APR 1 3 1979

50-410

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 13 1979

Docket Nos.: 50-358, 50-352/353, 50-367, 50-373/374, 50-387/388, 50-410, 50-322, 50-397

APPLICANT: Members of Mark II Owners Group

SUBJECT: MEETING WITH MARK II OWNERS GROUP TO DISCUSS INTERMEDIATE PLANT PROGRAM TASKS (MARCH 21, 1979)

Background

The purpose of this meeting was to discuss the status of several of the Mark II Owners' Intermediate Program Tasks. This included: an indepth preview of several new tasks (i.e., the condensation oscillation test task and the Bechtel improved chug load definition task); preliminary observations from the ongoing CREARE multivent subscale steam tests; and preliminary observations from the completed in-plant CAORSO SRV quencher tests.

An attendance list and a copy of the meeting handouts are enclosed.

Summary

Several new tasks were recently identified as a part of the Mark II owners' supporting program. In addition significant progress was made in several existing tasks in the supporting program. A summary of the status report provided to the staff by the Mark II owners relative to these programs is provided below.

1. Task A.17, Condensation Oscillation Test Program

The Mark II owners proposed additional full scale steam tests in the 4T facility at the February 13-14, 1979 Mark II owners meeting with the staff. These new tests are directed towards obtaining a better understanding of LOCA related condensation oscillations in the downcomers. Modifications in the full scale test facility vent length will allow a more conclusive assessment of vent length effects than is possible in subscale tests. The purpose of this presentation was to provide the staff with a description of the proposed test including: objectives, instrumentation, test matrix, and parameter control. In addition a description of the preliminary facility design was provided. The original 4T facility included a non-prototypical vent. In the new tests, the facility will be modified so that vent length would be prototypical of the Mark II plants. In addition, provisions will be made to incorporate a removable vent riser and jet deflector in the drywell.

The original 4T instrumentation system has been expanded to allow an indepth study of the steam condensation phenomena in the vent and at the pool boundary. New measurement techniques will be employed in these tests to enable accurate determination of vent air content.

These tests, which are still in the planning stages, are scheduled for completion in the second quarter of 1980 with reports to be issued in the fourth quarter of 1980. The tests are considered to be confirmatory by the Mark II owners. They will provide information to establish the conservative nature of the current lead plant steam loads. The Mark II owners stated that the thrust of these tests was to study condensation oscillation loads at the pool boundary. No attention is to be given, in these tests, to the further study of lateral loads on the vents.

2. <u>Task A.11 Multivent Subscale Testing</u>

Representatives of the Mark II Owners Group and Creare, Inc. reported on the preliminary results of Phase I of the 1/10 scale multivent tests. These tests consist of steam tests conducted with 1, 3 and 7 vents. These tests were directed at multivent phasing investigations. A presentation was made of the types of phasing data and studies of the 3 vent tests that are being conducted.

Preliminary results from these tests confirm that the use of a lead plant multivent multiplier of one is conservative. In addition, results of the tests show a reduction in the multivent multiplier with increasing number of vents.

Single vents tests conducted by Creare since November 1978 were also discussed. These tests were conducted to address questions relative to the repeatability of earlier single vent tests under conditions of varying vent air content. Improved repeatability was observed in these most recent tests.

To complete the first phase of the Creare test program, additional multivent tests at 1/6 scale are to be conducted with 1 and 3 vents. In addition, single and multivent tests are to be conducted to investigate the effect of pool size, vent location and drywell vent phasing.

3. Task A.16 Improved Chug Load Definition

Several different fluid structure studies of the 4T steam tests were discussed with the staff during the past year in an attempt to better define a more realistic chug source that can be applied to Mark II facilities. The current lead plant chugging load specification involves the direct application of the measured 4T wall pressures to Mark II containment walls. The Mark II owners have selected this most recent chugging load improvement program developed by Bechtel, as the generic methodology for the Intermediate Program.

The discussion included: studies of the 4T data to establish categories of condensation events encountered; numerical studies of the 4T tests using the K-FIX computer program; and acoustic model studies of the 4T tests.

This presentation was the staff's first exposure to this program. The program is still in its early stages of development. Preliminary results of the program indicate that with selected source functions it is possible to reproduce typical experimental pressure time histories and power spectral densities observed in the 4T tests. Additional work remains to establish a conservative chug specification, based on the existing data, for application to individual Mark II plants. The Mark II owners indicated that this chugging methodology would be discussed further at the next Mark II Owners Group meeting with the staff in about two months.

4. Task B.5, Caorso Tests

The results of the Caorso in-plant GE cross quencher SRV tests were discussed. These tests including single and multi-valve tests were completed in February 1979.

A total of 104 tests were conducted. The specific areas of interest addressed by this test program are:

A. Suppression pool boundary pressures;

B. Containment dynamic response;

C. SRV discharge line clearing and reflood transients;

D. Quencher structural response;

E. Suppression pool thermal mixing;

F. Submerged structure loads; and

G. Containment liner and downcomer vent structural response.

A preliminary assessment of the available Caorso test data indicates that, in general, observations either compare well or are conservatively bounded by test predictions based on existing design load methodology.

In certain areas (i.e., suppression pool boundary pressures) the test results indicate that the DFFR Rev. 2 cross quencher load specifications are very conservative.

The current plans are for issuance of a final report on the first phase of testing in May 1979, followed by a final report on the second phase of testing in December 1979.

Clifford Anderson

Clifford J. Anderson, A-8 Task Manager
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Enclosure:
As Stated

Distribution:
See attached pages

Mark II Meeting
March 21, 1979
San Jose, California

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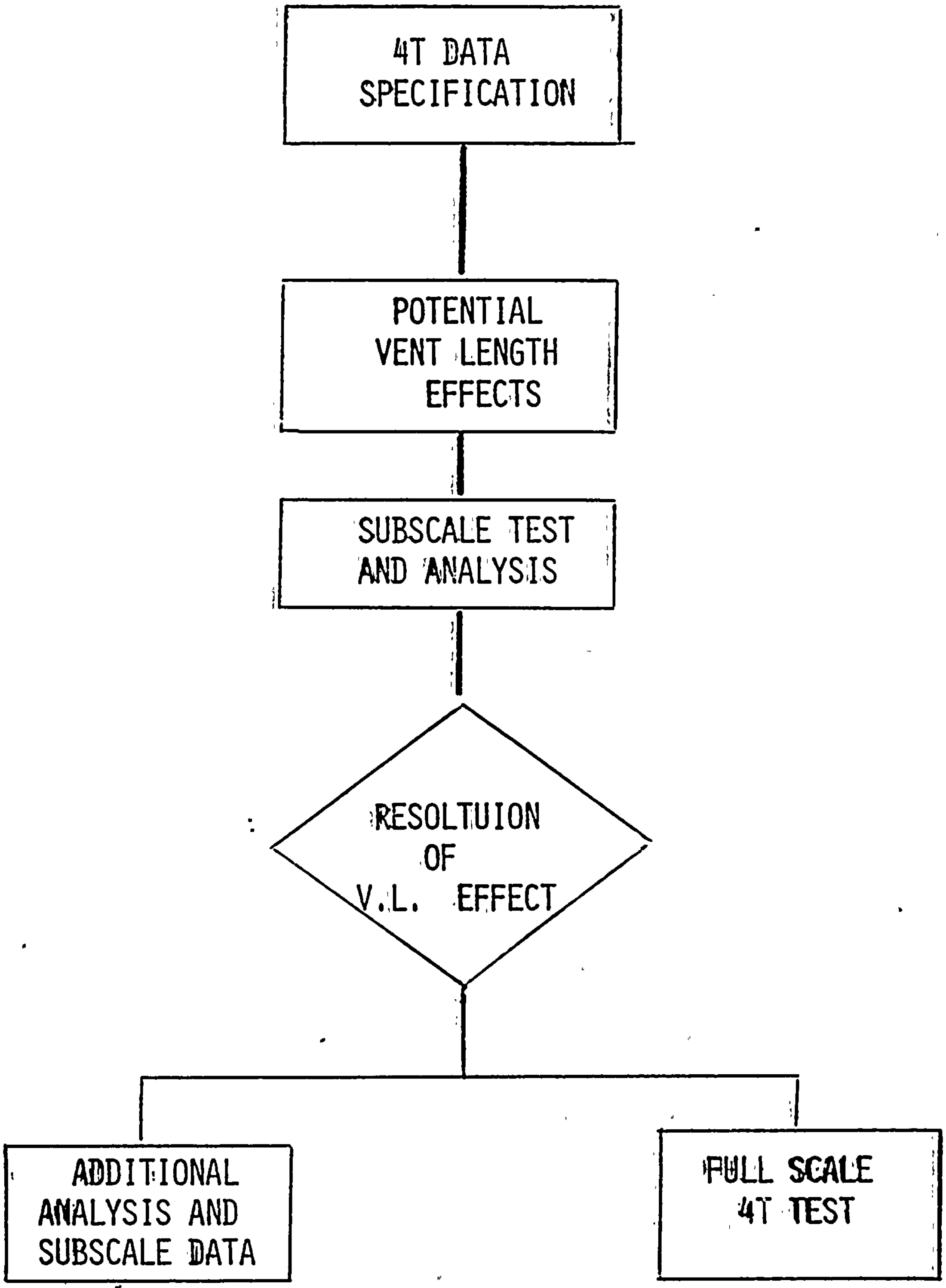
MARK II CONDENSATION OSCILLATION TEST

21 MARCH 1979

- OVERVIEW
- TEST DESCRIPTION
  - SPECIFIC OBJECTIVES
  - TEST EQUIPMENT (FACILITY/INSTRUMENTATION)
  - TEST PARAMETERS AND MATRIX
  - PARAMETER CONTROL
- PRELIMINARY FACILITY DESIGN
  - APPROACH BASED ON REQUIREMENTS
  - STATUS OF CURRENT WORK
  - PLANNED MODIFICATIONS IN 4T

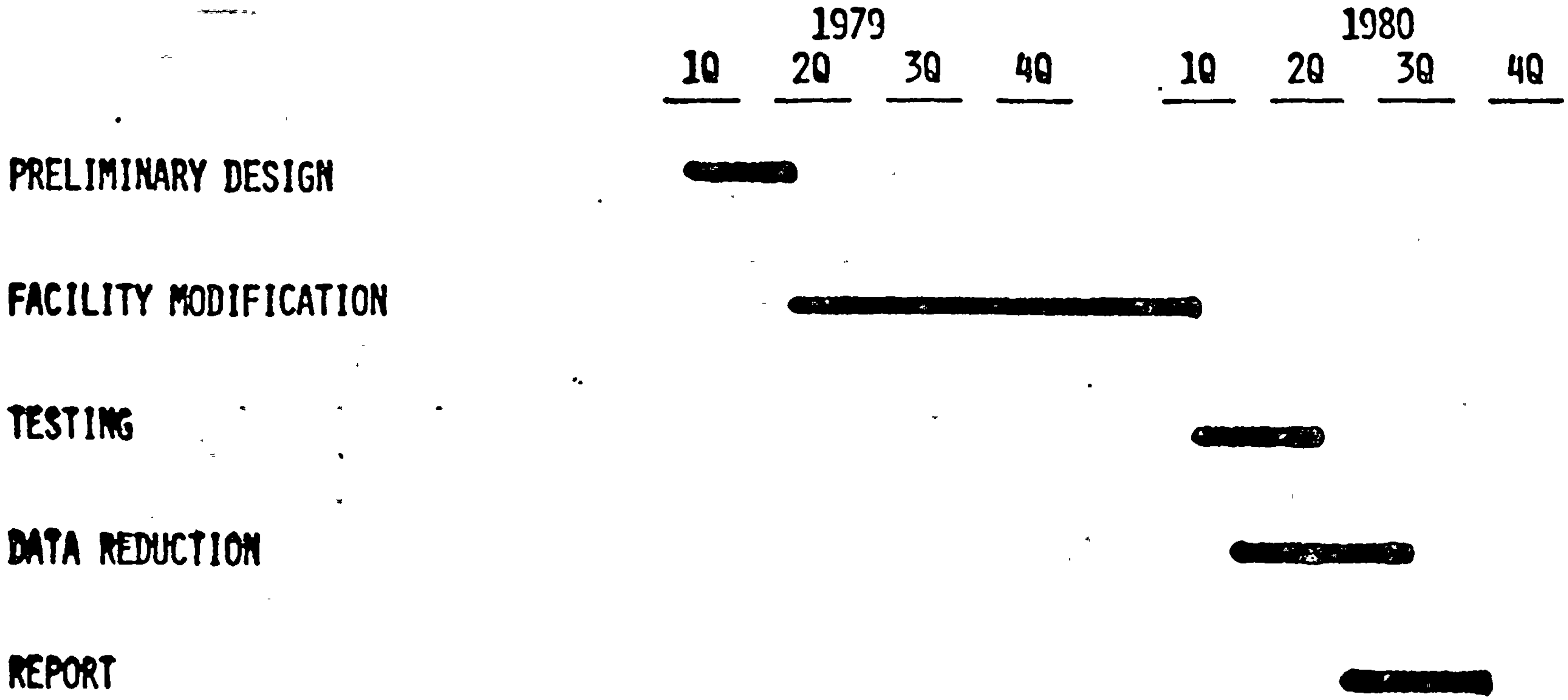
CONDENSATION OSCILLATION



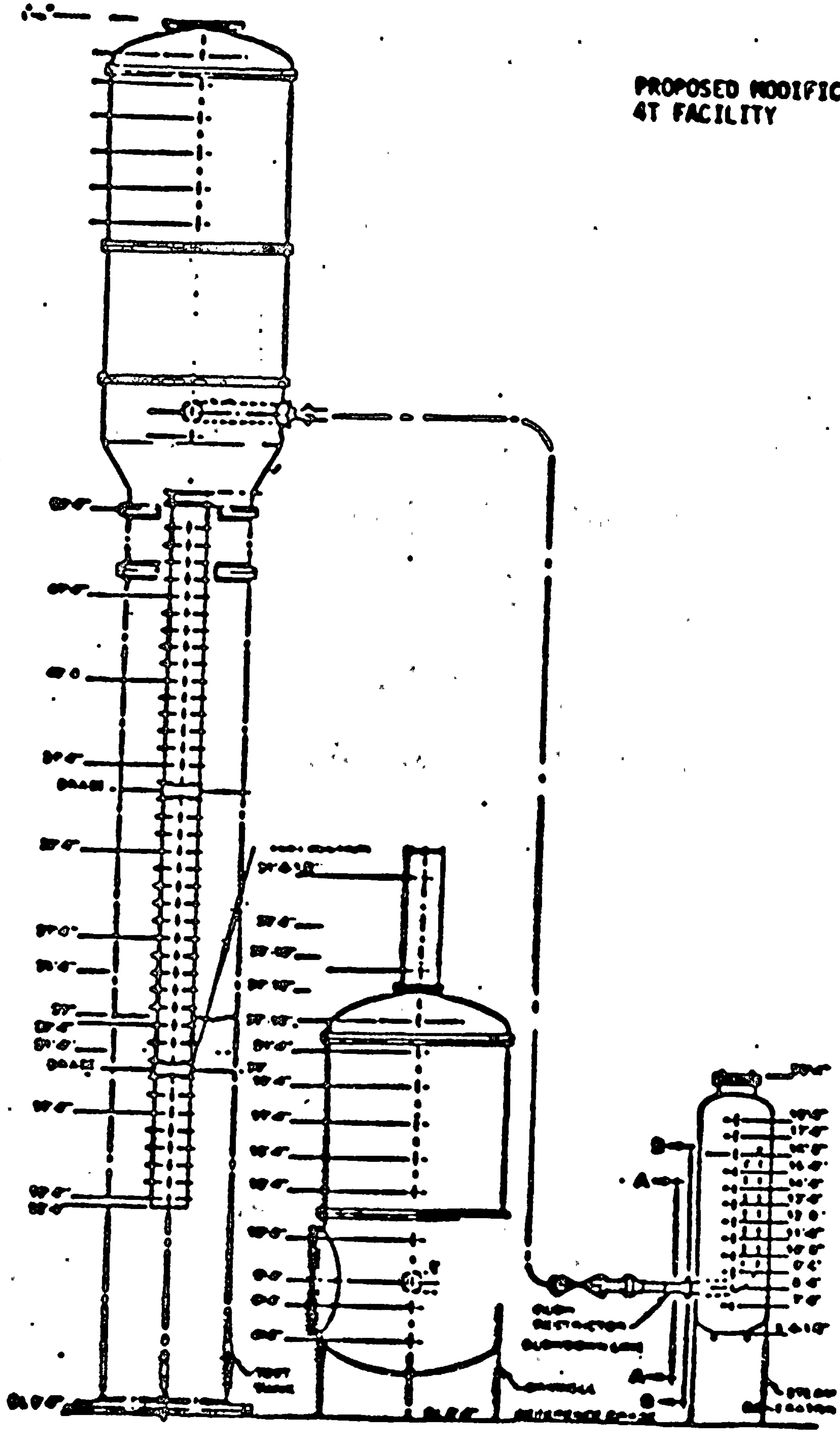
CONDENSATION OSCILLATION

- o NRC QUESTION STATED IN LOADS EVALUATION REPORT
  - POTENTIAL VENT LENGTH EFFECT ON C.O. LOAD
  - BELIEVED NOT TO BE CONTROLLING
- o TESTING
  - SCALED APPROACH
    - o RESULTS INCONCLUSIVE
    - o CLOSURE WITH NRC APPEARED LENGTHY
  - FULL SCALE APPROACH
    - o FASTER AND MORE DIRECT CLOSURE
- o FULL SCALE SELECTED
  - MINIMIZES MODELING REQUIREMENTS
  - DIRECT MEASUREMENT MORE CONVINCING TO NRC
  - TEST FACILITY RESOURCES AVAILABLE
  - MORE DIRECT COMPARISON POSSIBLE
  - NO IMPACT ON MULTIVENT TEST PROGRAM
- o FULL SCALE TEST
  - GENERIC TEST (4T)
    - o APPLIES TO ALL PLANTS
    - o CONSERVATIVE OUTPUT
    - o FOCUSES ON C.O.

4T C/O TEST SCHEDULE



PROPOSED MODIFICATION TO
4T FACILITY



MARK II FULL SCALE 4T

CONDENSATION OSCILLATION (C/O) TEST

TEST DESCRIPTION

- CONDENSATION OSCILLATION PHENOMENA
- NEED FOR FULL SCALE TEST
- TEST OBJECTIVE
- TEST REQUIREMENTS
- MEASUREMENT OBJECTIVES

3/21/79
PWM

MARK II FULL SCALE 4T C/O TEST

CONDENSATION OSCILLATION PHENOMENA

- OBSERVED PRIOR TO ONSET OF CHUGGING IN FULL SCALE BLOWDOWNS. (MEDIUM MASS FLUX WITH STEAM AND AIR BOTH PRESENT)
- CHARACTERIZED BY
  - CONTINUOUS CONDENSATION.
  - OSCILLATING WALL LOAD.
  - STEAM/WATER INTERFACE REMAINS ATTACHED TO END OF VENT.

3/21/79

PWM

MARK II FULL SCALE 4T C/O TEST

NEED FOR FULL SCALE TEST

- NEED FULL SCALE MARK II PROTOTYPICAL DATA.
  - C/O FREQUENCY CONTENT MAY DEPEND ON VENT LENGTH.
  - NONPROTOTYPICAL VENT LENGTH IN PREVIOUS 4T TESTS (ABOUT TWICE THE TYPICAL MARK II VENT LENGTH).
  - SCALED TESTS INCONCLUSIVE ON VENT LENGTH EFFECT.
- FACILITY MODIFICATION FOR NEW 4T C/O TEST UNDERWAY. (MOST APPROPRIATE WAY OF ADDRESSING THIS SPECIFIC ISSUE).

3/21/79
PWM

MARK II FULL SCALE 4T C/O TEST

TEST OBJECTIVE

- CONFIRM THE CURRENT MARK II C/O SPECIFICATION (DFFR, REV. 3)
- SPECIFICALLY, ADDRESS VENT LENGTH EFFECT
- PROVIDE DATA TO REFINE C/O SPECIFICATION, IF NECESSARY

3/21/79
PWM

MARK II FULL SCALE 4T C/O TEST

TEST REQUIREMENTS

- MARK II PROTOTYPICAL SIMULATION
  - VENT LENGTH (WITH DEFLECTOR PLATE)
  - GEOMETRY
  - BREAK TYPES AND SIZES
  - SYSTEM TRANSIENT RESPONSE

- 4T TIE BACK

  DUPLICATE SELECTED PREVIOUS 4T TESTS FOR DIRECT COMPARISON FOR VENT LENGTH EFFECT.

- ESTABLISH KEY PARAMETER EFFECTS
  - VENT SUBMERGENCE
  - INITIAL POOL TEMPERATURE
  - AIR CONTENT
  - MASS FLUX

3/21/79

PWM

MARK II FULL SCALE 4T C/O TEST

MEASUREMENT OBJECTIVES

- o POOL WALL PRESSURES
- o PRESSURES INSIDE VENT
- TEMPERATURES IN VICINITY OF VENT EXIT
- SYSTEM THERMODYNAMIC/HYDRODYNAMIC CONDITIONS
- VENT AIR CONTENT
- SELECTIVE INSTRUMENTS FOR TIE BACK TO PREVIOUS 4T DATA.

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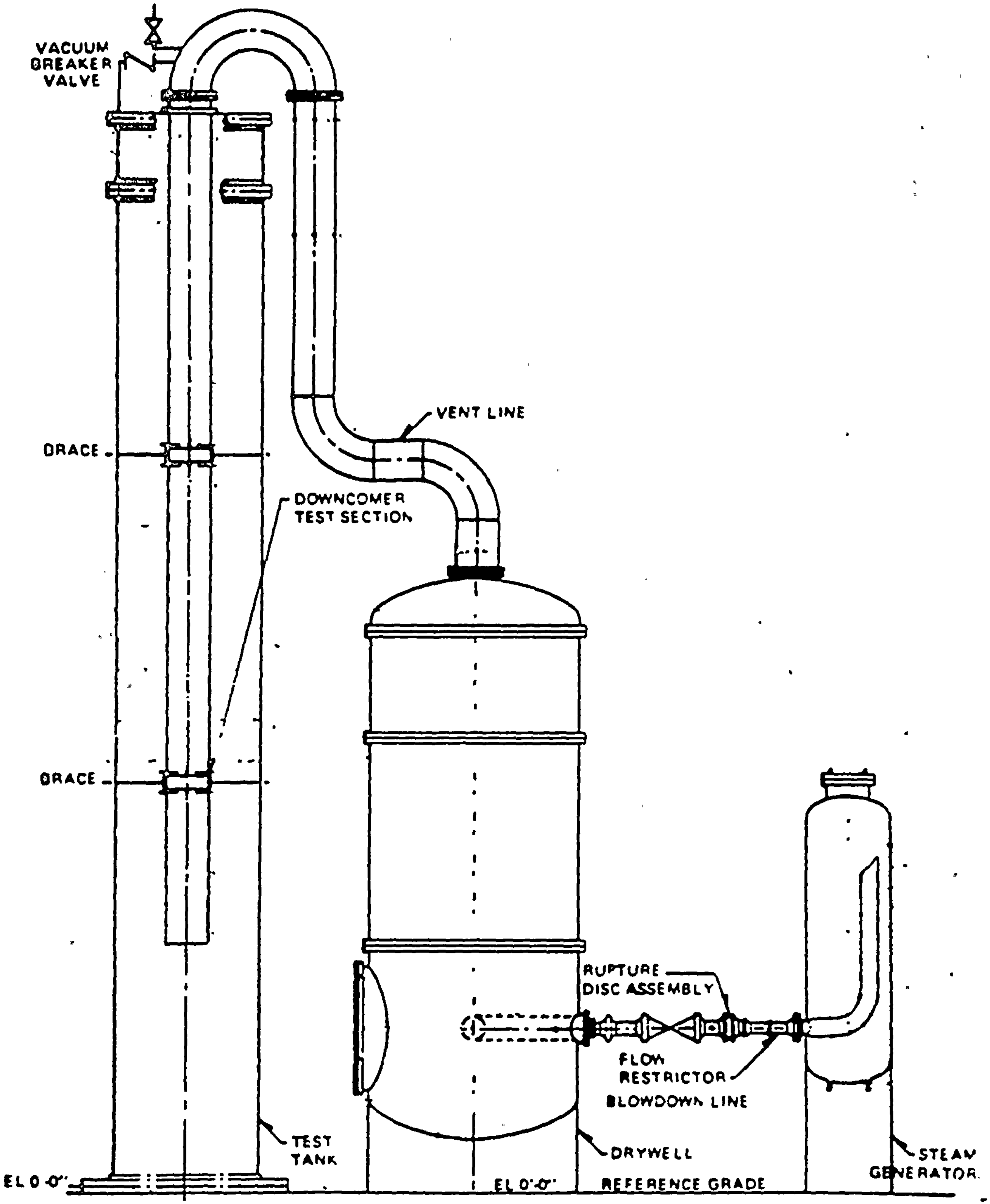
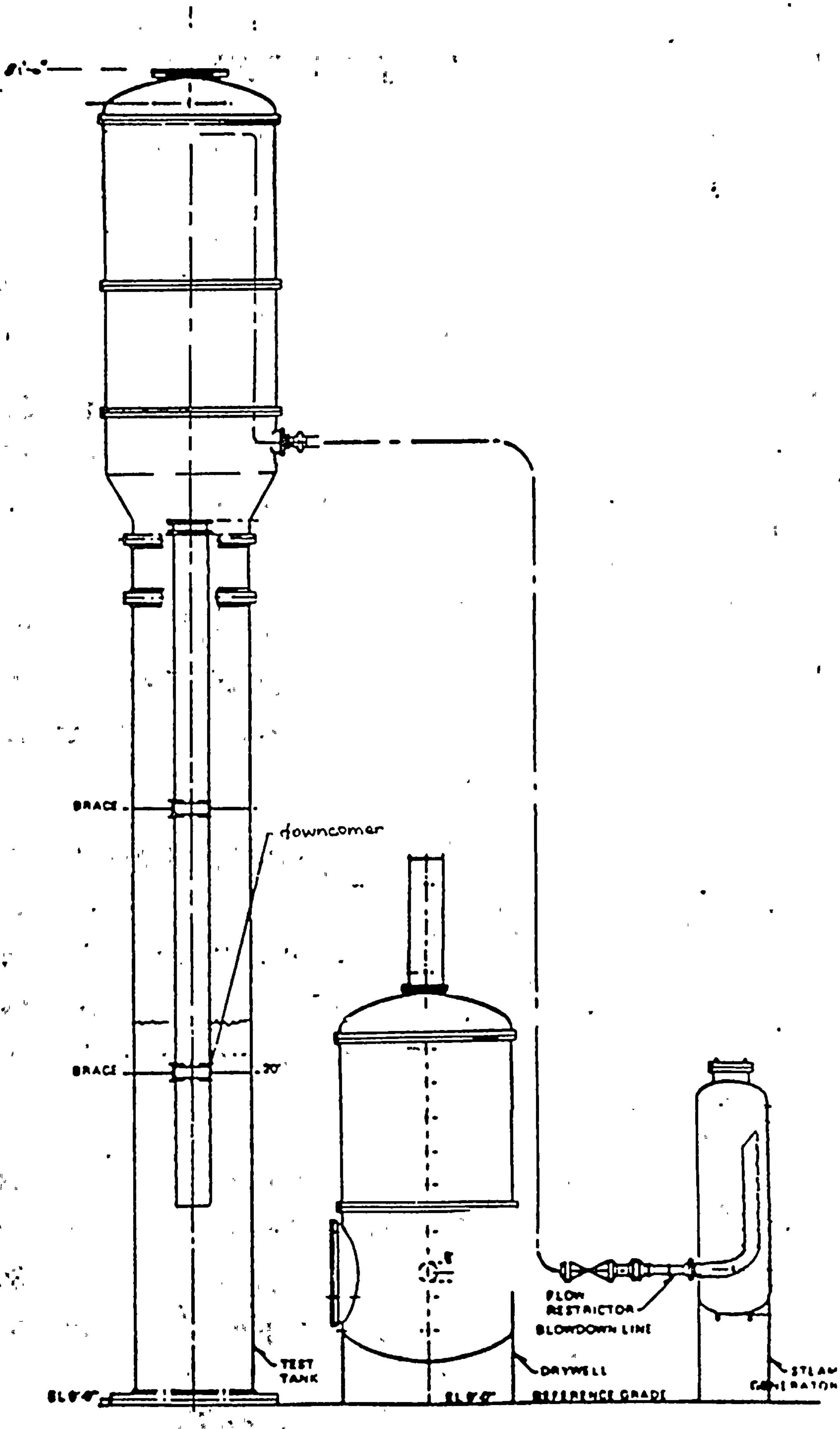
TEST CONFIGURATION FOR PREVIOUS MARK II TESTS



TEST CONFIGURATION FOR MARK II CONDENSATION OSCILLATION TESTS



COMPARISON OF FACILITY FEATURES

	PREVIOUS TESTS	NEW TESTS
0 STEAM VESSEL		
o VOLUME	160 FT^3	SAME
o BREAK TYPE	LIQUID & STEAM	SAME
0 BLOWDOWN LINE		
o TEST INITIATION	RUPTURE DISK PAIR	SAME
o LENGTH	~ 15 FT	~ 90 FT
o FLOW RESTRICTOR	VENTURI	SAME
0 DRYWELL		
o VOLUME	1900 FT^3	SAME
o POSITION	GROUND LEVEL	ABOVE WETWELL
o PREHEAT CAPABILITY	YES	YES
0 VENT		
o DIAMETER	20 AND 24 INCH	24-INCH
o LENGTH	~ 90 FT	45 FT
o BRACING	8 AND 24 FT	SAME
o JET DEFLECTOR	NONE	PROTOTYPICAL
o RISER	NONE	OPTIONAL
0 WETWELL		
o POOL AREA/VENT AREA	11.6	SAME
o VENT DISCHARGE ABOVE BOTTOM	12 FT	SAME
o NOMINAL SUBMERGENCE	11 FT	SAME
o FREESPACE VOLUME (NOMINAL)	1010 FT^3	SAME

GWF
3/16/79

SPECIAL REQUIREMENTS AND CONSIDERATIONS

O BLOWDOWN LINE

- o CAPABILITY TO PREHEAT
- o LARGE ENOUGH TO MAINTAIN CHOKED NOZZLE
- o SMALL ENOUGH TO AVOID PLUG OR SLUG FLOW

O DRYWELL

- o MINIMIZE HOLDUP VOLUME WITH NO RISER
- o PROVIDE FOR REDUCED INITIAL AIR MASS
- o REMOVABLE RISER

GWF
3/16/79

MARK II FULL SCALE 4T C/O TEST

MEASUREMENT OBJECTIVES

- o POOL WALL PRESSURES
- o PRESSURES INSIDE VENT
- o TEMPERATURES IN VICINITY OF VENT EXIT
- o SYSTEM THERMODYNAMIC/HYDRODYNAMIC CONDITIONS
- o VENT AIR CONTENT
- o SELECTIVE INSTRUMENTS FOR TIE BACK TO PREVIOUS 4T DATA.

3/21/79
UCS

INSTRUMENTATION

Location	Instrument Type	Measurement	Real Time (100 Hz/sec)	Replay (1000 Hz/sec)	Filt Freq. (Hz)
Wetwell & Suppression Pool	Flush Mount Press. xdcr	Pool Boundary Press.	10	10	10K
			1		30
		Wetwell airspace press.	1		30
	Accelerometers	Facility Response	3		30
		Local Wall Response	4	4	10K
	Strain gages	Local Wall Response	4	4	10K
	Thermocouples	Pool temperature	12		10
		Freespace temperature	1		10
Downcomer	Flush Mount Press. xdcr	Vent acoustics	5	5	10K
	Cavity ΔP xdcr	Vent flow	1		30
	Cavity press. xdcr	Vent flow	1		30
	Level probe	CO duration	1		-
	Accelerometers	CO duration	1	1	10K
	Thermocouples	Vent flow & temp.	1		10
Drywell	Flush Mount Press. xdcr	Dynamic pressure	2	2	10K
	Cavity press. xdcr	Static press.	1		30
	Cavity ΔP xdcr	Liquid retention	1		30
	Level Probe	Liquid retention	1		-
	Thermocouples	Drywell temperature	1		10
Blowdown Line	Cavity press. xdcr	Blowdown flow	1	1	30
	Thermocouples	Nozzle temp. & blowdwn line exit temp.	1		10
Steam Vessel	Cavity ΔP xdcr	Liquid blowdown flow	8		30
	Cavity press. xdcr	Vessel pressure	1		30
Vacuum Breaker	Micro Switch	Valve opening	1		
		Totals	64	27	

Note: Instrumentation plan also includes a downcomer grab sampler to measure vent flow air content

"PRELIMINARY" TEST MATRIX

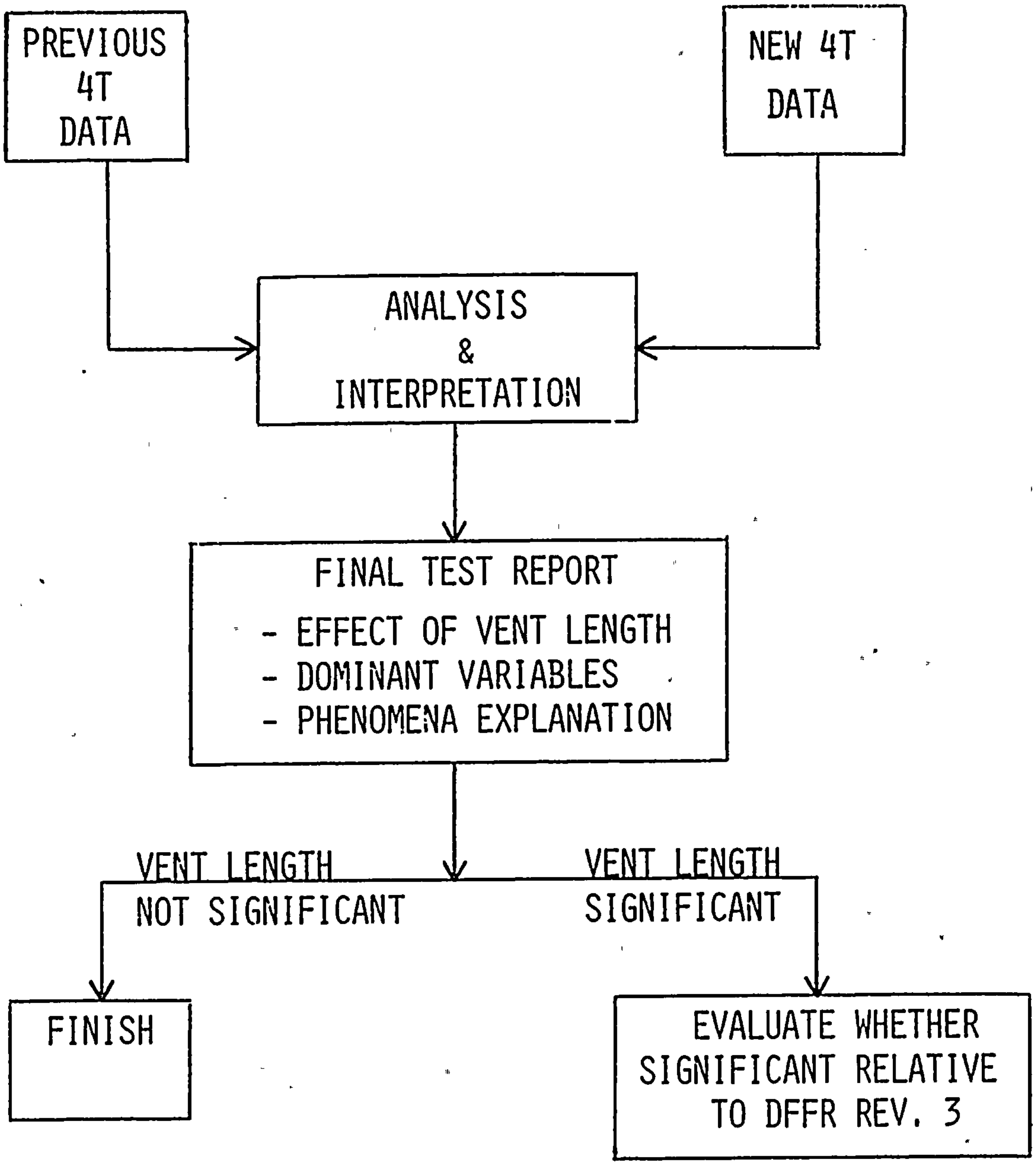
TEST	BREAK SIZE (%DBA)	BREAK TYPE	INITIAL POOL TEMP. (°F)	SUBMERG. (FT.)	DRYWELL INITIAL AIR MASS (%)	EFFECT UNDER INVESTIGATION
1	100	Steam	70	11	100	Temperature
2			120			
3			70	9		Submergence
4				13.5		
5	70			11		Vent Flow Rate
6	30					
7	100				50	Air Content
8	70					
9	30					
10	100				100	Repeat
11	70		120		100	Temperature
12	100	Liquid	70	11	100	Temp (LIQUID)
13			120			
14			70		50	Air Content (LIQUID)
15			120			
16	70	Liquid	120	11	100	Vent Flow Rate
17	30	Liquid	70	11	100	Vent Flow Rate
18	Repeat test -- Parameters to be established later					
19	Repeat test -- Parameters to be established later					
20	Repeat test -- Parameters to be established later					

(CONT'D)

"PRELIMINARY" TEST MATRIX

TEST	BREAK SIZE (%DBA)	BREAK TYPE	INITIAL POOL TEMP.(°F)	SUBMERG. (FT.)	DRYWELL INITIAL AIR MASS (%)	EFFECT UNDER INVESTIGATION
ADDITIONAL TESTS WITH VENT RISER						
1	100	Steam	70	11	100	Vent Riser (Loss Coeff.)
2	100	Liquid	70	11	100	Vent Riser
3	30	Liquid	70	11	100	Vent Riser

EVALUATION OF TEST DATA



KEY TEST ELEMENTS

TEST OBJECTIVES

TEST REQUIREMENTS

FACILITY FUNCTIONAL SPECIFICATION

FACILITY DESIGN

FACILITY CONSTRUCTION

TEST PLAN

TEST PROCEDURES

DATA ACQUISITION SOFTWARE QUALIFICATION

DATA REDUCTION SOFTWARE QUALIFICATION

INSTRUMENT CALIBRATIONS

AS-BUILT DRAWINGS

FACILITY ACCEPTANCE TESTS

FACILITY OPERATIONAL LIMITS

OPERATIONAL READINESS REVIEW

OPERATOR TRAINING & CERTIFICATION

TEST CONDUCT

QUICK LOOK DATA EVALUATION

FINAL DATA REDUCTION

DATA REPORT

DATA UTILIZATION

BFM
3/19/79

FACILITY DESIGN
MARK II 4TCO TEST

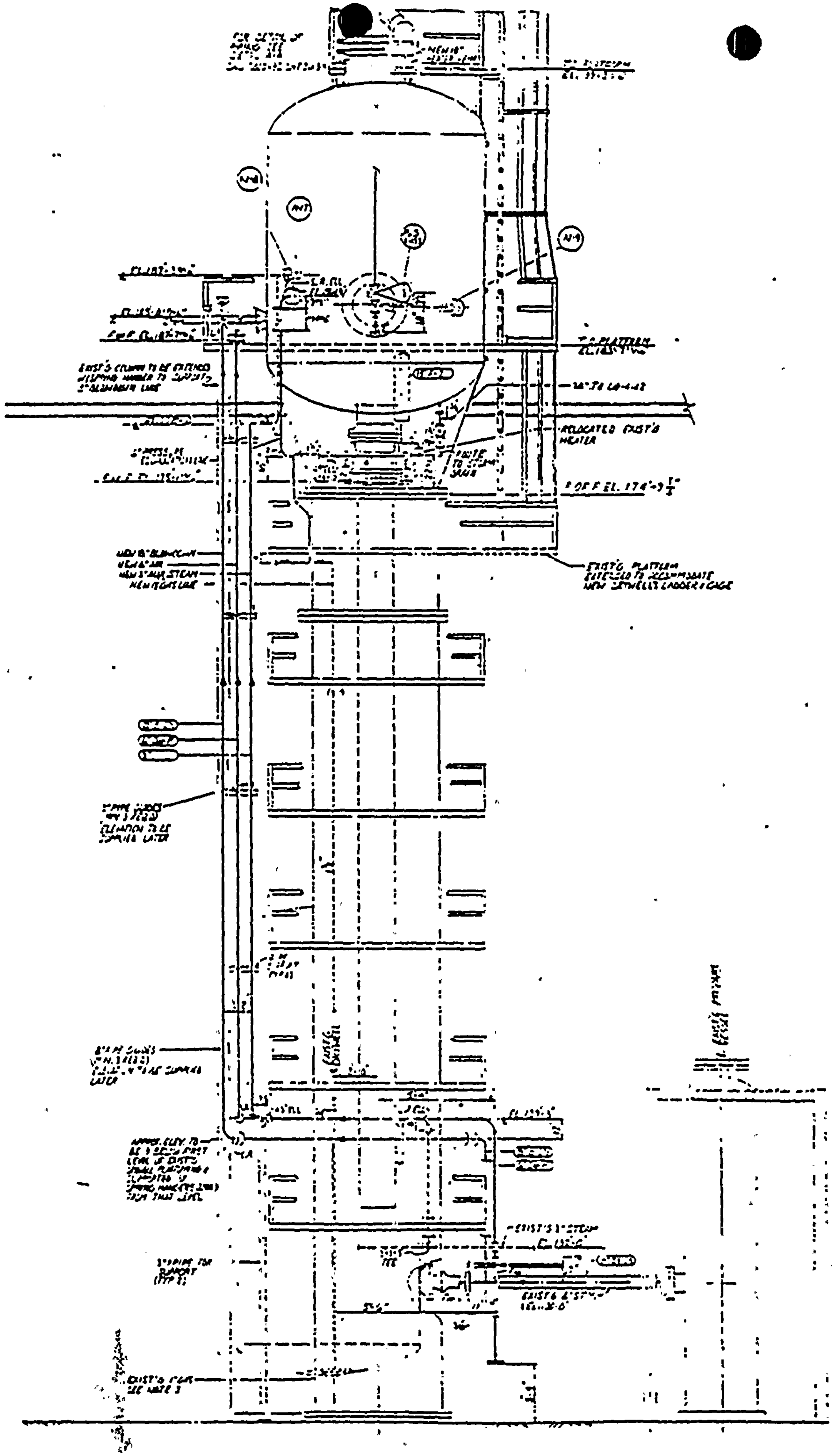
USE WITHOUT MODIFICATIONS FROM 4T

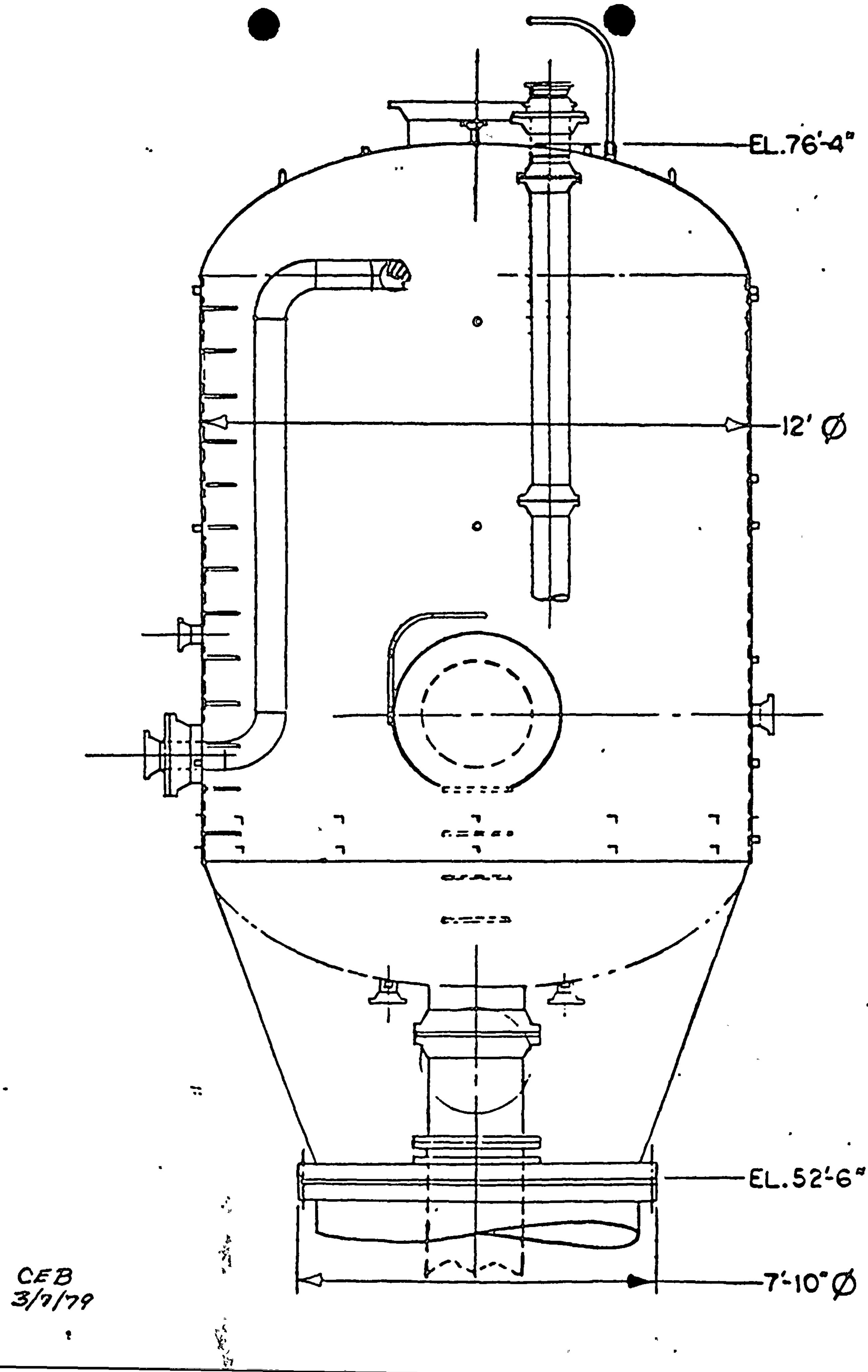
- STEAM GENERATOR
- 4T WETWELL
- DOWNCOMER
- RUPTURE DISC SYSTEM
- DATA ACQUISITION SYSTEM HARDWARE
- DATA ACQUISITION SOFTWARE
- CONTROL SYSTEM
- WATER TRANSFER & TREATMENT SYSTEM
- FOUNDATIONS

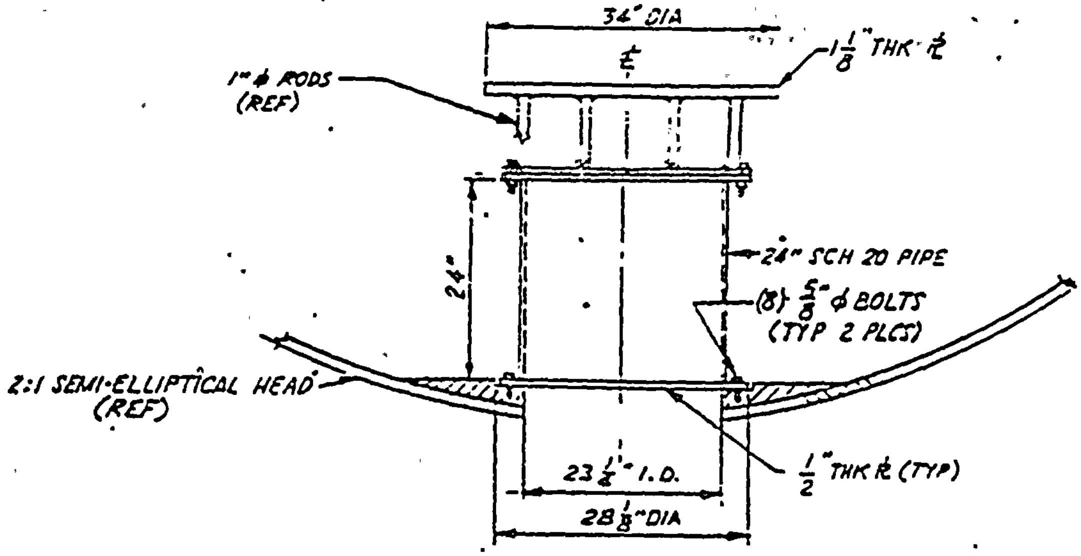
MODIFICATIONS REQUIRED

- DRYWELL & SPOOL PIECE
- BLOWDOWN LINE
  - EXTEND
  - HEAT TRACE
- VENT RISER
- INSTRUMENTATION & CABLE

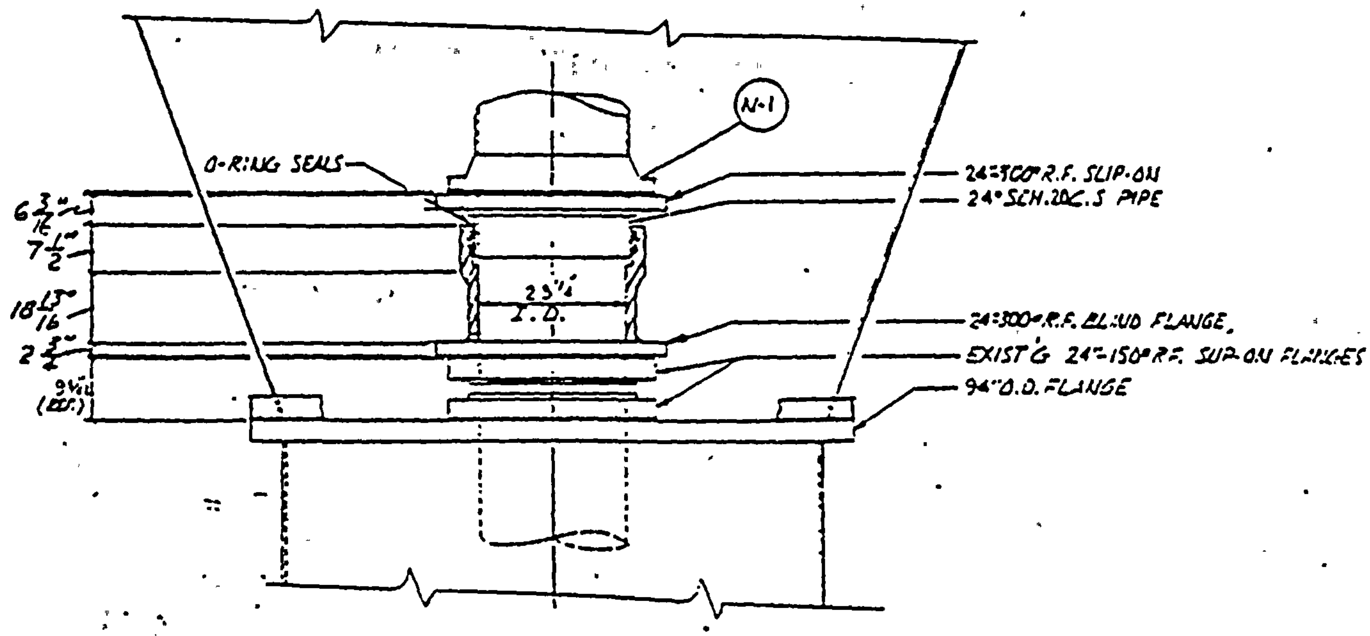
BFMc
3/29/79




EL.76'-4"
12' Ø
EL.52'-6"
7'-10" Ø
CEB
3/7/79


34" DIA
1 1/8" THK PL
1" ϕ RODS (REF)
24" SCH 20 PIPE
24"
(8) 5/8" ϕ BOLTS (TYP 2 PLCS)
2:1 SEMI-ELLIPTICAL HEAD (REF)
23 1/4" I.D.
1/2" THK PL (TYP)
28 1/8" DIA

DETAIL


N-1
O-RING SEALS
24"-300# R.F. SLIP-ON
24" SCH.20 C.S PIPE
6 3/16"
7 1/2"
18 13/16"
2 3/4"
23 1/4" I.D.
24"-300# R.F. BLIND FLANGE
EXIST'G 24"-150# R.F. SLIP-ON FLANGES
94" O.D. FLANGE

MARK II 4TCO FACILITY DESIGN

PRELIMINARY DESIGN ACTIVITIES

- TEST REQUIREMENTS SPECIFICATION
- FACILITY FUNCTIONAL SPECIFICATION
- PRELIMINARY DESIGN PACKAGE
  - P&ID
  - EQUIPMENT AGGT DRAWING
  - PIPING DRAWING
  - INSTRUMENT/EQUIPMENT LIST
  - FACILITY SPECIFICATION
  - LONG LEAD ITEM DESIGN (DRYWELL)
- PLACE DRYWELL ORDER
- OTHER ITEMS
  - DAS REVIEW (DATA ACQUISITION SYSTEM)
  - SITE CLEARANCE PERMIT
  - INSTRUMENTATION ORDERS

BFMc
3/L9/79

MULTIVENT TEST PROGRAM

PRELIMINARY 1/10 SCALE MULTIVENT DATA FROM 1, 3, 7 VENT TESTS

Creare Inc.
3/14/79

TABLE 1

PHASE I — MULTIVENT SCOPING TESTS, GEOMETRIC CONFIGURATIONS

Geometry Number	Number of Vents	Vent Diameter (in.)	Wetwell Diameter (in.)	Drywell Volume (ft^3)	Vent Offset (in.)	Test Matrix Type[c]
1	1	2.5	10	2.5	0	I
2	1	2.5	18	2.5	0	II
3	1	2.5	18	7.3	0	II
4	1	2.5	18	32	0	II
5(a)	1	2.5	18	2.5	4	II
6	1	2.5	30	2.5	0	II
7(b)	1	2.5	30	2.5	6	II
8(a)	1	2.5	30	2.5	10	II
9	1	4	18	11	0	I
10	3	2.5	18	7.3	—	I
11	3	2.5	18	32	—	II
12	3	4	30	33	—	I
13	3	4	30	93	—	II
14	7	2.5	28	17.3	—	I

NOTES:

(a) Same vent to wall spacing as geometry 1

(b) Same vent to wall spacing as geometry 2

(c) See Table 3 for definition of Test Matrix

TEST MATRIX

TABLE 3(a)

1/10 & 1/6 — SCALED MULTIVENT SCOPING TESTS

TYPE I TEST MATRIX FOR GEOMS. 1,9,10,12,14**

Pressure (psia)	4.5 or 7.5		14.7	45	
Steam Mass Flux (lbm/ft²sec)	0.1,0.2 0.5,1,2	0.1,0.5, 2	0.2,1, 4	0.5,1,2, 4,8,16	1,4, 16
Air Content (%)	0	0.1,0.2, 0.5	0	0	0.1,0.2, 0.5
Temperature (°F)	*90,130	90	90,130	90,130 160,200	130
Number of Tests	10	9	6	24	9
Total Number of Type I Tests: 58x5 = 290					

TABLE 3(b)

1/10 & 1/6 — SCALED MULTIVENT SCOPING TESTS

TYPE II TEST MATRIX FOR GEOMS. 2,3,4,5,6,7,8,11,13**

Pressure (psia)	4.5 or 7.5	45
Steam Mass Flux (lbm/ft²sec)	0.2,0.5,1	0.5,1,2,4,8,16
Air Content (%)	0	0
Temperature (°F)	90,130	130,160
Number of Tests	6	12
Total Number of Type II Tests: 18x9 = 162		

*Lower temperature desirable for low mass flux and will be run as conditions/facility allow it.

**See Table 1 for test geometry description.

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SUMMARY OF RESULTS TO DATE

- 1/10 SCALE SINGLE VENT DATA CONSISTENT WITH PREVIOUS SINGLE VENT TESTS.
- THE MULTIVENT MULTIPLIER IS LESS THAN ONE
- THE MULTIVENT MULTIPLIER DECREASES WITH INCREASING NUMBER OF VENTS.

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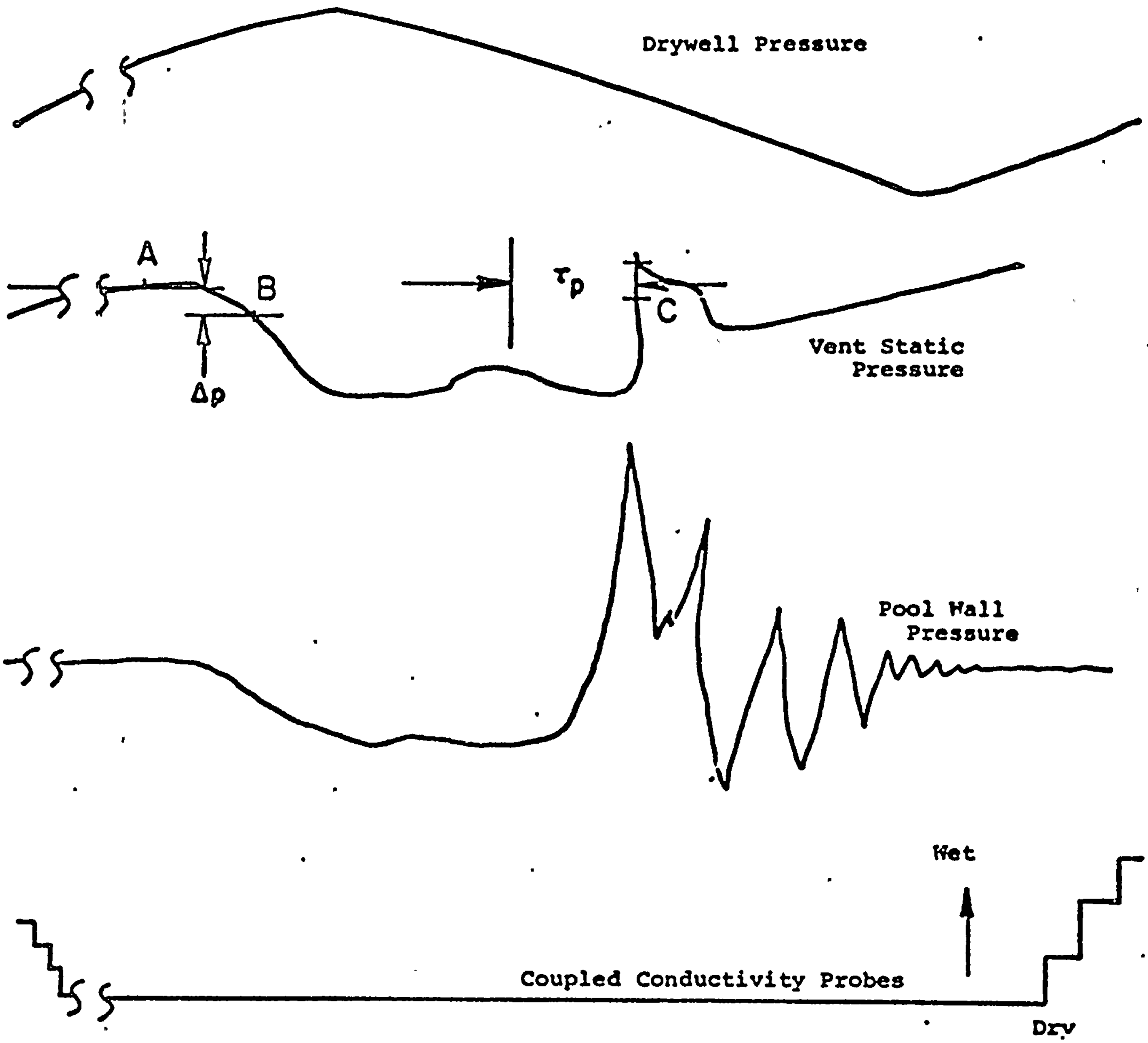

Signal Traces During a Chug

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PHASING

— PHASING DATA TO BE OBTAINED FOR THREE VENT GEOMETRIES ONLY.

— CRITERIA FOR A CHUG TO HAVE OCCURRED AT A VENT IN THE MULTIVENT GEOMETRY

- NO WATER IN THE VENT (DETERMINED FROM COUPLED CONDUCTIVITY PROBES)
- RAPID CONDENSATION AT VENT EXIT (DETERMINED FROM STATIC PRESSURE IN THE VENT)
- PRESSURE SPIKE OCCURRING AT THE POOL WALL (DETERMINED FROM POOL WALL PRESSURE TRANSDUCER)

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TYPICAL PHASING DATA

- PERCENTAGE OF VENT CHUGGING DURING A POOL CHUG (% OF TIME 1, 2, OR 3 VENTS CHUGGED)
- TIME WINDOW STATISTICS (MEAN TIME WINDOW AND STANDARD DEVIATION)

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REMAINING PHASE 1 TESTS

— MULTIVENT TESTS AT 1/6 SCALE (1, 3 VENTS). THESE TESTS WILL PROVIDE ADDITIONAL MULTIVENT DATA FOR COMPARISON WITH 1/10 SCALE DATA.

— SINGLE VENT AND MULTIVENT TESTS TO DETERMINE
  - EFFECT OF POOL SIZE ON WALL PRESSURES
  - EFFECT OF VENT LOCATION IN THE POOL ON WALL PRESSURE
  - EFFECT OF DRYWELL ON VENT PHASING

THESE TESTS WILL PROVIDE THE PHYSICAL INSIGHTS NEEDED TO EXPLAIN THE REDUCTION IN POOL WALL PRESSURES OBSERVED IN MULTIVENT CHUGGING.

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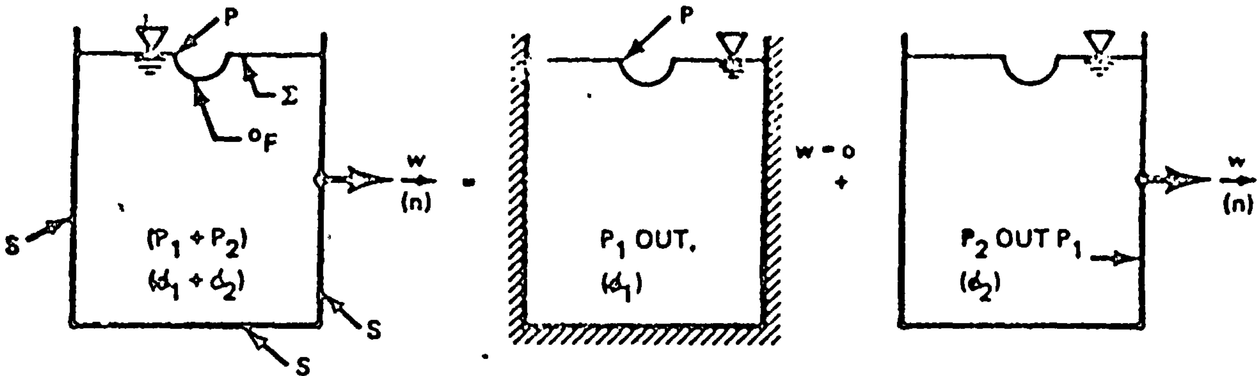
CHUGGING METHODOLOGY.

3/21/79



{ FLEXIBLE CONTAINER FORCING SIGNAL APPLIED WITHIN FLUID } = { RIGID CONTAINER FORCING SIGNAL APPLIED WITHIN FLUID } + { FLEXIBLE CONTAINER INCIDENT PRESSURE WAVE (P_1) APPLIED AT FLUID STRUCTURE INTERFACE }

$L^N(w) + \rho_s \ddot{w} = p_1 + p_2;$	$w = o;$	$L^N(w) + \rho_s \ddot{w} = p_1 + p_2;$
$\nabla^2(\phi_1 + \phi_2) = \frac{1}{c^2}(\ddot{\phi}_1 + \ddot{\phi}_2);$	$\nabla^2 \phi_1 = \frac{1}{c^2}\ddot{\phi}_1;$	$\nabla^2 \phi_2 = \frac{1}{c^2}\ddot{\phi}_2;$
$(p_1 + p_2) = \rho(\dot{\phi}_1 + \dot{\phi}_2);$	$p_1 = \rho\phi_1;$	$p_2 = \rho\phi_2;$
$\frac{\partial}{\partial n}(\phi_1 + \phi_2)\,]_S = \dot{w};$	$\frac{\partial\phi_1}{\partial n}\,]_S = o;$	$\frac{\partial\phi_2}{\partial n}\,]_S = \dot{w};$
$(p_1 + p_2)\,]_{\sigma_F} = p;$	$p_1\,]_{\sigma_F} = p;$	$p_2\,]_{\sigma_F} = o;$
$(p_1 + p_2)\,]_{\Sigma} = o;$	$p_1\,]_{\Sigma} = o;$	$p_2\,]_{\Sigma} = o;$

Category I Classical Chugs

Shape: damped sinusoidal

Predominant Frequencies: 20 to 30 Hz

Peak Pressure Amplitude: 34 to 138 kPa positive (5 to 20 psi)

28 to 96 kPa negative (-4 to -14 psi)

Category II C.O. Events

Shape: sinusoidal

Predominant Frequencies: 5, 13, 21 Hz

Peak Pressure Amplitude: 34 kPa positive and ~~24~~ 34 kPa negative (±5 psi)

Category III Mixed C.O. and Chugging

Shape: damped and undamped sinusoidal

Predominant Frequencies: 5, 13, 21 and 20 to 30 Hz

Peak Pressure Amplitude: 103 kPa positive and 103 kPa negative (±15 psi)

Category IV Other Events

Shape: irregular

Predominant Frequencies: mixture of 5, 13, 21, 30, 35 to 40, 45 to 50 Hz

Peak Pressure Amplitude: 34 kPa (<5 psi) or very low amplitude

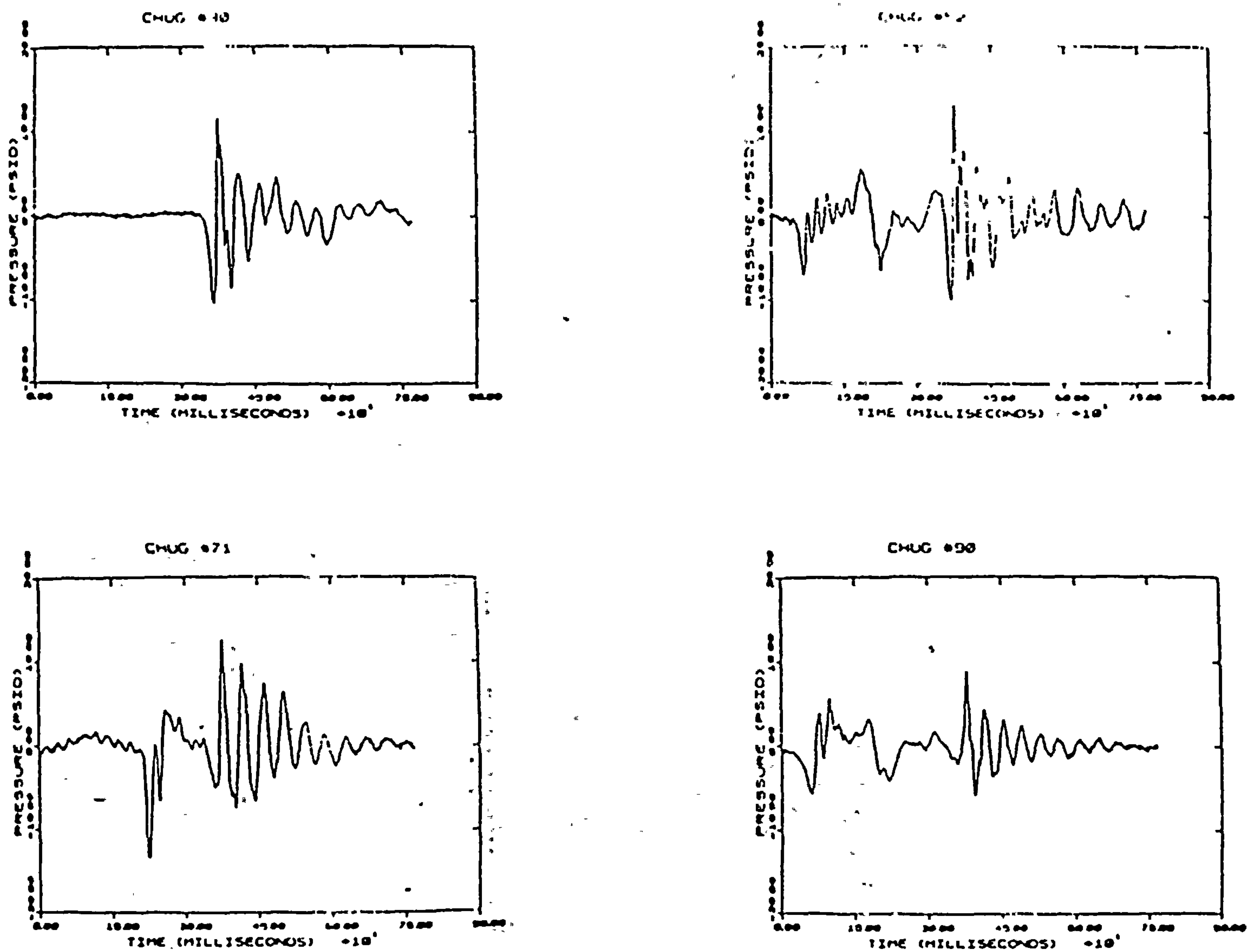


Figure 2-1 Examples of Category I Chugs

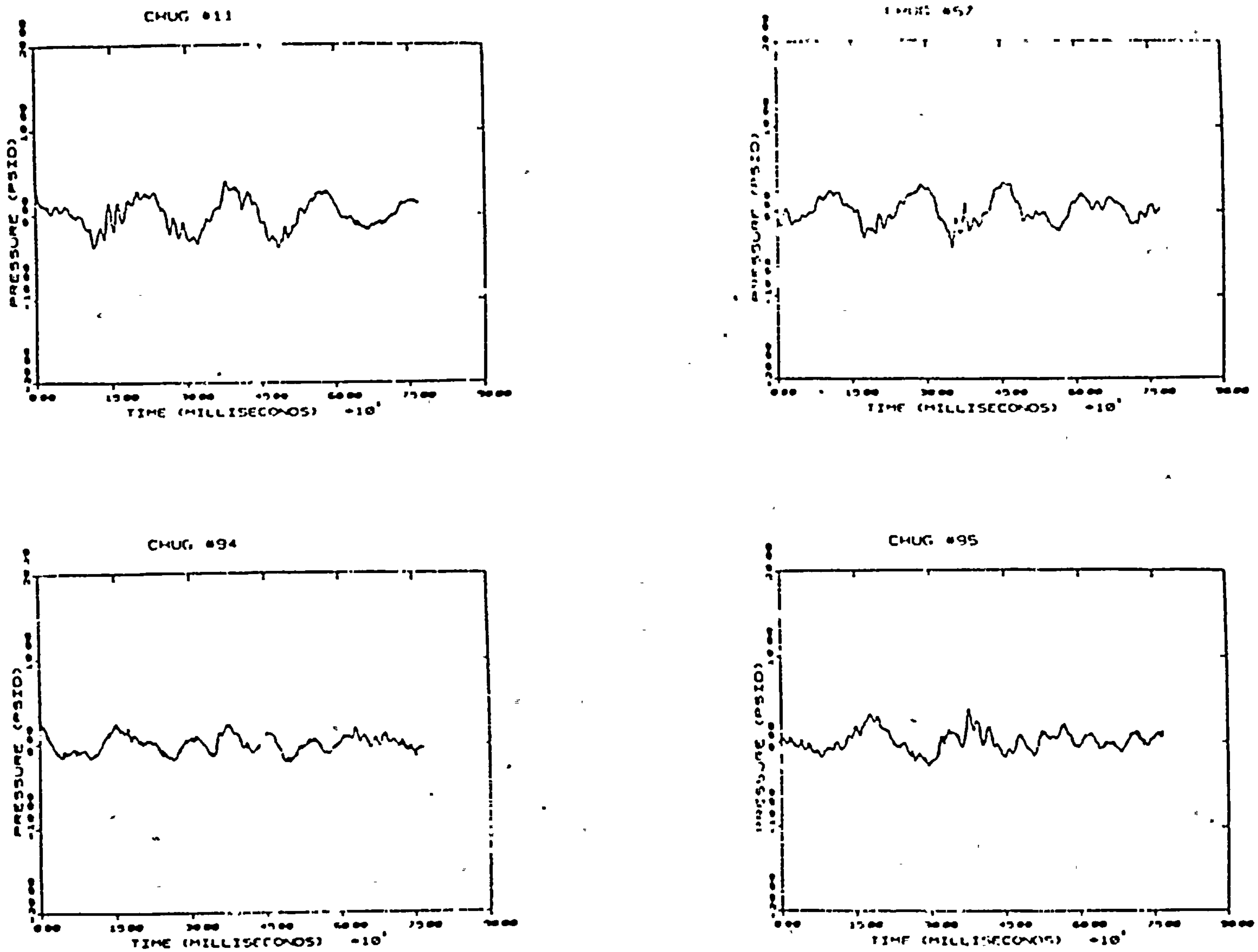


Figure 2-2 Examples of Category II Chugs

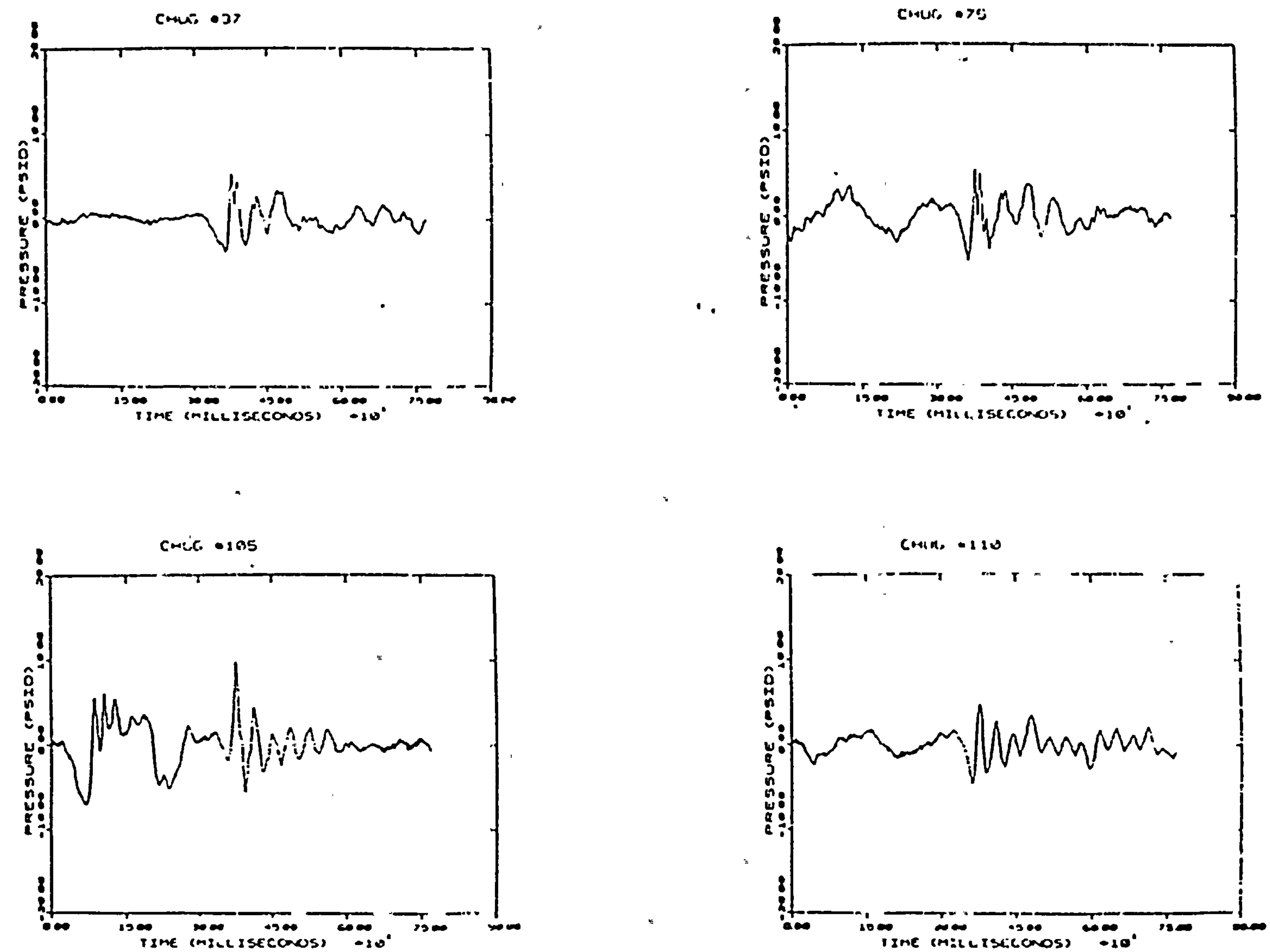


Figure 2-3 Examples of Category III Chugs

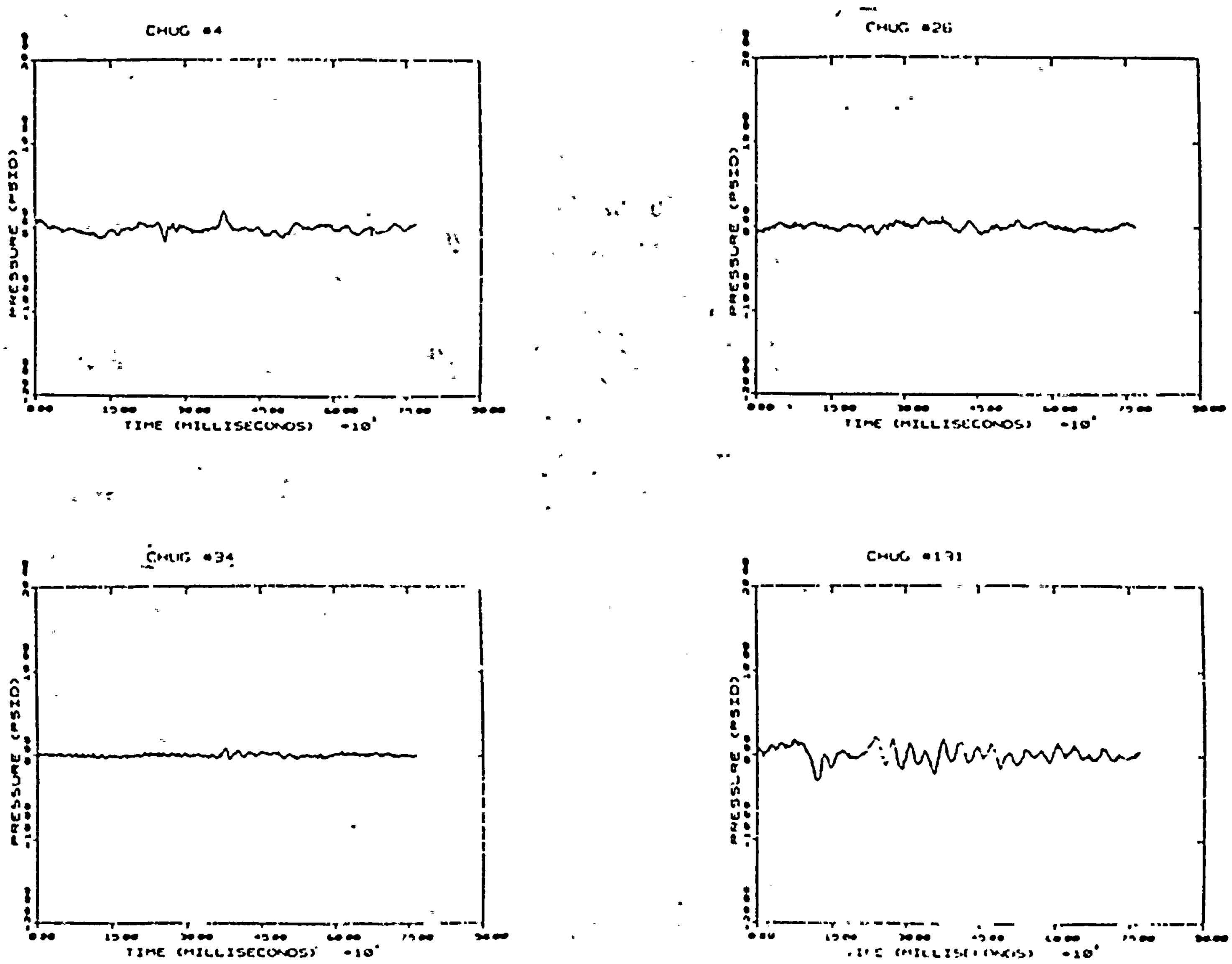


Figure 2-4 Examples of Category IV Chugs

CATEGORY	No. OF EVENTS	FRAC. TOTAL EVENTS	PRINCIPLE FREQ.	NORM. CONST.	FRAC. TOTAL POWER	POWER/EVENT
I. CLASSICAL	14	.102	5, 13, 21, 22 TO 31	124.15	0.20	8.87
II. C.O.	71	.518	5, 13, 21, 29	314.46	0.50	4.43
III. MIXED	25	.182	5, 13, 21, 22 TO 30	173.28	0.27	6.93
IV. OTHER	27	.197	5, 13, 21, 30, 36-40, 46-48	22.08	0.03	0.82
	137	1.000		633.97	1.00	

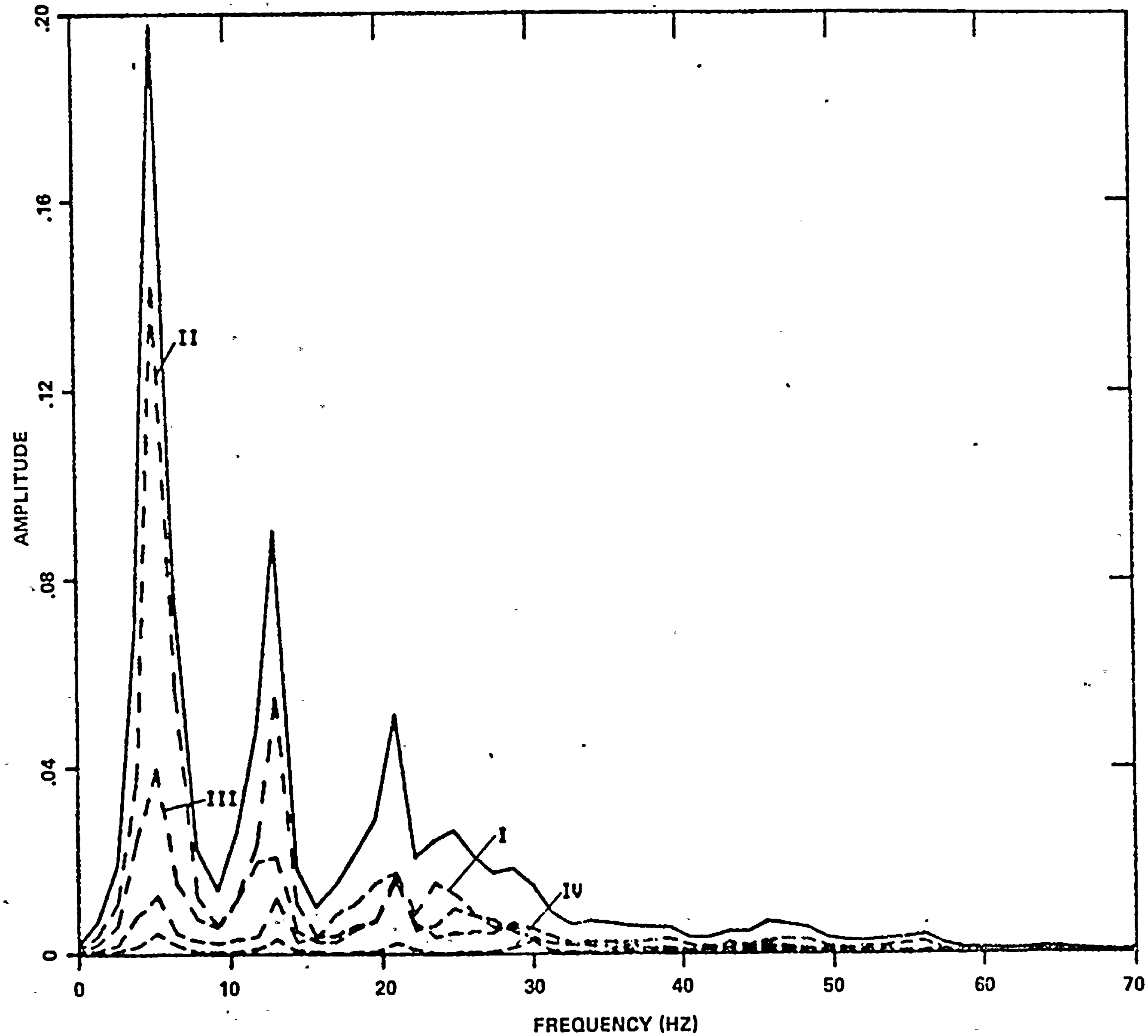


Figure 2-10 Composite PSD for Category I, II, III and IV Chugs

G1002820-10

VENT PIPE FREQUENCIES
IN 4T

$$F_N = (2N - 1)\,c / 4L\ ,\quad N = 1,2,3,\ldots$$

$$c = 478.5\ \text{M/S}\ \ (1570\ \text{FPS})\ ,\quad L = 28.65\ \text{M}\ \ (94\ \text{FT})$$

N	F_N	$F^*_{OBSERVED}$
1	4.18 HZ	5 HZ
2	12.53	13
3	20.88	21
4	29.23	29
5	37.58	39
6	45.93	48
7	54.28	56

* CATEGORY II AND CATEGORY IV CHUGS

POOL RINGOUT FREQUENCIES

IN 4T

$$F_N = (2N - 1)\, C / 4L \quad , N = 1,2,3,\ldots$$

$$C = C_0 / \sqrt{1 + BD/YE}$$

C_0 = SONIC VELOCITY = 1524 M/S

B = BULK MODULUS = 2.18×10^9 PA

Y = YOUNG'S MODULUS = 19.5×10^{10} PA

D = 4T DIAMETER = 2.13 M

E = 4T WALL THICKNESS = 1.59 CM

$C = C_0 / 1.58 = 965$ M/S (3164 FPS)

$L = 7.01$ M (23 FT)

N	F_N	$F_{OBSERVED}$
1	34.4 HZ	36.1 , 32.2 HZ
2	103.2	110
3	172.0	-

EFFECT OF ENTRAINED AIR ON POOL SONIC VELOCITY

CASE	SONIC VELOCITY	F_1	% REDUCTION
PURE WATER	1524 M/S (5000 FPS)	54.4 HZ	-
4 T FLEXIBILITY	965 M/S (3164 FPS)	34.4 HZ	37 %
ENTRAINED AIR	659 M/S (2162 FPS)	23.5 HZ*	32 %

* PEAK OF CATEGORY I CHUGS AVERAGED PSD

CONCLUSIONS
OF
4T DATA EVALUATION

CHUGGING INCLUDES A VARIETY OF RELATED, BUT DIFFERENT PHENOMENA (4 CATEGORIES).

CATEGORY I CHUGS DEPEND UPON POOL RINGOUT FREQUENCY (c/4L) AND HAVE TWICE THE POWER PER EVENT AS CATEGORY II CHUGS.

CATEGORY II CHUGS DEPEND UPON VENT ACOUSTICAL FREQUENCIES (c/4L).

THE SONIC VELOCITY IN THE POOL IS MODIFIED BY TANK FLEXIBILITY AND ENTRAINED AIR.

NUMERICAL SOLUTION OF 4T CHUGGING PROBLEM

- PURPOSE
  UNDERSTAND PHYSICS OF 4T CHUGGING
  RESPONSE APPROPRIATE ASSUMPTIONS
  TO DEVELOP SIMPLE MODEL (ACOUSTIC)

- ASSUMPTIONS
  RIGID TANK (LATER RELAXED)
  NEWTONIAN FLUIDS (STEAM AND WATER)

- FLUID FIELD EQUATIONS
  CONSERVATION OF MASS: $\partial\rho/\partial t + \vec{\nabla}\cdot(\rho\vec{v}) = 0$

  CONSERVATION OF MOMENTUM

  $$\rho[\partial\vec{v}/\partial t + (\vec{v}\cdot\vec{\nabla})\vec{v}] = \vec{\nabla}p - [\vec{\nabla}\vec{\tau}] + \rho\vec{g}$$

  CONSERVATION OF ENERGY

  $$\rho\ [\partial e/\partial t + \vec{v}\cdot\vec{\nabla}e] = -\vec{\nabla}\cdot\vec{q} - p\vec{\nabla}\cdot\vec{v} - [\vec{\tau}:\nabla\vec{v}]$$

- EQUATIONS OF STATE
  STEAM $p_s = \rho_s R_s T$

  WATER $p_\omega = B\ (1-\rho_o/\rho_\omega)$

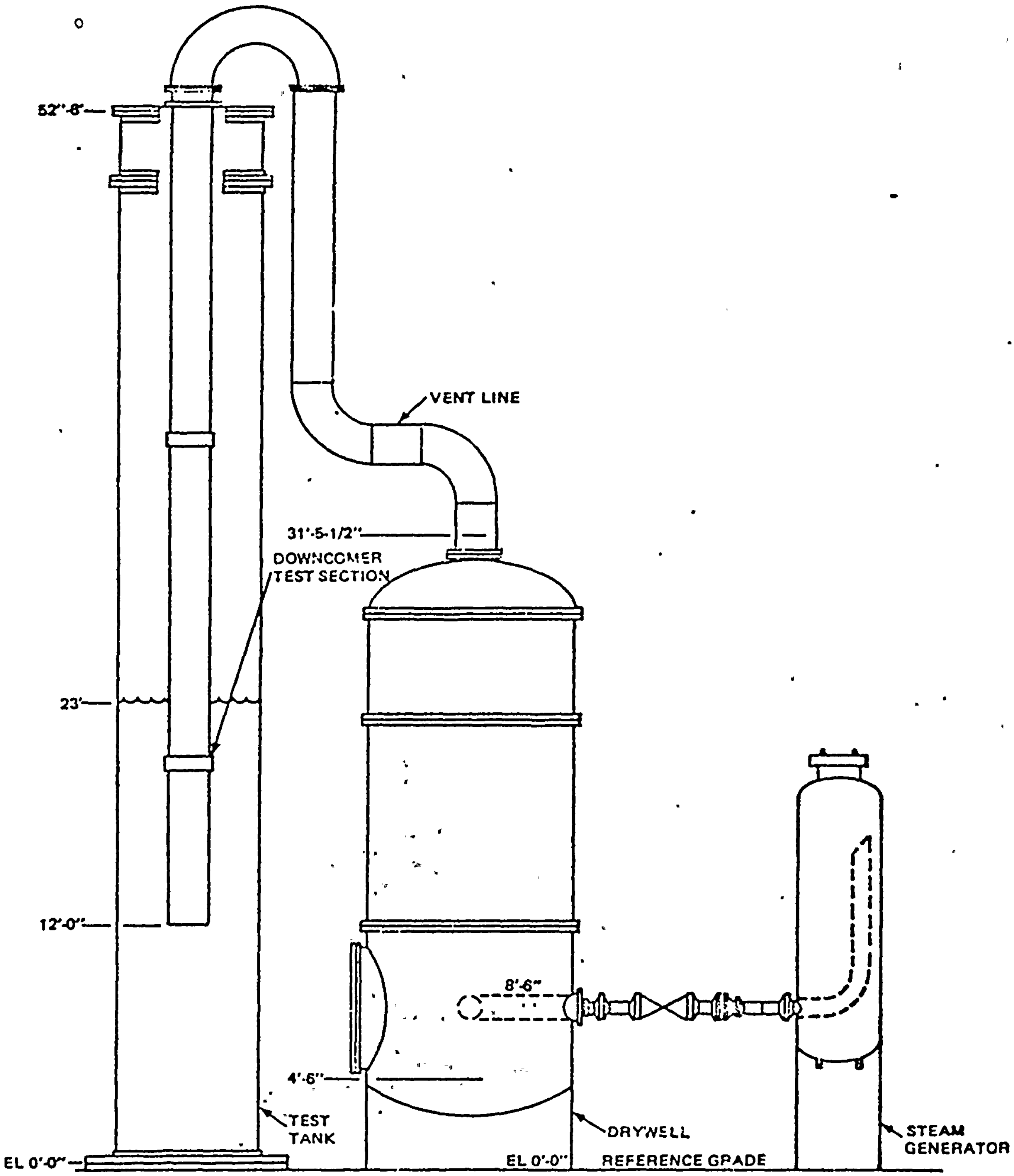


Figure 3-1 4T Test Facility Schematic

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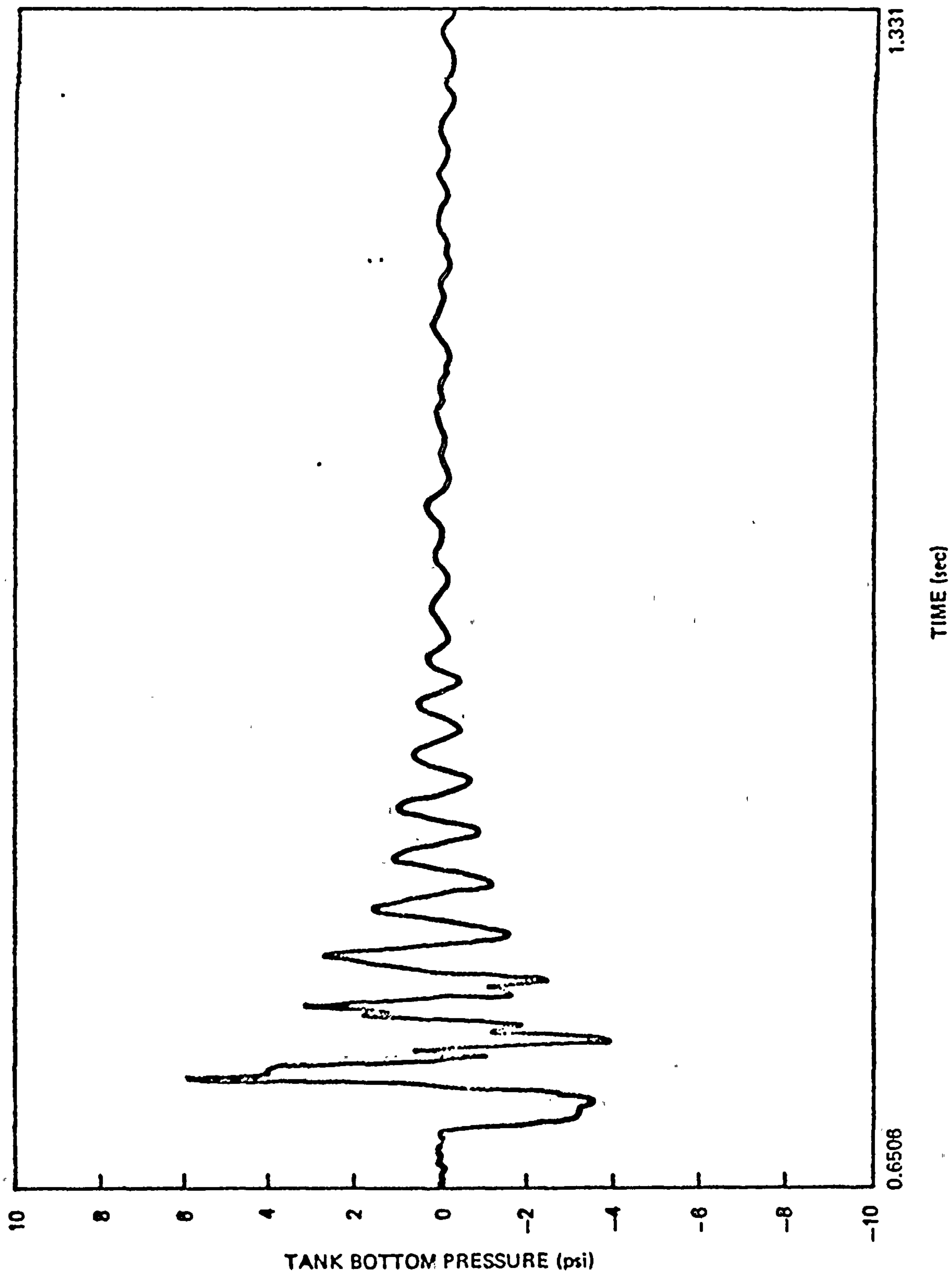

Figure 3-3 4T Bell Jar Test

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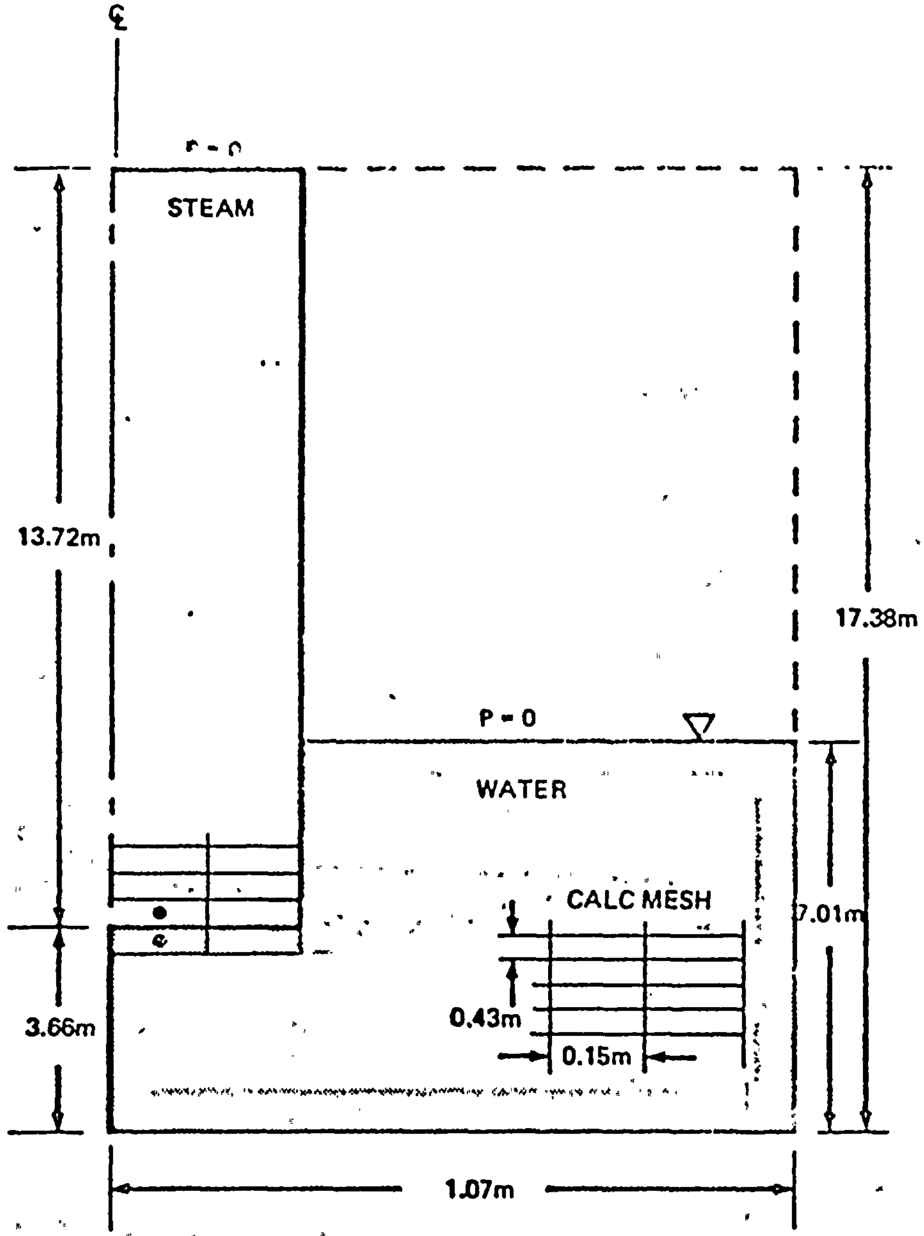

Figure 3-2 K-FIX Model of 4T Facility

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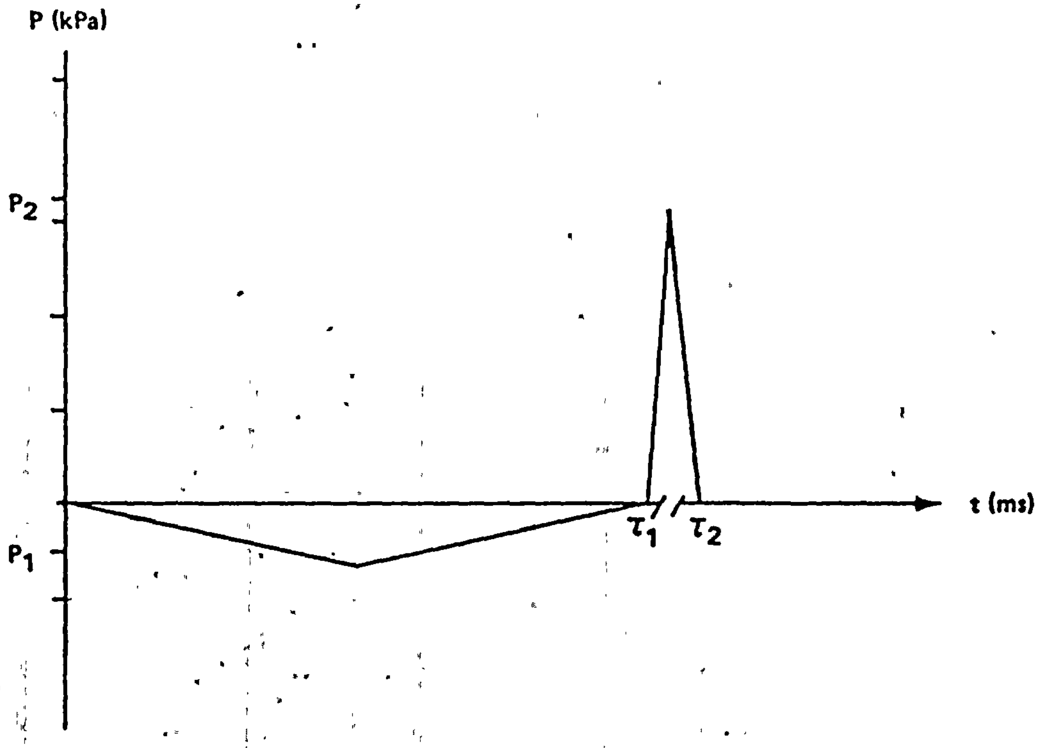


Figure 3-4 Estimated 4T Chug Source

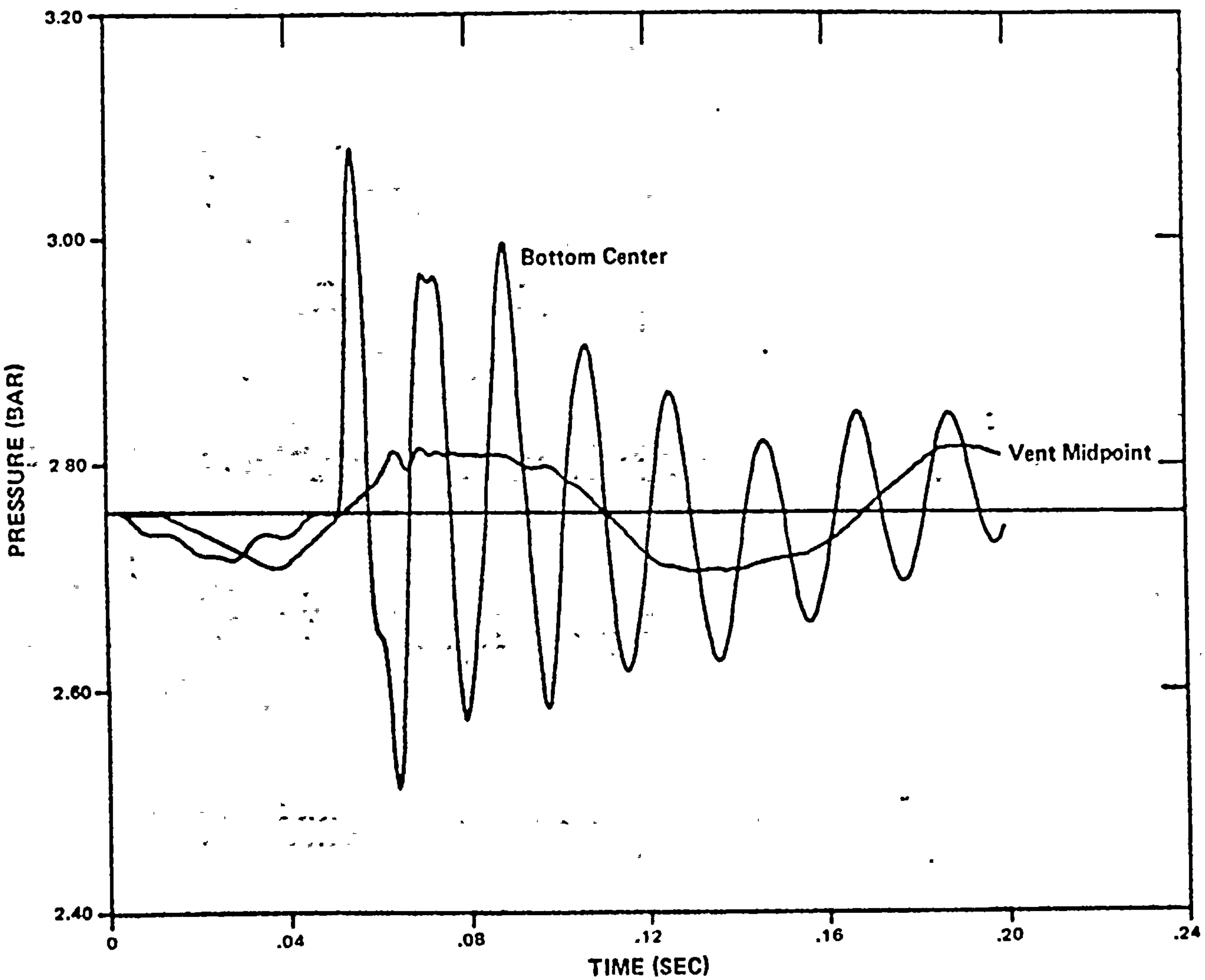


Figure 3-5 K-FIX Chug Simulation

C 1002820.45

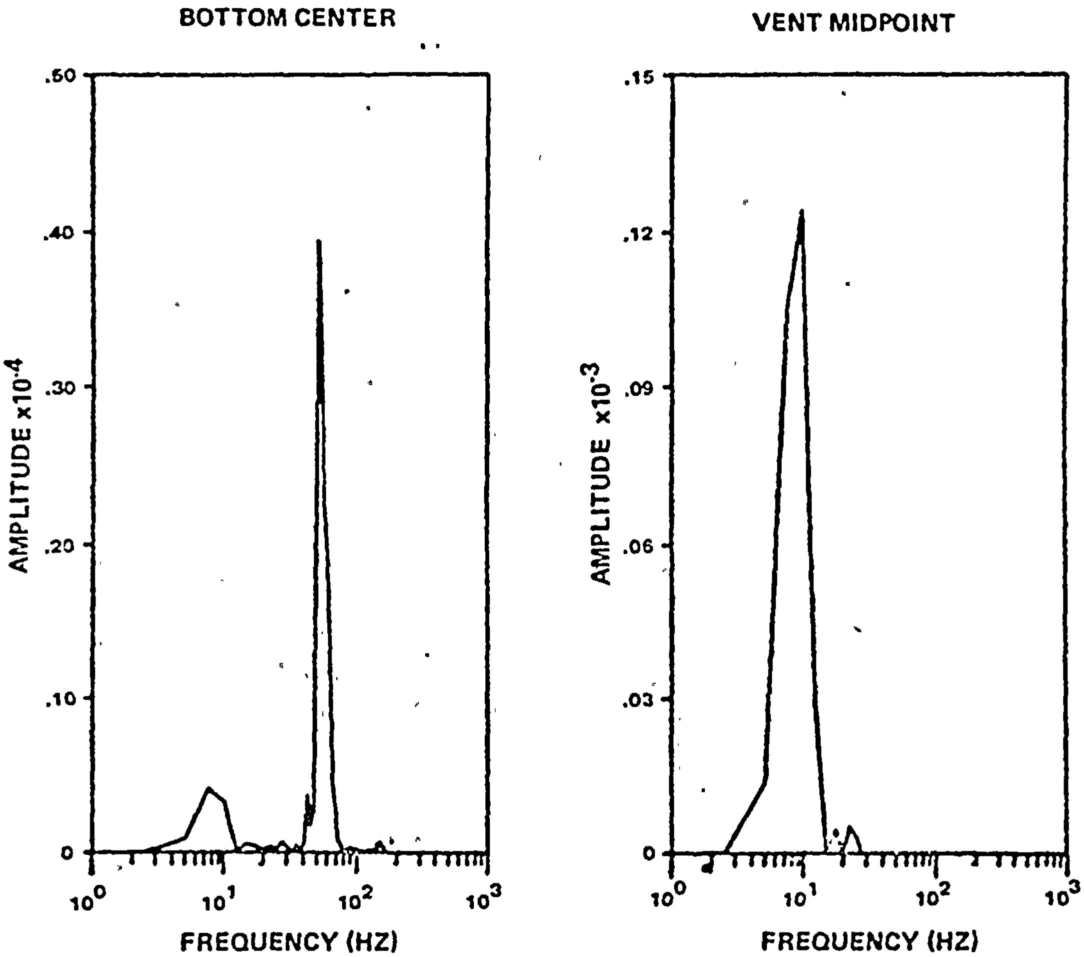


Figure 3-6 K-FIX Power Spectral Densities

G1002820-54

NUMERICAL SOLUTION CONCLUSIONS

- 4T CHUG SOURCE CAN BE "MODELED" AS BUBBLE COLLAPSE
- POOL IS ACOUSTICALLY DECOUPLED FROM VENT
- VENT SERVES AS LONG TERM SOURCE FOLLOWING IMPULSE
- FLUID RESPONSE LINEAR ($v \sim 1m/s \ll c$)
- PROBLEM CAN BE SOLVED ACOUSTICALLY ($\Box^2 p = -4\pi f$)
- POOL RING-OUT FREQUENCY REDUCED ~37% (FLEXIBLE WALL)
- PRESSURE AMPLITUDE REDUCED ~10% (FLEXIBLE WALL)

ACCUSTIC MODEL JUSTIFICATION

- ANALYTICAL SOLUTION
  - BETTER UNDERSTANDING OF PHYSICS
  - LOW COMPUTER COST
- STRAIGHT-FORWARD EXTENSION TO MARK II
- USEFUL TOOL FOR SOURCE DEFINITION

ACOUSTIC MODEL ASSUMPTIONS

- CHUGGING RESPONSE IS HARMONIC
- VENT DECOUPLED FROM POOL
- SIMPLE POINT SOURCE
- NEGLECT SOURCE/WAVE INTERACTIONS

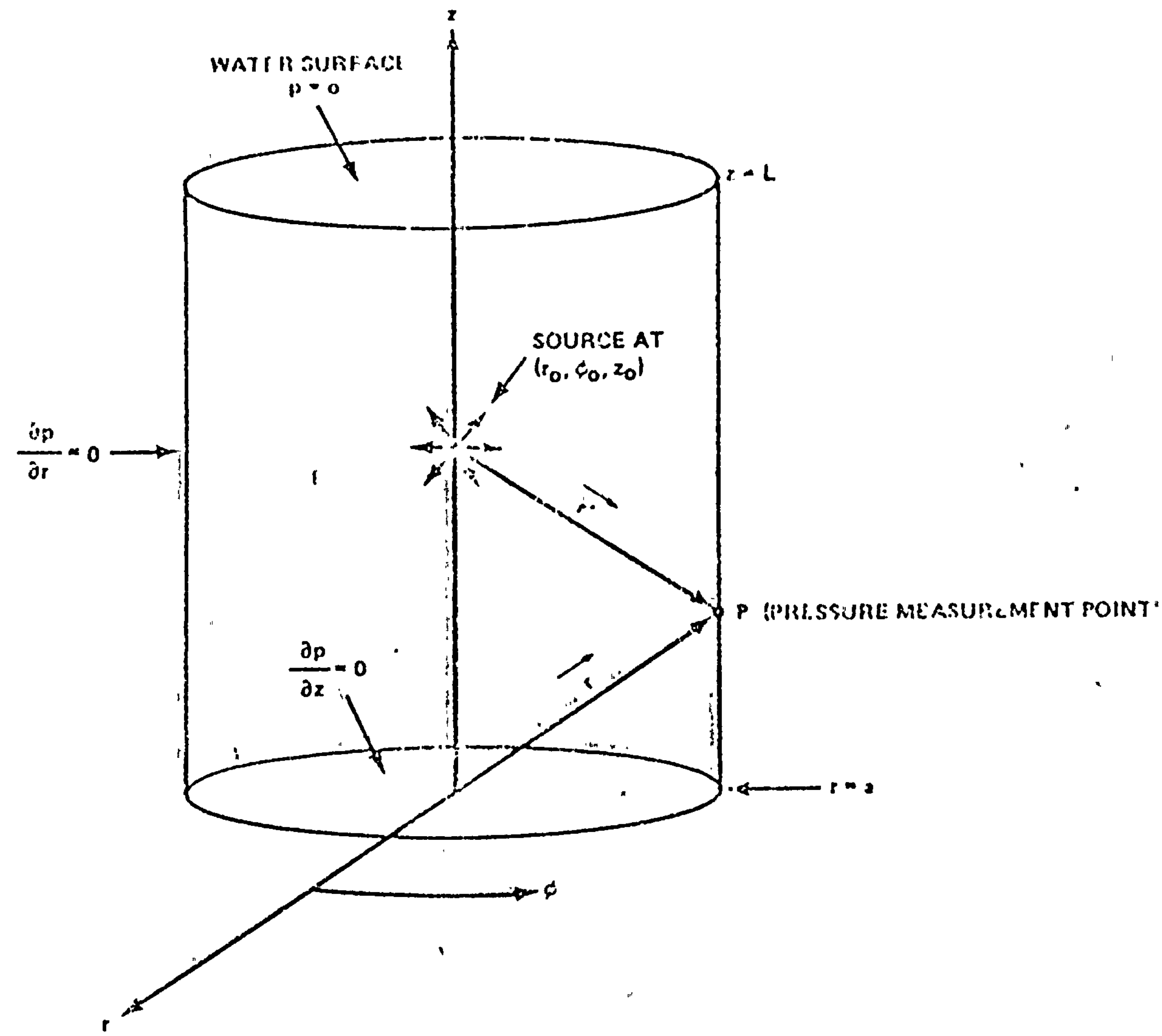
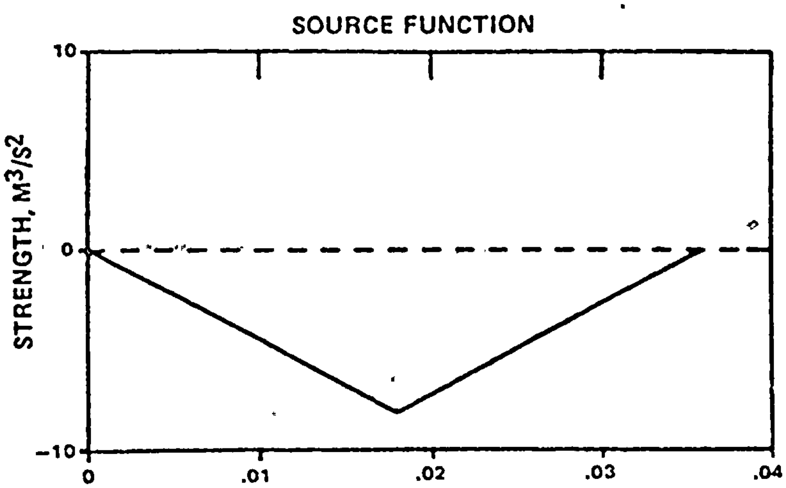
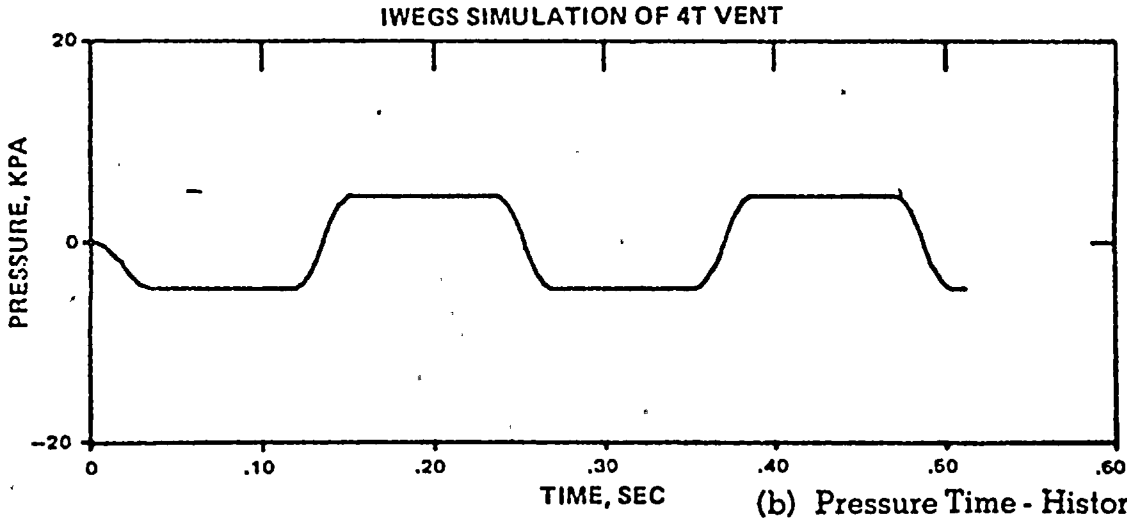


Figure 4-1 Acoustic Model Geometry

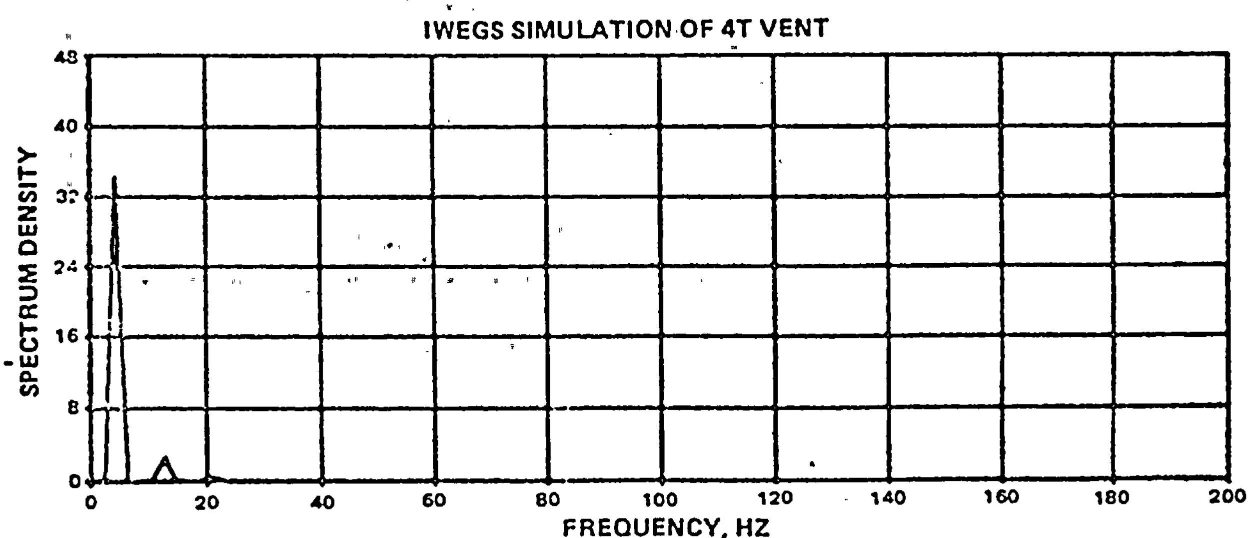
0105 . 70.09



(a) Source



(b) Pressure Time - History



(c) PSD

Figure 5-2 IWEGS Results for a 36 ms Impulse in the Vent

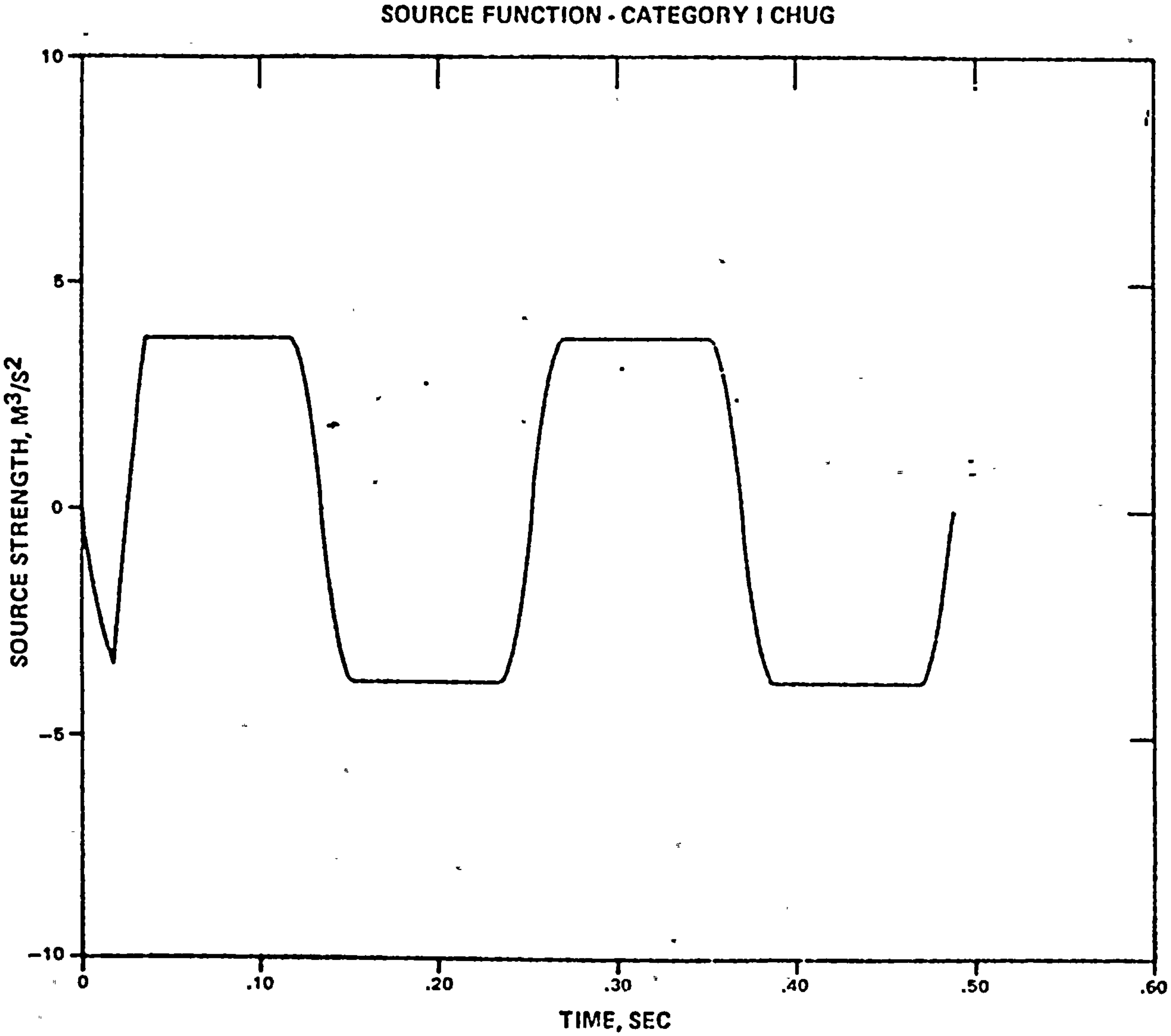


Figure 5-3 Category I Chug Source

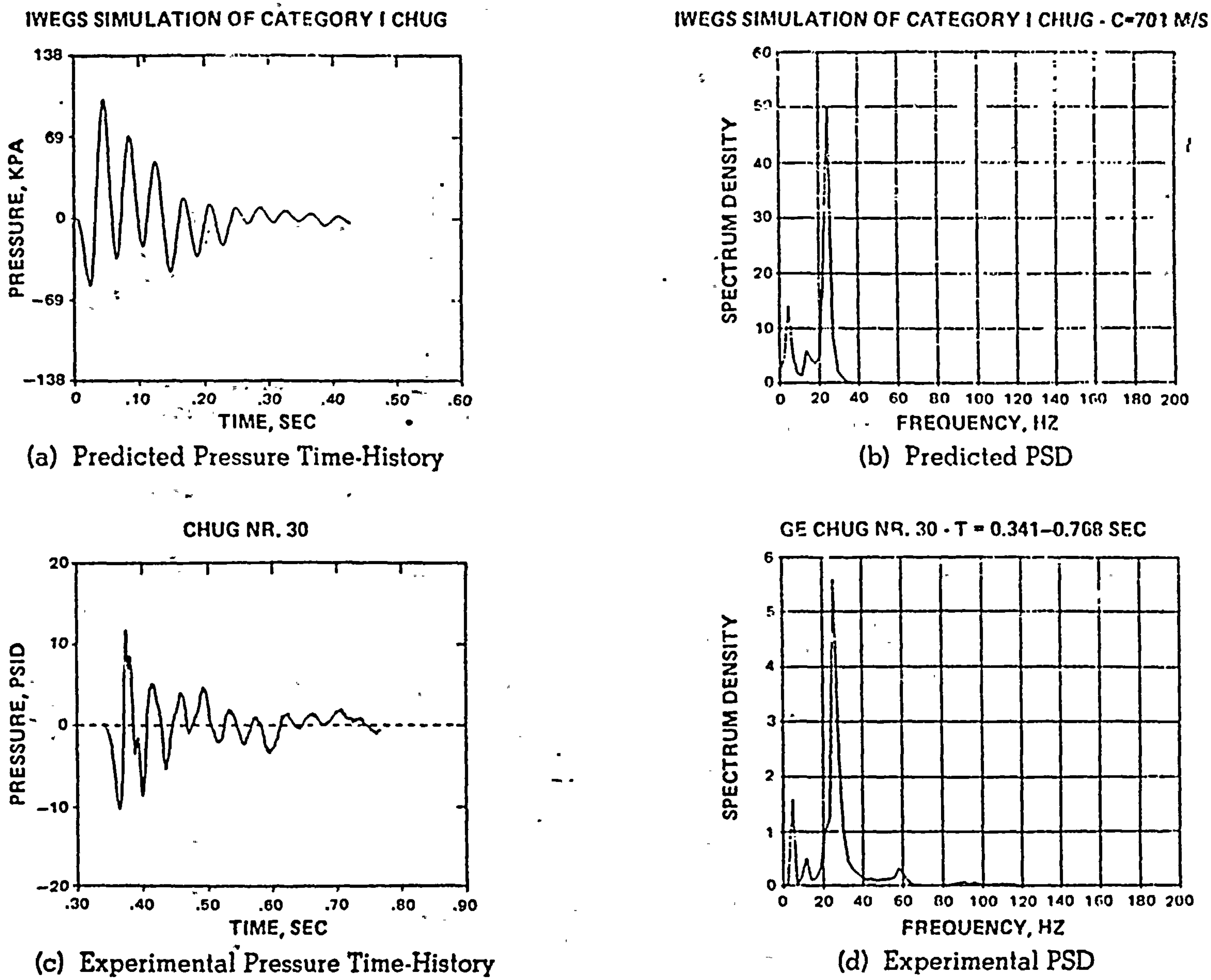
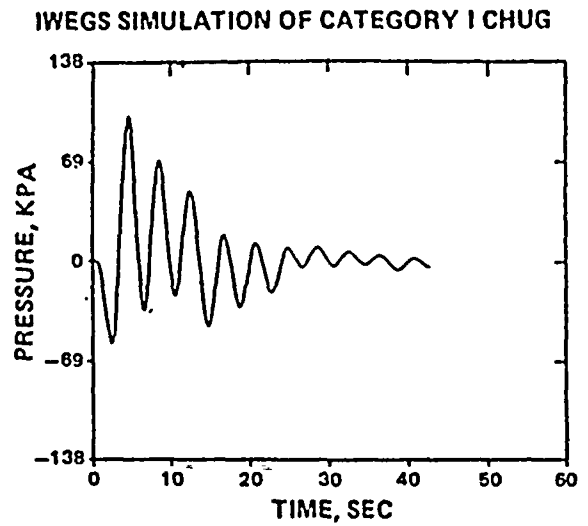
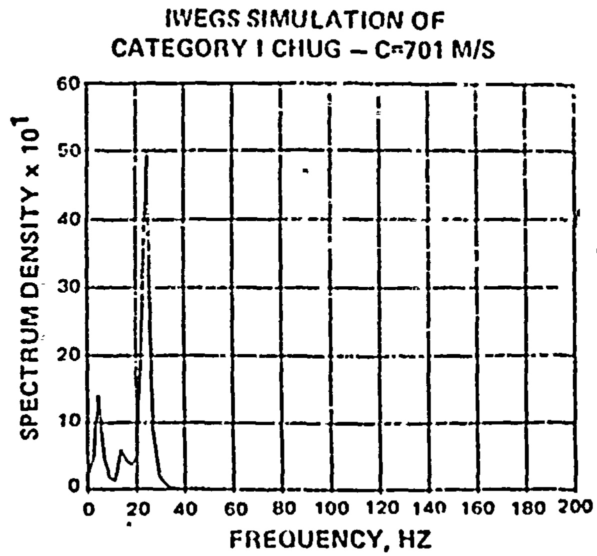


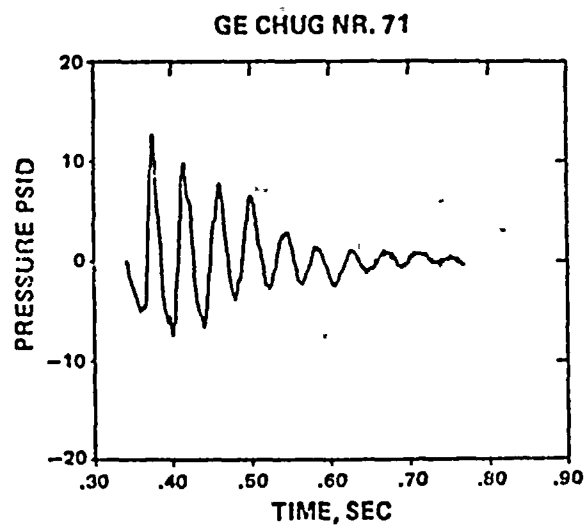
Figure 5-5 Comparison of IWEGS Results with Chug #30



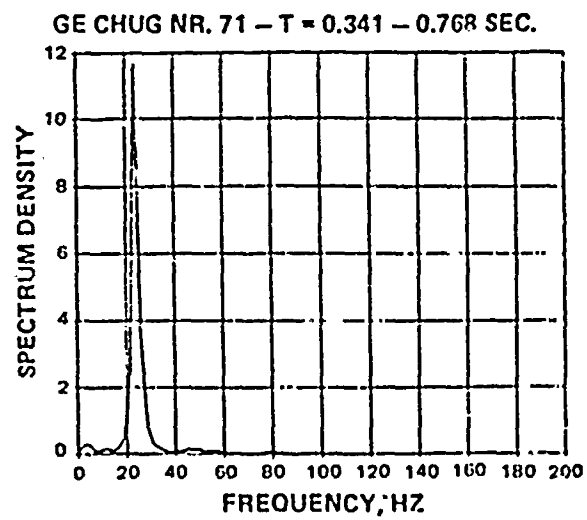
(a) Predicted Pressure Time-History



(b) Predicted PSD



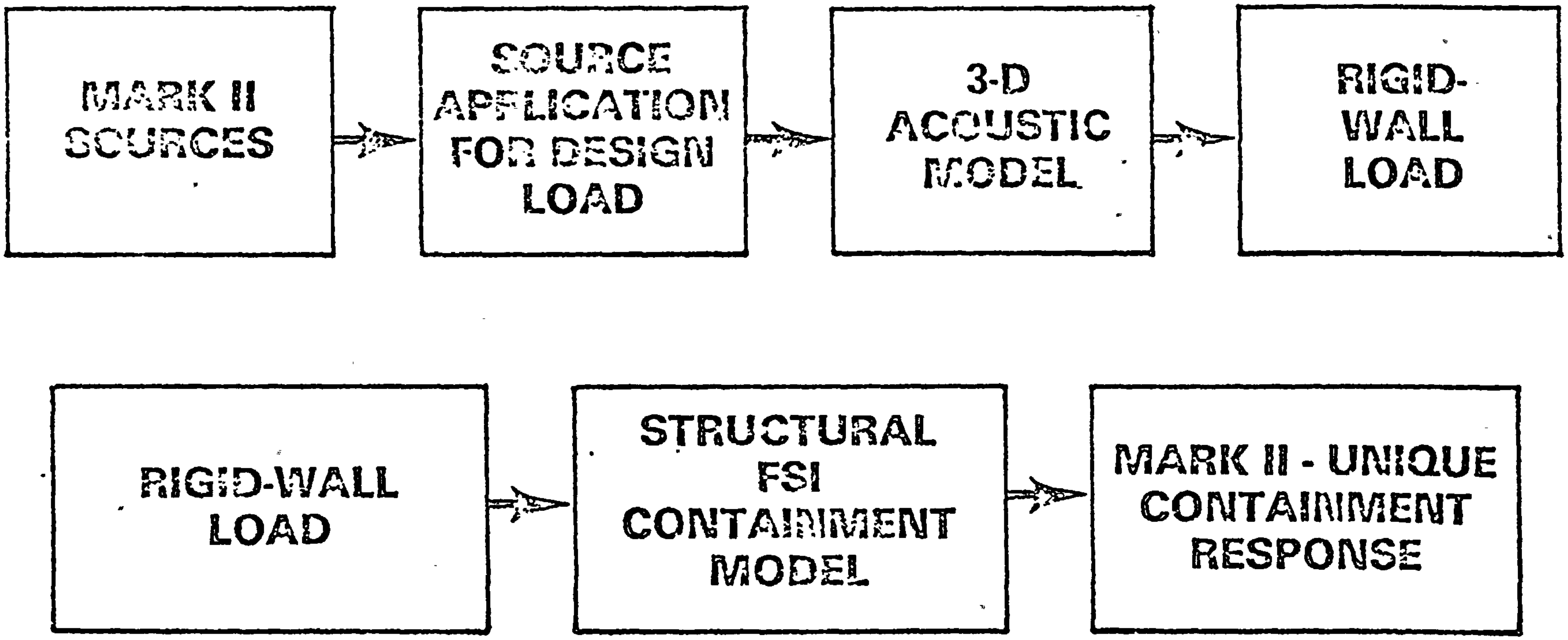
(c) Experimental Pressure Time-History



(d) Experimental PSD

Figure 5-6 Comparison of IWEGS Results with Chug #71

MARK II APPROACH



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CAORSO SAFETY/RELIEF VALVE LOADS TEST

PHASE 2 QUICK-LOOK TEST RESULTS REVIEW

REFERENCE : 1. CAORSO SRV TEST PLAN, REV. 2 ADDENDUM 2, APRIL 1978

2. TEST SPEC NO. 22A4381 AX, REV. 2, TABLE 6.1 TEST MATRIX (COPY ATTACHED)

TESTS PERFORMED :

- MULTIPLE VALVE ACTUATIONS
  - 2, 3, 4 ASYMMETRIC, 4 SYMMETRIC, 8 SYMMETRIC
- SINGLE VALVE ACTUATIONS - NORMAL REACTOR PRESSURE
  - SUBSEQUENT ACTUATIONS WITH 2 10-IN VACUUM BREAKERS
  - REPEAT PHASE 1 SUBSEQUENT ACTUATION TESTS
  - LEAKY VALVE
  - TEST OF REMOTE VALVE V
  - REPEAT SINGLE VALVE ACTUATION
- SINGLE VALVE ACTUATIONS - REDUCED REACTOR PRESSURE
- EXTENDED BLOWDOWN
- ALL TESTS COMPLETED. NO ADDITIONAL TESTS ARE PLANNED.

MET
3/79

Test #	Test Type (1) (2) (10) (13)	Valve	Initial Pipe Conditions (3)	Discharge Time, Sec.	Valve Closed Time CVA, Sec	Valve Closed Time Pipe Cooling Hrs.
1401	SVA	A	CP, NWL, 10" VB	5	2(15)	--
1402	CVA	A	WP, TWL, 10" VB	5	2(15)	--
1403	CVA	A	WP, TWL, 10" VB	5	2(15)	--
1404	CVA	A	HP, TWL, 10" VB	5	2(15)	--
1405	CVA	A	HP, TWL, 10" VB	5	--	>2
15	SVA	F	CP, NWL, 10" VB	5	--	>2
16	SVA	F	CP, NWL, 10" VB	5	--	>2
17	SVA	E	CP, NWL, 10" VB	5	--	>2
18	SVA	E	CP, NWL, 10" VB	5	--	>2
19	SVA	U	CP, NWL, 10" VB	5	--	>2
20	SVA	U	CP, NWL, 10" VB	5	--	>2
21	SVA	A	CP, NWL, 10" VB	20	--	>2
2201	SVA	A	CP, NWL, 10" VB	20(8)	10(4)	--
2202	CVA	A	HP, TWL, 10" VB	5	10(4)	--
2203	CVA	A	HP, TWL, 10" VB	5	10(4)	--
2204	CVA	A	HP, TWL, 10" VB	5	10(4)	--
2205	CVA	A	HP, TWL, 10" VB	5	--	>2
23	Retest of Tests 1 Through 22 as Required					
24	MVA B/C	A,F	CP, NWL, 10" VB	5,10(9)	--	>2
25	MVA	A,F	CP, NWL, 10" VB	5,10(9)	--	>2
26	MVA B/C/B	A,F,E	CP, NWL, 10" VB	5,10,15(9)	--	>2
27	MVA [illegible]	A,F,E,U	CP, NWL, 10" VB	5,10,15,20(9)	--	>2
28	MVA	A,F,E,U	CP, NWL, 10" VB	5,10,15,20(9)	--	>2
29	MVA	A,F,E,U	CP, NWL, 10" VB	5,10,15,20(9)	--	>2
30	MVA	A,F,E,U	CP, NWL, 10" VB	5,10,15,20(9)	--	>2
31 (16)	MVA B/B/B/C	B,C,D,L	CP, NWL, 10" VB	5,10,15,20(9)	--	>2
32	MVA [illegible] A/C/D/D	A,B,D,H K,L,R,V	CP, NWL, 10" VB	5,10,15,20,25, 30,35,40(9)	--	>2

6-3

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Test #	Test Type (1) (2) (10) (13)	Valve	Initial Pipe Conditions (3)	Discharge Time, Sec.	Valve Closed Time CVA, Sec	Valve Closed Time Pipe Cooling, Hrs.	
33	50 psia Reactor Pres (10) SVA	A	CP, NWL, 10" VB	20	--	> 2	
34	100 psia Reactor Pres (10) SVA	A	CP, NWL, 10" VB	20	--	> 2	
35	200 psia Reactor Pres (10) SVA	A	CP, NWL, 10" VB	20	--	> 2	
36	400 psia Reactor Pres (10) SVA	A	CP, NWL, 10" VB	20	--	> 2	
37	600 psia Reactor Pres (10) SVA	A	CP, NWL, 10" VB	20	--	> 2	
38	800 psia Reactor Pres (10) SVA	A	CP, NWL, 10" VB	20	--	> 2	
39	SVA	A	CP, NWL, 10" VB	20	--	> 2	
40	Extended Blowdown	A	CP, NWL, 10" VB	(11) (12)	--	> 2	
41	SVA (13)	A	LV, NWL, 10" VB	5	--	> 2	Optional
42	SVA	A	LV, NWL, 10" VB	5	--	> 2	Optional
43	SVA	A	LV, NWL, 10" VB	5	--	> 2	Optional
4401	SVA (13)	A	LV, NWL, 10" VB	5	10 (4)	--	Optional
4402	CVA	A	LV, TWL, 10" VB	5	10 (4)	--	Optional
4403	CVA	A	LV, TWL, 10" VB	5	10 (4)	--	Optional
4404	CVA	A	LV, TWL, 10" VB	5	10 (4)	--	Optional
4405	CVA	A	LV, TWL, 10" VB	5	10 (4)	> 2	Optional
45	Retests of Tests 24 Through 41 as Required						

6-3A

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TABLE 6.1

Test Matrix

Additions and Retest Description

	TEST NO.	TEST TYPE	VALVE	INIT. PIPE CONDITION	DISCH TIME,SEC.	VALVE CLOSED TIME CVA,SEC	PIPE COOL,HR
	22A01	SVA	U	CP,NWL,2 10" VB	20	15	-
	22A02	CVA	U	WP,TWL,2 10" VB	5	15	-
	22A03	CVA	U	WP,TWL,2 10" VB	5	15	-
	22A04	CVA	U	HP,TWL,2 10" VB	5	15	-
	22A05	CVA	U	HP,TWL,2 10" VB	5	-	> 2
Repeat 601-605	2301	SVA	A	CP,NWL,10 IN.VB	5	15	-
	2302	CVA	A	WP,TWL,10 IN.VB	5	15	-
	2303	CVA	A	WP,TWL,10 IN.VB	5	15	-
	2304	CVA	A	HP,TWL,10 IN.VB	5	15	-
	2305	CVA	A	HP,TWL,10 IN.VB	5	-	> 2
Repeat 1401-1405	2311	SVA	A	CP,NWL,10 IN.VB	5	2	-
	2312	CVA	A	HP,TWL,10 IN.VB	5	2	-
	2313	CVA	A	HP,TWL,10 IN.VB	5	2	-
	2314	CVA	A	HP,TWL,10 IN.VB	5	2	-
	2315	CVA	A	HP,TWL,10 IN.VB	5	-	> 2
Repeat 2201-2202	2321	SVA	A	CP,NWL,10 IN.VB	20	15	-
	2322	CVA	A	HP,TWL,10 IN.VB	5	15	-
	2323	CVA	A	HP,TWL,10 IN.VB	5	15	-
	2324	CVA	A	HP,TWL,10 IN.VB	5	15	-
	2325	CVA	A	HP,TWL,10 IN.VB	5	-	> 2

Additional Tests

44F01 - 44F05 - Same as 4401 - 4405 Except No PCM Data For 44F01

	TEST NO.	TEST TYPE	VALVE	INIT. PIPE CONDITION	DISCH TIME,SEC.	VALVE CLOSED TIME CVA,SEC	PIPE COOL,HR
Repeat 27-30	4501	MVA	A,F,E,U	CP,NWL,10 IN.VB	5,10,15,20	-	> 2
	4502	MVA	A,F,E,U	CP,NWL,10 IN.VB	5,10,15,20	-	> 2
	*26-V	SVA	V	CP,NWL,2 10 IN.VB	120	-	> 2
	*26-A	SVA	A	CP,NWL,10 IN.VB	60	-	> 2

* Tests performed 2-16-78 in conjunction with STI-26, SRV Flow Capacity Test

C. MULTIPLE VALVE TIMING

TEST/SEQUENCE	TIMING* - MSEC 1	2	3	4	5	6	7	8
24	0 A	26 F						
25	0 F	21 A						
26	0 A	62 E	101 F					
27	0 F	67 A	178 E	217 U				
28	0 F	100 A	144 E	165 U				
29	0 F	31 E	40 A	62 U				
30	0 U	52 E	79 F	92 A				
45-1	0 U	5 E	6 F	21 A				
45-2	0 A	9 F	70 U	72 E				
31	0 C	52 D	87 B	116 L				
32	0 H	6 R	61 B	68 D	69 K	111 V	194 L	222 A

* VALVE ACTUATION SWITCH

D. CONTAINMENT DYNAMIC RESPONSE

- RANGE OF ACCELERATION 0.04G TO 0.20G (RPV HEAD FLG.)
- PEAK ACCELERATION FOR 8-VALVE MVA TEST = 0.15G (RPV HD. FLG.)
- NO TRENDS EASILY IDENTIFIABLE FROM REAL-TIME DATA
- PROPER CONCLUSIONS TO BE DEVELOPED FROM DETAILED COMPUTER ANALYSES

E. EXTENDED BLOWDOWN

- SRV DISCHARGED FOR 13 MIN. 6 SEC.
  - BLOWDOWN TERMINATED WHEN PLANT TEMPERATURE SENSOR (#302) AT PEDESTAL NEAR QUENCHER A REACHED CAORSO TECH. SPEC. LIMIT ($39^oC = 102.2^oF$)
- LOCAL-TO-BULK TEMPERATURE DIFFERENCE PROBABLY WITHIN RANGE OF 10 TO 20F
- THE AVERAGE PLANT TEMPERATURE SENSORS DATA GAVE REASONABLE INDICATION OF BULK POOL TEMPERATURE

OVERALL CONCLUSIONS

- OBJECTIVES OF CAORSO SRV TEST PROGRAM HAVE BEEN SATISFIED
- TEST RESULTS CONFIRM THE CONSERVATISM IN SRV QUENCHER DISCHARGE SUPPRESSION POOL DESIGN LOADS