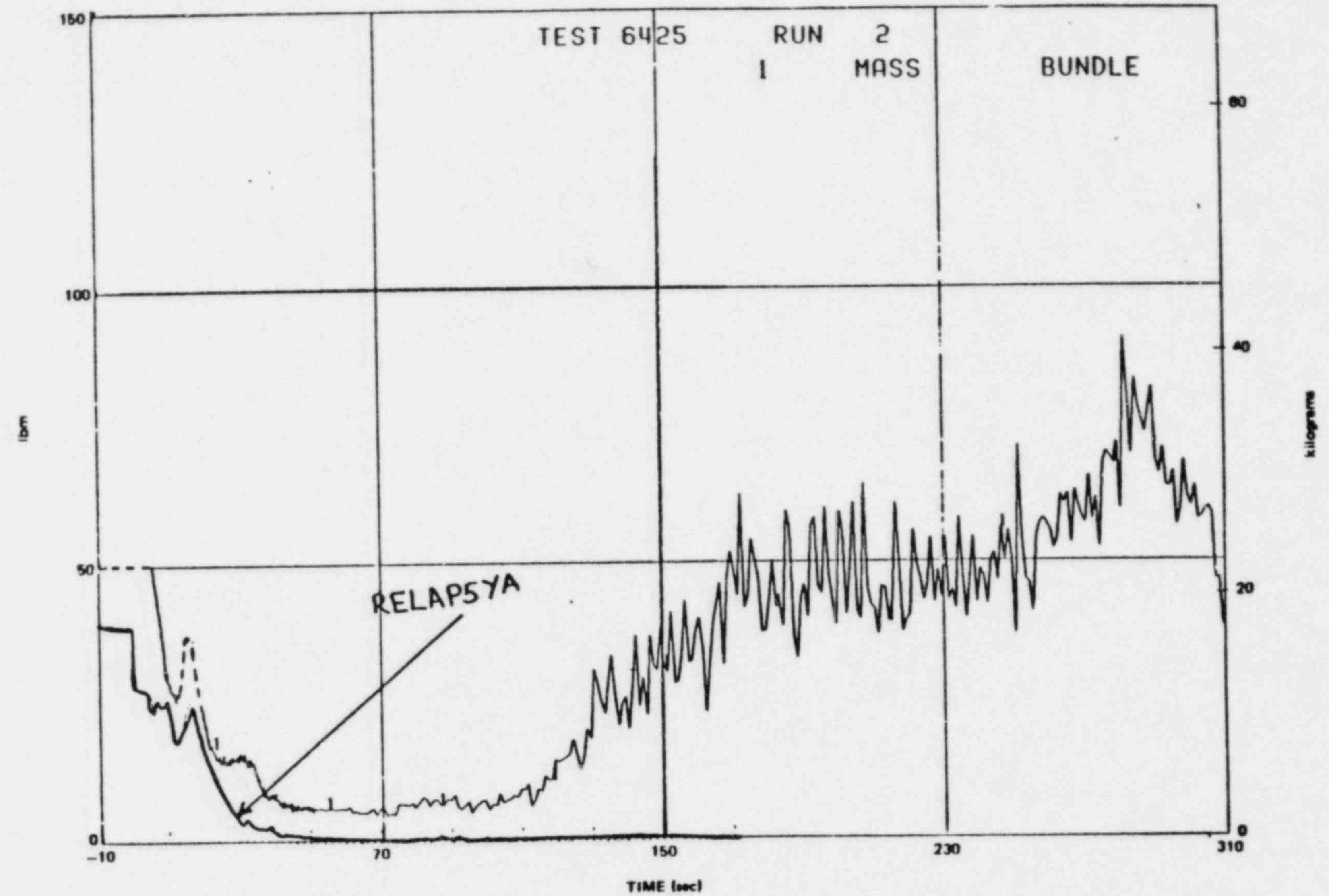


Figure J-50. Bundle Fluid Mass

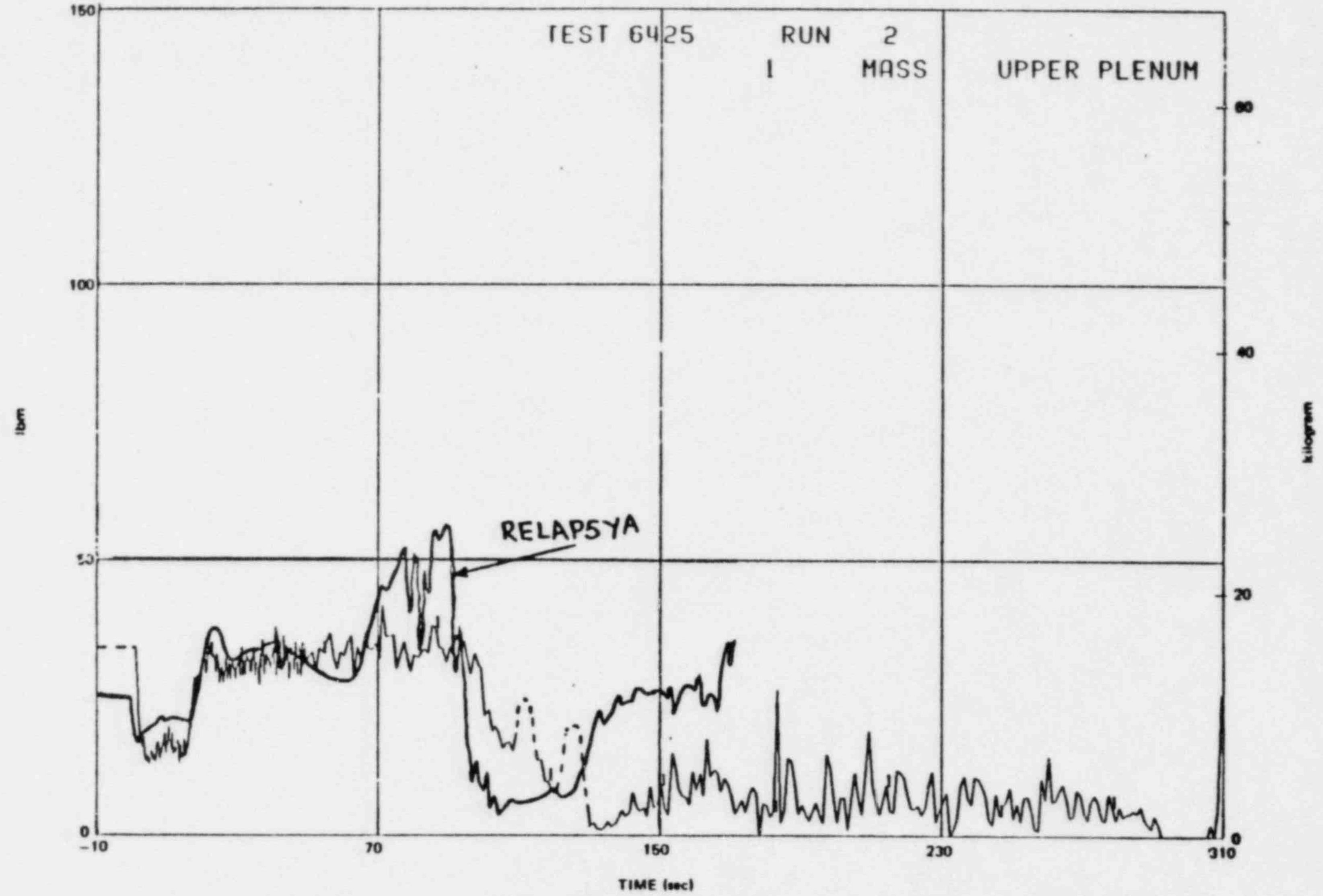


Figure J-54. Upper Plenum Fluid Mass

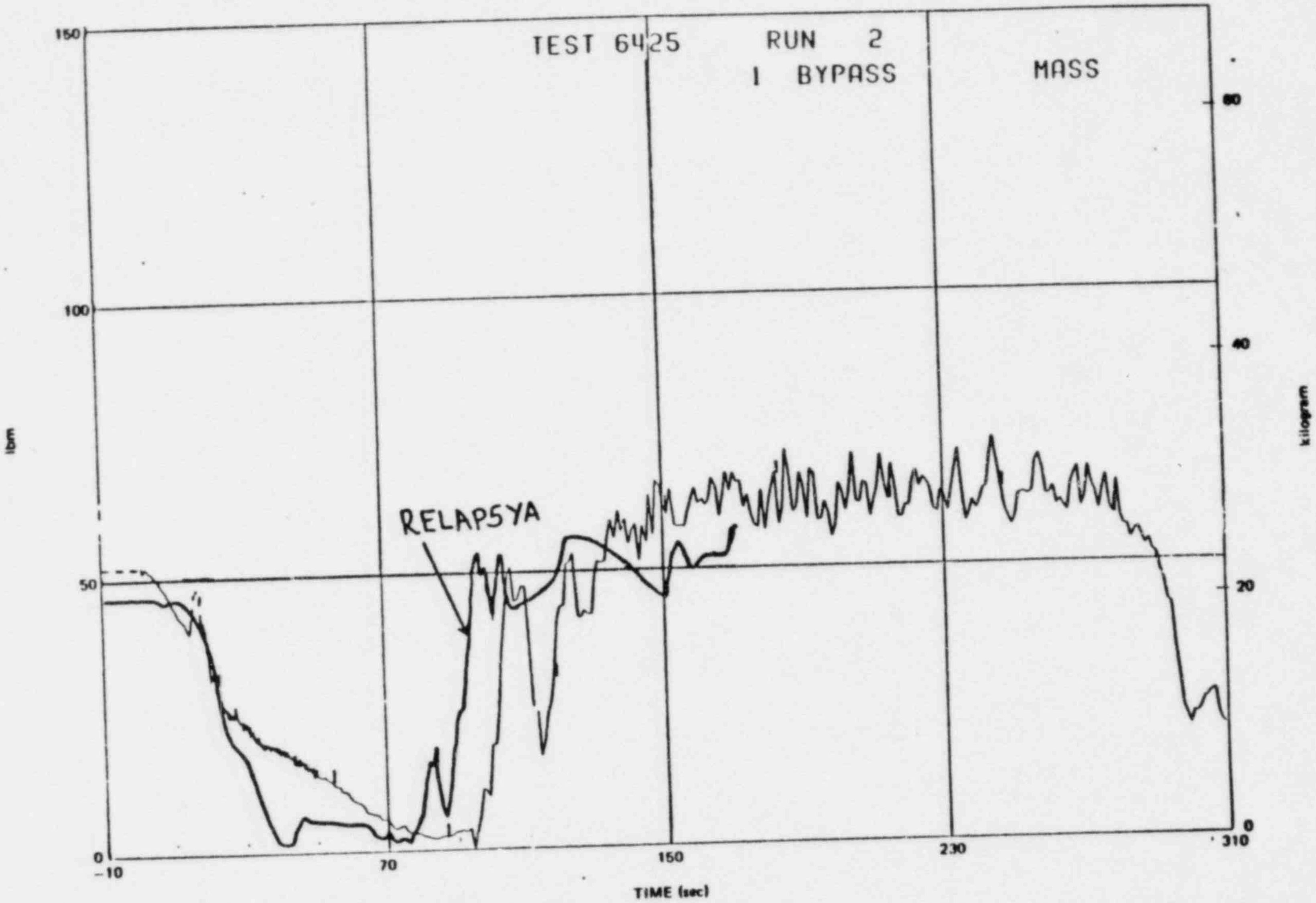


Figure J-53. Bypass Fluid Mass

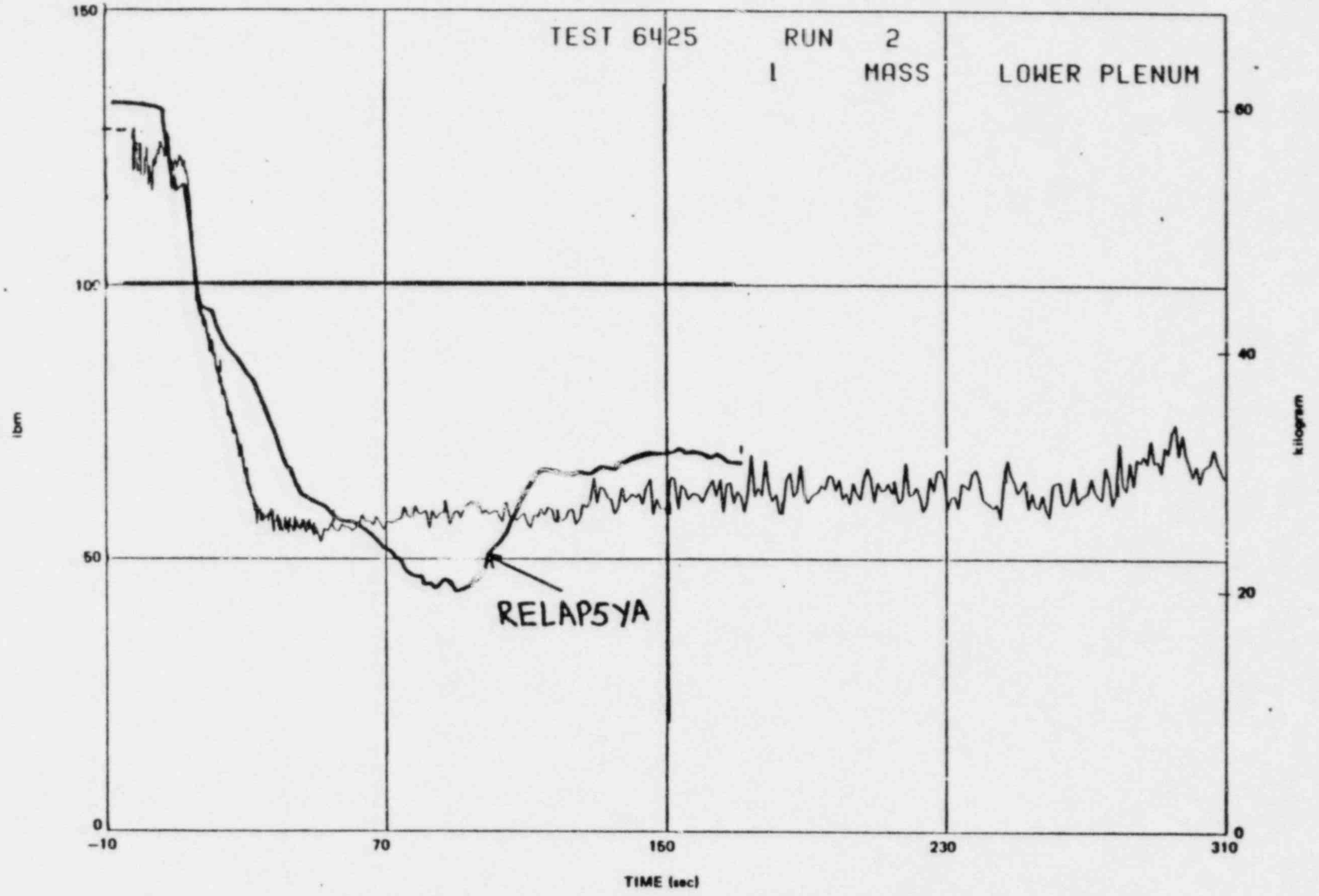


Figure J-49. Lower Plenum Fluid Mass

TLTA LARGE BREAK

TEST 6426/1

(AVG. POWER, NO ECC.)

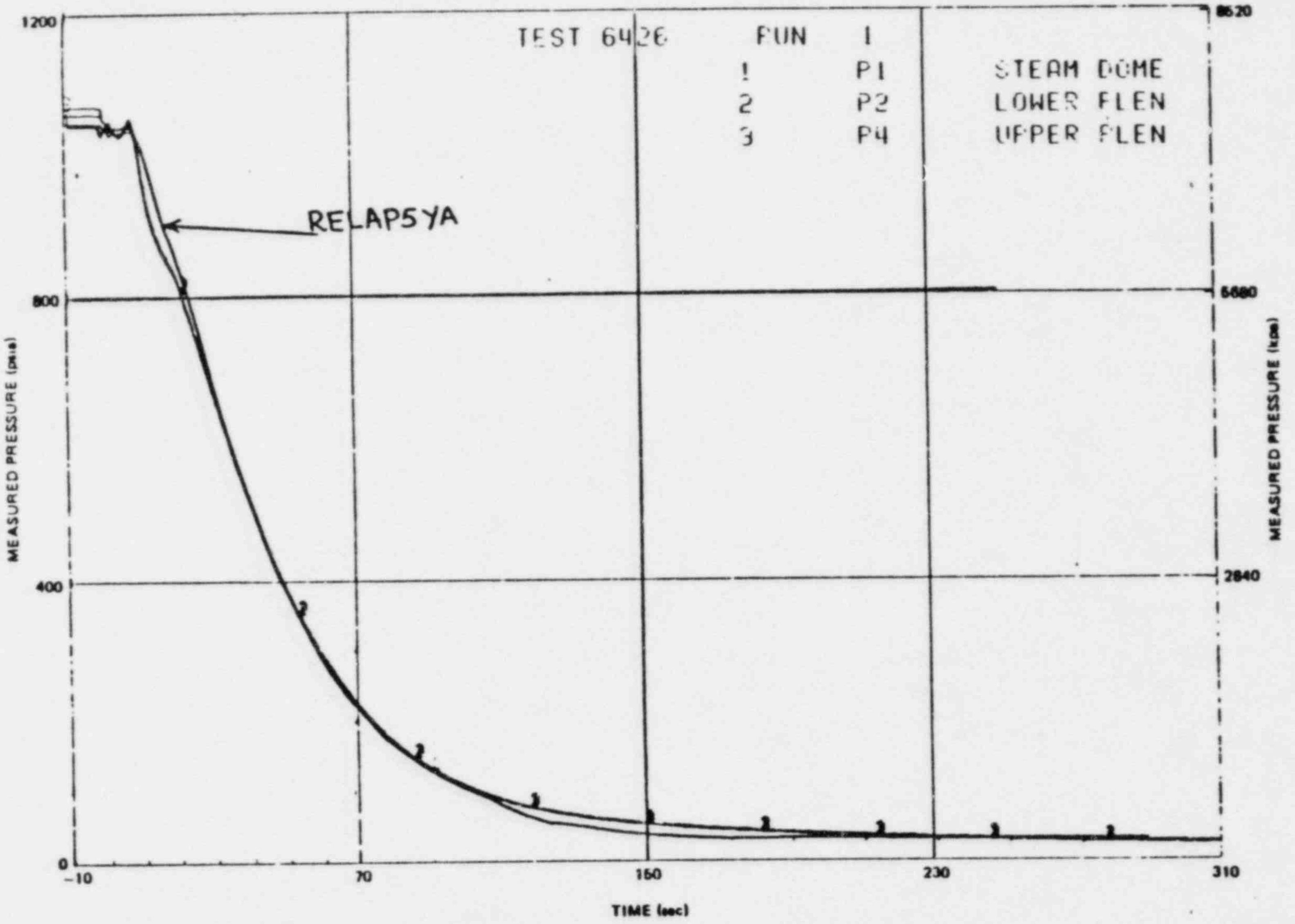


Figure L-5. System Pressures

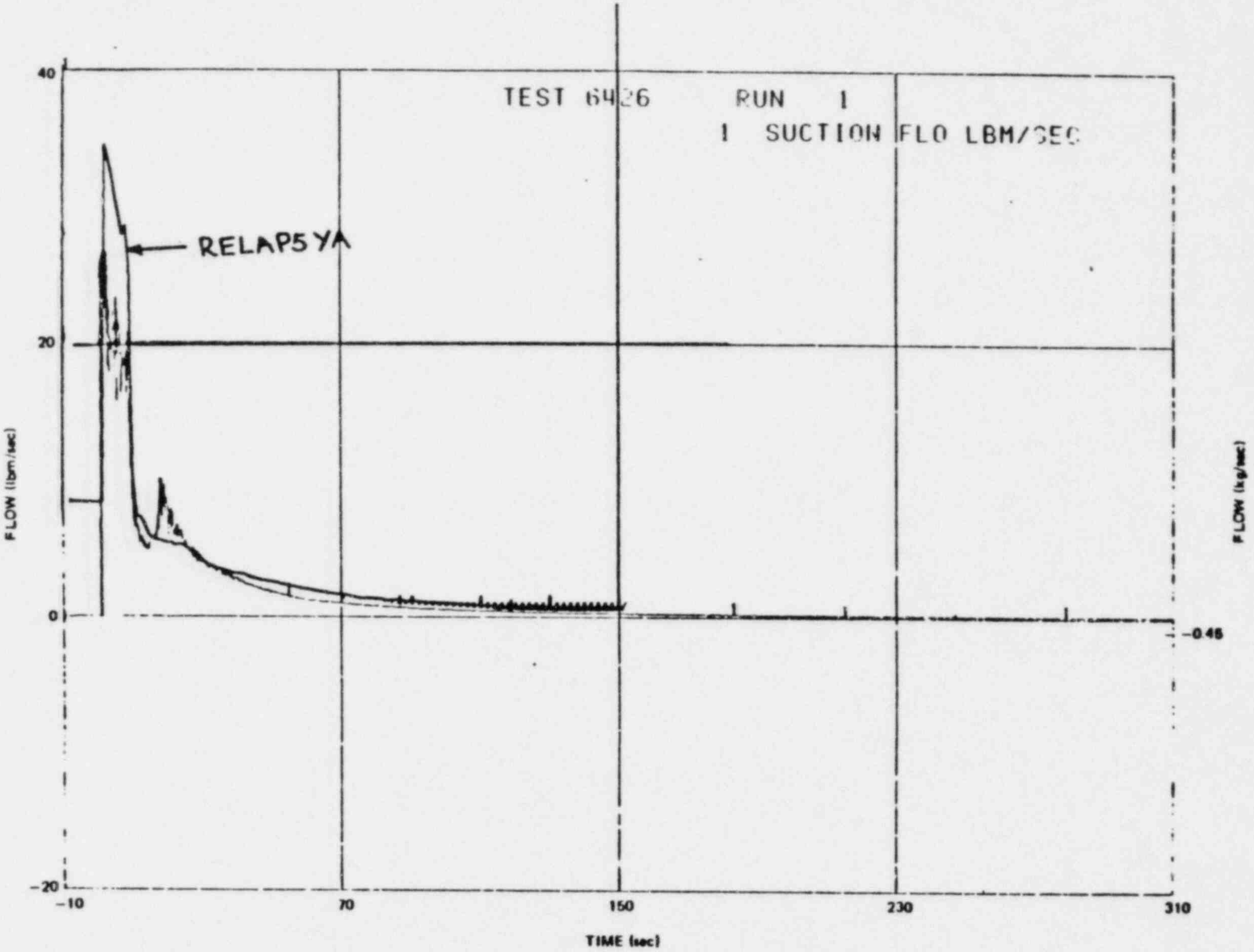


Figure L-50. Suction Line Break Mass Flow Rate

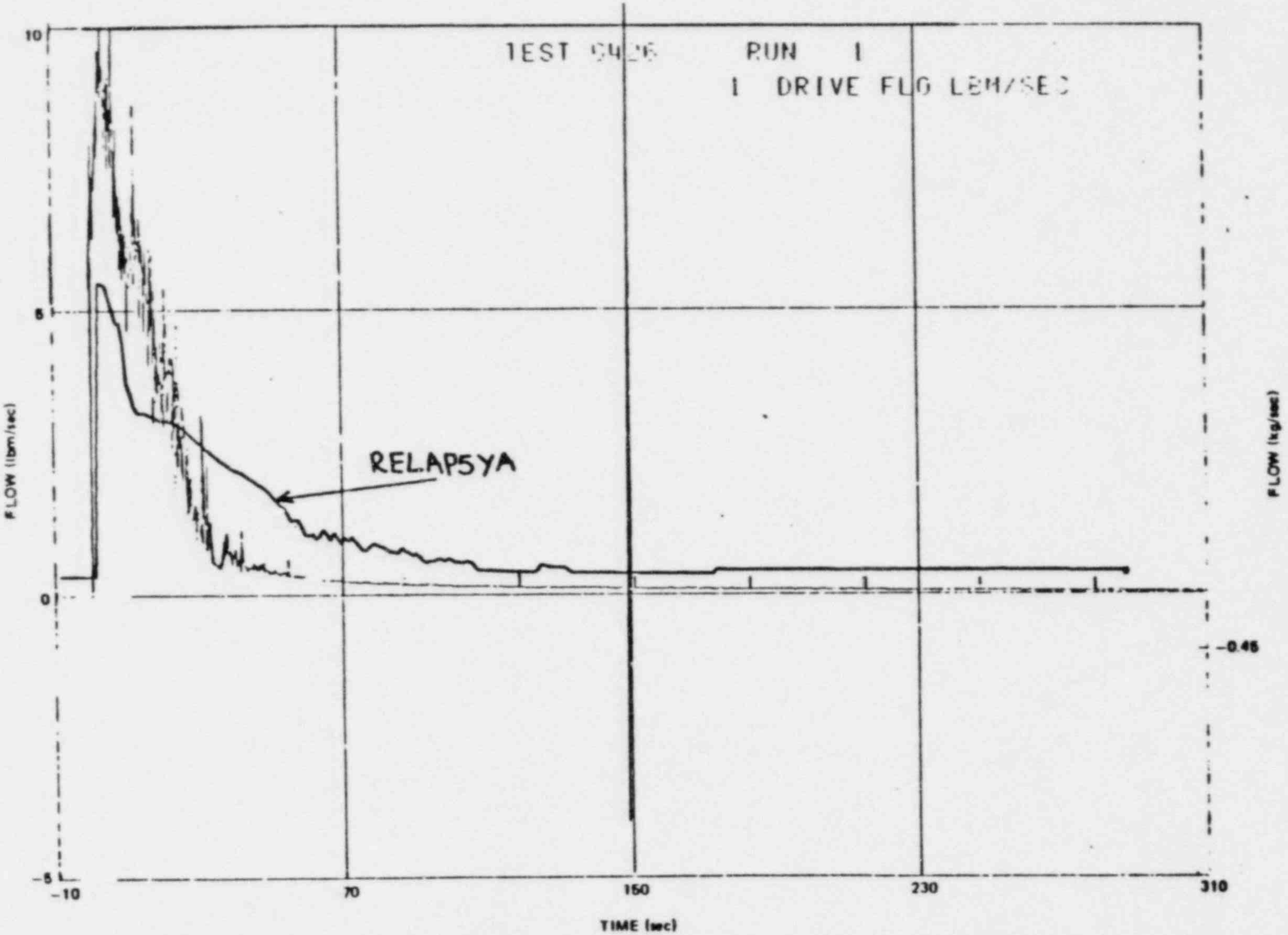


Figure L-49. Drive Line Break Mass Flow Rate

(2)

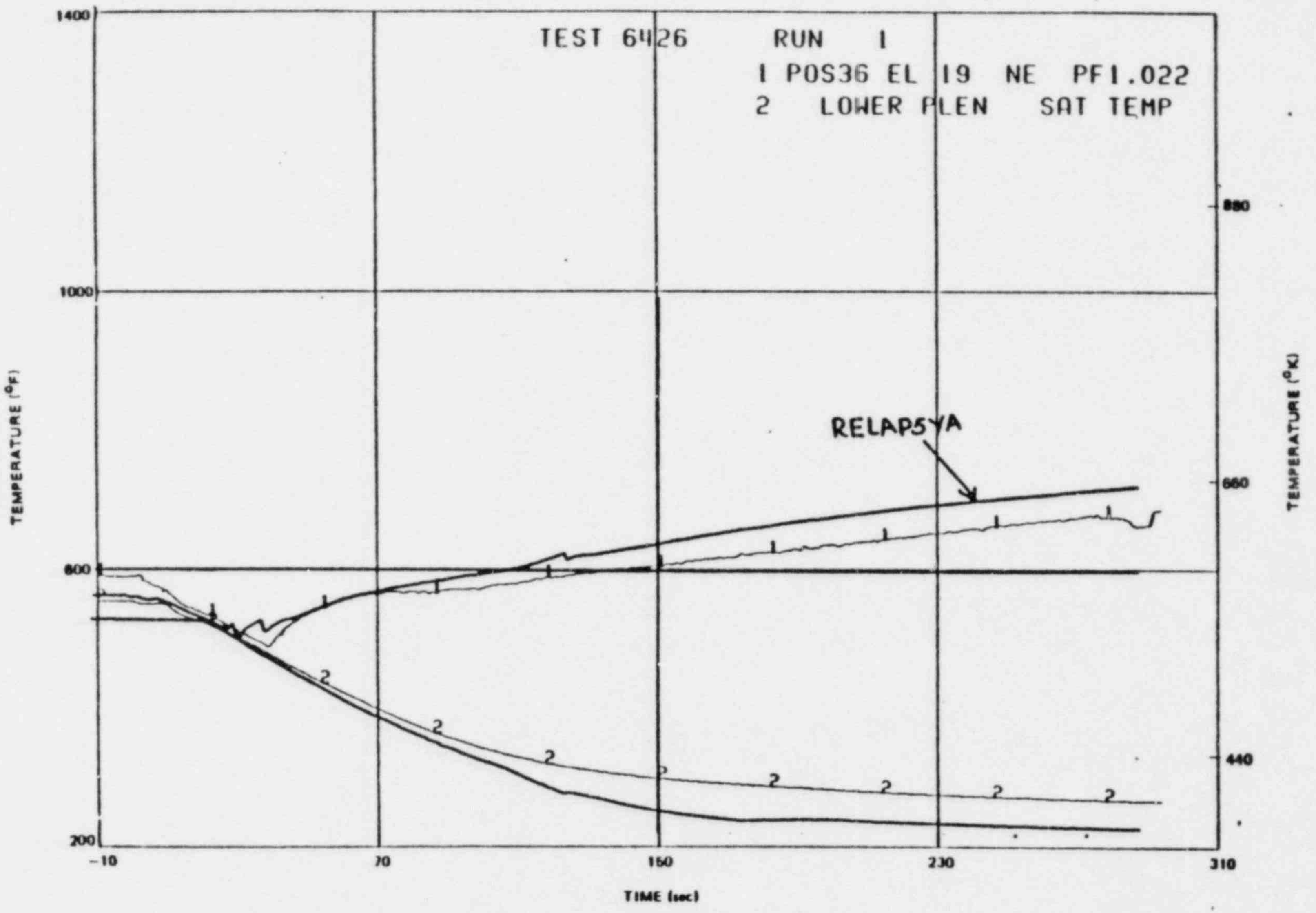


Figure L-76. Inside Clad Temperature - Elevation 19 in.

(5)

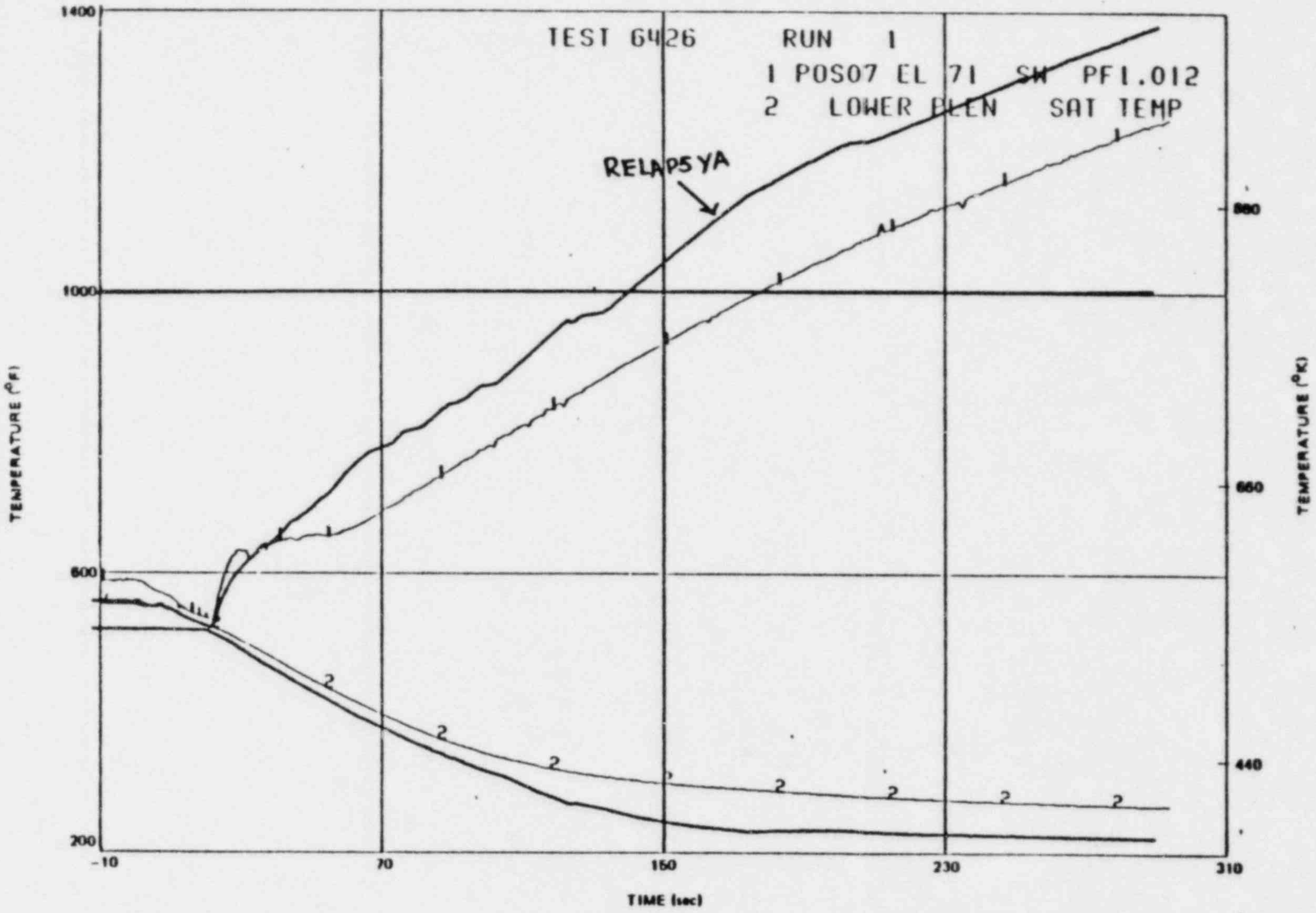


Figure L-74. Inside Clad Temperature - Elevation 71 in.

⑦

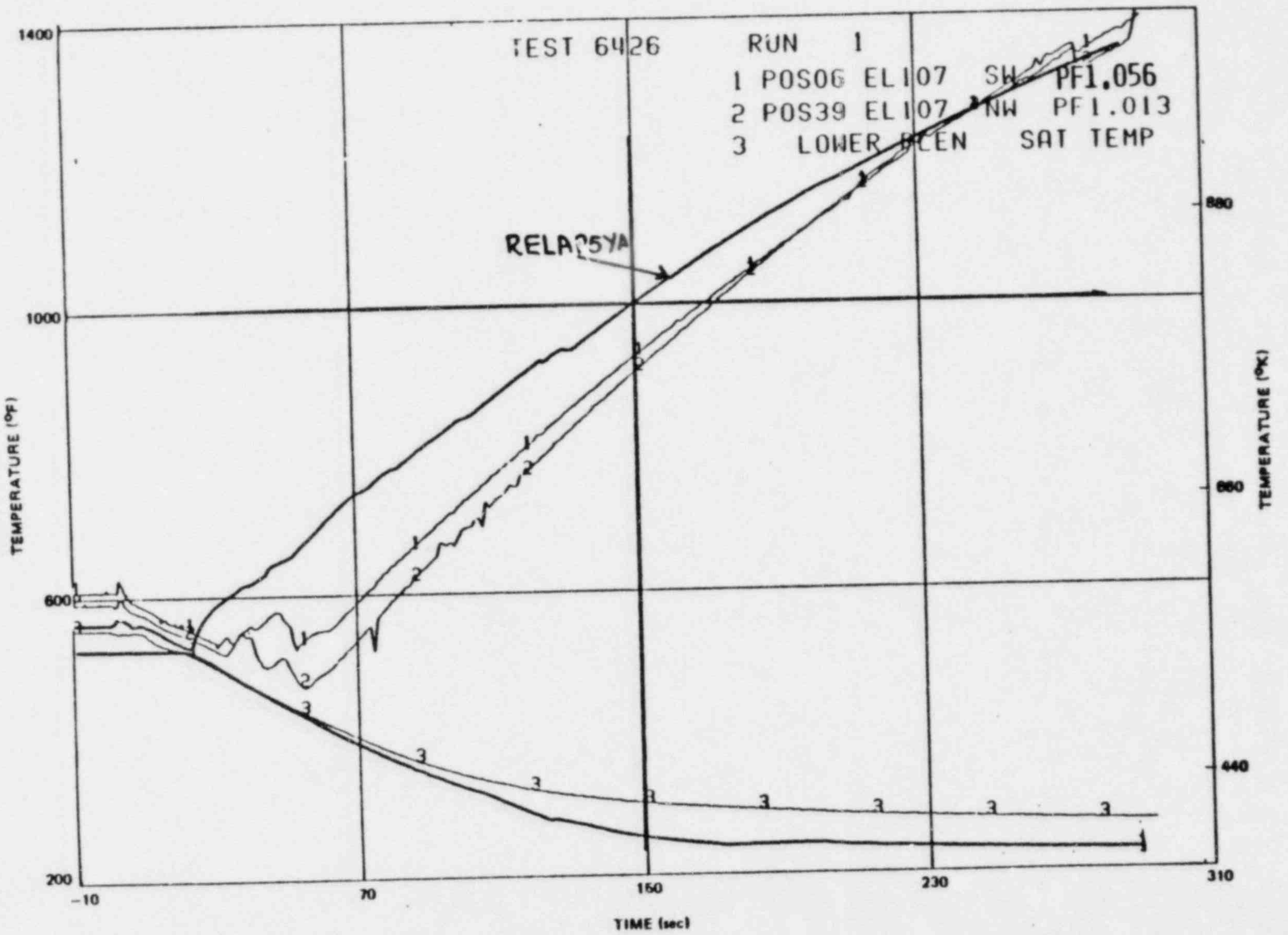


Figure L-69. Inside Clad Temperature - Elevation 107 in.

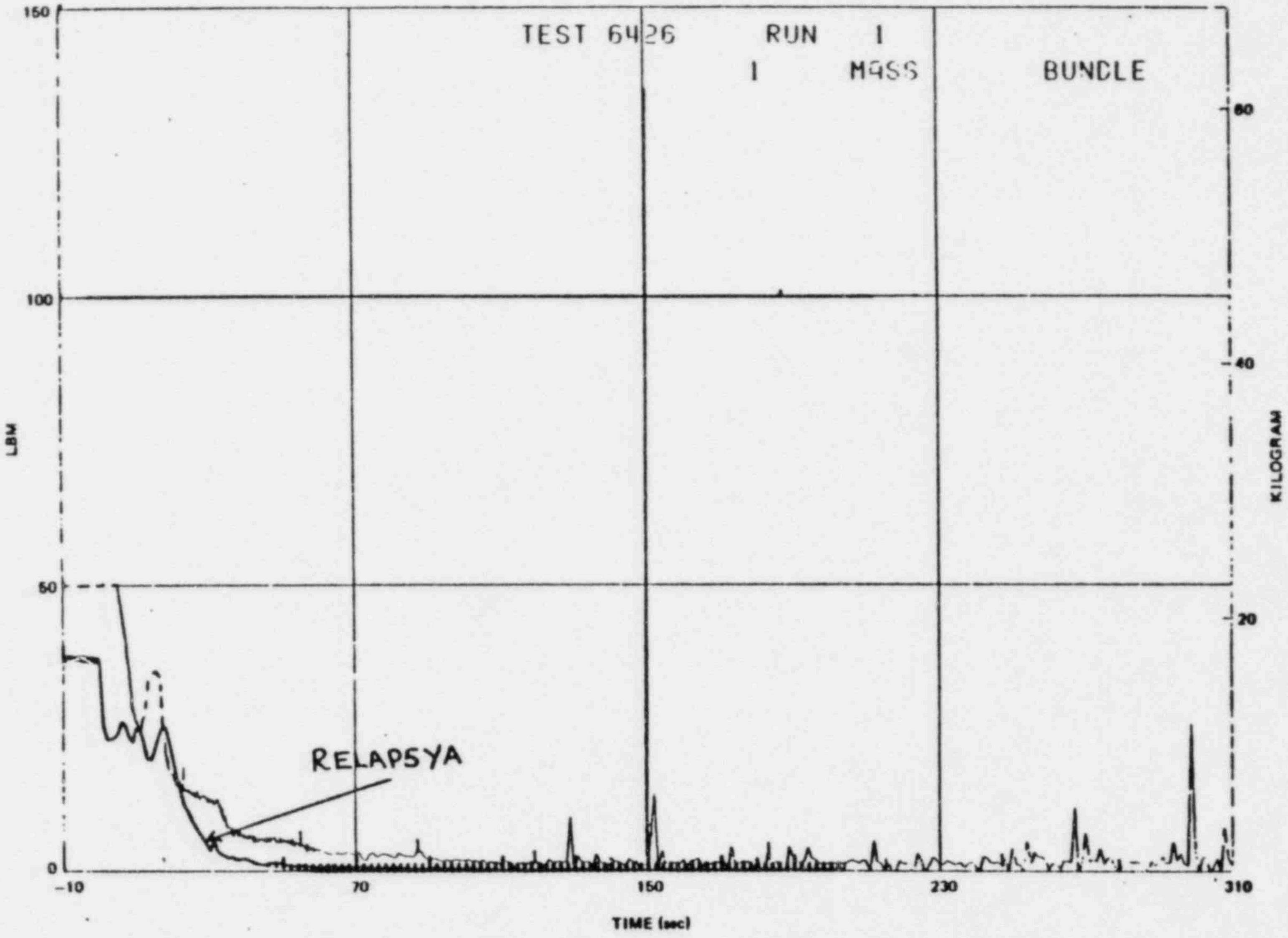


Figure L-39. Bundle Fluid Mass

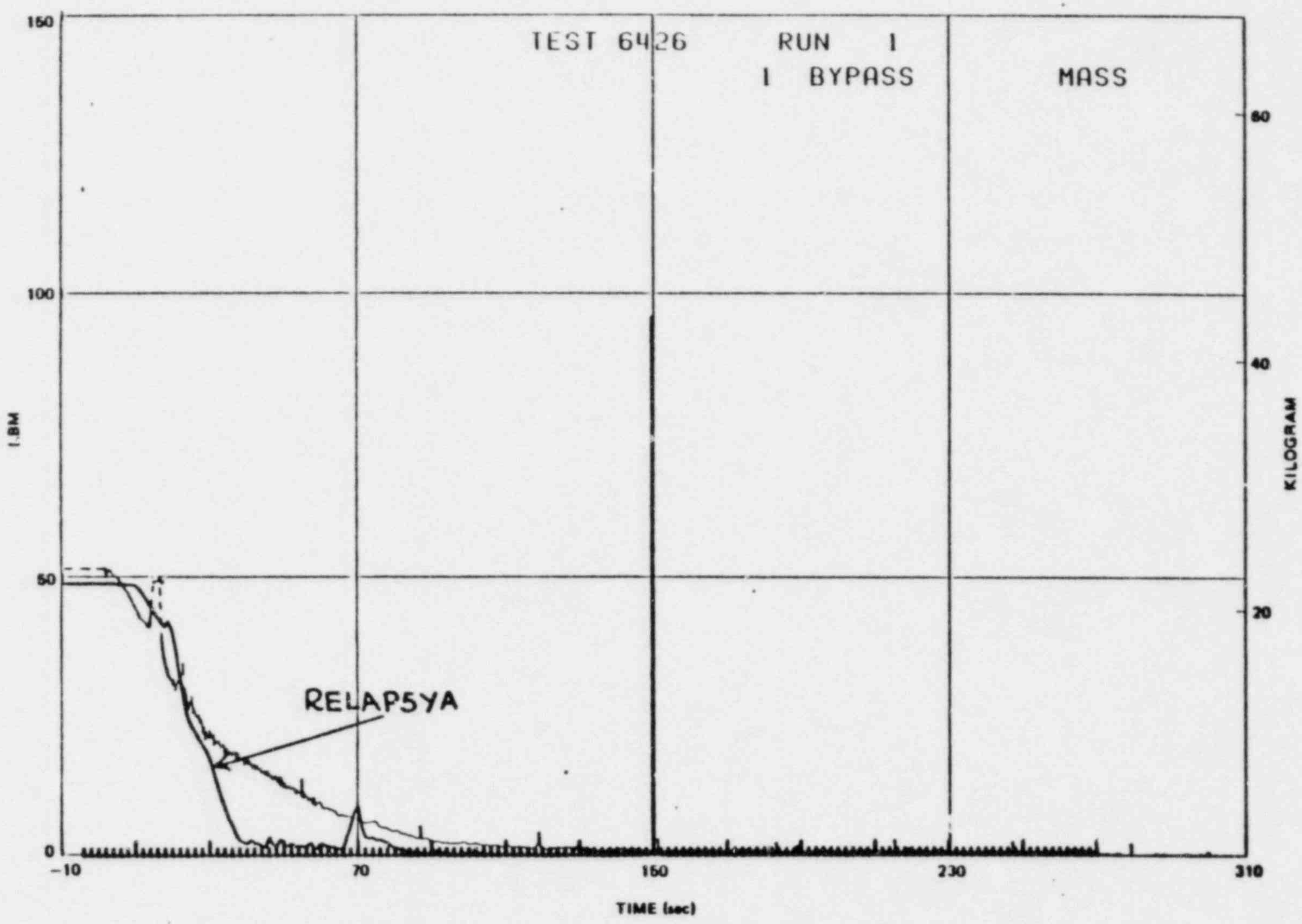


Figure L-42. Bypass Fluid Mass

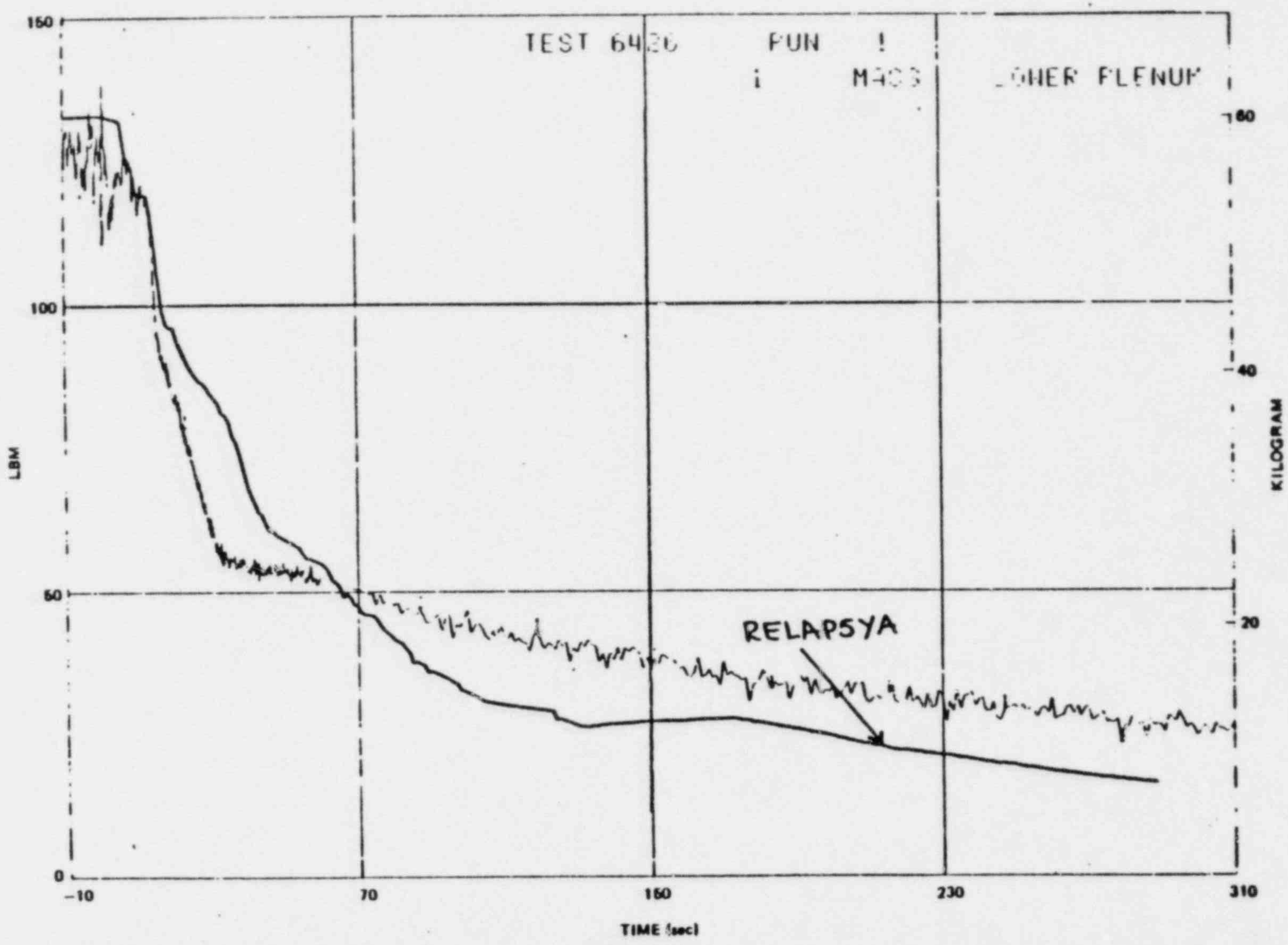


Figure L-38. Lower Plenum Fluid Mass

TLTA SMALL BREAK

TEST 6432/1

(DELAYED ADS
DEGRADED ECC)

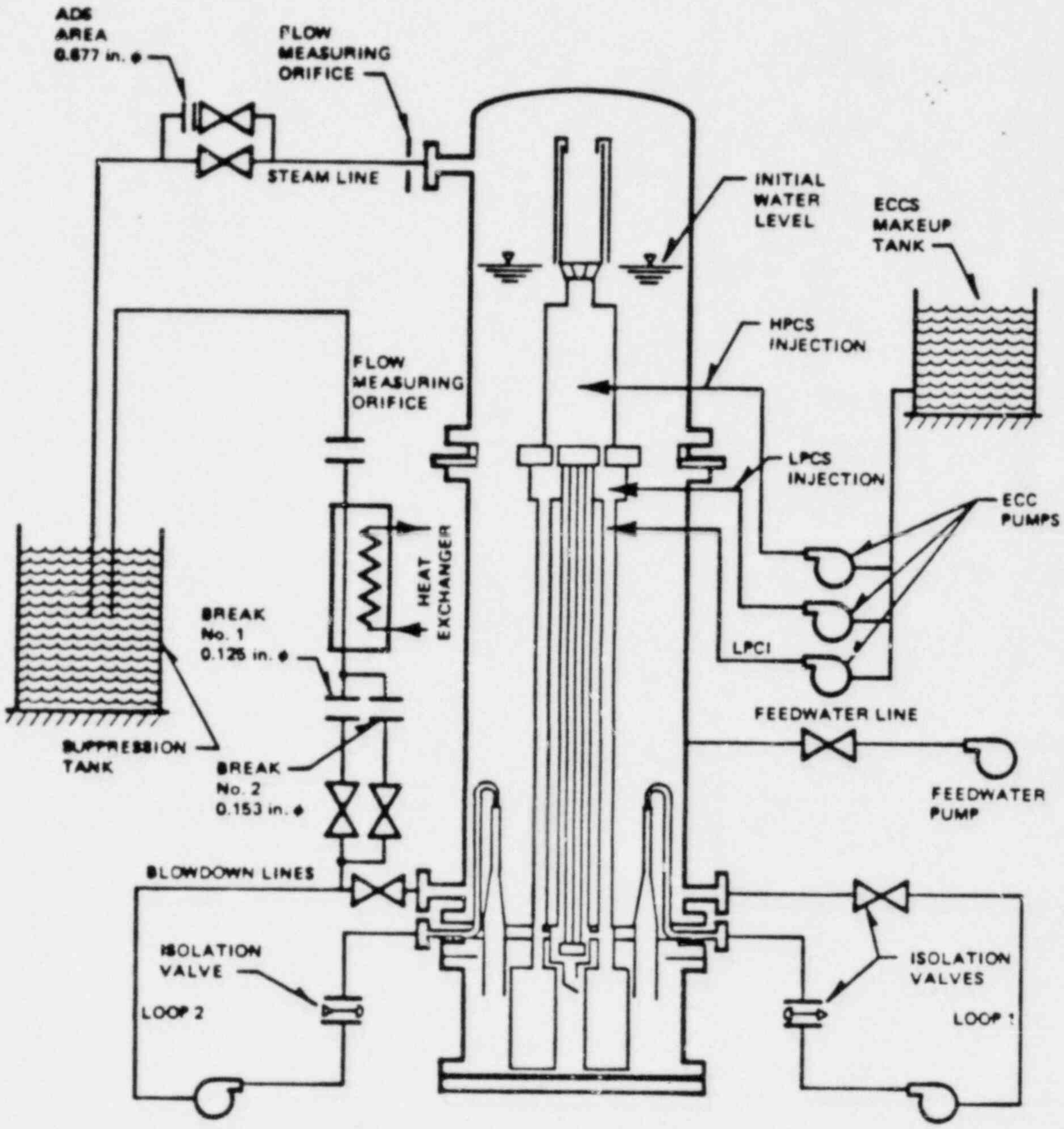


FIG: TLTA-5C CONFIGURATION FOR SMALL BREAK TEST II.

Table 4-2

COMPARISON OF TEST CONDITIONS

(TLTA Small Break Test No. II, 6432/Run 1)

Break Size	Specified	Measured
Line No. 1	0.125±0.001 in. diameter	0.125±0.001 in. diameter
Line No. 2	0.153±0.001 in. diameter	0.153±0.001 in. diameter
ADS Orifice Size	0.677±0.001 in. diameter	0.677±0.001 in. diameter
ECCS		
Inlet Fluid Temperature	80±15°F	90±4°F
HPCS	HPCS deactivated	deactivated
LPCS (see Figure 2-6)	activated	activated
LPCI (see Figure 2-7)	activated	activated
Initial Condition		
Steam Dome Pressure	1050±20 psia	1048±5 psia
Water Level (Outside Shroud)	283±6 in. EL	283±3 in. EL
Bundle Flow (Core Flow)	34±5 lbm/sec.	34±5 lbm/sec.
Bypass Flow, Total	1.5±0.5 lbm/sec.	2.1±0.5 lbm/sec.
Steam Flow	1.4±0.5 lbm/sec.	1.6±0.5 lbm/sec.
Bundle Inlet Subcooling	23±5°F	21±4°F
Downcomer Temperature		
Above F.W. Sparger	T sat	553±4°F
Below F.W. Sparger	(T sat-23°F)±5°F	532±4°F
Timings		
Pump No. 1 Trip	0.0±0.2 sec.	0.0±0.1 sec.
Pump No. 2 Trip	4.0±1.0 sec.	4.0±0.2 sec.
Feed Water Trip	0.0±0.5 sec.	0.1±0.5 sec.
Break Open Line No. 1	t≥140 sec.±1 sec.	t≥138±1 sec.
Break Open Line No. 2	140≤t≤286 sec.	138±1≤t≤286±1 sec.
ADS Opening	286±2 sec.	286±1 sec.
MSIV (Steam Valve) Closure	166±2 sec.	165±1 sec.
ECCS Activated	37±1 sec.	37±1 sec.
Intact Recirculation Loop (No. 1 Isolated)	20±1 sec.	20±0.5 sec.

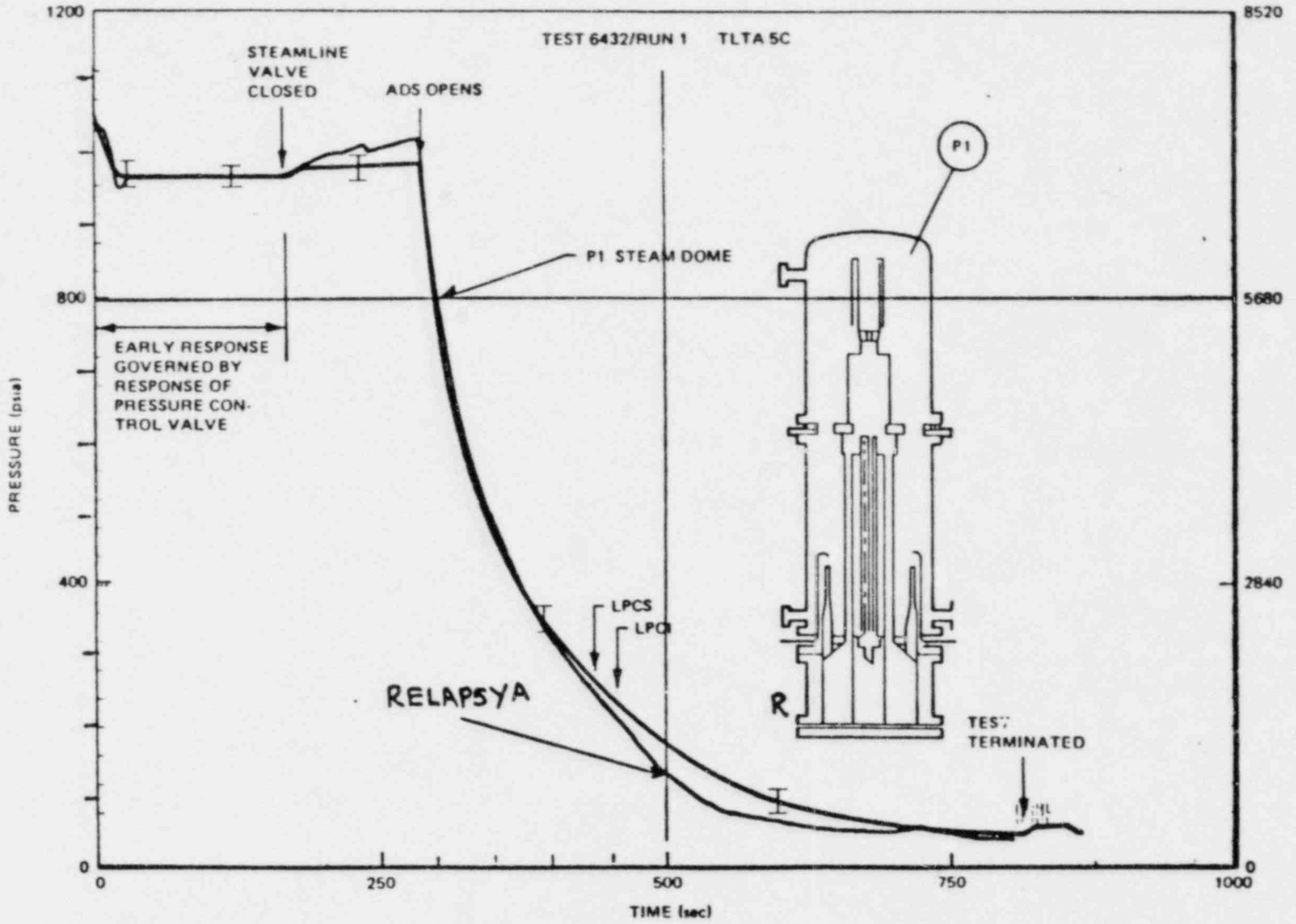


Figure D-2. System Pressure

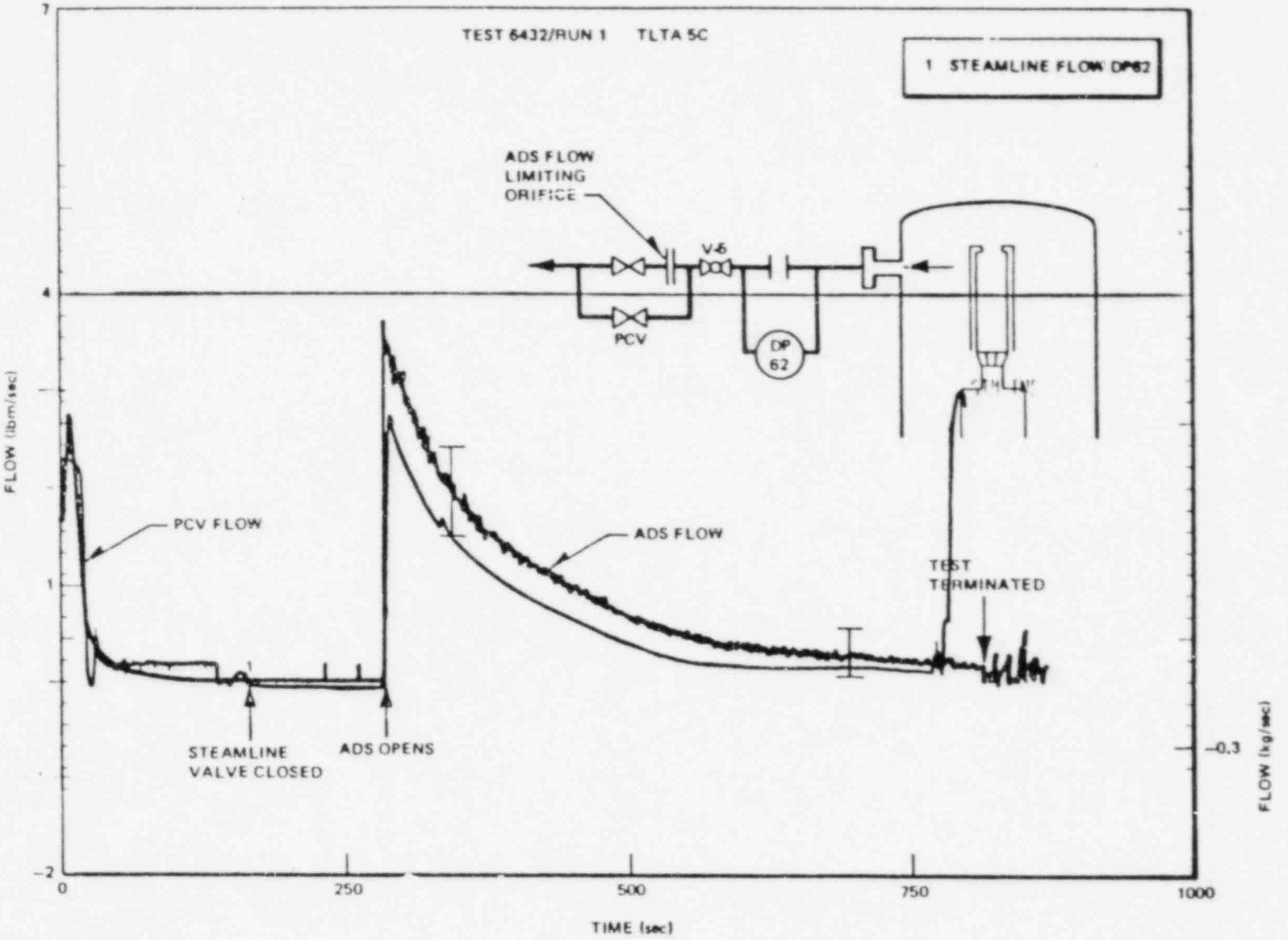


Figure D-5. Steam Line Flow

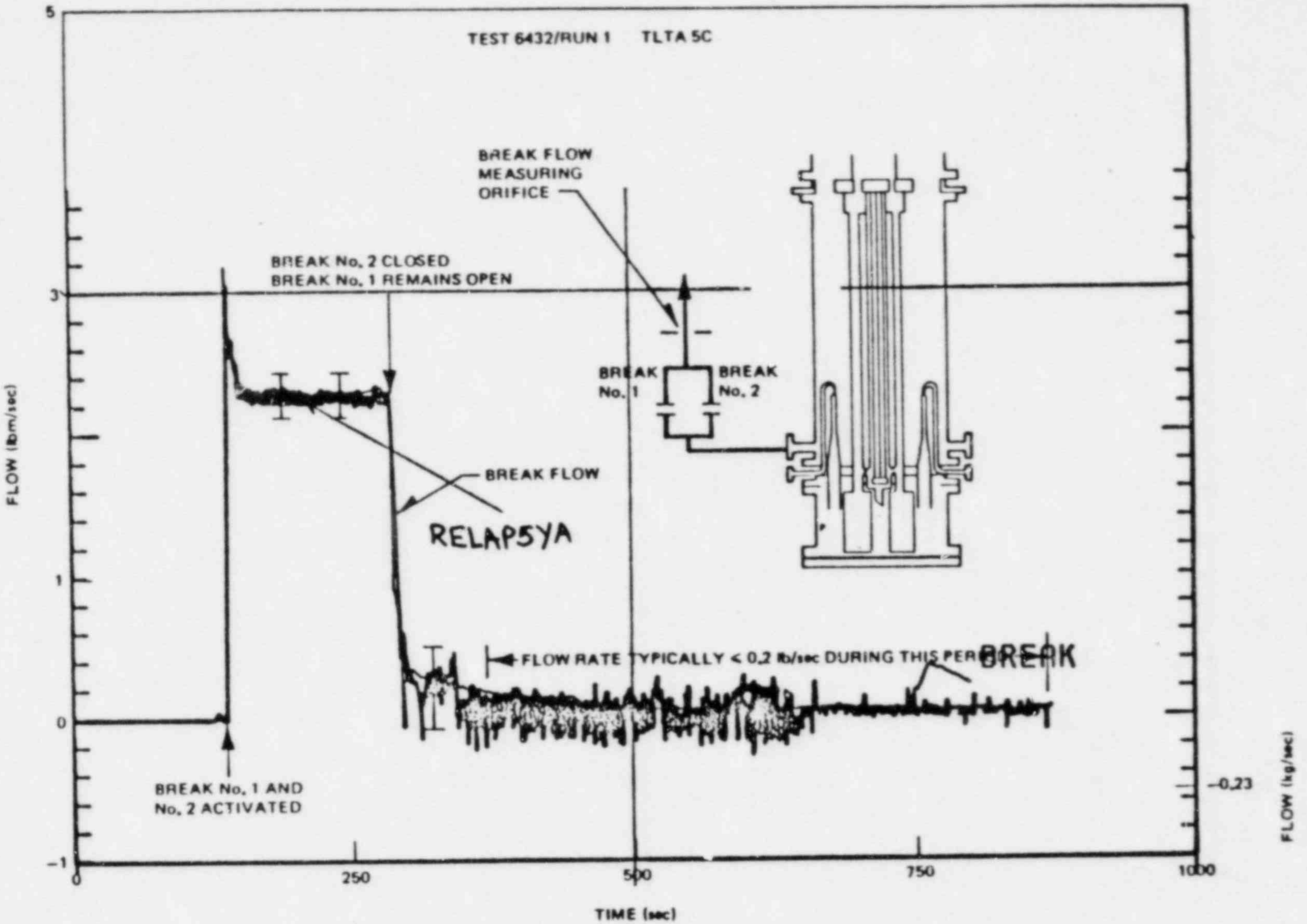


Figure D-8. Break Flow

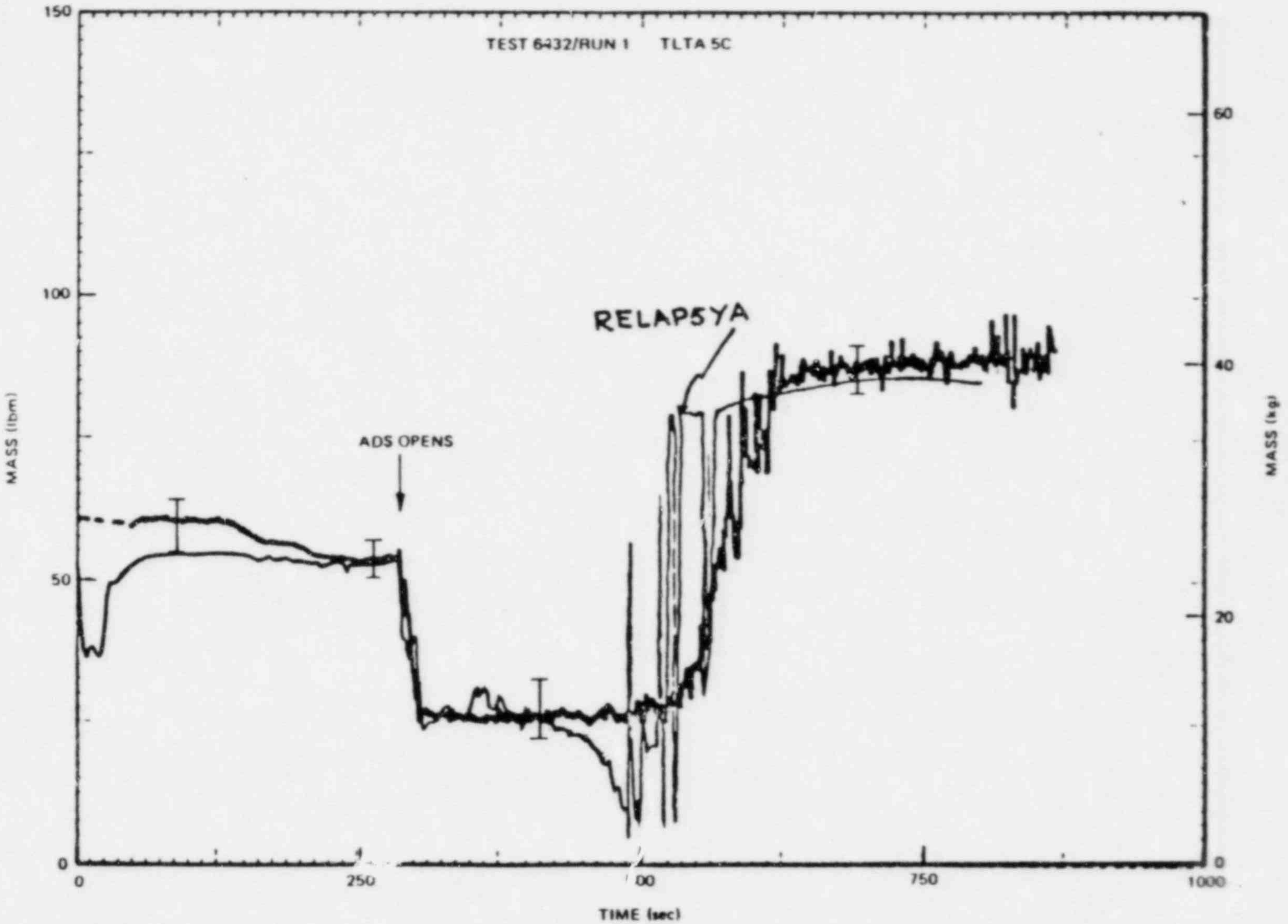
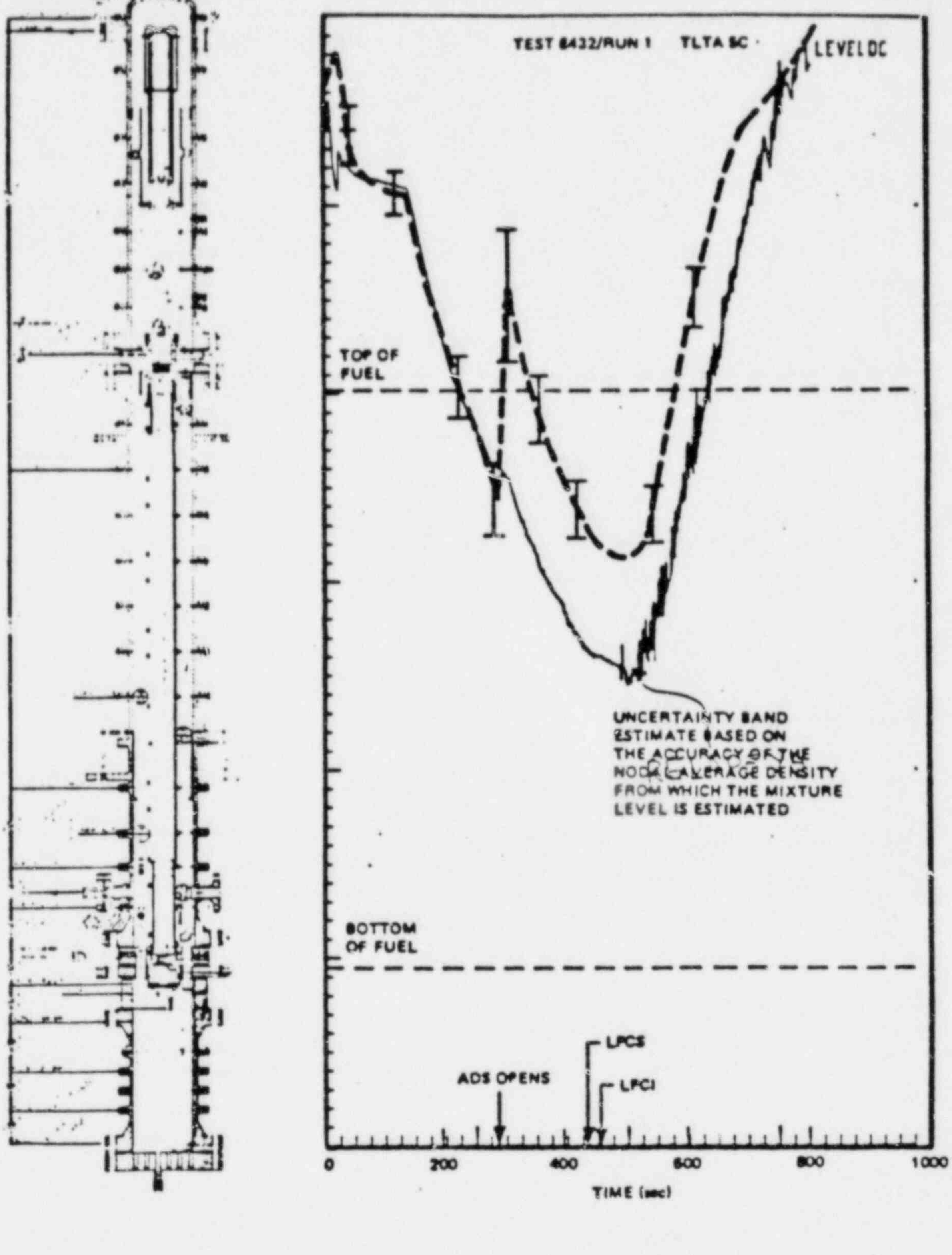


Figure D-58. Bundle Mass



UNCERTAINTY BAND ESTIMATE BASED ON THE ACCURACY OF THE NODAL AVERAGE DENSITY FROM WHICH THE MIXTURE LEVEL IS ESTIMATED

Figure D-10. Two-Phase Mixture Level - Outside the Shroud

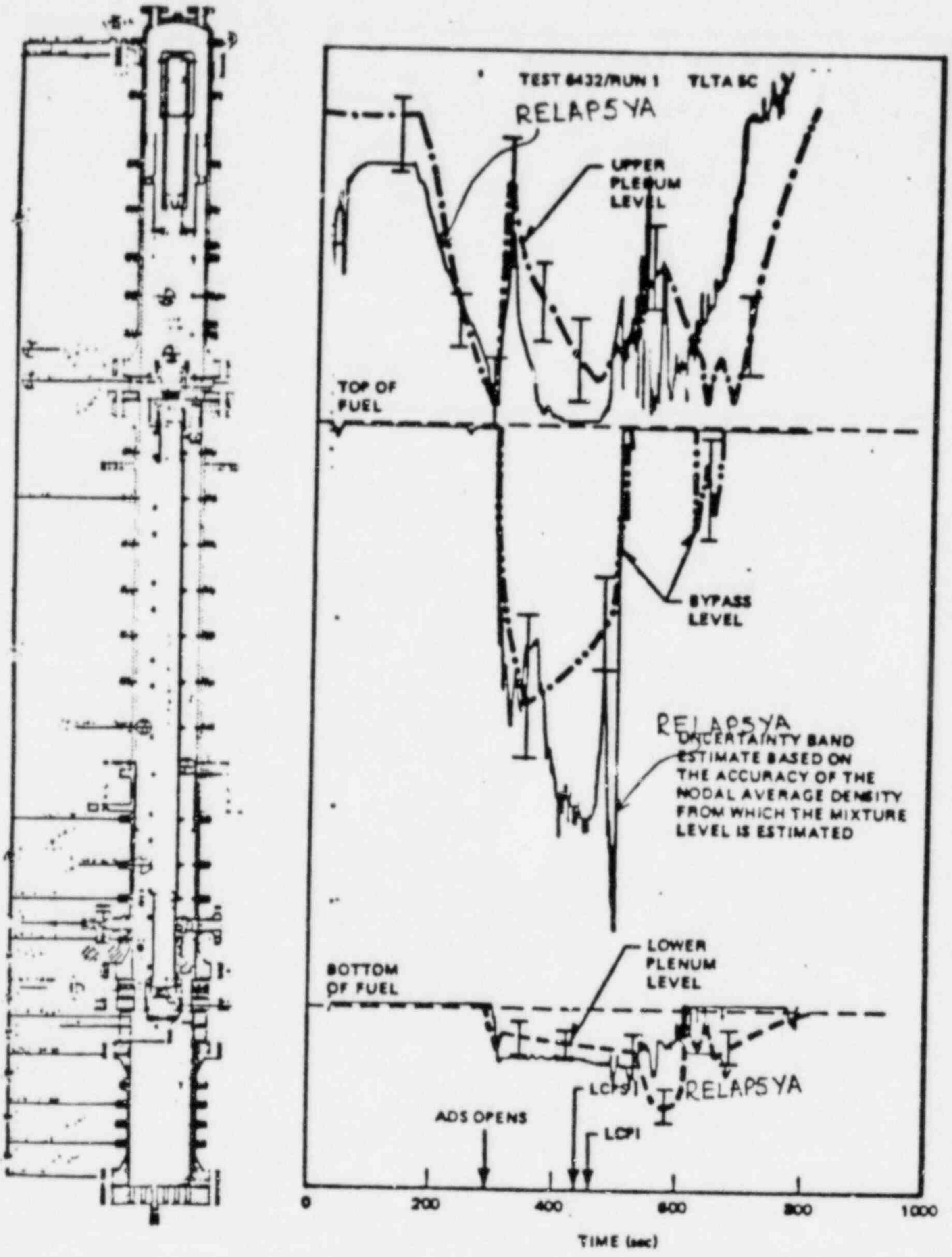
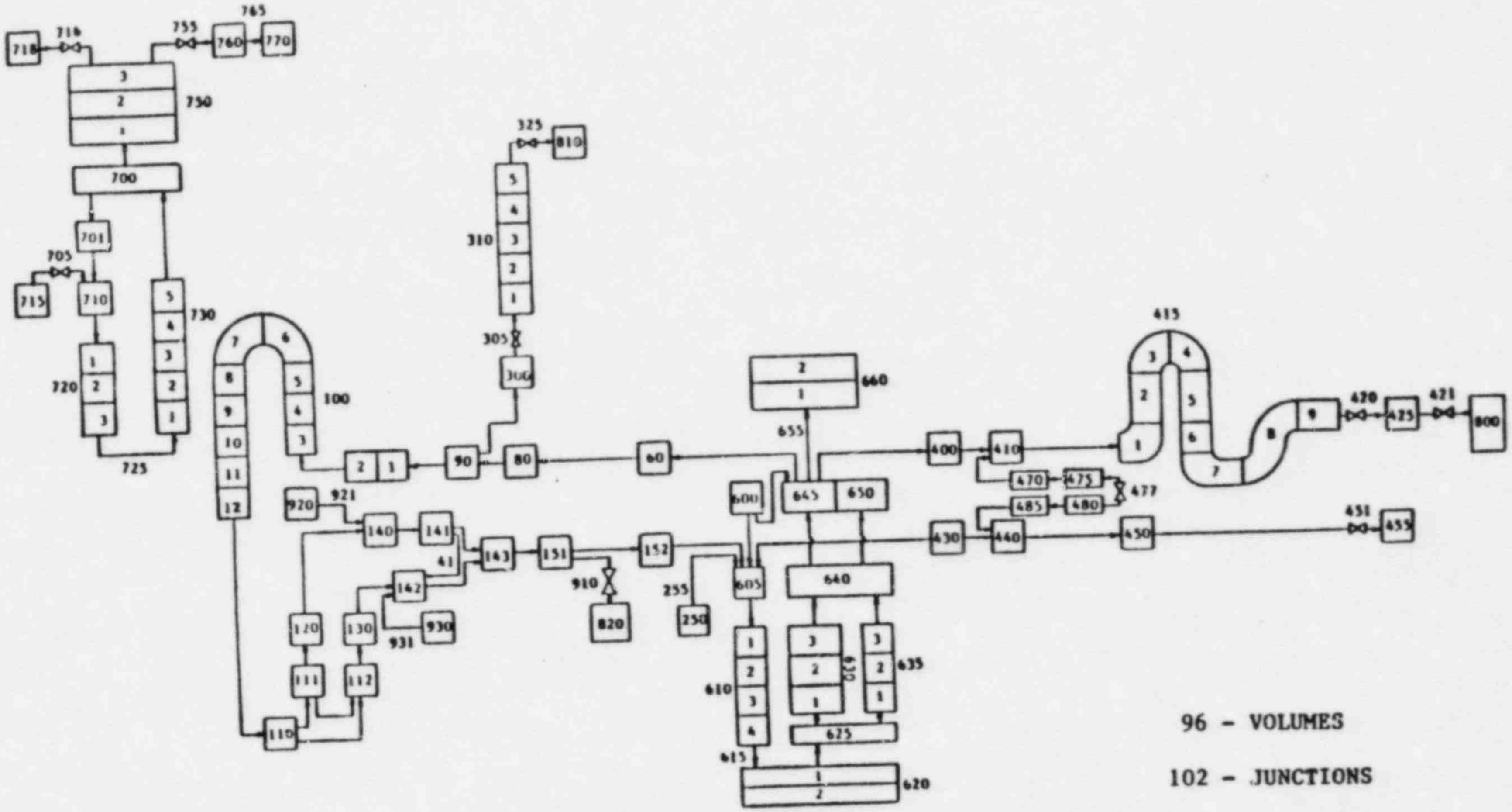


Figure D-9. Two-Phase Mixture Level - Inside the Shroud

LOFT L3-6

- BACKGROUND
- MODEL DESCRIPTION
- COMPARISON TO DATA
    - PRESSURE
    - BREAK FLOW
    - DENSITY
    - SYSTEM INVENTORY
- SUMMARY

RELAP5YA LOFT L3-6 NODALIZATION

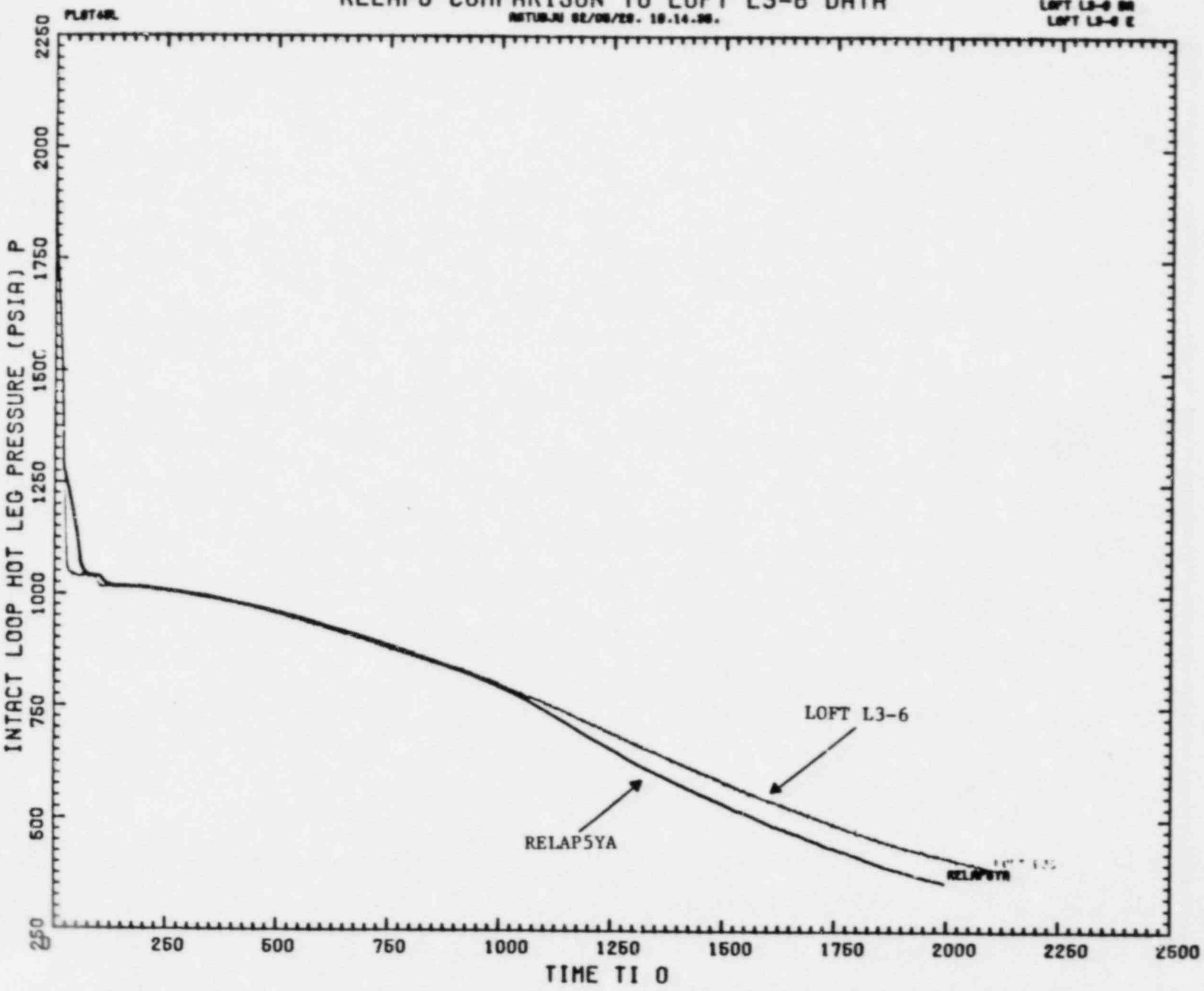


96 - VOLUMES

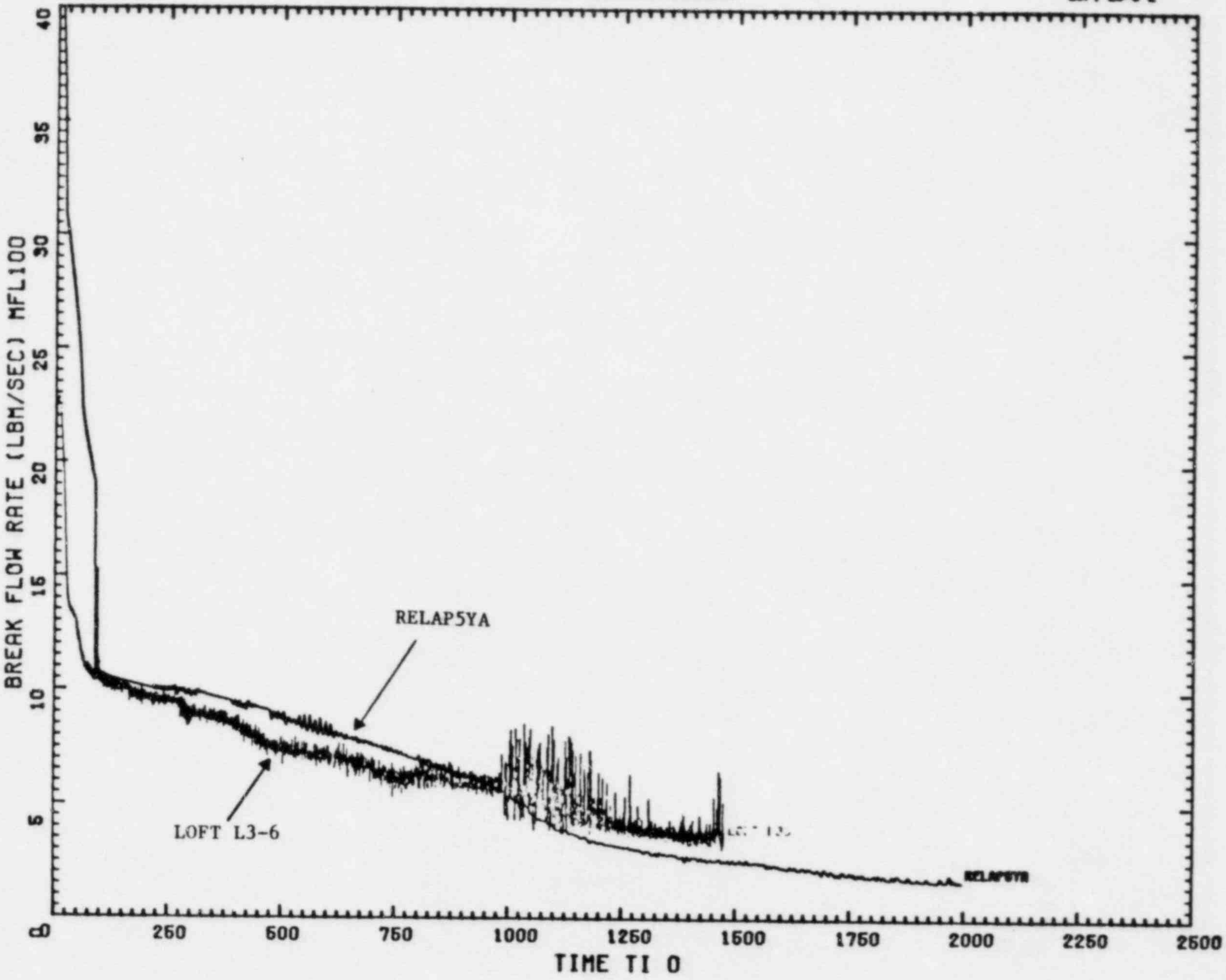
102 - JUNCTIONS

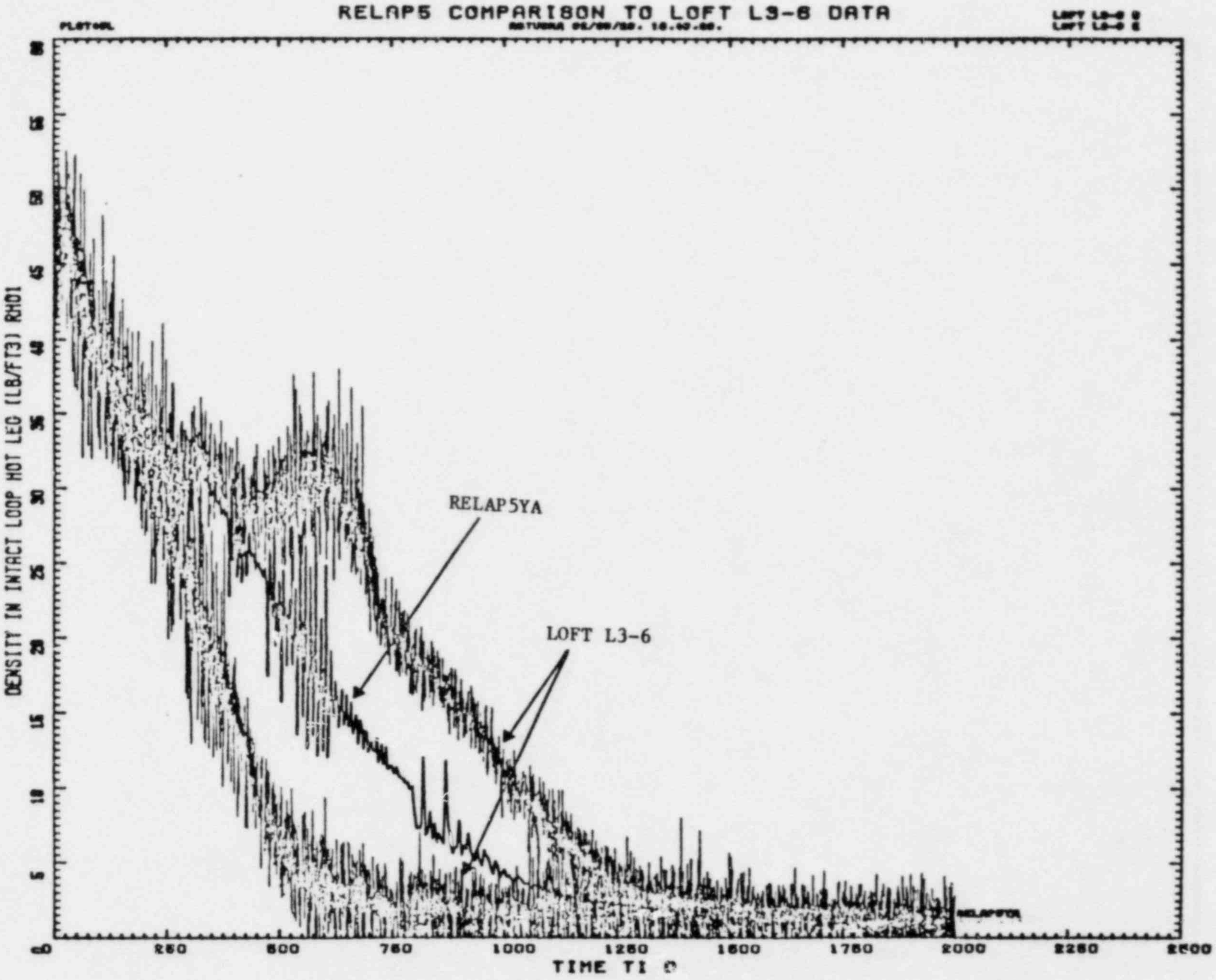
59 - HEAT SLABS

RELAP5 COMPARISON TO LOFT L3-6 DATA

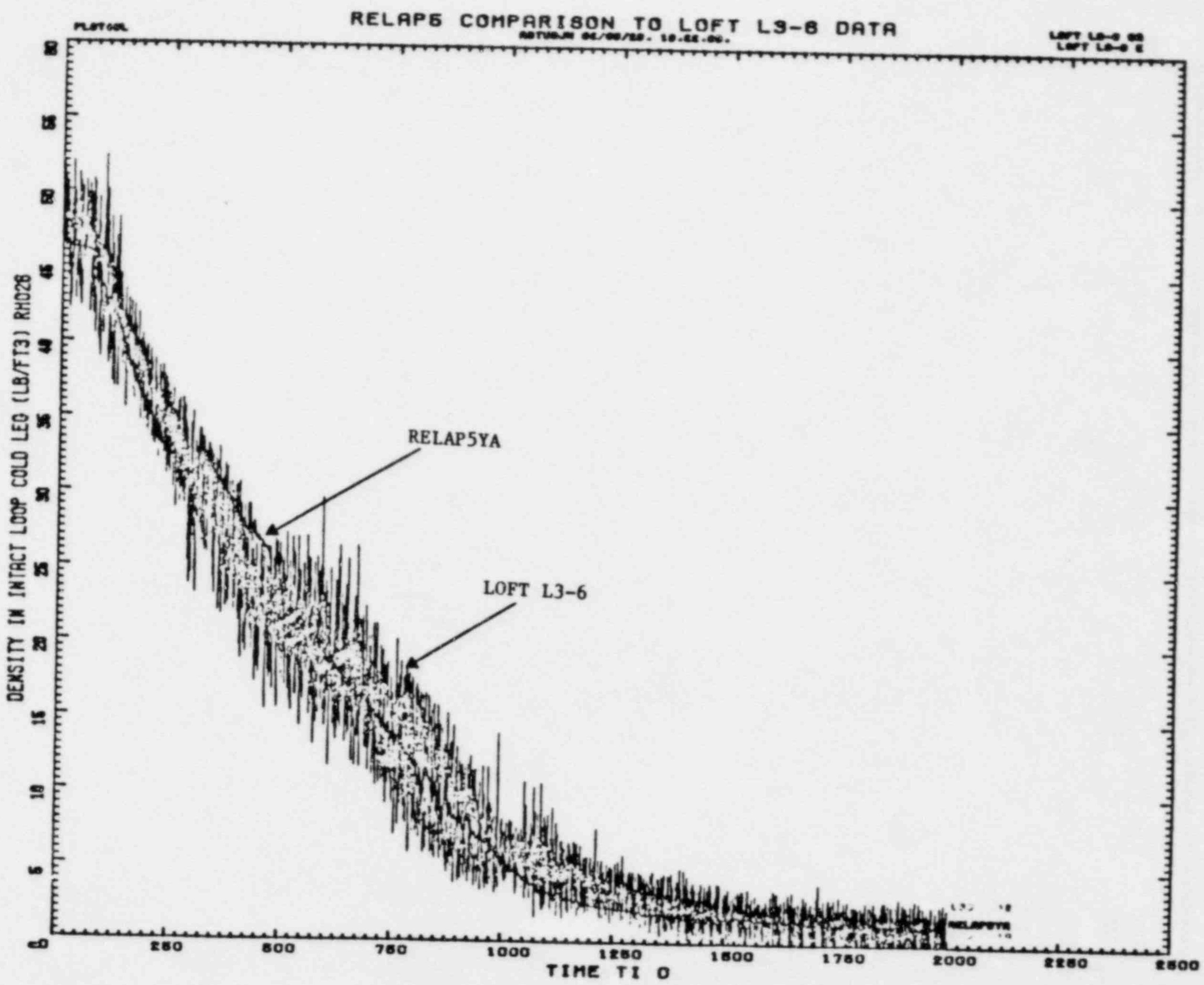


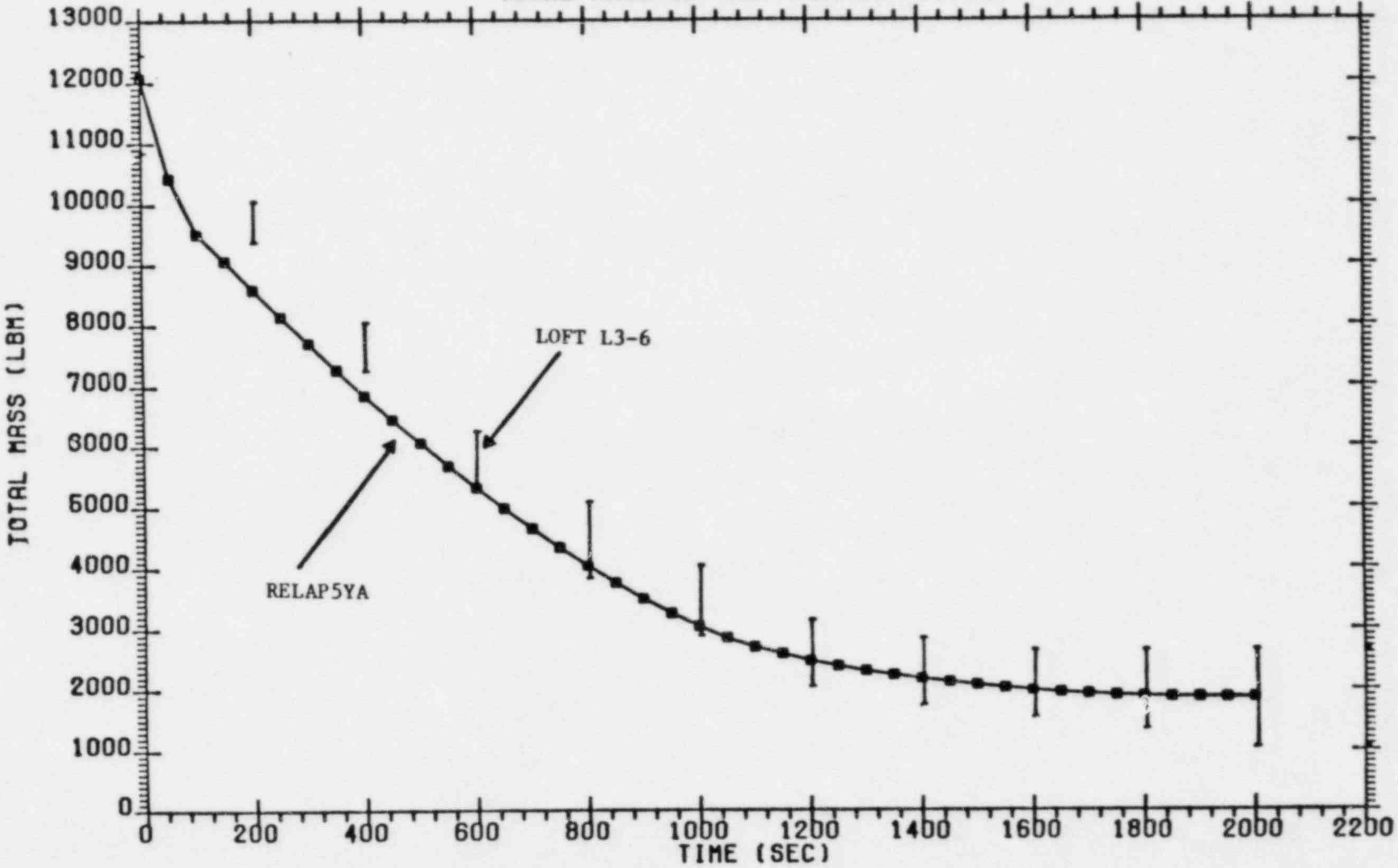
RELAP5 COMPARISON TO LOFT L3-6 DATA





RELAP5 COMPARISON TO LOFT L3-6 DATA


RELAP5 COMPARISON TO LOFT L3-6 DATA
DENSITY IN INTACT LOOP COLD LEG (LB/FT3) RHO26
0
5
10
15
20
25
30
35
40
45
50
55
60
TIME TI 0
250
500
750
1000
1250
1500
1750
2000
2250
2500
RELAP5YA
LOFT L3-6



RELAP5 COMPARISON TO LOFT L3-6 DATA
TOTAL MASS IN THE PRIMARY SYSTEM

SUMMARY

PARAMETER	DATA UNCERTAINTY	MAXIMUM DEVIATION BETWEEN RELAP5YA-DATA
PRIMARY PRESSURE	± 37 PSI	~50 PSI
BREAK FLOW	unqualified (0 - 50 sec) ± 15% (50 - 1435 sec) ± 1.65 LBM/SEC (> 1435 sec)	~ 1 LBM/SEC
DENSTIY	± 5 LBM/FT3	< 5 LBM/FT3
SYSTEM INVENTORY	± 660 LBM	~1000 LBM early on later on very small