ROUGH DRAFT

SAND79-1963C

TWO-PHASE JET LOADS

David Tomasko
Sandia Laboratories
Albuquerque, NM 87185

Presented at the Seventh Water Reactor Safety Research Information Meeting, November 5-9, 1979, Gaithersburg, Maryland.

1602 321

SAND79-1963C

Two-Phase Jet Loads*

David Tomasko
Sandia Laboratories
Albuquerque, NM 87185

Prediction of Two-Phase Jet Forces

The ultimate objective of the Sandia Labs Program on two-phase jet loads is the development of an approximate engineering model to characterize two-phase jets emanating from circumferential or longitudinal breaks in a typical PWR piping system.

To accomplish this objective two concurrent paths will be followed. The first is to develop a model analytically beginning with first principles and making the minimum number of approximations. The Moody[6,7] model, currently used by NRC licensing, will serve as a starting point for this development.

The second path is the use of large computer codes to produce data on a wide variety of full scale PWR pipe breaks. These data will form the structure of an engineering model which will supplement and support the analytic expression and, in addition, provide more specific and accurate predictions in certain cases. To increase the reliability of these data, the codes will be verified against existing two-phase jet load data from small scale up to approximately full scale.

Most of the work performed to date has focused on this second task. Three computer codes have been employed to investigate jet load experiments in detail. These are: BEACON/MOD2-INEL(1); CSQ - Sandia Labs(2); and TRAC-P1A - LASL(3). Experimental data used in this evalaution were obtained from two sources in the

---

*This work was supported by the United States Nuclear Regulatory Commission.

1602 322

Federal Republic of Germany: RS-93[4] - Kraftwerk Union, Erlangen; and RS-50[5] - Battelle-Frankfurt, Frankfurt. Based on comparisons with data and code evaluation, the following conclusions have been drawn:

BEACON/MOD2 - BEACON/MOD2 exhibited a high degree of sensitivity to the evaporation rate multipler (λ_e) and the drag coefficient (K) used in the constitutive relations. It had to be run as a containment code, requiring time dependent input boundary conditions which are generally not experimentally available, and it required the LASL equation of state (EOS) option (incompressible liquid and ideal gas steam). These problems precluded its use in a detailed two-phase jet parameter study. However, many of these limitations may be overcome in the MOD3 version to be released later this year. At that time, BEACON will be re-evaluated.

CSQ - CSQ did a fairly good job of simulating a two-phase jet under equilibrium conditions. Its multi-material capability allowed the determination that the jet-air interaction is probably small and could be ignored in future work. It seems, however, that early time non-equilibrium phenomena may be important in two-phase jet modelling. This necessitates using a code with a non-equilibrium capability.

TRAC-P1A - Of the codes evaluated to date, TRAC-P1A produced the best agreement with the jet data. TRAC-P1A was employed in two distinct modes. A 1-D pipe representation for break flow and a vessel representation. The 1-D pipe simulation consisted of an accumulator and pipe connected to a break. Initially the pipe and accumulator were set to conditions matching those of the experiment being simulated, while the break was maintained at ambient conditions. Since TRAC-P1A does not have a containment component model, a unique vessel model was developed to simulate fluid reservoir, piping, and containment. The vessel model used consisted of a vessel component which had all internals removed and appropriate flow areas set to zero to simulate the experimental blowdown geometry and connecting pipes exiting to breaks to allow venting of the blowdown fluid. The calculation of steady-state blowdown forces

$$F_B = (P_E - P_A)A + \rho v^2 A$$

and pipe reaction forces, $F_R = F_B + F_w$,

where $$F_w = \frac{\partial}{\partial t}\int_0^L \rho v A dz$$

was possible with either model. Two-phase jet characteristics, however, could only be obtained with the vessel model.

Comparisons of TRAC-P1A pipe models to Kraftwerk Union and Battelle-Frankfurt data generally yield good agreement. They also pointed out the need to accurately model friction effects during blowdown.

Early attempts at using the vessel models failed because of large pressure spikes and asymmetries which appeared to be caused by water packing in downstream cells. This problem was greatly reduced by a modification of the time-step control logic. If ΔP/P for any cell exceeded a maximum value (5%) for any time step, that time step was reduced by a factor of two, and if ΔP/P exceeded a smaller value (3%) time step growth was inhibited. Results obtained with vessel models using the modified time step logic are generally in fairly good agreement with experimental data. They also point out the need of using non-equlibrium thermodynamics during the initial transient portion of the blowdown.

Present work on two-phase jets includes performing a parametric study of typical PWR cold leg breaks (ZION) using TRAC-P1A, modelling other tests and facilities with TRAC-P1A and CSQ (HDR, CANON, MARVIKEN), obtaining additional experimental data for model assessment, evaluating other computer codes (KFIX, COMMIX-2, and BEACON/MOD3 when available), and beginning the development of an approximate engineering model.

References:

1. C. R. Broadus, S. W. James, W. H. Lee, J. F. Lime, and R. A. Pate "BEACON/MOD2 A CDC 7600 Computer Program for Analyzing the Flow of Mixed Air, Steam, and Water in a Containment System," CDAP-TR-002, EG&G Idaho, Dec. 1977.

2. S. L. Thompson,"CSQ-A Two-Dimensional Hydrodynamic Program With Energy Flow and Material Strength," SAND74-0122, Sandia Laboratories, Albuquerque, NM 87185, Aug. 1975.

3. TRAC-P1A, "An Advanced Best Estimate Computer Program for PWR LOCA Analysis," NUREG/CR-0063, LA-7279MS Vol. 1.

4. R. Fichler, W. Kastner, H. Lochner, and K. Riedle, "Studies on Critical Two-Phase Flow," NRC-477.

5. "LOCA Experiments with a PWR Multi-Compartment Model Containment," BF-RS50-62-5, Battelle Institut, E. V. Frankfurt Am Main.

6. "Fluid Reaction and Impingement Loads," F. J. Moody, Conference on Structural Design of Nuclear Plant Facilities, Vol. 1, Chicago, Illinois, Dec. 17-18, 1973.

7. "Prediction of Blowdown Thrust and Jet Forces," F. J. Moody, ASME Paper No. 69-HT-31, August, 1969.

I. PURPOSE -- THE DEVELOPMENT OF AN IMPROVED APPROXIMATE ENGINEERING MODEL TO CHARACTERIZE TWO-PHASE JETS EMANATING FROM CIRCUMFERENTIAL OR LONGITUDINAL BREAKS IN A TYPICAL PWR PIPING SYSTEM.

MODEL DEVELOPMENT STRATEGY

1. Subject Groundwork
2. Code Installation -- BEACON/MOD2, TRAC
3. Code Investigation -- BEACON/MOD2, TRAC, CSQ
4. Develop Basic Nodalization
5. Perform Parameter Study
6. Perform Code Assessment Using Experimental Data Obtained From the Open Literature and Foreign Sources
7. Develop an Approximate Engineering Model Based on Calculations, Experimental Data and Physical Arguments

COMPUTER CODES FOR TWO-PHASE JETS

1. BEACON/MOD2

   CAPABILITIES

   A. Two-Phase Two-Component
   B. UVUT
   C. 1-D, 2D, 2D-Axisymmetric
   D. Finite Difference with Eulerian Mesh
   E. Incompressible Fluid EOS

2. CSQ

   CAPABILITIES

   A. Multi-Material
   B. TE
   C. 2-D Eulerian-Lagrangian Code
   D. Modelling by Eulerian Mesh (Perpendicular cell boundaries)

3. TRAC-P1A

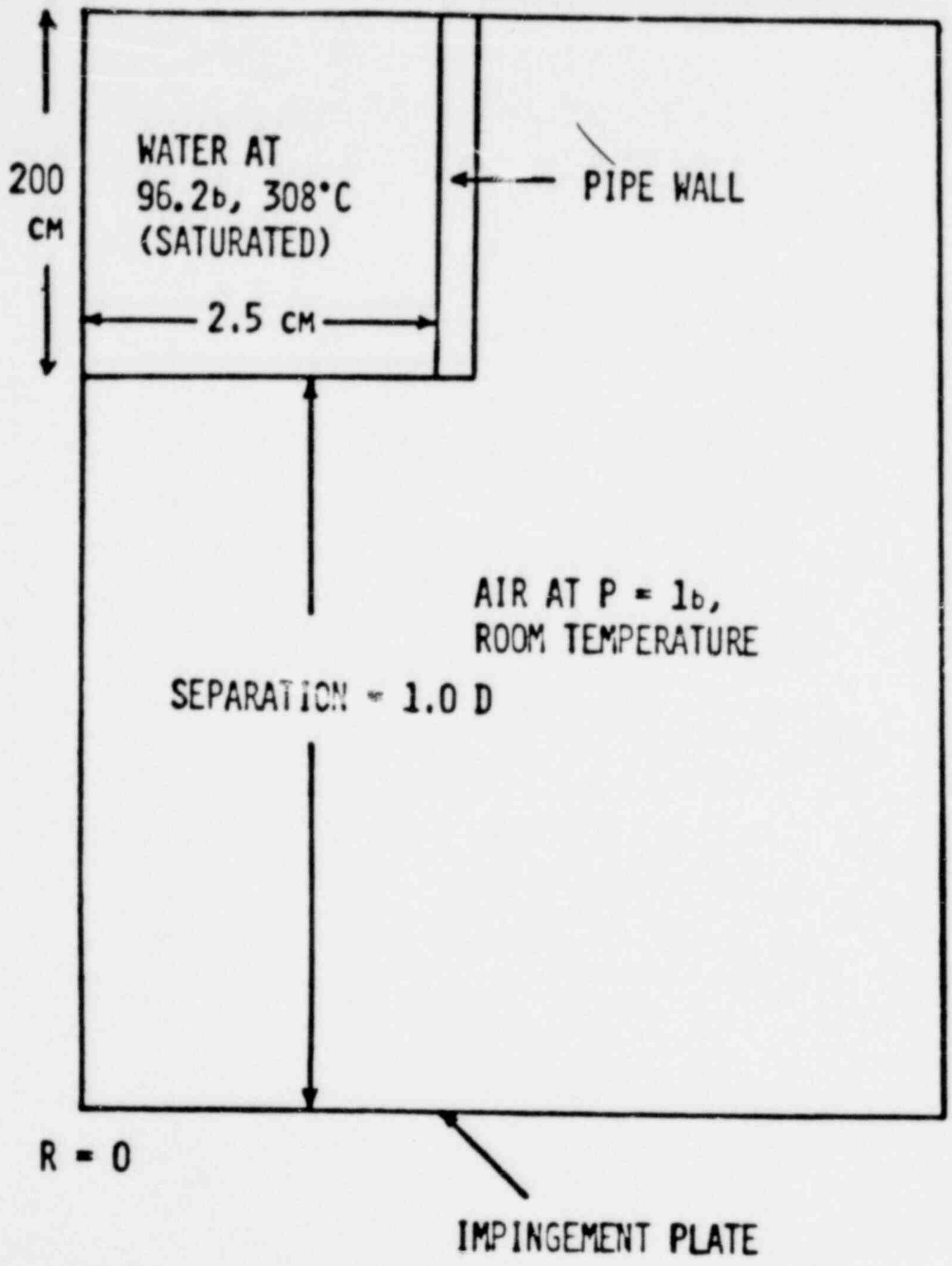
   CAPABILITIES

   A. Two-Phase
   B. UVUT
   C. 1-D Implicit Finite Difference for Pipes and Valves (Newton-Raphson)
   D. 3-D Implicit Finite Difference for Vessel (Gauss-Seidel)
   E. Model by Component

TABLE I

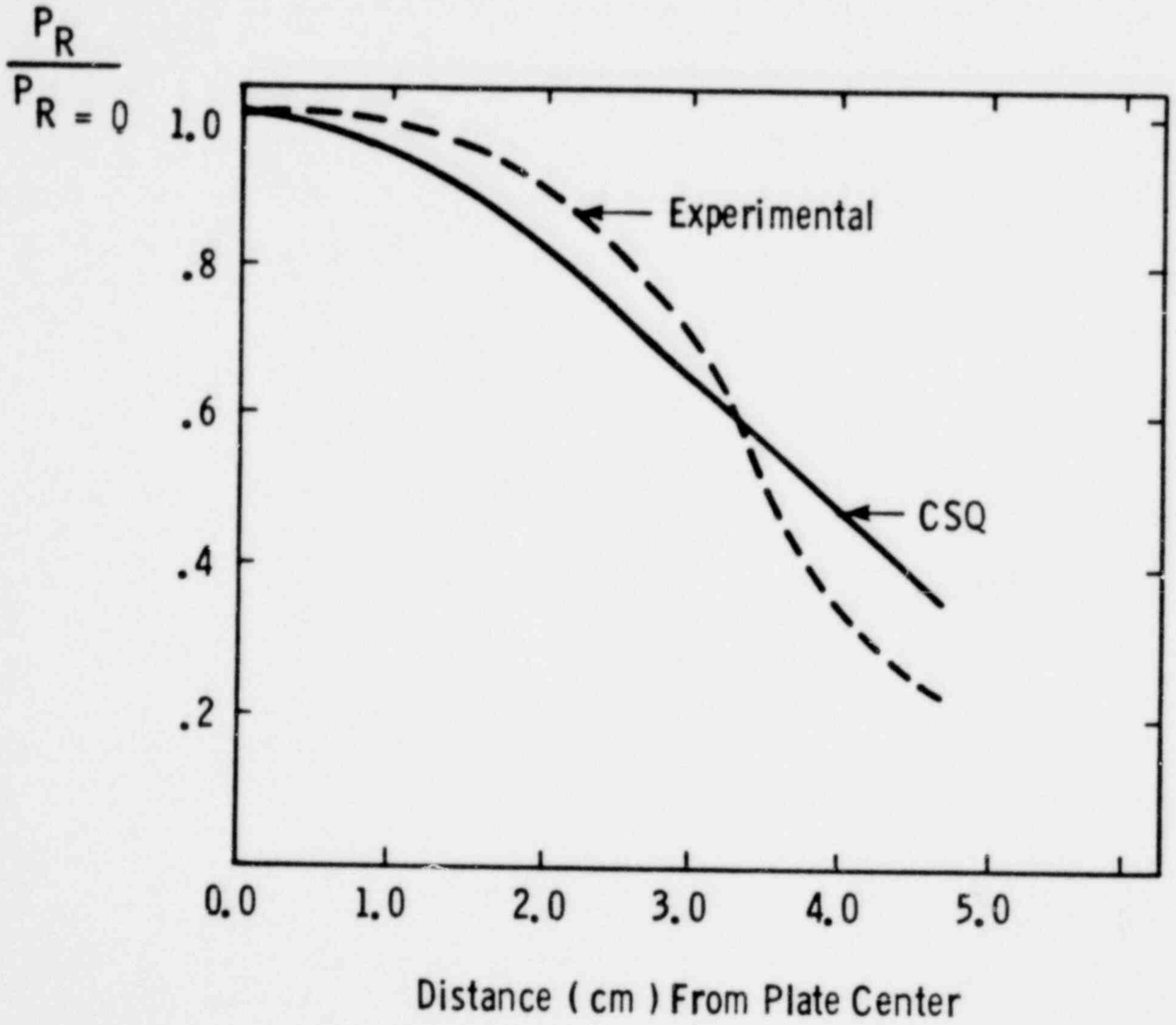
FACILITY	PRESSURE (b)	TEMPERATURE (°C)	DIAMETER CM	MASS FLOW KG/SEC	MASS FLUX KG/SEC/M^2	COMMENTS
ZION	157.23	276.7	69.85	4606	12019	PWR COLD LEG
KWU	30-100	234-311	1,2.5, 5,6.5	80	24108-1.E6 1.E6	TAPERED NOZZLE, ADIABATIC EXIT PIPE
BATTELLE-FRANKFURT	140_{MAX}	300_{MAX}	10.	400 (DOUBLE ENDED BREAK)	50929	PRESSURE VESSEL + STEAM GENERATOR. 1/64 SCALE BIBLIS, A PWR
HDR SERIES 1	88_{MAX}	220_{MAX}	35.0	1222_{MAX} (STEAM)	12701	400% FLOW (ALL HEADERS ATTACHED)
SERIES 3	110_{MAX}	310_{MAX}	35 OR 45	1222_{MAX} (STEAM)	7683 OR 12701	400% FLOW

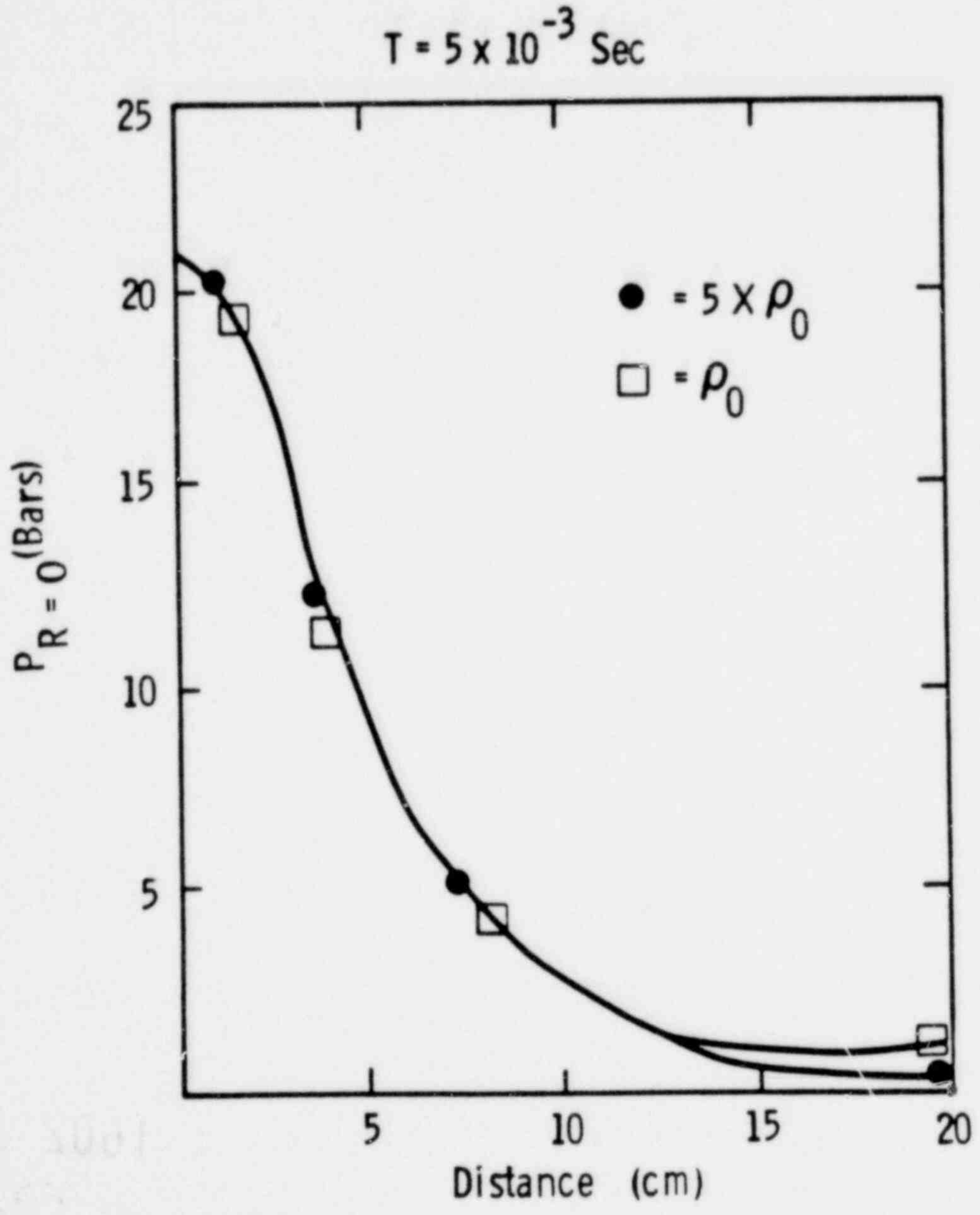
CSQ PIPE BLOWDOWN MODEL
OF KWU TEST 6



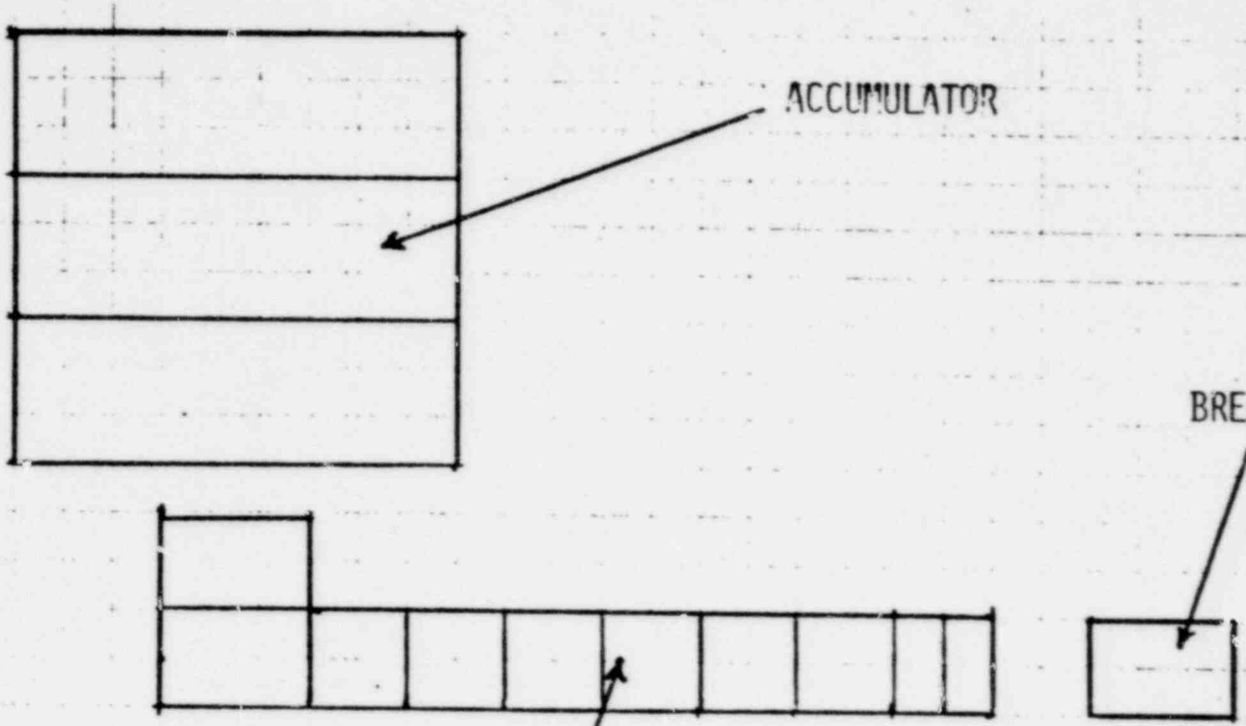
Radial Pressure At T = .003 sec.

Separation = 1.0 D





EFFECT OF AIR DENSITY - CSQ



TRAC-P1A PIPE MODEL

TRAC-P1A AND KWU TEST COMPARISONS

TEST	PRESSURE (B)	BREAK FLOW (KG/SEC)			STEADY-STATE IMPINGEMENT LOAD (NT)				
								MOODY MODEL	
		EXP	TRAC	MOODY	EXP MEASURED RECOIL**	EXP ORIFICE	TRAC	HOMOGENEOUS FLOW	SEPARATED FLOW
NW 25									
3	99.4	15.7	16.5	19.2	2520***	5288	5080	6900	7300
5	52.4	12.2	10.2	18.0	2765***	3145	2590	3000	3200
NW 50									
6	96.2	56.4	63.6	76.6	15428	19740	19070	23600	24900
			58*				17400*	20000****	
NW 65									
3	98.7	75.4	106.9	129.6	26041	28233	32440	41000	42500
4	53.1	53.7	70.8	121.5	14518	16102	16600	19000	22000

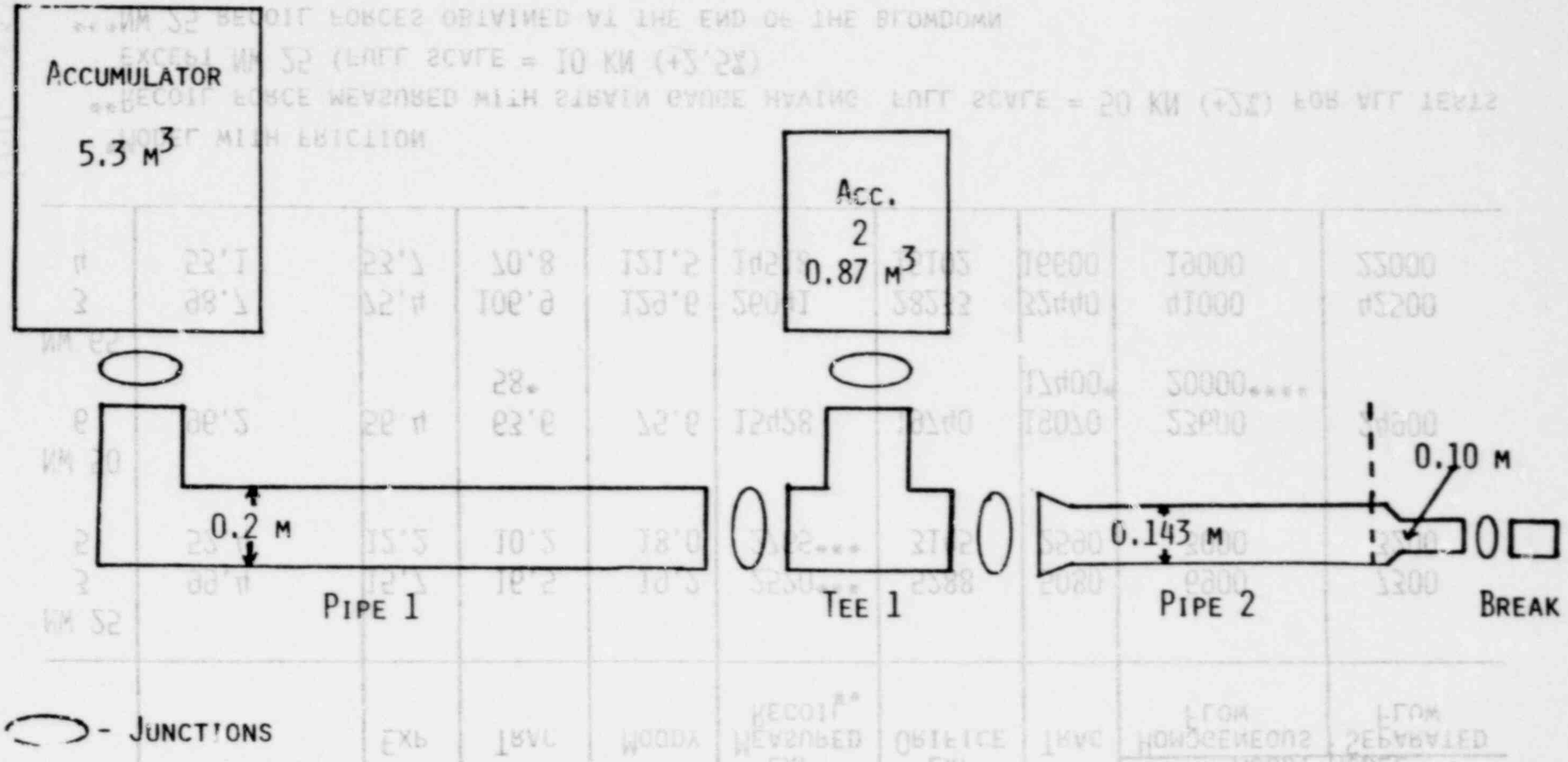
*MODEL WITH FRICTION

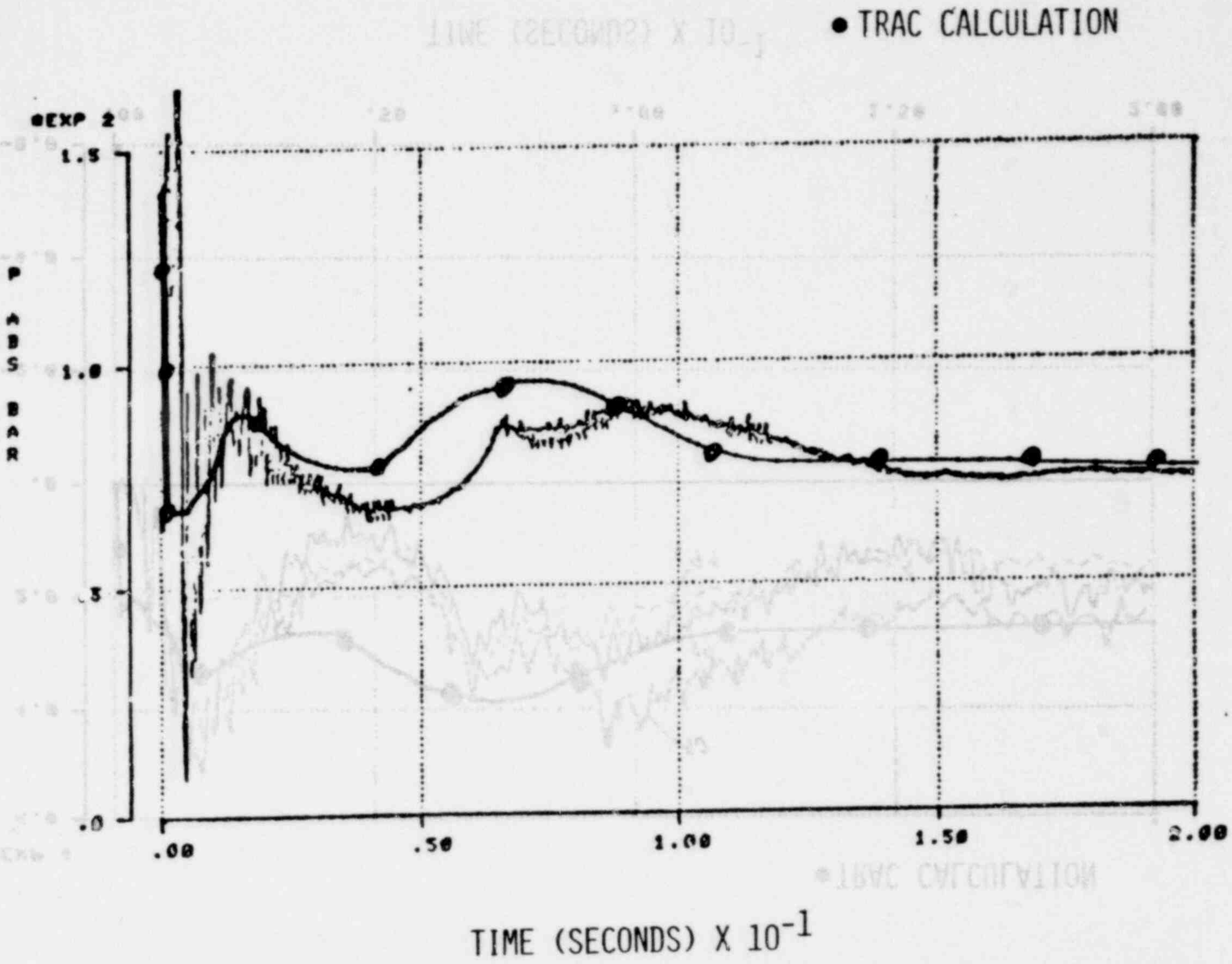
**RECOIL FORCE MEASURED WITH STRAIN GAUGE HAVING FULL SCALE = 50 KN (±2%) FOR ALL TESTS EXCEPT NW 25 (FULL SCALE = 10 KN (±2.5%)

***NW 25 RECOIL FORCES OBTAINED AT THE END OF THE BLOWDOWN

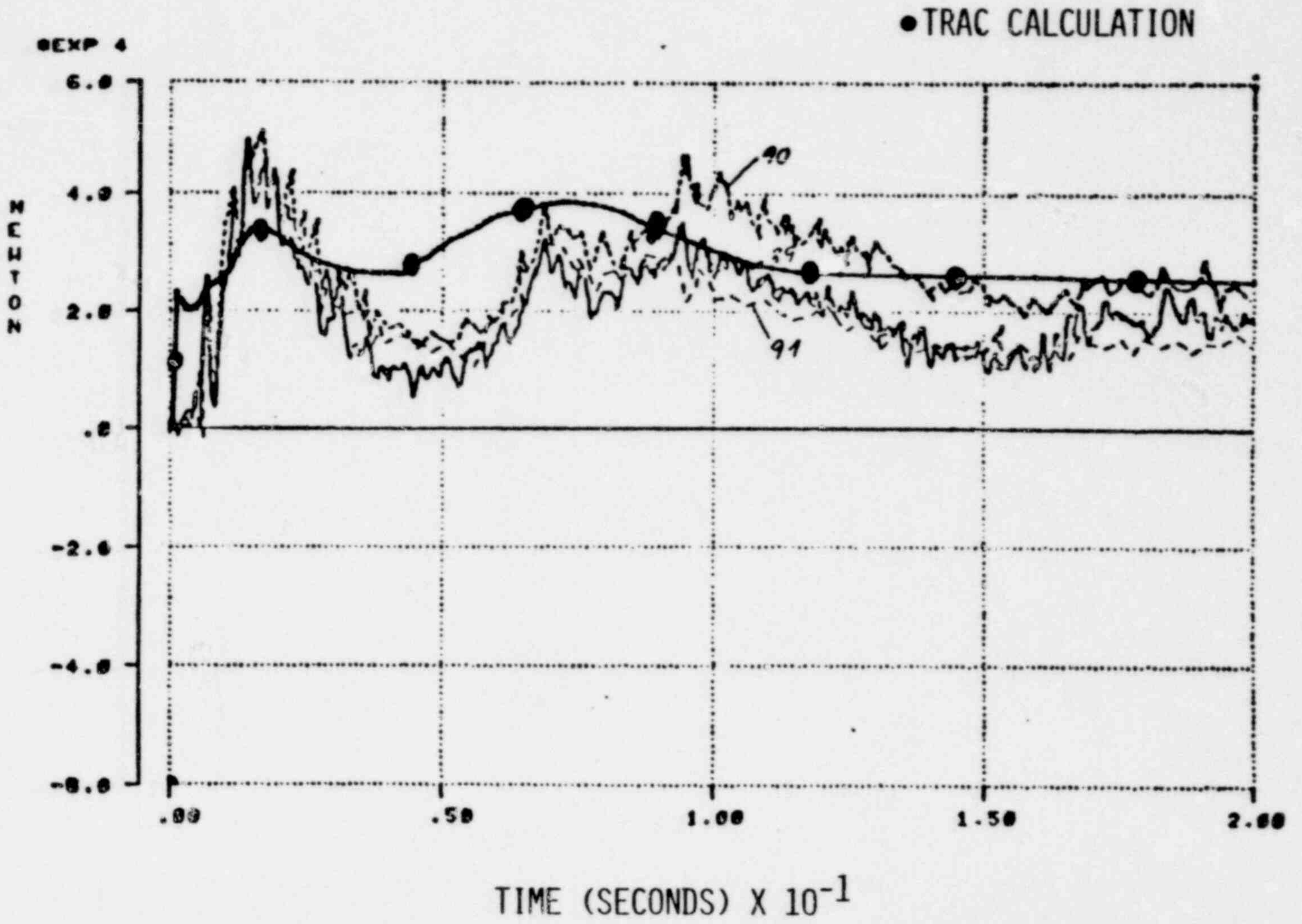
****USING FL/D = 0.81

TRAC 6 COMPONENT RS-50 MODEL



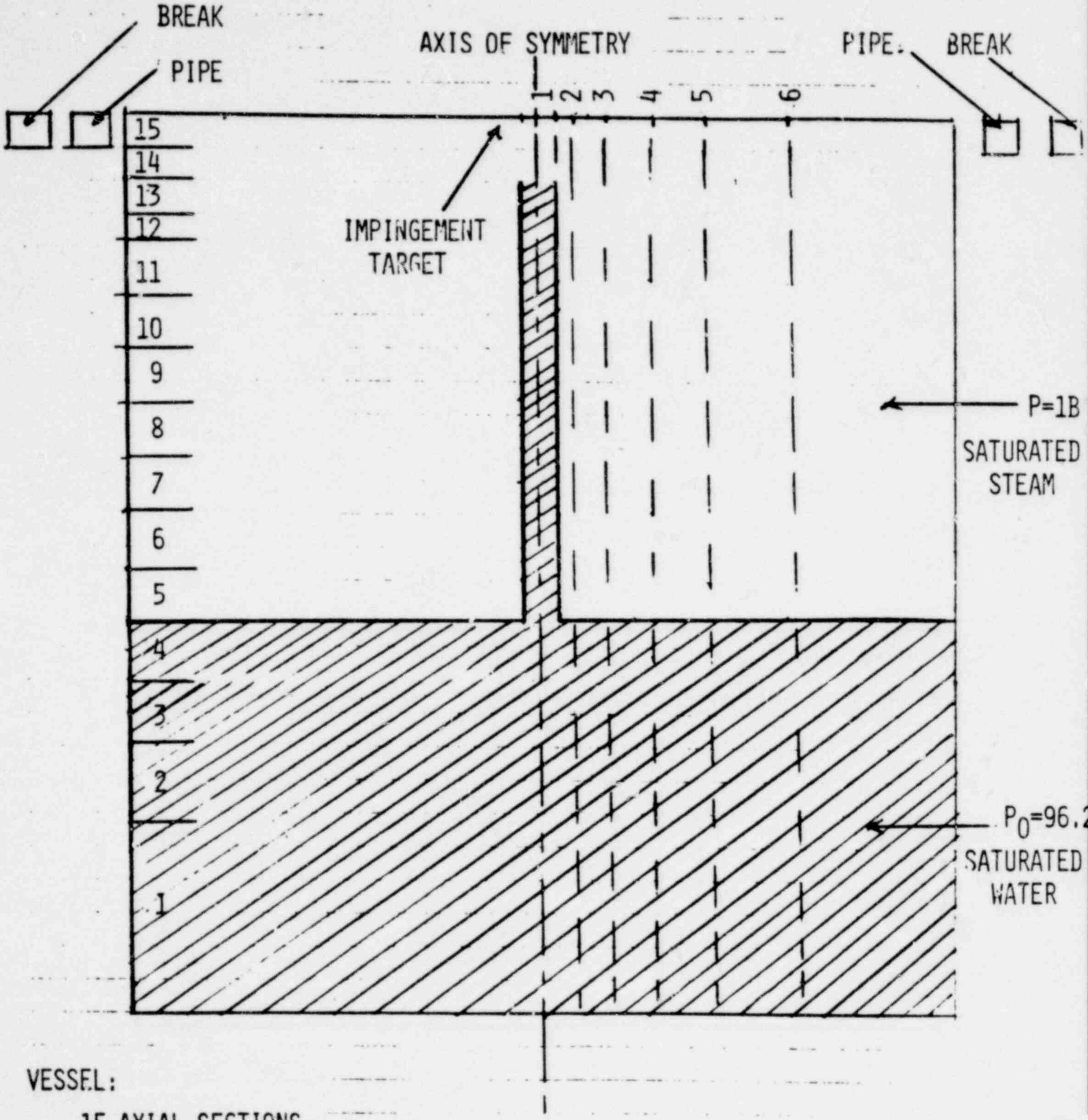

● TRAC CALCULATION
EXP 2
1.5
1.0
.5
.0
P ABS BAR
.00
.50
1.00
1.50
2.00
TIME (SECONDS) X 10^-1

1602 337


●TRAC CALCULATION
*EXP 4
6.0
4.0
2.0
.0
-2.0
-4.0
-6.0
NEWTON
.00
.50
1.00
1.50
2.00
TIME (SECONDS) X 10^{-1}
90
91

1602 338

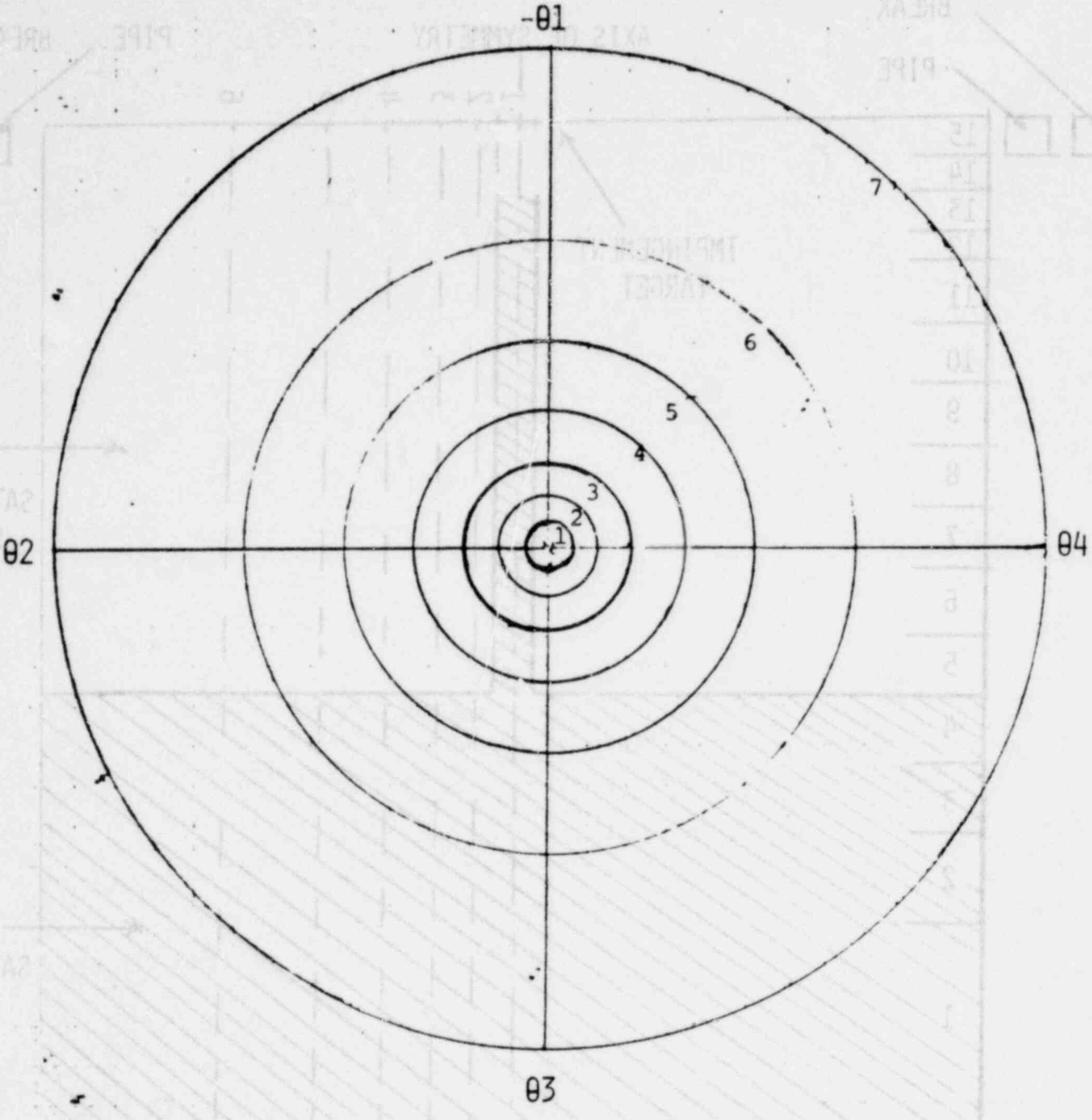
TRAC-P1A KWU MODEL



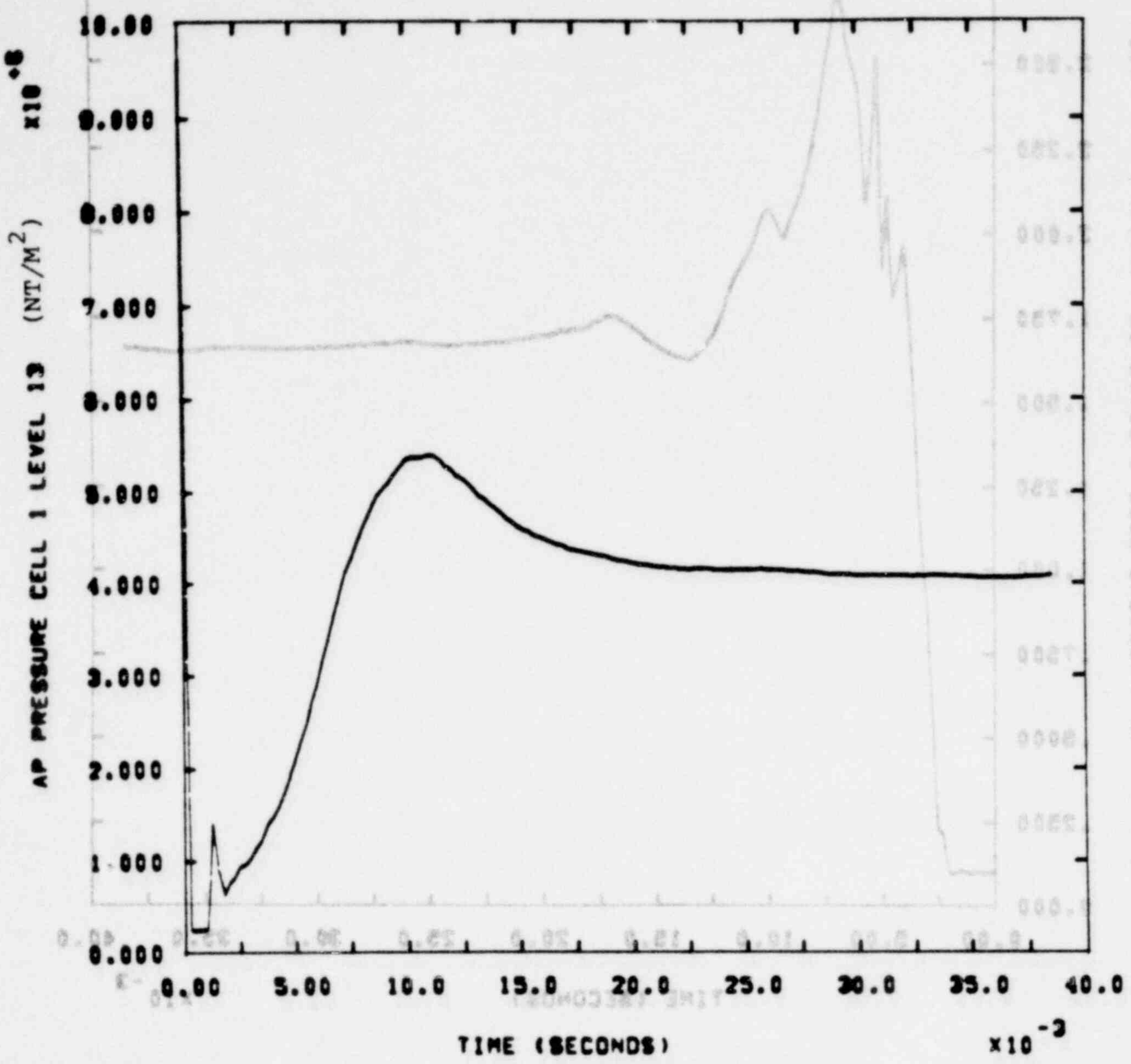
VESSEL:

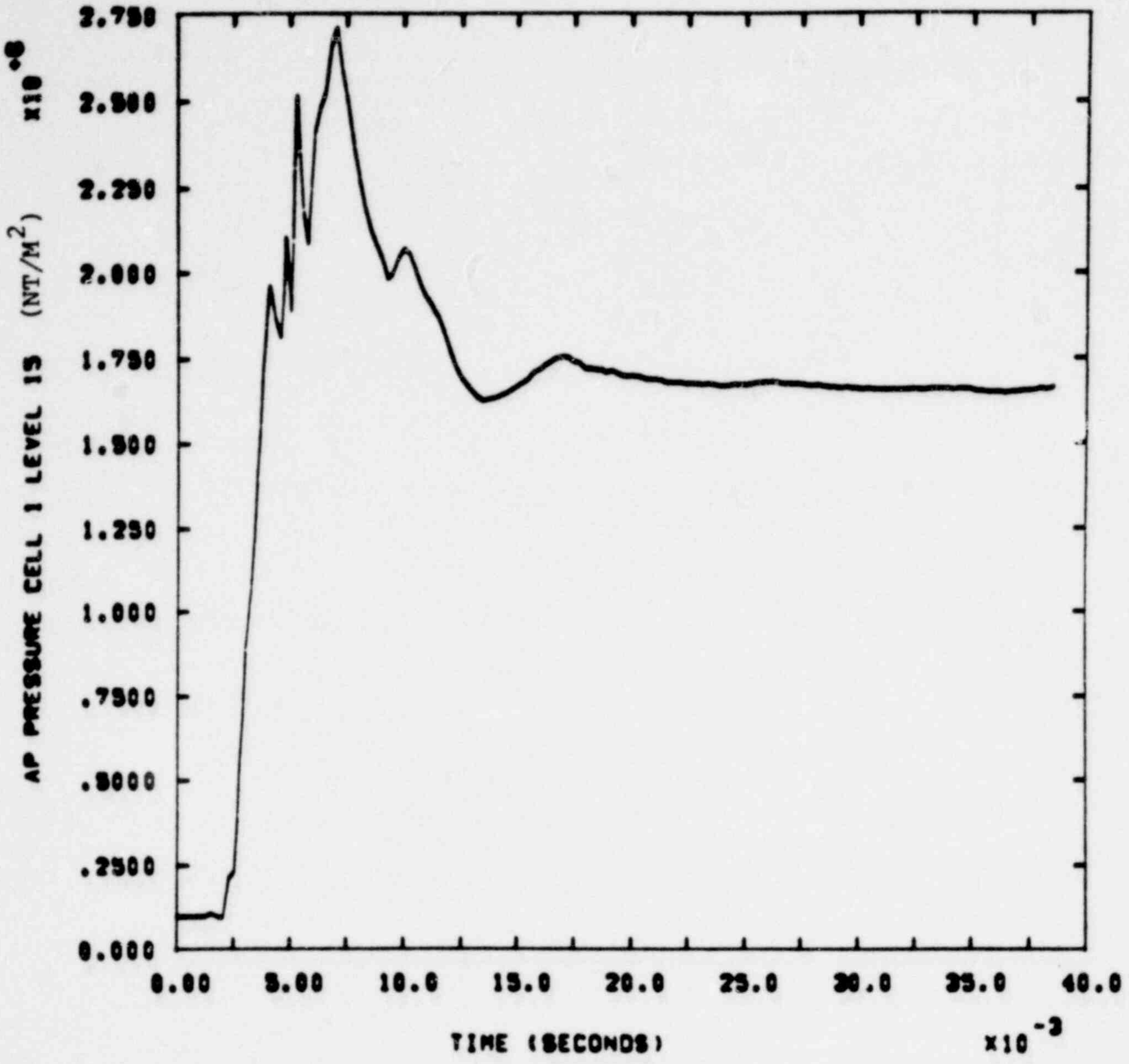
15 AXIAL SECTIONS
7 RINGS
4 ANGLES

4 PIPES
4 BREAKS

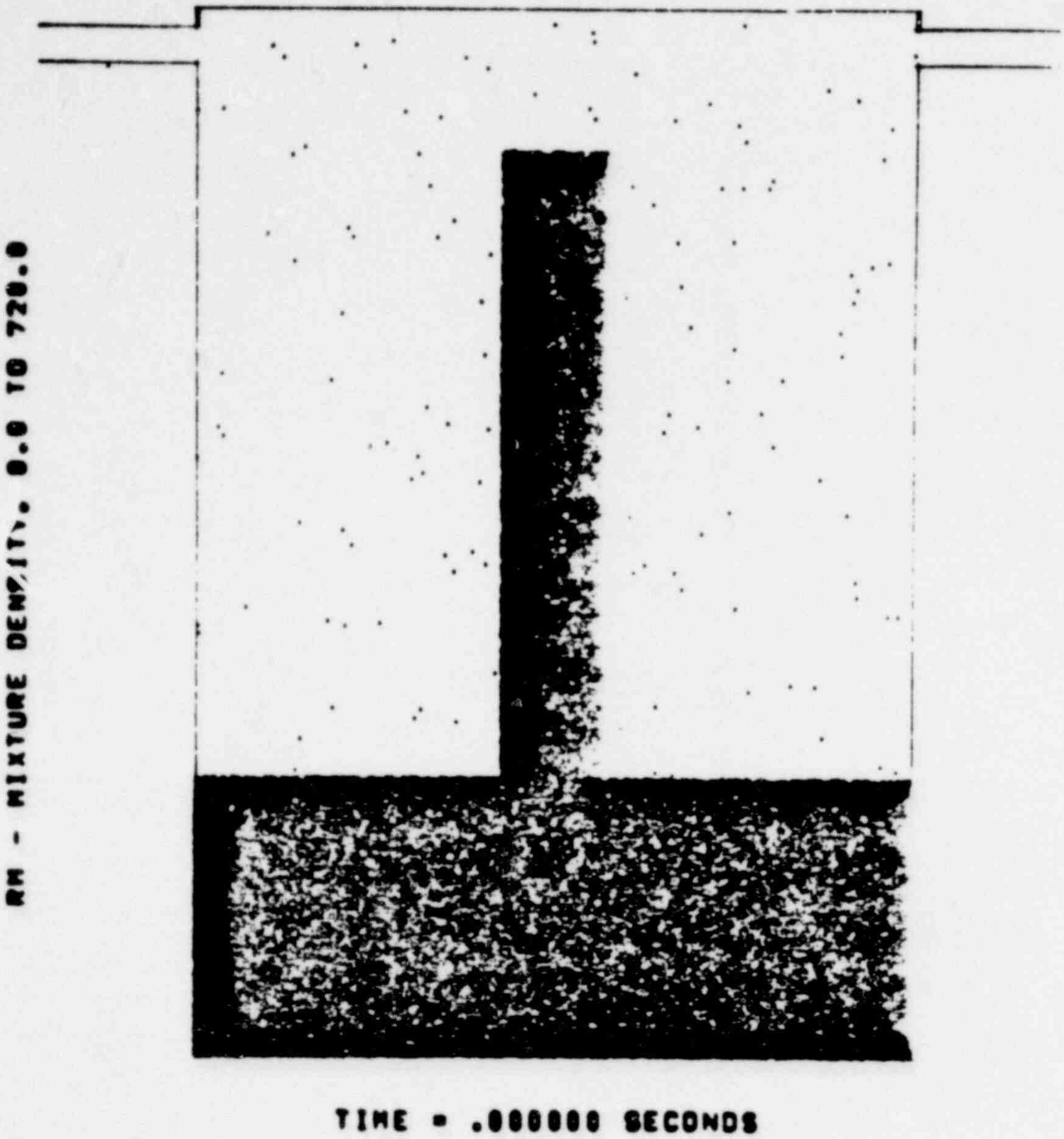


TOP VIEW OF VESSEL SHOWING
4 ANGLES, 7 RINGS MODEL

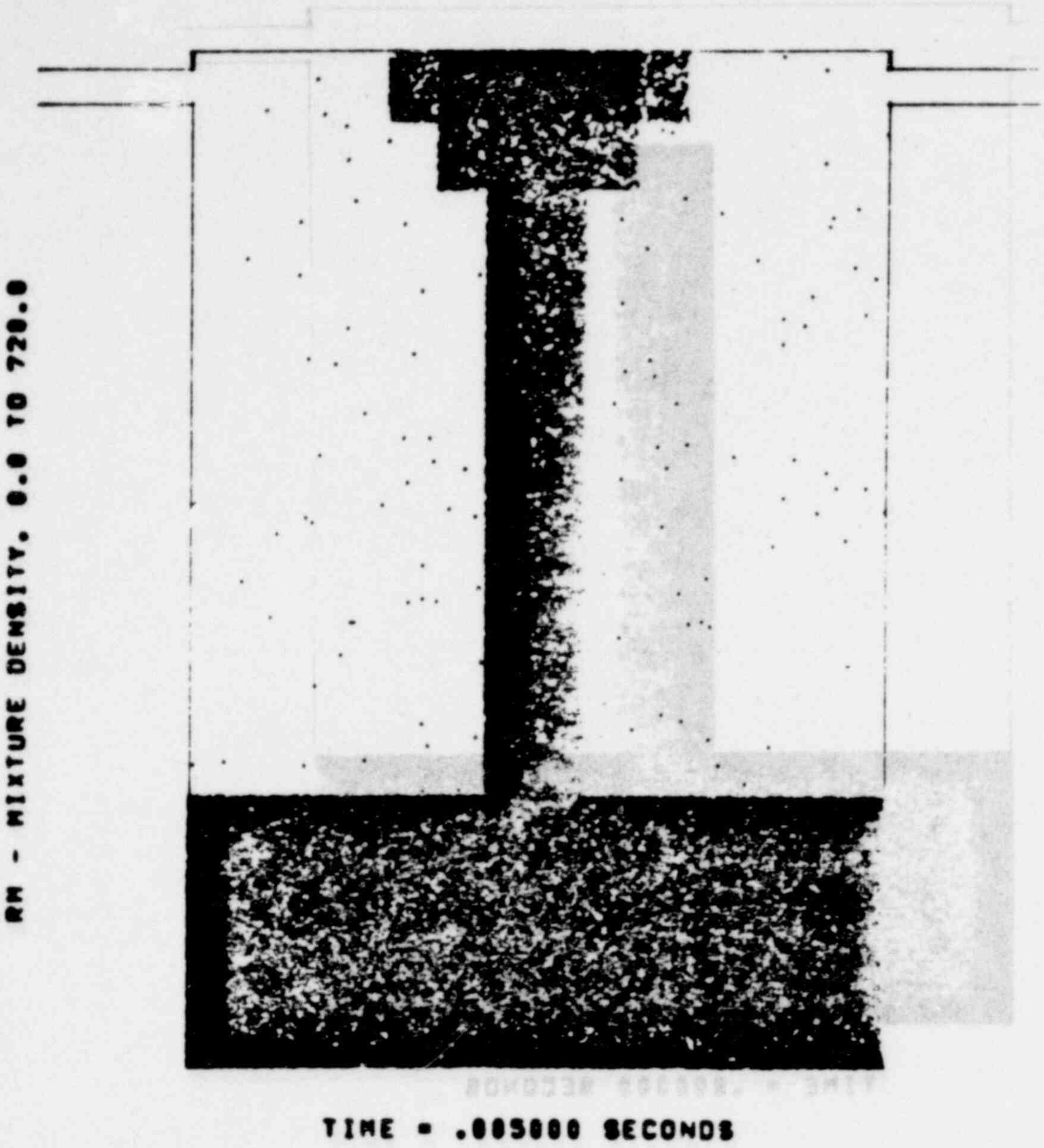

AP PRESSURE CELL 1 LEVEL 13 (NT/M^2) x10^6
10.00
9.000
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
0.00
5.00
10.0
15.0
20.0
25.0
30.0
35.0
40.0
TIME (SECONDS)
x10^{-3}


ΔP PRESSURE CELL 1 LEVEL 15 (NT/M^2)
x10^6
2.750
2.500
2.250
2.000
1.750
1.500
1.250
1.000
.7500
.5000
.2500
0.000
0.00
5.00
10.0
15.0
20.0
25.0
30.0
35.0
40.0
TIME (SECONDS)
x10^{-3}

1602 342



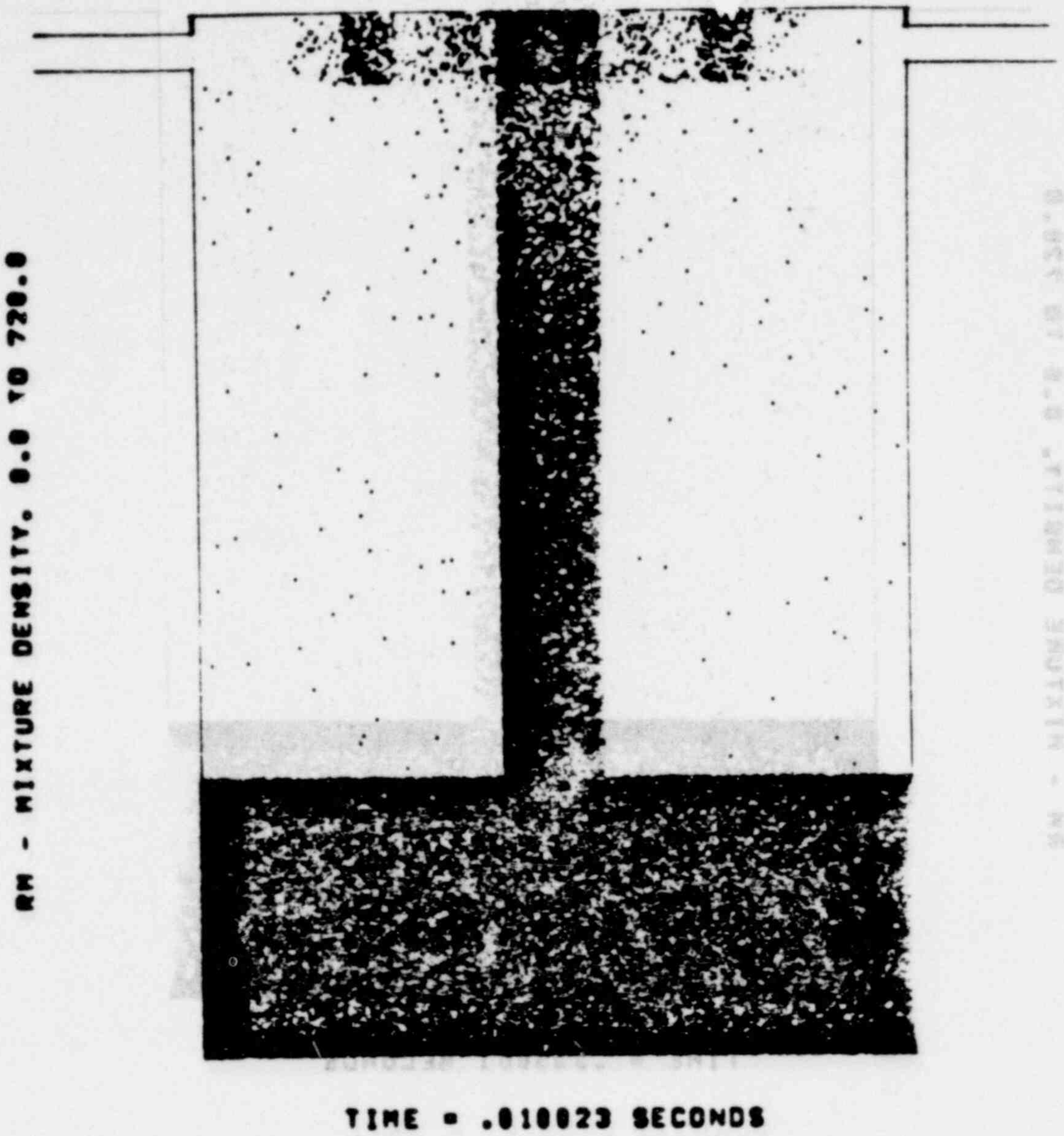
TRAC-P1A DENSITY



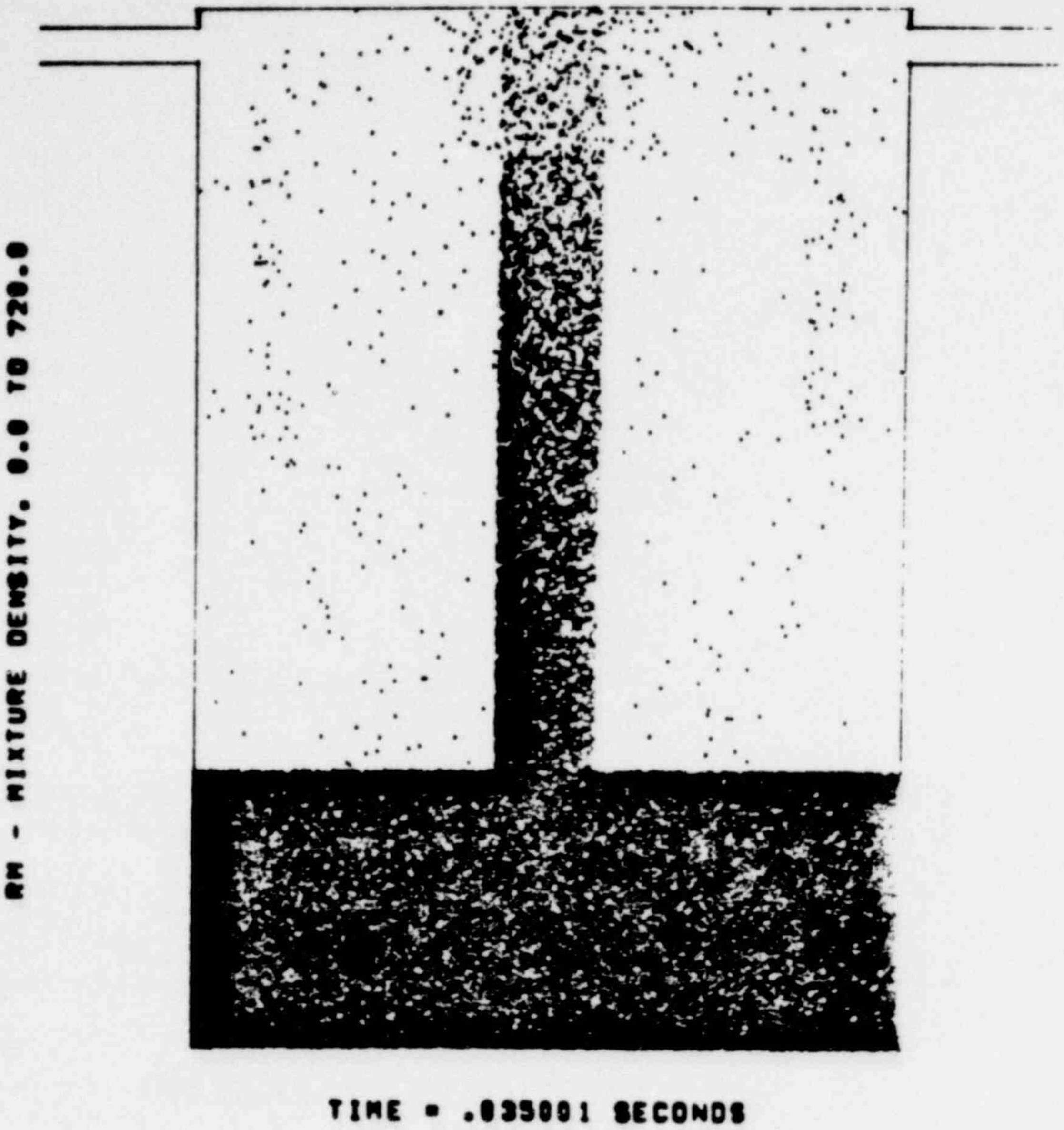
1602 344

TRAC-P1A DENSITY

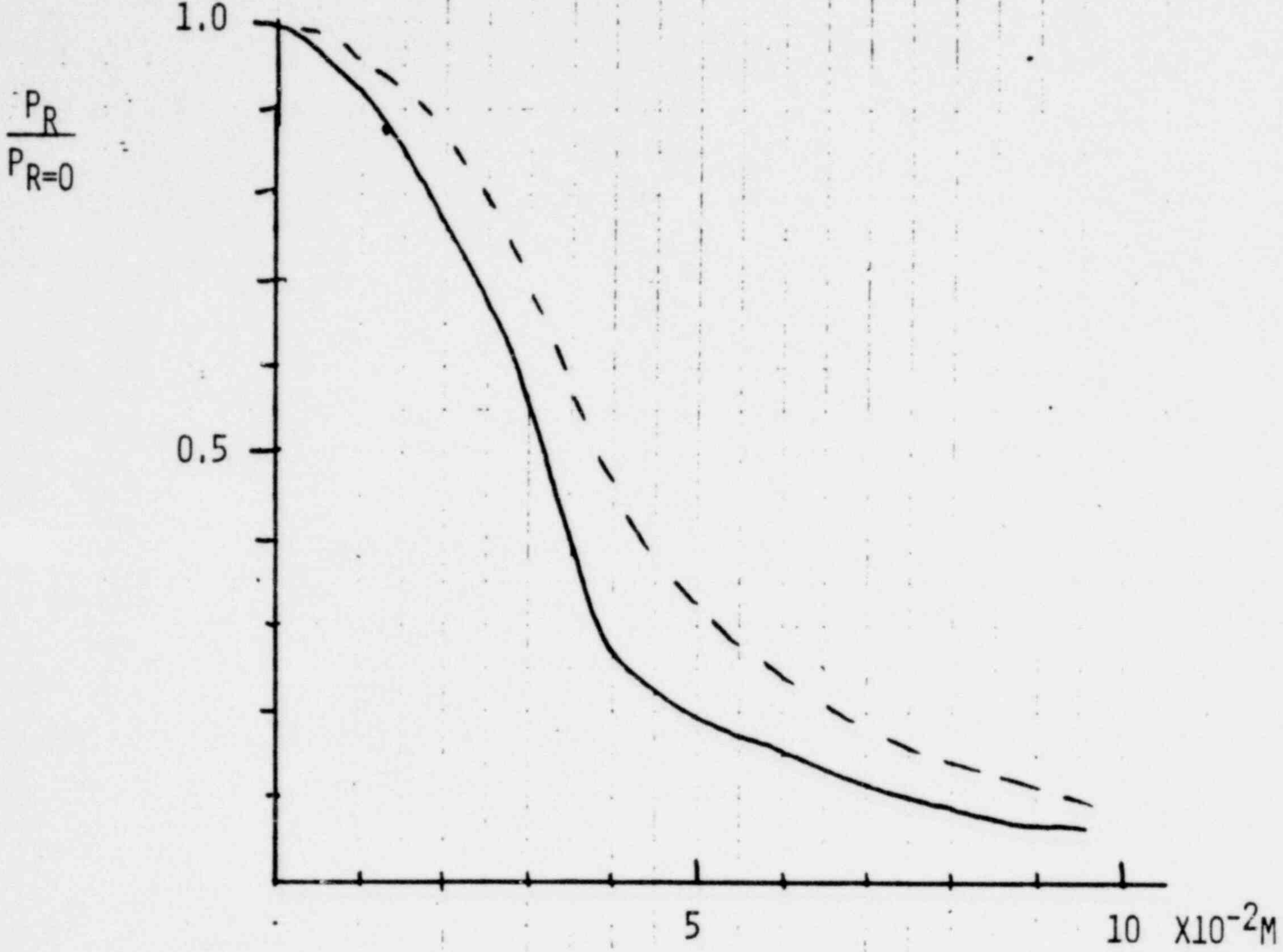
POOR ORIGINAL



TRAC-P1A DENSITY



TRAC-P1A DENSITY



TRAC-P1A PLATE STAGNATION PRESSURE