3628

GENERAL ELECTRIC

NUCLEAR ENERGY DIVISION

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BWR PROJECTS DEPARTMENT

September 24, 1975

Mr. R. L. Tedesco
Assistant Director for Containment Safety
Division of Technical Review
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Tedesco:

Attached are three copies of the visual aids used in presentations to members of your staff at generic meetings held in San Jose on September 16-18, 1975. Portions of the material contain information which the General Electric Company customarily maintains in confidence and withholds from public disclosure. The information has been handled and classified proprietary by GE in accordance with the procedures and standards set forth in Attachment A to this letter; and we hereby request that the material identified as proprietary be witheld from public disclosure in accordance with the provisions of 10CFR2.790.

The proprietary information in this transmittal is necessary for our business and gives us an opportunity to obtain an advantage over competitors who do not have access to it. The data was obtained at considerable expense to General Electric or via exchange agreements with other sources which require proprietary treatment. Its release would allow competitors to confirm similar designs without incurring similar expense. Extensive measures have been employed to guard such information, and to the best of our knowledge, the information has been released outside the company only in accordance with contractual proprietary agreements.

Please call if you have any questions or comments on this material.

Sincerely,

Geza Gyorey

Geza L. Gyorey, Manager
BWR Licensing

Attachments
cc: L. S. Gifford
cb

F-2

Attachment A

GENERAL ELECTRIC

PROPRIETARY CLASSIFICATION SYSTEM

General Electric proprietary documents contain information and are of the type which General Electric customarily maintains in confidence and withholds from public disclosure. To the best of General Electric's knowledge and belief, such documents have consistently been maintained in confidence and no public disclosure has been made of them.

Documents are classified proprietary pursuant to standard General Electric procedures pertaining to such classification. General Electric's definition of proprietary information is similar to that used in the courts to define "trade secrets". The definition encompasses "any formula, pattern, device or compilation of information which is used in one's business and which gives him an opportunity to obtain an advantage over competitors who do not know or use it." Additionally, a substantial element of secrecy must exist, so that, except by the use of improper means, there would be difficulty in acquiring the information. Some factors to be considered in determining whether given information is proprietary are: (1) the extent to which the information is known outside the busines; (2) the extent to which it is known by employees and others involved at General Electric; (3) the extent of measures taken to guard the secrecy of the information; (4) the value of the information to General Electric and its competitors; (5) the amount of effort of money expended by General Electric in developing the information; and (6) the ease or difficulty with which the information could be properly acquired or duplicated by others. Additional information treated as confidential consists of business intelligence such as business plans, forecasts, financial data and similar information which, if obtained by competition, could compromise the interest of the Company.

"LICENSING TOPICAL REPORT"

OUTLINE:

1. INTRODUCTION
2. S/RV LOADS WITH QUENCHER
3. LATERAL LOADS ON DOWNCOMER VENT
4. TEMPERATURE THRESHOLD LIMIT FOR HIGH TEMPERATURE CONDENSATION VIBRATION.

SECTION - 1 INTRODUCTION

I. BACKGROUND:

- QUENCHER DESIGNED TO REDUCE AIR-CLEARING LOAD
- DEFINE DYNAMIC LOADS ON THE VENTS
- ESTABLISH A SUPPRESSION POOL TEMPERATURE TO AVOID STEAM CONDENSATION VIBRATIONS.

II PURPOSE:

TO PROVIDE CONTAINMENT DYNAMIC LOADS SUPPORTING DATA IN THE THREE AREAS MENTIONED ABOVE.

SECTION 2 S/RV LOADS WITH QUENCHER

1. INTRODUCTION
2. DESCRIPTION OF PHENOMENA
3. DEVELOPMENT OF MII AND III QUENCHER DESIGN LOADS

A. SMALL SCALE TEST

- LIST OF TEST PARAMETERS AFFECTING THE QUENCHER LOADS
- DESCRIPTION OF SMALL SCALE TEST SETUP
  - SKETCH OF THE TEST FACILITY SHOWING DETAILS OF
    - A. OUTLAY AND CONFIGURATION OF VARIOUS ELEMENTS OF THE TEST FACILITY
    - B. LOCATION OF PRESSURE AND TEMPERATURE TRANSDUCERS AND OTHER INSTRUMENTATION
    - C. IMPORTANT DIMENSIONS AND SIZES
- EFFECTS OF DIFFERENT PARAMETERS
  - TEST RESULTS
  - DISCUSSION
  - APPLICATION TO LARGE SCALE TEST

B. LARGE SCALE TEST :

- SKETCH SHOWING DETAILS OF
  - OUTLAY AND CONFIGURATION OF TEST FACILITY
  - LOCATION OF PRESSURE AND TEMPERATURE TRANSDUCERS
  - RELEVANT DIMENSIONS AND SIZES
- RESULTS OF THE LARGE SCALE TESTS
  - SINGLE ACTUATION TESTS
  - ACTUATION OF MULTIPLE VALVES
  - CONSECUTIVE ACTUATION OF THE SAME VALVE
- COMPARISON OF PREDICTED AND MEASURED VALUES OF LOADS.

C. MARK II AND III AIR-CLEARING LOAD PREDICTION

- DESCRIPTION OF PREDICTION METHOD USING THE SMALL AND LARGE SCALE FIRST AND SUBSEQUENT ACTUATION DATA

- STATISTICAL EVALUATION OF THE SMALL AND LARGE SCALE DATA
  - CALCULATION OF MEAN VALUE OF MEASURED LOADS AND THEIR STANDARD DEVIATION
  - CALCULATION OF QUANTITATIVE EFFECT OF VARIOUS PARAMETERS ON AIR-CLEARING LOADS

- STATISTICAL EVALUATION OF THE PREDICTION METHOD FOR M II AND III QUENCHER LOADS.

4. ATTENUATION, FREQUENCY AND WAVE SHAPE OF THE CONTAINMENT LOADS

- METHOD OF ATTENUATION OF LOADS IN THE SUPPRESSION POOL
  - JUSTIFICATION FROM FULL SCALE DATA
- LOADING OSCILLATION FREQUENCY AND WAVE SHAPE
  - JUSTIFICATION FROM FULL SCALE DATA

SECTION 3. LATERAL LOADS ON DOWNCOMER VENT :

I. INTRODUCTION

A. GENERAL — INTRODUCTION OF LOADS AND PURPOSE OF REPORT

B. PHENOMENA - DISCRIPTION OF LOAD PHENOMENA WITH ILLUSTRATIVE SKETCHES

II. TEST FACILITY AND PROCEDURE

A. FACILITY - DISCRIPTION OF FACILITY, INCLUDING FIGURES

B. INSTRUMENTATION AND CALIBRATION

- INSTRUMENTATION — LIST OF PRESSURE, TEMPERATURE AND FORCE MEASURING POINTS. AND FIGURES SHOWING THEIR LOCATION
- CALIBRATION — DESCRIPTION OF CALIBRATION PROCEDURES OF STRAIN GAGES AND LONGITUDINAL DISPLACEMENT TRANSDUCERS

C. PROCEDURE - DESCRIPTION OF TEST PROCEDURE.

III TEST RESULTS AND DISCUSSION

A. PRESSURE AND LATERAL LOADS - GENERAL DESCRIPTION OF RESULTS, TABULATION OF MEASURED VALUES WITH ILLUSTRATIVE SKETCHES

B. DISCUSSION

- EFFECT OF POOL TEMPERATURE
- EFFECT OF AIR TEMPERATURE
- EFFECT OF MASS FLUX DENSITY
- REPRODUCIBILITY
- FREQUENCY DISTRIBUTION OF TRANSVERSE FORCES
- DIRECTION OF LOAD

C. SUMMARY OF RESULTS

D. APPLICABILITY OF RESULTS

- TABULATION OF MAJOR TEST PARAMETERS RELATED TO LATERAL LOADS AND G.E. BWR'S.
- DISCUSSION OF APPLICABILITY

SECTION 4. TEMPERATURE THRESHOLD LIMIT FOR HIGH TEMPERATURE CONDENSATION VIBRATION.

1. INTRODUCTION

- FUNCTION OF SUPPRESSION POOL
- POSSIBILITY OF SIGNIFICANT VIBRATIONS WITH LIMITING-CASE ASSUMPTIONS

2. FIELD EXPERIENCE

- EVENT 1. STUCK OPEN S/RV INDUCES VIBRATION ABOVE 160°F; STRUCTURAL DAMAGE OBSERVED.
- TWO OPENED S/RVS' DURING TEST INDUCE VIBRATION. CATWALK SHAKEN DOWN. INSTRUMENT LINES BROKEN.
- DOMESTIC PLANT RELIEF VALVE OPERATION:- MOST PLANTS HAVE RAMS HEAD. NO INCIDENTS OBSERVED.

3. PHENOMENA DISCUSSION

- STEAM CONDENSATION ALWAYS COMPLETE. G-MAP ILLUSTRATES DIFFERENT MODES OF CONDENSATION FOR STRAIGHT PIPES.

4. RAMS HEAD DISCHARGE DEVICE

- EFFECTS OF SPLITTING DISCHARGE FLOW
- DIRECTIONAL EFFECTS
- DISCUSSION OF PERFORMANCE OF DEVICES SIMILAR TO RAMS HEAD
- TEMPERATURE THRESHOLD LIMITS FOR HIGH TEMPERATURE CONDENSATION VIBRATION.

5. DEVELOPMENT OF QUENCHER

I. SMALL-SCALE MODEL TESTS, 1:100 VOLUMETRIC

- TEST STAND STRUCTURE
- INSTRUMENTATION — PRESSURE AND TEMPERATURE TRANSDUCERS' LOCATION
- TEST PROCEDURES
- TESTING WITH DIFFERENT NOZZLE CONFIGURATIONS
- EVALUATION OF PERFORMANCE OF PERFORATED PIPE NOZZLES
- PERFORATED PIPE HOLE OPTIMIZATION

II. LARGE-SCALE MODEL TESTS, 1:4 VOLUMETRIC

- TEST STAND STRUCTURE
- INSTRUMENTATION — PRESS. AND TEMPERATURE TRANSDUCERS' LOCATION
- TEST PROCEDURES
- 7 NOZZLE VERSIONS TESTED
- RESULTS - TEMPERATURE DISTRIBUTION, PRESS. AMPLITUDE AND FREQUENCY DISCUSSED. G-MAP DEVELOPED
-

III. Application Of Test Rig Results To Large Scale Quencher Facility

- Test With Large Scale Nozzle In A Plant
- Nozzle Geometry, Arrangement Specified
- Resulting Loads And Temperature Limits Discussed, Compared To Test Rig Values

CURRENT MASS TRANSER MODEL

MAJOR ASSUMPTIONS:

1. DROPLET TEMPERATURE IS EQUAL TO THE ADIABATIC SATURATION (WET BULB) TEMPERATURE.

2. ALL HEAT TRANSFER ENERGY IS USED TO VAPORIZE THE LIQUID.

3. THE CHANGE IN SENSIBLE ENERGY OF THE DROPLET IS NEGLIGIBLE.

4. GOOD MIXING IN THE DROPLET.

PROPOSED MODEL IMPROVEMENTS

1. INCLUSION OF DROPLET SENSIBLE ENERGY.

2. CHANGE FROM THE ENERGY METHOD OF CALCULATING MASS TRANSFER TO THE PARTIAL PRESSURE METHOD.

CURRENT MODEL

EQUATIONS:

EVAPORATION RATE:

$$\dot{m}_e = \frac{\pi D^2 h (T_A - T_D)}{\lambda}$$

WHERE: D = DROPLET DIAMETER
h = CONVECTIVE HEAT TRANSFER COEFFICIENT
T_A = AMBIENT AIR TEMPERATURE
T_D = DROPLET TEMPERATURE
λ = LATENT HEAT OF VAPORIZATION

THE HEAT TRANSFER COEFFICIENT IS DETERMINED FROM:

$$h = \frac{k \, Nu}{D}$$

WHERE: k = THERMAL CONDUCTIVITY OF AIR
[illegible] NUMBER.

AND.

$$Nu = 2.0 + 0.6 \, S_c^{1/3} R_e^{1/2}$$

GENERAL ELECTRIC CO.
Nuclear Energy Division
ENGINEERING CALCULATION SHEET

DATE September 17, 1975

SHOP ORDER NO. RELAP 3 & 4 Discussions

SUBJECT ______ BY MRW SHEET ____ OF ____

NRC/GE GENERIC MEETING

- RELAP-4 Improvements
- Review Key Assumptions
- Discussion of GE/NRC Analysis
  - Revised GE Analysis
  - Reactor Shield Wall and Reactor Skirt Pressure comparisons
  - Shear Force Comparison
- Conclusions

FORM NO. NED 47

GENERAL ELECTRIC CO.
Nuclear Energy Division
ENGINEERING CALCULATION SHEET

SHOP ORDER NO. RELAP 3 & 4 DATE 7-17
SUBJECT DISCUSSIONS
BY MRW SHEET ___ OF ___

MODELING IMPROVEMENTS INCORPORATED INTO RELAP-4

- MOMENTUM FLUX
  - AREA CHANGES
  - DENSITY CHANGES
  - HEAT ADDITION
- BRANCHING FLOW PATHS
- ADDITIONAL CHOKING OPTIONS
- ECCS IMPROVEMENTS
- NODE STATIC PRESSURE AVAILABLE

FORM NO. NED-87

Nuclear Energy Division
ENGINEERING CALCULATION SHEET

DATE --13-75

SHOP ORDER NO. RELAP 3 & 4 Discussions

SUBJECT ______ BY MRW ______ SHEET ____ OF ____

SUMMARY OF GE RELAP-4 MODEL OF RSW/RPV ANNULUS

- 30 Nodes and 55 Junctions
- One-Half the Annulus Considered
- Moody Model Used for Blowdown Flow Rate
- All The Blowdown Flow Enters the Annulus
- Accounted for FLOW Area and Form Losses* due to Pipes Crossing the Annulus
- Accounted for Turning Losses*
- Used a .6 Moody Multiplier between Nodes
- Insulation treated Conservatively
- Initial Conditions are a Homogeneous Water-Steam Mixture
- Neglected Momentum Flux and Compressibility of Flow in the Region of the Break

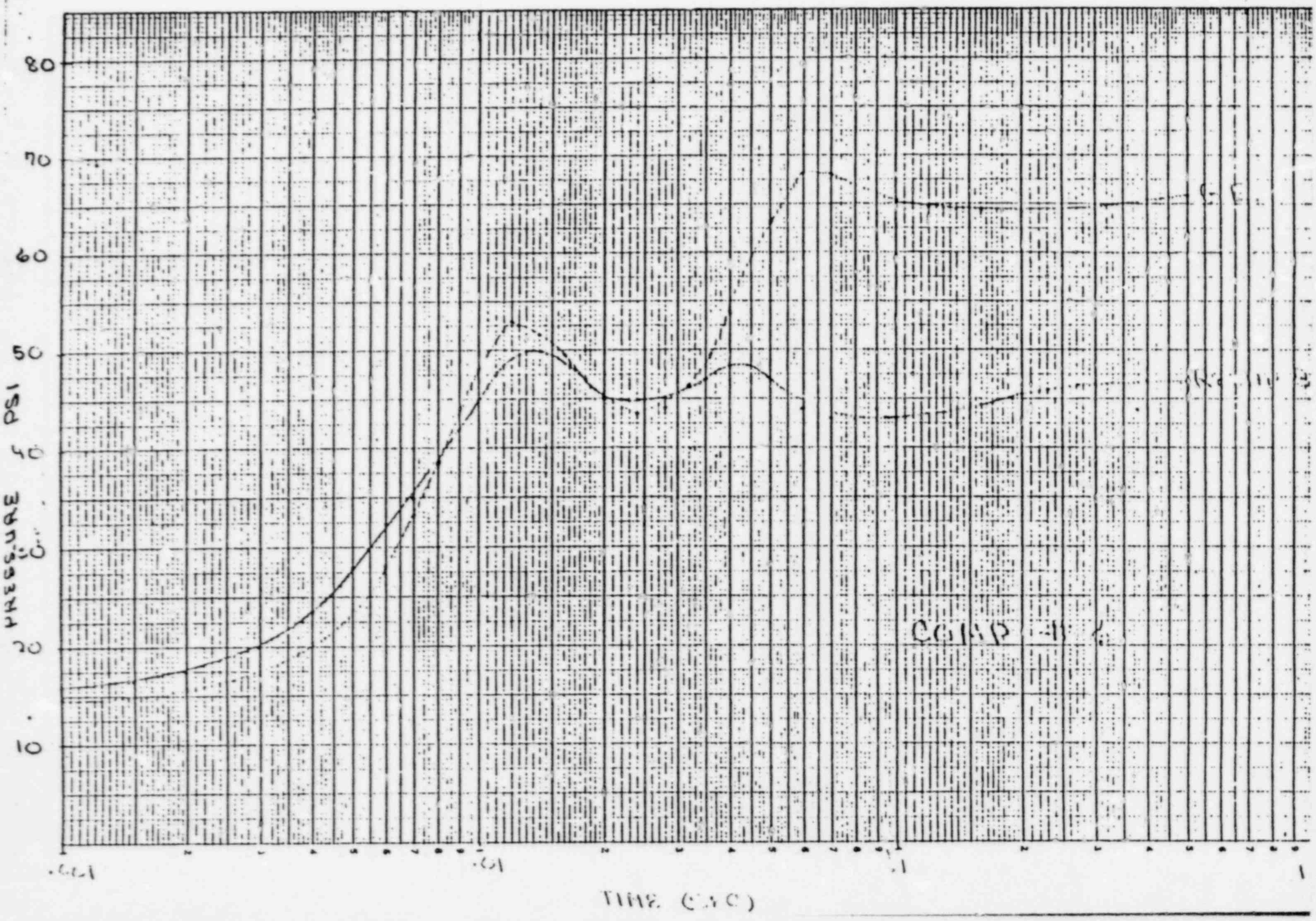
* I'del chik

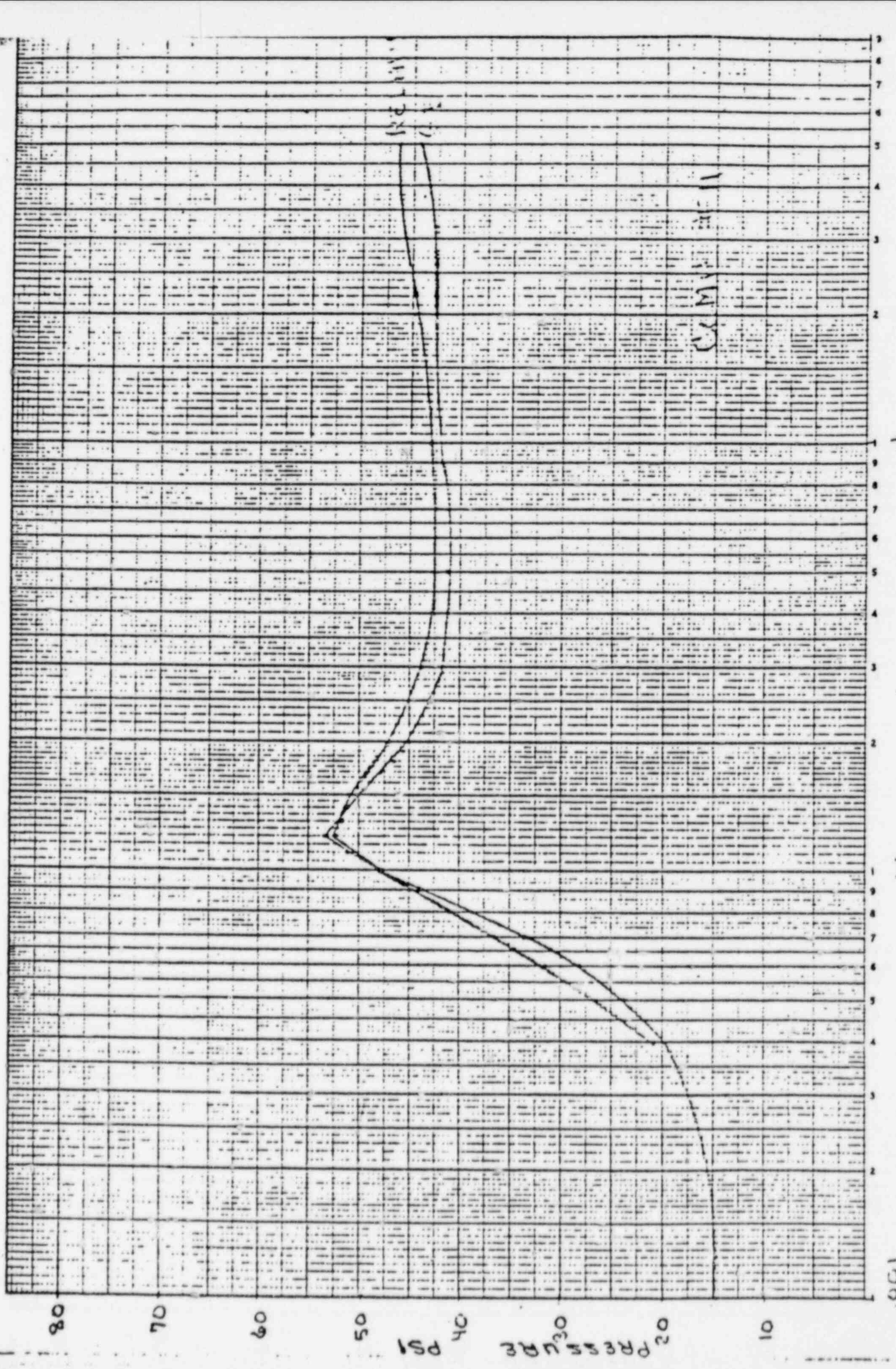
FORM NO. NED47

IMPROVEMENTS IN G.E. METHODS

	GESSAR	NOW	EFFECT
• TIME STEP	.002	.0001	MORE ACCURATE ANALYSIS [SHEAR FORCE UP ≈ 10%]
• INITIAL CONDITIONS	15.95 PSIA X = 100%	14.95 PSIA X = 92.6%	SHEAR FORCE UP BY 5%

FN-265-A (8-50) GENERAL ELECTRIC COMPANY. SCHENECTADY, N. Y., U.S.A. 3 cys. x 170 1mm Divisions




PRESSURE PSI
TIME (SEC)
10
20
30
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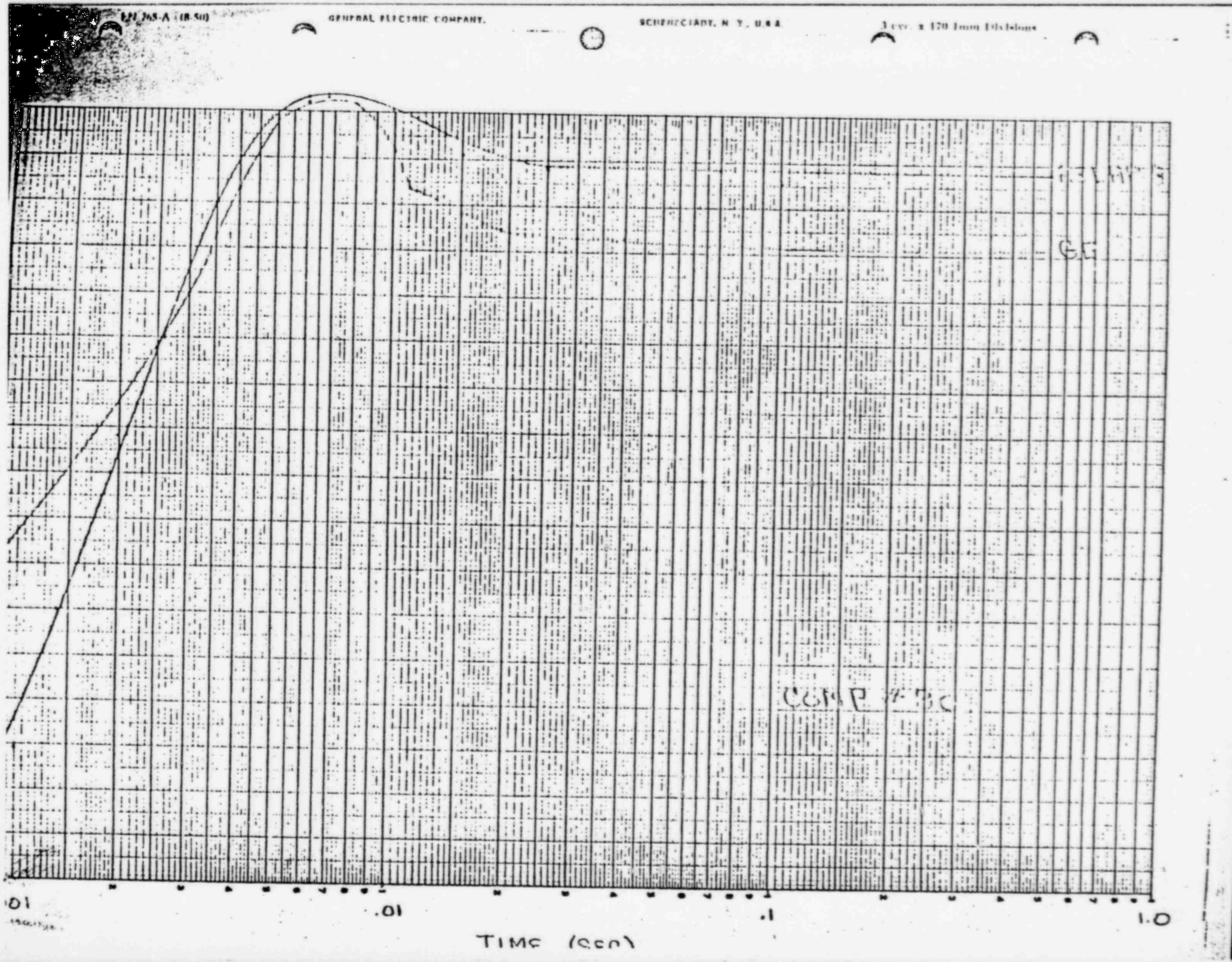
50
60
70
80



GENERAL ELECTRIC COMPANY.
SCHENECTADY, N. Y., U.S.A.
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Nuclear Energy Division
ENGINEERING CALCULATION SHEET

DATE 4-16-75

SHOP ORDER NO. RELAP 3 & 4 Discussion

SUBJECT ______ BY MRW ______ SHEET ______ OF ______

COMPARISON OF GE AND NRC ANALYSIS

	GE	NRC	DIFFERENCE
AVERAGE SKIRT PRESSURE	58.5 PSIA (@ t=.5 sec)	47.6 PSIA (MAXIMUM)	23%
AVERAGE RSW PRESSURE	46.9 PSIA (@ t=.5 sec)	47.4 PSIA (MAXIMUM)	1%

FORM NO. NED 47

GESSAR
VESSEL PRESSURE DIFFERENTIAL
AT DIFFERENT LEVELS

Projected area for 30^0 segment = $\frac{\pi D*30*h}{360}$

= .262 Dh

Projected area for 45^0 segment = $\frac{\pi D*45*h}{360}$

= .393 Dh

Force = Pressure in compartment * projected area * cosine angle horizontal component of force cancel due to symmetry.

Force per Dh

Time		Level 1	Level 2	Level 3	Level
	GESSAR	24.6	24.4	23.52	14.3
0.02	RELAP-3	28.9	29.9	29.0	18.5
	GESSAR	22.6	18.1	11.68	6.04
0.05	RELAP-3	13.8	15.6	14.5	5.8
	GESSAR	12.6	6.74	7.34	5.32
0.5	RELAP-3	13.7	13.7	13.5	13.4

GESSAR DATA SHOULD BE INCREASED 10% -15% [TIME STEP AND INITIAL CONDITIONS ADJUSTMENTS]

SUMMARY AND CONCLUSIONS

- RELAP 4 CONTAINS IMPROVED ANALYTICAL MODELING.

- G.E. IS USING CONSERVATIVE INPUT ASSUMPTIONS

- RELAP 4 CONSERVATIVE FOR RPV SKIRT AND SHIELD WALL PRESSURE CALCULATIONS (UP TO 20% ABOVE RELAP 3)

- RELAP 4 SHEAR FORCE CALCULATIONS APPROXIMATELY 15% BELOW NRC CALCULATIONS

- RELAP 4 IS AN APPROPRIATE DESIGN TOOL.

NEDE-20942-P

- PURPOSE – TO DOCUMENT RECENT MODEL DEVELOPMENT AND REFINEMENTS

- MODELS:

    PIPE CLEARING TRANSIENT
    BUBBLE DYNAMICS
    PRESSURE DISTRIBUTION IN POOL

- RECENT DEVELOPMENTS:

    INITIAL BUBBLE POSITION
    EFFICENCY OF BUBBLE FORMATION PROCESS
    BOUNDARY EFFECTS
        RIGID BOUNDARIES
        FREE SURFACE
    MOTION OF C.G. OF BUBBLE

- RESULTS:

    BETTER AGREEMENT WITH DATA
    BOUNDARY CONDITIONS SATISFIED
    BETTER REPRESENTATION OF PHENOMENA

- UNDER STUDY:

    SECOND POP PHENOMENON (DATA NEEDED)

PIPE CLEARING MODEL

MAX. PIPE PRESSURE DEPENDS ON:

1) WATER LEG
2) fL/D for COMPRESSIBLE FLOW
3) INITIAL CONDITIONS IN PIPE AND POOL

BACK PRESSURE SIMPLY ADDS TO MAX. PIPE PRESSURE
SAME THING WITH FRICTIONAL EFFECTS FOR WATER.

MAX. PIPE PRESSURE WILL BE CACULATED USING:

MAX. WATER LEG (SECOND POP)

MAX. POOL WATER LEVEL

WORST ENVIRONMENTAL CONDITIONS

CONSERVATIVE fL/D, flow rate and set POINT

LOCAL PRESSURE CALCULATION

Assuming Bubbles all in phase:

$$P - P_\infty = (P_B - P_\infty) R_B \sum \frac{1}{r_i}$$ will not satisfy B.C. on Bubble surface.

$$\therefore \; P - P_\infty = X \sum \frac{1}{r_i}$$

Such that, on bubble surface:

$$P_B - P_\infty = X \sum \frac{1}{r'_i}$$ where r'_i = distance from point on bubble surface to bubble # i

$$X = \frac{P_B - P_\infty}{\sum \frac{1}{r'_i}}$$

and $\therefore$
$$P - P_\infty = \frac{P_B - P_\infty}{\sum \frac{1}{r'_i}} \sum \frac{1}{r_i} \qquad (1)$$

Method used by G.E. is:

$$P - P_\infty = (P_B - P_\infty) R_B \sqrt{\left(\sum \frac{1}{r_i}\right)_1^2 + \left(\sum \frac{1}{r_i}\right)_2^2 + \cdots} \qquad (2)$$

where subscripts 1, 2, ... refer to actual bubbles.

Eq. (1) results in $P_B - P_\infty$ on the bubble.

Eq. (2) " " $P - P_\infty > P_B - P_\infty$ on the bubble

In general, Eq. (2) is more conservative

TEST SERIES 5006
INTERPRETATION

- TWELVE 1/3 SCALE AIR TESTS (JUNE-JULY 1975)
- OBJECTIVES
  - IDENTIFY INFLUENCE OF VENT FLOW COMPOSITION ON POOL SWELL VELOCITY AND LIGAMENT THICKNESS PROFILES.
  - PROVIDE ADDITIONAL DATA FOR POOL SWELL SCALING STUDIES AND ANALYTICAL MODEL VERIFICATION.
- PRELIMINARY TEST RESULTS REVIEWED BY NRC JUNE 1975.
- PRELIMINARY CONCLUSIONS (AUGUST 1975)
- CONCLUSIONS
  - FOR COMPARABLE TEST CONDITIONS, SWELL VELOCITIES ARE ~ 20% HIGHER FOR AIR.
  - BREAK THROUGH ELEVATION INDEPENDENT OF CHARGING RATE.
- DOCUMENTATION - REPORT, OCTOBER 31, 1975

MARK III LOADS PERSPECTIVE

1. PIPES
2. BEAMS
3. HCU FLOOR ΔP
4. TOTAL MARGINS AVAILABLE
5. PRACTICAL PROBLEMS
6. SUMMARY

PRACTICAL PROBLEMS IN DESIGNING FOR HIGH LOADS

1. SUPPORTS AND HANGERS COMPLEX
   - A. MANY SUPPORTS AND HANGERS EVERY 3-4 FEET
   - B. LONG DISTANCES TO ANCHORING STRUCTURE
   - C. SUPPORT STRUCTURE TO PIPE INCREASES LOAD
   - D. SUPPORT STRUCTURE TO PIPE ITSELF BECOMES A MAJOR STRUCTURE
2. THERMAL DESIGN PROBLEMS
   - A. STIFFER PIPE INCOMPATIBLE WITH THERMAL REQUIREMENTS
   - B. MAY HAVE TO WELD STIFFENERS TO PIPE ITSELF TO ACCOMMODATE LOADS
3. OTHER CRITERIA DIFFICULT TO MEET
   - A. I.S.I. LESS EFFECTIVE
   - B. SEPARATION CRITERIA LESS EASILY MET
4. ANCHOR LOADS HIGH
   - A. INTEGRATED LOADS VERY HIGH TO STRUCTURE
   - B. MANY PIPES ARE INVOLVED

MARGIN IDENTIFICATION

DESIGN CONDITION : DBA LOCA

PIPES

B 31.1 CODE

TYPICAL MATERIAL : A155, CL 2 KC 70

- ALLOW STRESS : 15.75 15.75
- YIELD STRENGTH : 35 KSI
- ULT STRENGTH : 70 KSI

FOR ONE-TIME LOAD, MARGIN ON ULT:

$$\text{FACTOR} = \frac{70}{15.75} = 4.4$$

BEAMS

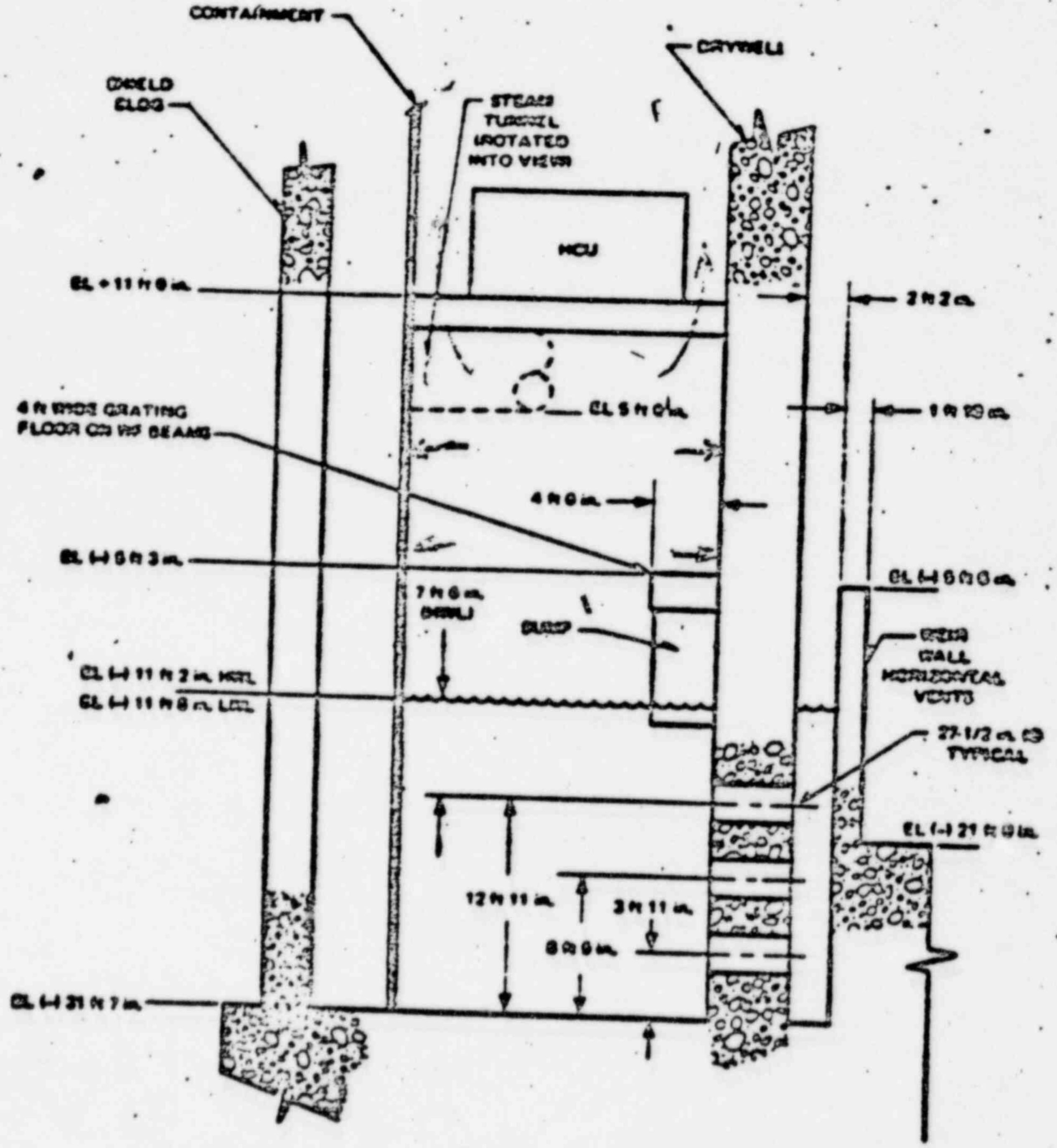
AISC

TYPICAL MAT'L : A 36 STEEL

- ALLOW STRESS : 0.9 YIELD = 32.4 KSI
- ULT STRENGTH : 58-80 KSI

FOR ONE-TIME LOAD, MARGIN ON ULT :

$$\text{FACTOR} = \frac{58}{32.4} = 1.8$$


CONTAINMENT
DRYWELL
STEAM
(ROTATED
INTO VIEW
HCU
2 ft 2 in.
4 ft WIDE GRATING
4 ft 0 in.
SUMP
WALL
VENTS
27-1/2 in.
TYPICAL
12 ft 11 in.
3 ft 11 in.

SUMMARY

- TESTS THEMSELVES ARE REPRESENTATIVE OF REAL STRUCTURES AND ARE CONSERVATIVE
- LARGE UNCERTAINTY FACTORS NOT NEEDED ON LOADS
- LARGE MARGINS ON LOADS THEMSELVES ARE UNCALLED FOR
- THERE IS AMPLE CONSERVATISM IN STRUCTURAL DESIGN
- LOAD SPECS WITH A REASONABLE MARGIN WOULD BE

PIPES	30 PSI X 1.30 = ≈40 PSI
BEAMS	60 PSI X 1.30 = ≈80 PSI
HCU FLOOR	3.3 PSI X 1.30 = ≈4.5 PSI ΔP

- LOADS MUCH IN EXCESS OF ABOVE MAKE THE TECHNICAL VIABILITY QUESTIONABLE
- G.E. CURRENT SPECS ARE SPECIFIED AS FOLLOWS IN ATTEMPT TO BE VERY CONSERVATIVE:

PIPES	60 PSI
BEAMS	115 PSI
HCU	11 PSI

- G.E. SPECS ARE OVER CONSERVATIVE AND NRC SHOULD CONSIDER LOWER VALUES, NOT HIGHER ONES TO ACHIEVE BOTH AN OVERALL SAFER DESIGN AND ONE THAT IS POSSIBLE.

PREDICTION OF M III CONTAINMENT AIR-CLEARING LOADS WITH QUENCHER

I. SMALL SCALE TEST DATA

- IMPORTANT PARAMETERS AFFECTING LOADS
- SENSITIVITY OF LOADS TO IMPORTANT PARAMETERS

II. LARGE SCALE TEST AND VERIFICATION OF PREDICTION METHOD

- LARGE SCALE TEST SCALING FACTORS
- PREDICTION OF LARGE SCALE TEST 1st ACTUATION LOADS
- COMPARISON OF PREDICTED AND MEASURED LARGE SCALE RESULTS FOR 1st ACTUATION.
- LARGE SCALE TEST DATA FOR SUBSEQUENT ACTUATION.

III PREDICTION OF M. III CONTAINMENT LOADS

- SCALING FACTORS ; LARGE SCALE → M. III
- M. III LOAD PREDICTION INCLUDING SUBSEQUENT ACTUATION

Scr.

I SMALL SCALE TEST:

- IMPORTANT PARAMETERS AFFECTING AIR CLEARING LOADS:
  1. AIR VOLUME IN PIPE / QUENCHER CROSS SECTION AREA
  2. FREE WATER SURFACE AREA / QUENCHER CROSS SECTION AREA
  3. TOTAL AIR VOLUME AT TIME OF BLOWOUT / TOTAL QUENCHER HOLE OPENING AREA
  4. POOL TEMPERATURE
- PARAMETERS WITH NO SIGNIFICANT INFLUENCE ON LOADS:
  1. VALVE OPENING TIME
  2. SUBMERGENCE DEPTH BETWEEN 4 m TO 6 m
  3. WETWELL PRESSURE
  4. BLOWOUT PRESSURE

- SENSITIVITY OF LOADS TO VARIOUS PARAMETERS
  - STATISTICAL ANALYSIS OF TEST DATA.

include fig. showing the effect of the time
" " " " " Submergence

GE-NRC MEETING

ASEA ATOM, MARK II, MARK I TEST STATUS

I. ASEA ATOM COOPERATIVE TEST PROGRAM

- OBJECTIVES
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS AND RESULTS

II. MARK II POOL SWELL TESTS - FIRST PHASE

- OBJECTIVES
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS - TENTATIVE SCHEDULE

III. MARK I POOL SWELL 1/12-SCALE TESTS

- OBJECTIVES
- SCALING STUDY
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS AND RESULTS - INCLUDING MOVIE

I. ASEA ATOM COOPERATIVE TEST PROGRAM

- OBJECTIVES
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS AND RESULTS

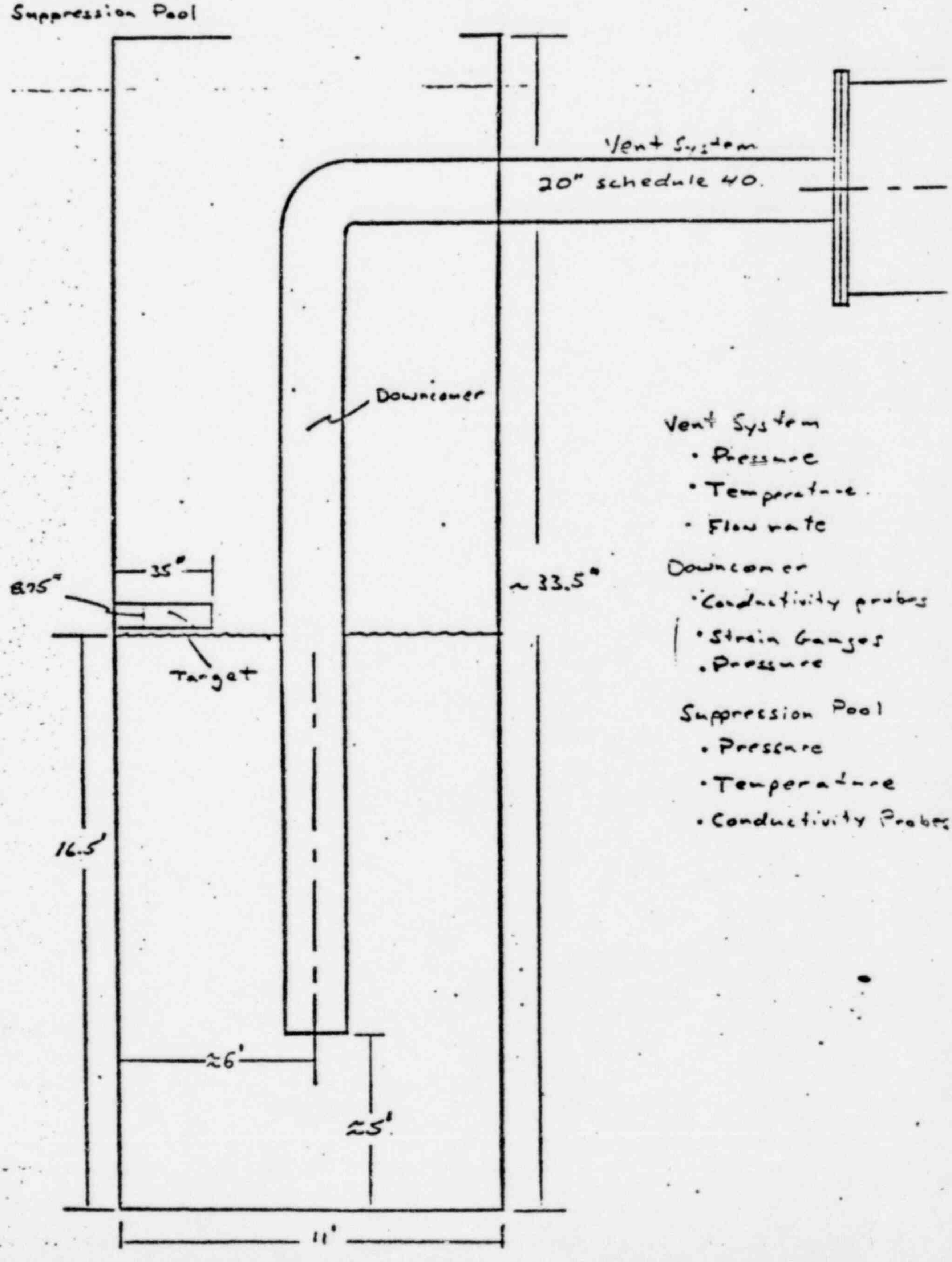
ASEA ATOM COOPERATIVE TEST PROGRAM

OBJECTIVES

- TEST TO CONFIRM DESIGN OF AIR CUSHION DAMPER FOR STRUCTURE LOCATED ABOVE SUPPRESSION POOL

- DETERMINE AIR CUSHION DAMPER VS FLAT STRUCTURE EFFECT

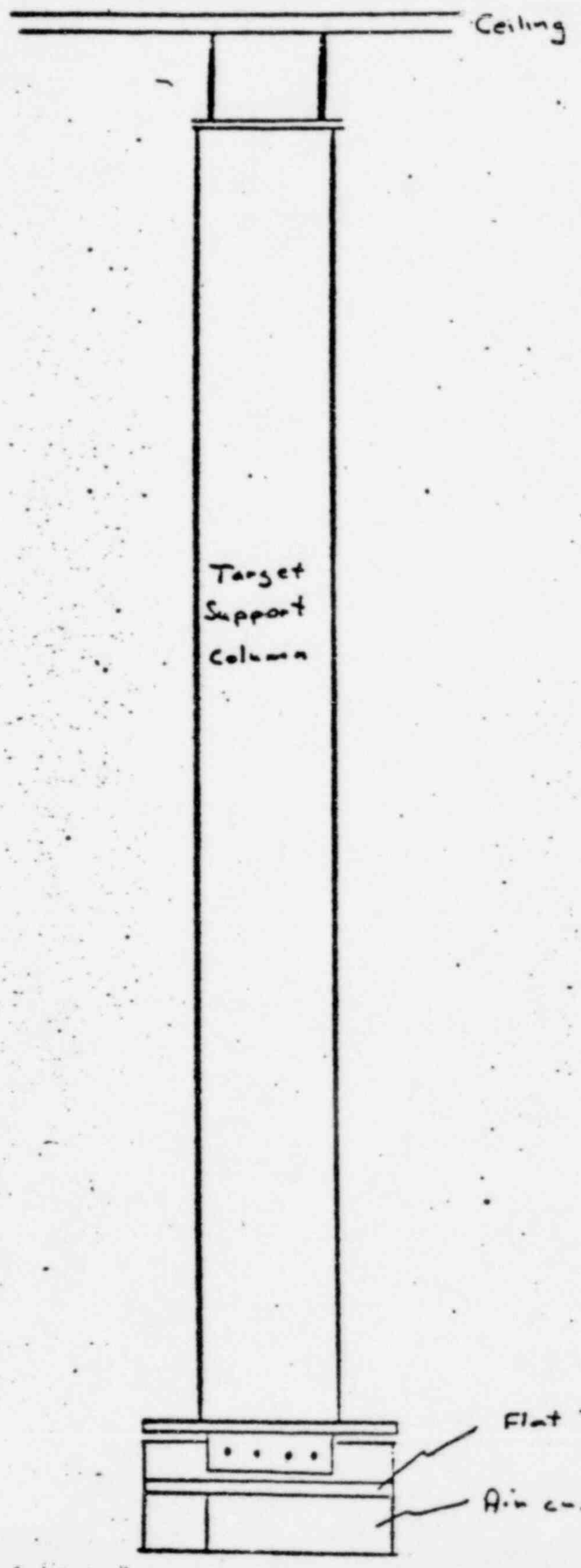
Facility Design and Instrumentation



Vent System
- Pressure
- Temperature
- Flow rate

Downcomer
- Conductivity probes
- Strain Gauges
- Pressure

Suppression Pool
- Pressure
- Temperature
- Conductivity Probes



Target Support Column
- Strain Gauges
- Accelerometers

Target
- Pressure
- Accelerometers

ASEA ATOM COOPERATIVE TEST PROGRAM

TEST MATRIX

- FLAT PLATE TARGET - 6 TESTS
  - 2 BLOWDOWN FLOW RESTRICTOR SIZES
  - 3 INITIAL TARGET CLEARANCES

- AIR DAMPER TARGET - 10 TESTS
  - 3 BLOWDOWN FLOW RESTRICTOR SIZES
  - 6 INITIAL SUBMERGENCES

ASEA ATOM COOPERATIVE TEST PROGRAM

TEST STATUS

- TESTS COMPLETED
- DATA REDUCED
- ANALYSIS UNDERWAY
- REPORT IN PROGRESS

ASEA ATOM COOPERATIVE TEST PROGRAM

PRELIMINARY RESULTS

- POOL SURFACE FLAT AT ELEVATION OF TARGET IMPACT
- IMPACT ON FLAT PLATE CHARACTERIZED BY HIGH NARROW PEAK
- AIR DAMPER REDUCED LOCAL IMPACT PRESSURE BY FACTOR OF ~3
- TEST REPEATABILITY WAS WITHIN ±10%
- IMPACT MEASUREMENTS SUPPORTED DESIGN CALCULATIONS

II. MARK II POOL SWELL TEST
(FIRST PHASE)

- OBJECTIVES
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS - TENTATIVE SCHEDULE

MARK II POOL SWELL TEST

OBJECTIVES

1. A. MEASURE AND EVALUATE VELOCITY, SLUG THICKNESS, AND HEIGHT OF LIQUID SWELL OVER A RANGE OF BLOWDOWN CONDITIONS IN ORDER TO PROVIDE DATA BASE THAT CAN BE USED TO SUPPORT ANALYSES OF THE MARK II POOL SWELL TRANSIENT

   B. MEASURE BUBBLE BREAKTHROUGH HEIGHT

2. EVALUATE THE EFFECT OF WETWELL BACK PRESSURE ON POOL SWELL

3. MEASURE WETWELL PRESSURE DURING POOL SWELL TO CHECK ASSUMPTIONS ON WETWELL TO DRYWELL DIAPHRAGM FLOOR LOADING

4. MEASURE FLUID/FROTH INTERACTION PRESSURE AT THE POOL CEILING, IF ANY

5. MEASUREMENT OF LATERAL LOADING ON VENT PIPING

TENTATIVE MARK II POOL SWELL TEST MATRIX

For 2 1/2" Diameter Blowdown Venturi

Submergence (ft)	24" Downcomer		20" Downcomer	
	Open Pool	Closed Pool	Open Pool	Closed Pool
9'	x	x	x	x
11'	x	x	x	x
13.5'	x	x	x	x

For 3" Diameter Blowdown Venturi

9'	x	x	x	x
11'	x	x	x	x
13.5'	x	x	x	x

Total number of tests = 24

III. MARK I POOL SWELL 1/12 SCALE TESTS

- OBJECTIVES
- SCALING RELATIONSHIPS
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS AND RESULTS INCLUDING MOVIE

MARK I 1/12 SCALE TEST
OBJECTIVES

- VISUALLY OBSERVE POOL SWELL BEHAVIOR FOR A RANGE OF SCALED LOCA CONDITIONS.
- MEASURE POOL SWELL VELOCITY AT RING HEADER.
- ESTIMATE BREAK THROUGH LOCATION.
- MEASURE NET UPWARD AND DOWNWARD TORUS FORCES DURING POOL SWELL PHASE OF BLOWDOWN.

MARK I 1/12 SCALE TEST
SCALING RELATIONSHIPS

- VELOCITY $\frac{V_{SCALE}}{V_{FULL\ SCALE}} = \sqrt{\frac{L_{SCALE}}{L_{FULL\ SCALE}}}$
- PRESSURE $\frac{P_{SCALE}}{P_{FULL\ SCALE}} = \frac{L_{SCALE}}{L_{FULL\ SCALE}}$
- TIME $\frac{T_{SCALE}}{T_{FULL\ SCALE}} = \sqrt{\frac{L_{SCALE}}{L_{FULL\ SCALE}}}$
- $\frac{L_{SCALE}}{L_{FULL\ SCALE}}$ SCALE FACTOR = 1/12

MARK I 1/12 SCALE TEST

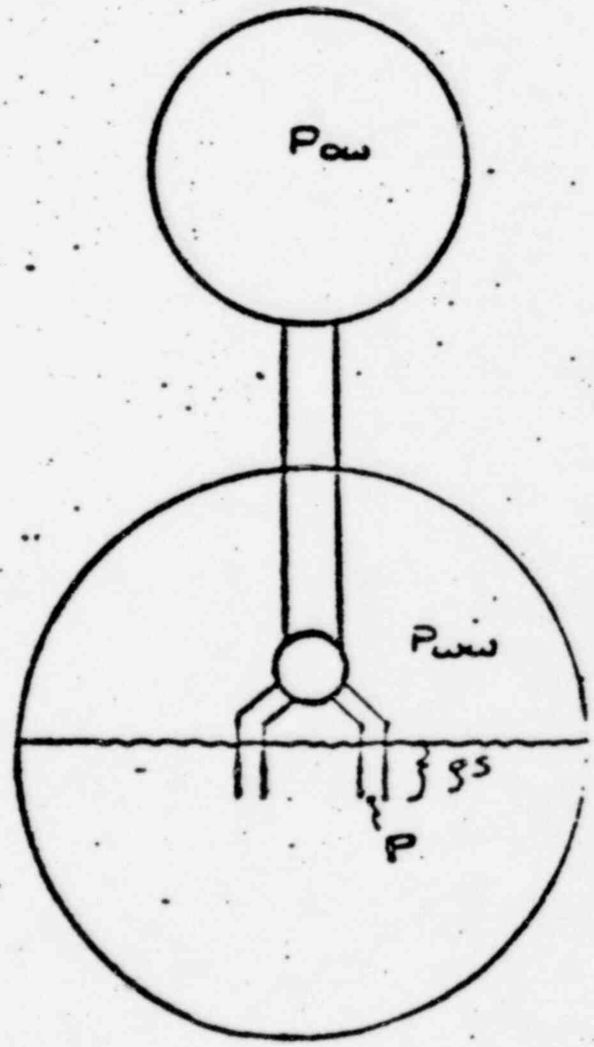
STATUS

- TESTS COMPLETE
- DATA REDUCED
- ANALYSIS, INTERPRETATION AND APPLICATION UNDERWAY

TEST UNCERTAINITIES

1. DRYWELL PRESSURE (INITIAL AND TRANSIENT)
2. VENT RESISTANCE
3. HIGH WATER LEVEL IN VENTS

Mark I 1/12 Scale Test



$P = P_{DW} - P_{WW} - \rho s = \Delta P$ @ vent exit

<u>WORK TO BE DONE</u>

FURTHER ANALYSIS OF DATA

MODELING CONSIDERATIONS

COMPARISON OF GE AND SRI TEST RESULTS

MODELING

A POWERFUL SOLUTION METHOD

* OFTEN ECONOMICAL
* SOMETIMES THE ONLY WAY

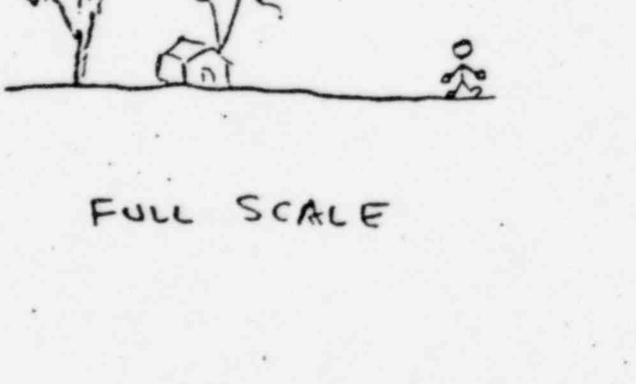
PURPOSE:

* TO SUMMARIZE WHAT MODELING INVOLVES
* TO DESCRIBE TECHNIQUES FOR DETERMINING MODELING LAWS
* TO APPLY MODELING METHODS IN A SOLUTION OF CONTAINMENT POOL MOTION CAUSED BY DBA.

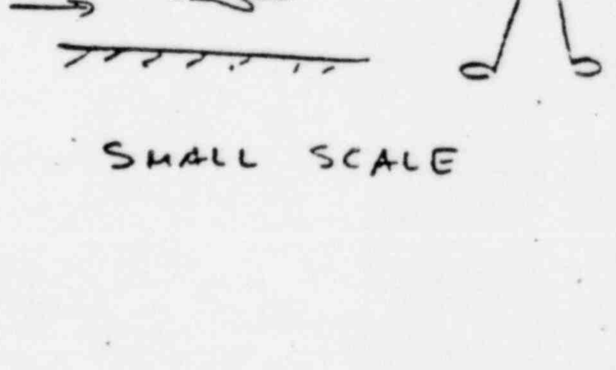
DEFINITION OF MODELING :

MODELING IS THE PROCESS OF SPECIFYING A SMALL SCALE TEST THAT WILL PROVIDE MEASURABLE BEHAVIOR, WHICH WILL DUPLICATE EXPECTED FULL SCALE BEHAVIOR IF LENGTH, TIME, AND OTHER MEASURABLES ARE MULTIPLIED BY APPROPRIATE SCALE FACTORS.

FOR EXAMPLE :



FULL SCALE

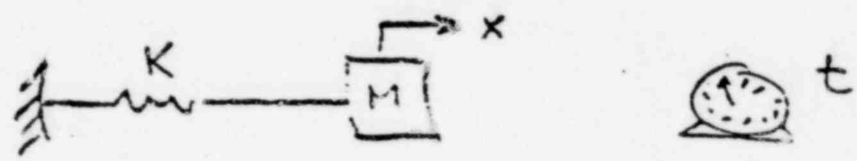


SMALL SCALE

WHEN MODELING IS NOT NEEDED

THE PROBLEM PHENOMENA CAN BE FORMULATED AND A SATISFACTORY ANALYTICAL SOLUTION CAN BE OBTAINED FOR THE VARIABLES REQUIRED

EXAMPLE :



GOVERNING EQUATION

$$\frac{d^2x}{dt^2} + \frac{K}{M}x = 0$$

INITIAL CONDITIONS

$$t = 0$$

$$x = x_0$$

$$\frac{dx}{dt} = V_0$$

SOLUTION

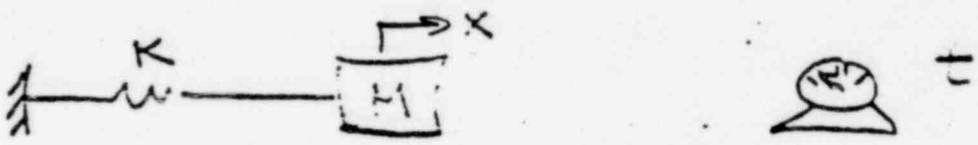
$$X = X_0 \cos\sqrt{\frac{K}{M}}\,t + V_0\sqrt{\frac{M}{K}}\,\sin\sqrt{\frac{K}{M}}\,t$$

MODELING NOT NEEDED

WHEN MODELING IS USEFUL

① PROBLEM PHENOMENA CAN BE FORMULATED, BUT A SATISFACTORY ANALYTICAL SOLUTION CANNOT BE OBTAINED FOR THE REQUIRED VARIABLES.

EXAMPLE :



FORMULATION :

GOVERNING EQUATION

$$\frac{d^2x}{dt^2} + \frac{K}{M}x = 0$$

INITIAL CONDITIONS

$$t = 0$$
$$x = x_0$$
$$\frac{dx}{dt} = V_0$$

SUPPOSE CANNOT SOLVE ANALYTICALLY.

NON-DIMENSIONALIZE THE GOVERNING EQUATION AND INITIAL CONDITIONS

$$X^* = \frac{X}{X_0} \quad , \quad t^* = t\sqrt{\frac{K}{M}}$$

G.EQ. $$\frac{d^2X^*}{dt^{*2}} + X^* = 0$$

I.C. $$t^* = 0$$

$$X^* = 1$$

$$\frac{dX^*}{dt^*} = \frac{V_0}{X_0}\sqrt{\frac{M}{K}}$$

WITHOUT SOLVING, CONCLUDE THAT ANY TWO SYSTEMS WILL GIVE THE SAME NON-DIMENSIONAL SOLUTION

$$\boxed{X^* = f(t^*)}$$

IF THE MODELING PARAMETER $\boxed{\frac{V_0}{X_0}\sqrt{\frac{M}{K}}}$ IS IDENTICAL IN EACH.

THEN . . .

$$X^* = \frac{X_{MODEL}}{X_{0\,MODEL}} = \frac{X_{FULL}}{X_{0\,FULL}}$$

$$t^* = t_{MODEL}\sqrt{\frac{K_{MODEL}}{M_{MODEL}}} = t_{FULL}\sqrt{\frac{K_{FULL}}{M_{FULL}}}$$

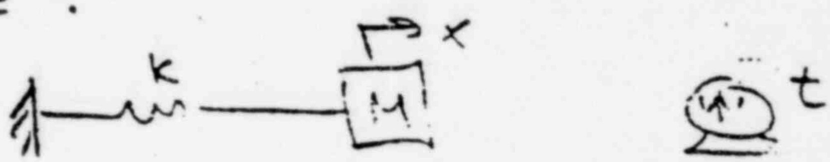
$$X_{FULL} = X_{MODEL}\left(\frac{X_{0\,FULL}}{X_{0\,MODEL}}\right)$$

$$t_{FULL} = t_{MODEL}\sqrt{\frac{M_{FULL}}{M_{MODEL}} \cdot \frac{K_{MODEL}}{K_{FULL}}}$$

ALSO, MODELING IS USEFUL IF

(2) PROBLEM PHENOMENA CANNOT EVEN BE FORMULATED

EXAMPLE :



LIST VARIABLES & PARAMETERS WHICH PROBABLY AFFECT BEHAVIOR

x
t
K
M
x_0
V_0

BUCKINGHAM π-THEOREM LEADS TO :

$$\boxed{\frac{x}{x_0}\ ,\ t\sqrt{\frac{K}{M}}\ ,\ \frac{V_0}{x_0}\sqrt{\frac{M}{K}}}$$

NON-DIMENSIONAL GROUPS

DISADVANTAGES OF π-THEOREM :

* MAY INCLUDE TOO FEW OR TOO MANY EFFECTS.

* EFFECTIVENESS DEPENDS ON USER.

* DOES NOT SHOW WHICH MODELING PARAMETERS ARE IMPORTANT AND WHICH ARE NOT.

∴ MODELING WORKS BEST WHEN THE PHENOMENA CAN BE FORMULATED BUT NOT SATISFACTORILY SOLVED BY ANALYTICAL METHODS.

METHOD

* FORMULATE THE GOVERNING EQUATIONS, BOUNDARY CONDITIONS, INITIAL CONDITIONS

* NON-DIMENSIONALIZE SO THAT THE INDEPENDENT VARIABLES AND THEIR DERIVATIVES BECOME $O(1)$ IN MAGNITUDE.

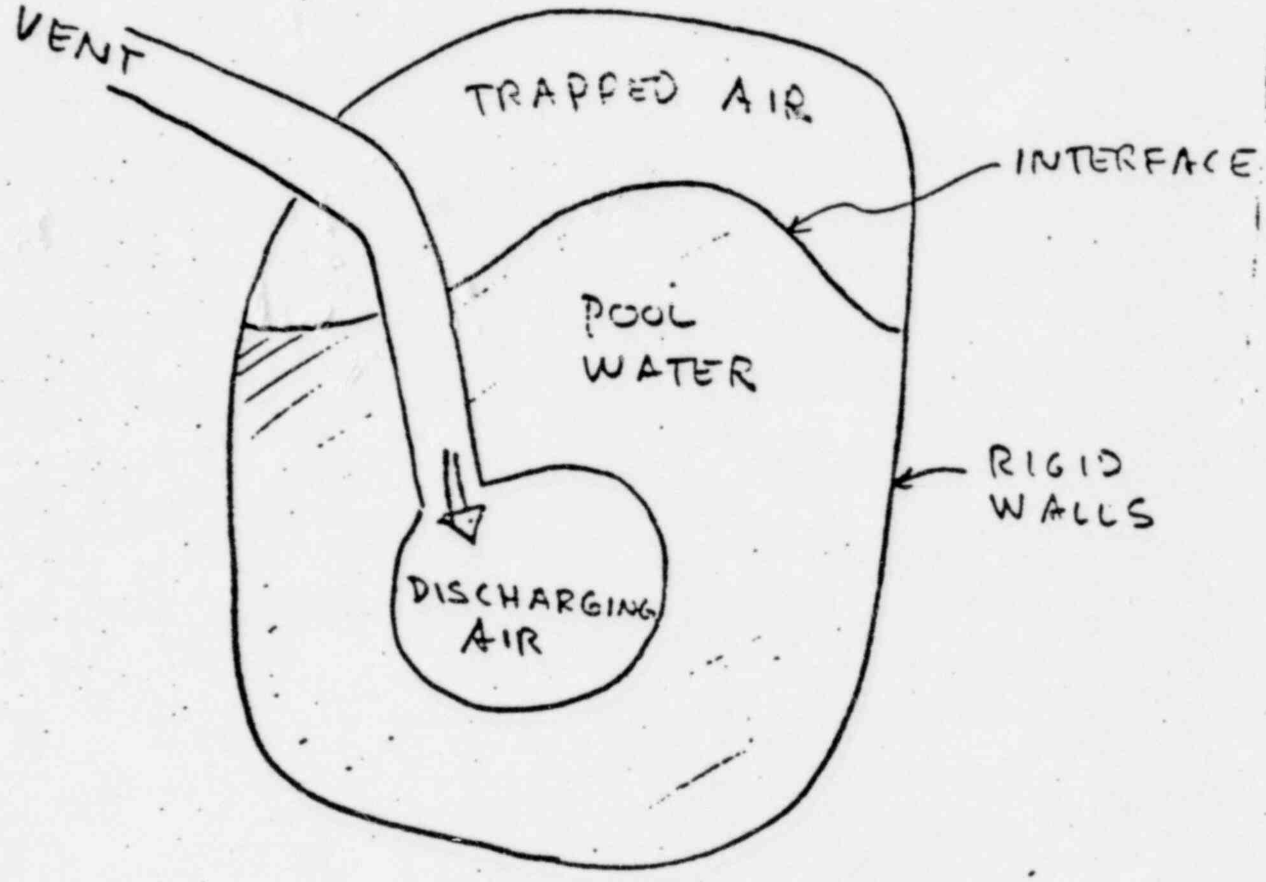
* EXTRACT MODELING PARAMETERS

* EXCLUDE OBVIOUSLY SMALL EFFECTS

* SPECIFY SMALL SCALE TEST

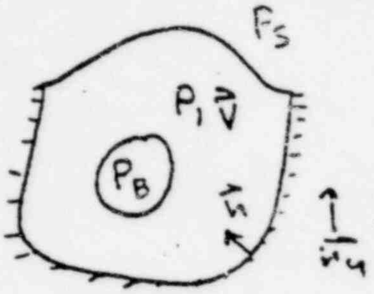
APPLICATION

POOL MOTION DURING VENT WATER EXPULSION AND AIR DISCHARGE



GOVERNING EQUATIONS

POOL MOTION :



MASS CONSERVATION

$$\nabla \cdot \vec{v} = 0$$

MOMENTUM CONSERVATION

$$\left(\frac{\partial}{\partial t} + \vec{v}\cdot\nabla\right)\vec{v} + \frac{1}{\rho}\nabla p + g\vec{n}_y = \nu\nabla^2\vec{v}$$

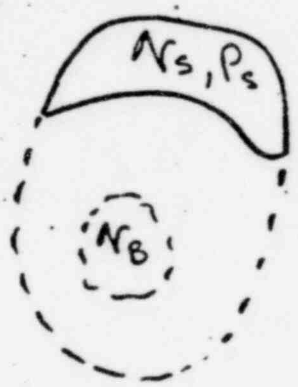
WALLS

$$\vec{v}\cdot\vec{n} = 0$$

INTERFACE

$$p_i - p_s = T\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

TRAPPED AIR :



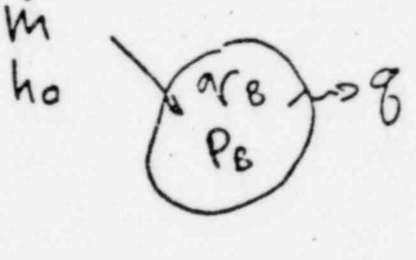
ADIABATIC COMPRESSION

$$p_s V_s^{\gamma} = p_{si} V_{si}^{\gamma}$$

$$V_s + V_B = V_{si}$$

$$p_s = p_{si}\left(1 - \frac{V_B}{V_{si}}\right)^{-\gamma}$$

SUBMERGED AIR :



$$(\gamma-1)q + \gamma p_B \frac{dV_B}{dt} + V_B \frac{dp_B}{dt} = (\gamma-1)h_o\dot{m}$$

NON-DIMENSIONALIZE

$$\ell^* = \frac{\ell}{L} \qquad \vec{V}^* = \frac{\vec{V}}{\sqrt{gL}}$$

$$t^* = t\sqrt{\frac{g}{L}} \qquad V^* = \frac{V}{V_{si}}$$

$$p^* = \frac{p}{\rho g L} \qquad q^* = \frac{q}{q_R}$$

GOVERNING EQUATIONS BECOME:

$$\nabla^* \cdot \vec{V}^* = 0$$

$$\left(\frac{\partial}{\partial t^*} + \vec{V}^* \cdot \nabla^*\right)\vec{V}^* + \nabla^* p^* + \vec{n}_y = \underbrace{\left(\nu\sqrt{\frac{1}{gL^3}}\right)}_{< 10^{-7}} \nabla^{*2}\vec{V}^*$$

$< 10^{-7}$ VISCOUS EFFECT

$$\vec{V}^* \cdot \vec{n} = 0$$

$$p^* - p_s^* = \underbrace{\left(\frac{\sigma}{\rho g L^2}\right)}_{10^{-6}}\left(\frac{1}{r_1^*} + \frac{1}{r_2^*}\right)$$

10^{-6} SURFACE TENSION EFFECT

$$p_s^* = \left(\frac{p_{si}}{\rho g L}\right)\left(1 - V_B^*\right)^{-\gamma} \qquad \text{TRAPPED AIR}$$

$$(\gamma - 1)\underbrace{\left(\frac{q_R\sqrt{\frac{L}{g}}}{p_{si} V_{si}}\right)}_{< 0.01} q^* + \gamma p_s^* \frac{dV_B^*}{dt^*} + V_B^* \frac{dp_B^*}{dt^*} = \frac{(\gamma - 1) h_0 \dot{m}}{p_{si} V_{si}}\sqrt{\frac{L}{g}}$$

< 0.01

FOR ACCURATE MODELING, MUST HAVE

$$\boxed{\frac{p_{si}}{\rho g L}} \quad \text{and} \quad \boxed{\frac{h_0 \dot{m}\sqrt{\frac{L}{g}}}{p_{si} V_{si}}} \quad \text{the same}$$

• THE MODELING PARAMETER $\frac{P_{si}}{\rho g L}$ IS MADE IDENTICAL IN FULL SCALE AND THE SMALL SCALE MODEL :

$$\left(\frac{P_{si}}{\rho g L}\right)_M = \left(\frac{P_{si}}{\rho g L}\right)_F$$

BUT BOTH FULL AND SMALL SCALE USE WATER IN A GRAVITY FIELD. THEREFORE

$$\rho_M = \rho_F$$

$$g_M = g_F$$

SO,

$$\boxed{P_{si\,M} = P_{si\,F} \frac{L_M}{L_F}}$$

I.e., PRESSURES IN SCALE MODEL MUST BE REDUCED FROM FULL SCALE VALUES BY THE SCALING FACTOR $\frac{L_M}{L_F}$

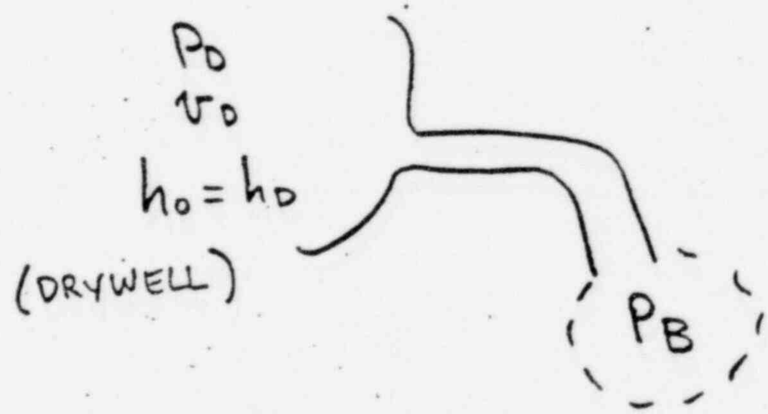
THE MODELING PARAMETER $\dfrac{h_o \dot{m} \sqrt{\frac{L}{g}}}{\rho_{si}\, \nu_{si}}$

MUST BE THE SAME IN FULL SCALE AND THE SCALE MODEL :

$$\left(\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{\rho_{si}\, \nu_{si}} \right)_M = \left(\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{\rho_{si}\, \nu_{si}} \right)_F$$

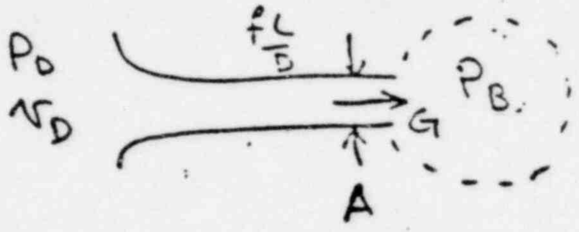
$$\boxed{\frac{h_{oM}\, \dot{m}_M}{h_{oF}\, \dot{m}_F} = \sqrt{\frac{L_F}{L_M}}\; \underbrace{\frac{\rho_{si\,M}}{\rho_{si\,F}}}_{\frac{L_M}{L_F}}\; \underbrace{\frac{\nu_{si\,M}}{\nu_{si\,F}}}_{\frac{L_M^3}{L_F^3}} = \left(\frac{L_M}{L_F}\right)^{\frac{7}{2}}}$$

STAGNATION ENTHALPY h_o IS DETERMINED FROM DRYWELL PROPERTIES :



$$\boxed{h_o = \frac{\gamma}{\gamma - 1} P_D v_D}$$

AIR FLOW RATE IN VENT IS OBTAINED FROM



$$\dot{m} = A\,G$$

$$G = \sqrt{\gamma g_c \frac{P_D}{v_D}}\; \mathcal{Y}\left(\frac{P_B}{P_D}, \frac{fL}{D}\right)$$

THEN

$$\frac{h_{oM}\dot{m}_M}{h_{oF}\dot{m}_F} = \frac{P_{DM}\, v_{DM}\, A_M \sqrt{\frac{P_{DM}}{v_{DM}}}\; \mathcal{Y}\left(\frac{P_{BM}}{P_{DM}}, \left(\frac{fL}{D}\right)_M\right)}{P_{DF}\, v_{DF}\, A_F \sqrt{\frac{P_{DF}}{v_{DF}}}\; \mathcal{Y}\left(\frac{P_{BF}}{P_{DF}}, \left(\frac{fL}{D}\right)_F\right)} = \left(\frac{L_M}{L_F}\right)^{\frac{7}{2}}$$

$$\frac{v_{DM}\sqrt{\frac{P_{DM}}{v_{DM}}}}{v_{DF}\sqrt{\frac{P_{DF}}{v_{DF}}}} = \frac{\sqrt{\gamma g_c P_{DM} v_{DM}}}{\sqrt{\gamma g_c P_{DF} v_{DF}}} = \underbrace{\frac{C_M}{C_F}}_{\text{SONIC SPEED}} \approx 1.0$$

IF ALL PRESSURES WERE SCALED,

$$\frac{P_{DM}}{P_{DF}} = \frac{L_M}{L_F}$$

$$\frac{P_{BM}}{P_{DM}} = \frac{P_{BF}}{P_{DF}}$$

AND IF $\left(\frac{fL}{D}\right)_M \approx \left(\frac{fL}{D}\right)_F$,

THEN $\mathcal{Y}\left(\frac{P_{BM}}{P_{DM}}, \left(\frac{fL}{D}\right)_M\right) \approx \mathcal{Y}\left(\frac{P_{BF}}{P_{DF}}, \left(\frac{fL}{D}\right)_F\right)$

AND

$$\frac{h_{oM}\dot{m}_M}{h_{oF}\dot{m}_F} = \frac{L_M}{L_F}\frac{A_M}{A_F} = \left(\frac{L_M}{L_F}\right)^{7/2}$$

WHICH REQUIRES

$$\boxed{\frac{A_M}{A_F} = \left(\frac{L_M}{L_F}\right)^{5/2}}$$

TO OBTAIN IDENTICAL VALUES OF THE AIR DISCHARGE PARAMETER $\dfrac{h_o \dot{m}\sqrt{\frac{L}{g}}}{P_{si}\, \forall_{si}}$.

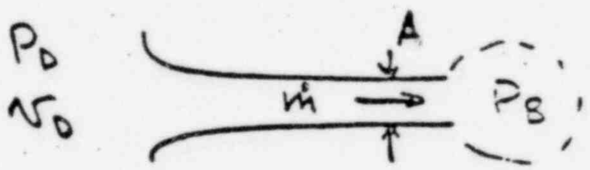
BUT FROM GEOMETRIC SCALING,

WE HAVE $\boxed{\dfrac{A_M}{A_F} = \left(\dfrac{L_M}{L_F}\right)^2}$

THEREFORE, IT IS IMPOSSIBLE TO HAVE EXACTLY SCALED DRYWELL PRESSURE AND SATISFY THE $\boxed{\dfrac{h_o \dot{m}\sqrt{\frac{L}{g}}}{P_{si}\, \forall_{si}}}$ AIR DISCHARGE PARAMETER UNLESS THE VENT AREA SUDDENLY DECREASED AFTER FULL WATER EXPULSION. A RESTRICTION IN THE VENT PERHAPS COULD APPROXIMATELY SATISFY THIS.

THERE IS ANOTHER METHOD TO SATISFY MODELING REQUIREMENTS OF THE AIR DISCHARGE PARAMETER $\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{P_{si} v_{si}}$ WHICH INVOLVES DRYWELL PRESSURE.

TO IDENTIFY REQUIREMENTS OF DRYWELL PRESSURE, NEGLECT VENT FRICTION, AND NOTE THAT CORRESPONDING AIR FLOW RATE IS



$$\dot{m} = A \sqrt{\frac{2 \gamma g_c}{(\gamma - 1)} \frac{P_D}{v_D}} \left(\frac{P_B}{P_D}\right)^{\frac{1}{\gamma}} \left[1 - \left(\frac{P_B}{P_D}\right)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{1}{2}}$$

MAINTAIN GEOMETRIC SIMILARITY OF WETWELL, POOL, AND VENTS SO THAT

$$\frac{A_M}{A_F} = \left(\frac{L_M}{L_F}\right)^2$$

THEN REQUIRING

$$\left(\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{P_{si} v_{si}}\right)_M = \left(\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{P_{si} v_{si}}\right)_F$$

IT FOLLOWS THAT

$$\sqrt{\frac{L_F}{L_M}} \left(\frac{P_D}{P_{si}}\right)_M^{\frac{\gamma-1}{2\gamma}} \sqrt{\left(\frac{P_D}{P_{si}}\right)_M^{\frac{\gamma-1}{\gamma}} - \left(\frac{P_B}{P_{si}}\right)_M^{\frac{\gamma-1}{\gamma}}} = \left(\frac{P_D}{P_{si}}\right)_F^{\frac{\gamma-1}{2\gamma}} \sqrt{\left(\frac{P_D}{P_{si}}\right)_F^{\frac{\gamma-1}{\gamma}} - \left(\frac{P_B}{P_{si}}\right)_F^{\frac{\gamma-1}{\gamma}}}$$

WHICH RELATES PRESSURE IN MODEL DRYWELL TO FULL SCALE DRYWELL PRESSURE.

SINCE IN THE SUPPRESSION CHAMBER WE HAVE PRESSURES SCALED,

$$\left(\frac{P_B}{P_{si}}\right)_M = \left(\frac{P_B}{P_{si}}\right)_F$$

COMPUTATIONS SHOW THAT IF DRYWELL PRESSURE IN THE MODEL IS ABOUT $\boxed{0.7 \frac{L_{MODEL}}{L_{FULL}}}$ OF FULL SCALE DRYWELL PRESSURE, THE AIR DISCHARGE PARAMETER $\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{P_{si} V_{si}}$ WILL BE CLOSELY MODELED.

CONCLUSIONS

MODELING LAWS FOR POOL MOTION ARE:

$$\frac{P_{MODEL}}{P_{FULL}} = \frac{L_{MODEL}}{L_{FULL}} \quad \text{DURING WATER EXPULSION}$$

$$\frac{A_{MODEL}}{A_{FULL}} = \left(\frac{L_{MODEL}}{L_{FULL}}\right)^2$$

$$\frac{V_{MODEL}}{V_{FULL}} = \left(\frac{L_{MODEL}}{L_{FULL}}\right)^3$$

SATISFIED BY GEOMETRIC SCALING

AND $\frac{h_{oM}\dot{m}_M}{h_{oF}\dot{m}_F} = \left(\frac{L_{MODEL}}{L_{FULL}}\right)^{7/2}$, WHICH IS

APPROXIMATED EITHER BY HAVING

$$\frac{P_{DRYWELL,MODEL}}{P_{DRYWELL,FULL}} \approx 0.7\,\frac{L_{MODEL}}{L_{FULL}}$$

DURING AIR DISCHARGE; OR BY HAVING THE DRYWELL PRESSURE MODELED, AND VENT AREAS

$$\frac{A_{VENT,MODEL}}{A_{VENT,FULL}} = \left(\frac{L_{MODEL}}{L_{FULL}}\right)^{5/2}$$

THIS MIGHT BE ACCOMODATED BY AN ORIFICE OR NOZZLE IN THE VENT WHICH RESTRICTS THE MODEL AREA TO $\sqrt{\frac{L_M}{L_F}}$ OF ITS UNRESTRICTED VALUE, IF IT DOES NOT STRONGLY AFFECT THE WATER EXPULSION PHENOMENA.

3533 *

Aerojet Nuclear Company

Interoffice Correspondence

File

October 10, 1975

J. H. Ramsthaler
Rogers 220

BWR DYNAMICS POSITION LETTER - LLW-61-75

This letter documents informal transmittal of an ANC summary position letter on General Electric (GE) analyses and experiments related to the GE Pressure Suppression Test Facility (PSTF). The attached report: "PSTF Scaling, Test Repeatability, and HCU Froth Loading", SSRD-14-76 is authored by B. A. Bush and B. S. Anderson. The report presents conclusions and recommendations based on available data, and qualifies certain conclusions based on future receipt of confirmatory data from GE. The scaling analysis and conclusions are directed toward BWR pool motion parameters, and not toward other indirect phenomena such as air bubble shape, formation, structural pressure loads, etc.

By copy of this letter, the reference report is being sent to NRC-TR (R.L. Tedesco and J.A. Kudrick) and ERDA-ID (T.D. Knight).

L. L. Wheat

L. L. Wheat, Manager
Containment Systems Project
Reactor Behavior Program

dp

Attachment as stated

cc: BSAnderson
BABush
EPEales
IAEngen
WHLe
WJMings
CLNalezny
DCSlaughterbeck
RRStiger
File C2.0

F-3

Report No. SSRD-14-76

Date October, 1975

PROPRIETARY INFORMATION

PSTF Scaling, Test Repeatability, and HCU Froth Loading

BY

B. A. BUSH

B. S. ANDERSON

Approved:

Supervisor

Manager

Program Manager

SYSTEMS SAFETY RESEARCH DIVISION

Aerojet Nuclear Company

G. Lainas, DSS

6 *

Aerojet Nuclear Company

Interoffice Correspondence

April 19, 1976

J. H. RAMSTHALER
ROGERS 220

CRITIQUE OF GENERAL ELECTRIC SAFETY-RELIEF VALVE ANALYTICAL MODELS - LLW-18-76

References: (1) JIMills, "Analysis of the General Electric Safety-Relief Valve Discharge Analytical Models", SRD-71-76, April 1976.
(2) SCChang, "Critique of the General Electric Safety-Relief Valve Discharge Analytical Models", SRD-79-76, April 1976.

This letter informally transmits Reference (1), authored by Dr. Jim Mills, an ANC consultant, and Reference (2), authored by Dr. Sin Chung Chang, completing the laboratory's initial review of documented General Electric Safety-Relief (S/R) valve analytical models. A recently received General Electric amendment to their model report is currently being reviewed on a part time basis, and will be critiqued in a later report.

The conclusions provided in the two references raise several questions about the General Electric models and conclusions. Until satisfactory resolution of the main concerns is obtained, the INEL staff position is that the General Electric models and General Electric conclusions about those models are not technically substantiated.

This work is a partial fulfillment of the level of effort task entitled "BWR Dynamic Phenomena Investigations" of the I-214 Containment Analysis project.

Copies of the two proprietary referenced reports are being informally sent to:

NRC:	DHKShum	JAKudrick (3)
	WLJensen	RLTedesco
	PENorian	LSlegers
	ZRRosztoczy	DFRoss
ERDA-ID:	PELittleneker	TDKnight

L. L. Wheat

L. L. Wheat, Manager
Containment Systems Project
Reactor Behavior Program

la

Attachment as stated

F-4

PROPRIETARY INFORMATION

REPORT NUMBER SRD-79-76

DATE April, 1976

CODE DEVELOPMENT-VERIFICATION-APPLICATION

SYSTEMS RESEARCH

SYSTEMS ANALYSIS-EXPERIMENT SPECIFICATION

CRITIQUE OF THE GENERAL ELECTRIC SAFETY-RELIEF VALVE DISCHARGE ANALYTICAL MODELS

by

S. C. CHANG

APPROVED:

Supervisor

Systems Research Division

Reactor Behavior Program

IDAHO NATIONAL ENGINEERING LABORATORY

Aerojet Nuclear Company

ATTACHMENT IS PROPRIETARY

12 *

IDAHO NATIONAL ENGINEERING LABORATORY

AEROJET NUCLEAR COMPANY 550 SECOND STREET, IDAHO FALLS, IDAHO 83401 • (208) 526-0111

FILE

JUN 30 1976

Mr. P. E. Litteneker, Chief
Reactor Behavior Branch
Idaho Operations Office - ERDA
Idaho Falls, Idaho 83401

BWR POOL SWELL MODEL COMPARISON - RAM-374-76

Reference: (a) JIMills, "BWR Pool Swell Model Evaluation for Mark III PSTF Test Data," SRD-116-76, June 1976

This letter transmits Reference (a), which is a proprietary report containing data provided by the General Electric Company. The attachment describes a model comparison effort, of a rather limited scope, where an INEL one-dimensional pool swell digital computer code model was compared with General Electric data on BWR pool motion resulting from air blowdown into the pool. Generally good agreement between the model and data was obtained when a reasonable fraction of the pool water was allowed to interact with the air bubble in the calculations. The conclusions are: (1) the model will closely predict both pool surface position and velocity, using a reasonable interacting pool surface area, and (2) a correlation is needed to select the fraction of pool surface area interacting with the air bubble. This work was completed under the I-214 Containment Analysis level of effort task entitled "BWR Dynamics," Node 46, of the I-214 Pert Chart.

J. H. Ramsthaler, Manager
Reactor Behavior Program

LLW/cb

Attachment as stated

cc: LSlegers, NRC-RSR
WLJensen, NRC-DSS
JAKudrick, NRC-DSS (2)
GLainas, NRC-DSS
DFRoss, NRC-DSS
ZRRosztoczy, NRC-DSS
RLTedesco, NRC-DSS
WHLovelace/RCRossi, NRC-MIPC
RWBarber, ERDA-RSRC
TDKnight, ERDA-ID
FHTingey, ANC, w/o Attach.

F-5

PROPRIETARY INFORMATION

REPORT NUMBER SRD-116-76

DATE June 1976

CODE DEVELOPMENT-VERIFICATION-APPLICATION

SYSTEMS RESEARCH

SYSTEMS ANALYSIS-EXPERIMENT SPECIFICATION

BWR POOL SWELL MODEL EVALUATION
FOR MARK III PSTF TEST DATA

By

J. I. MILLS
(Consultant)

ENERGY SAFETY ENVIRONMENT

IDAHO NATIONAL ENGINEERING LABORATORY

Aerojet Nuclear Company

File 20*
SRV - Ramshead

EG&G Idaho, Inc.

P. O. Box 1625
Idaho Falls, Idaho 83401

November 24, 1976

Mr. P. E. Litteneker, Chief
Reactor Safety Behavior Branch
Idaho Operations Office - ERDA
Idaho Falls, Idaho 83401

REVIEW OF GENERAL ELECTRIC SAFETY - RELIEF VALVE MODELS - Stig-91-76

Ref: J. I. Mills and R. A. Pate, "Review of Safety - Relief Valve Analytical Models", PG-R-76-002 (November 1976).

Dear Mr. Litteneker:

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This task was funded by Project A6009, Containment Analysis, and no schedule node is associated with the task.

Very truly yours,

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Z. R. Rosztoczy, NRC-DSS
L. S. Rubenstein, NRC-NRR
L. Slegers, NRC-RSR
N. Su, NRC-DSS (6)
R. L. Tedesco, NRC-DSS
F. H. Tingey, EG&G w/o Attach.

F-6

Report Number PG-R-76-002

Date November 1976

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REVIEW OF SAFETY RELIEF-VALVE ANALYTICAL MODELS

by

J. I. Mills

R. A. Pate

Approved:

R. A. Wells, Supervisor

E. P. Eales, Manager
Systems Research Division

L. L. Wheat
Reactor Behavior Program

IDAHO NATIONAL ENGINEERING LABORATORY

EG&G

EG&G Idaho, Inc.
P.O. Box 1625
Idaho Falls, Idaho 83401

TEST CONCLUSIONS

SERIES 5806

- VENT CLEARING TRANSIENTS ARE COMPARABLE FOR AIR AND STEAM BLOWDOWNS.
- DURING POOL SWELL VENT FLOW IS INDEPENDENT OF VENT SUBMERGENCE.
- RATE OF DECREASE IN DIMENSIONLESS SLUG LENGTH IS INDEPENDENT OF DRYWELL PRESSURE RATE AND INITIAL SUBMERGENCE.
- POOL SWELL BREAKTHROUGH ELEVATION SIMILAR FOR BOTH AIR AND STEAM BLOWDOWNS.
- AIR TESTS YIELD HIGHER SWELL VELOCITIES THAN STEAM TESTS.
- POOL SWELL IN 1/3 AND FULL SCALE IS GENERALLY COMPARABLE.

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- BASIC UNDERSTANDING OF SYSTEM PERFORMANCE
- VERTICAL VENT CONTAINMENT DESIGN BASES
- VERIFICATION OF ANALYTIC MODELS

1970 THRU 1973 SMALL HORIZONTAL VENT TESTING

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- 1972 AND 1973 PSTF CONSTRUCTION
- LARGE SCALE CONFIRMATORY TESTS STARTING NOVEMBER 1973

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PSTF DESIGN PARAMETERS

PARAMETER	PSTF	251 BWR/6 MARK III	PSTF MARK III
BLOWDOWN VESSEL PRESSURE	1,015 PSIA	1,050 PSIA	
BLOWDOWN VESSEL VOLUME	160 FT^3	21,222 FT^3	1/132
BLOWDOWN AREA (LIQUID)	0.0246 FT^2*	3.10 FT^2	1/126
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DESIGN DRYWELL PRESSURE	75 PSIG	25 PSIG	
DRYWELL VOLUME	2,365 FT^3*	302,500 FT^3	1/128
HORIZONTAL VENT AREA	4.1 FT^2*	507 FT^2	1/124
SUPPRESSION POOL VOLUME	1,150 FT^3*	149,000 FT^3	1/130
SUPPRESSION POOL DEPTH	21 FT*	21 FT	
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* PARAMETER IS ADJUSTABLE TO SMALL VALUES

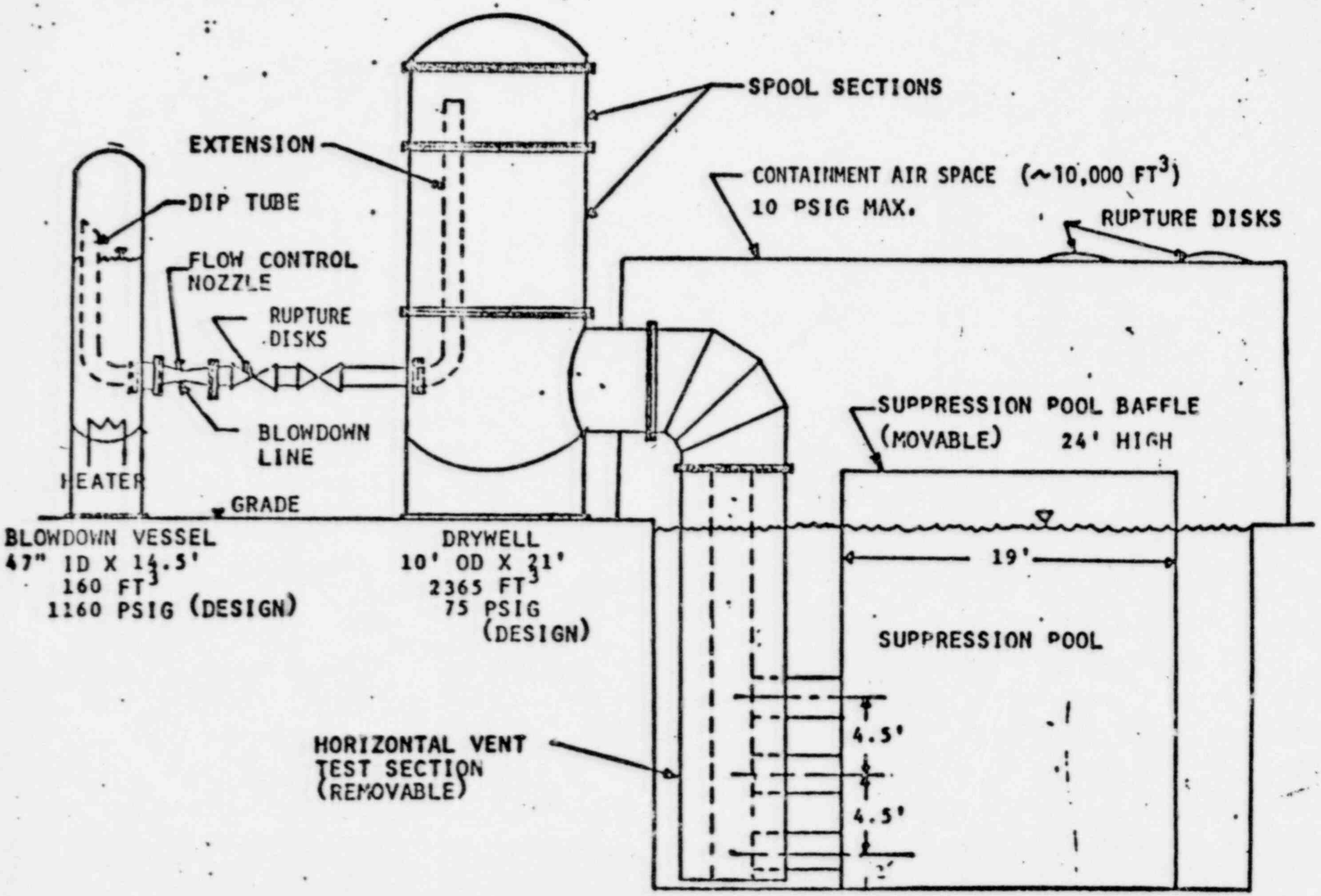


Figure 3 -- PRESSURE SUPPRESSION TEST FACILITY

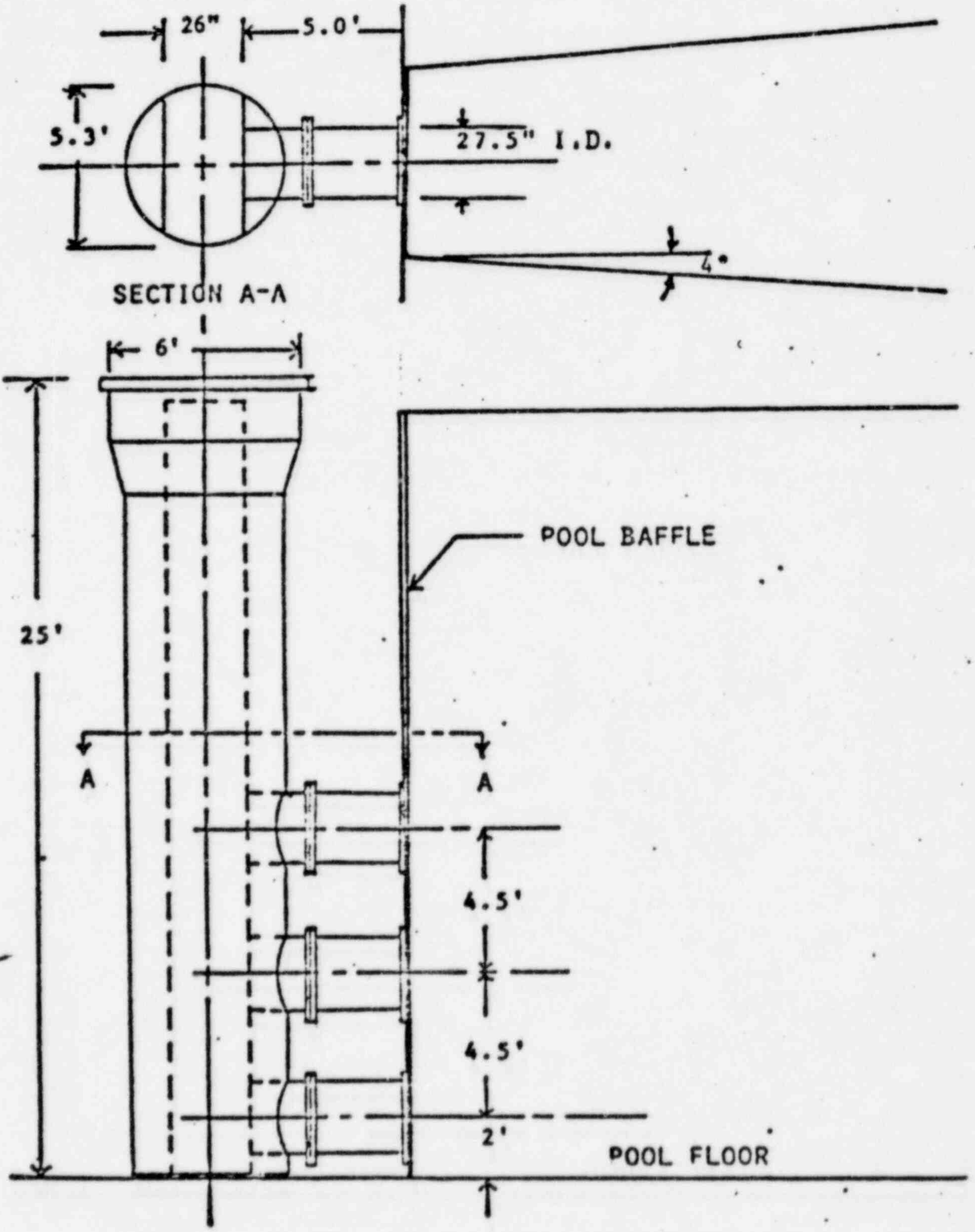
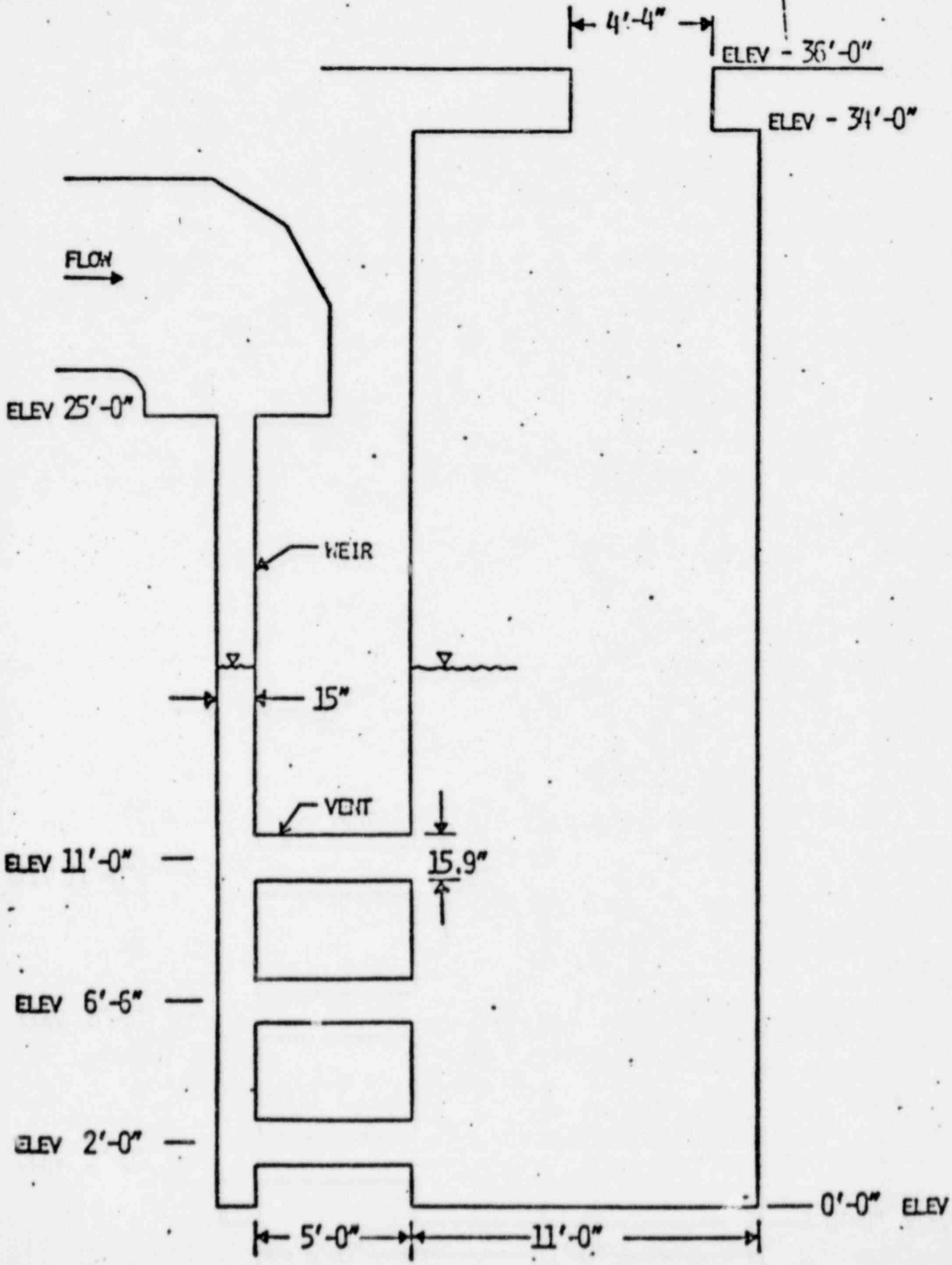


Figure 2 -- TYPICAL HORIZONTAL VENT TEST SECTION

1/3 SCALE VENT-POOL CONFIGURATION



MARK III CONFIRMATORY TEST PROGRAM

SUMMARY

FULL SIZE VENT TESTS

STEAM BLOWDOWNS

Tests	Count	Data
5701, 5702, 5703	41 TESTS	• GENERAL BLOWDOWN RESPONSE • VENT CLEARING • CONDENSATION EFFECTIVENESS • CHUGGING DATA

AIR BLOWDOWNS

Tests	Count	Data
5705, 5706	12 TESTS	• POOL SWELL DATA • STRUCTURAL IMPACT ABOVE POOL

1/3 SCALE VENT TESTS

STEAM BLOWDOWNS

Tests	Count	Data
5801, 5802, 5803, 5804	29 TESTS	• POOL SWELL DATA • ΔP AT HCU FLOOR • POOL WALL LOADS • DRYWELL AND VENT RESPONSE
5805	51 TESTS	• FLUID IMPACT ON STRUCTURES

AIR BLOWDOWNS

Tests	Count	Data
5806	12 TESTS	• POOL SWELL

FUTURE TEST SUMMARY

1/3 SCALE STEAM TESTS

- SMALL BLOWDOWN RESPONSE (CHUGGING)
- SUPPRESSION POOL THERMAL STRATIFICATION
- HOT POOL VIBRATIONS
- LIQUID BLOWDOWNS
- CHUGGING WALL LOADS

1/9 SCALE STEAM TESTS

- ADJACENT VENT INTERACTIONS

LARGE SCALE TESTS

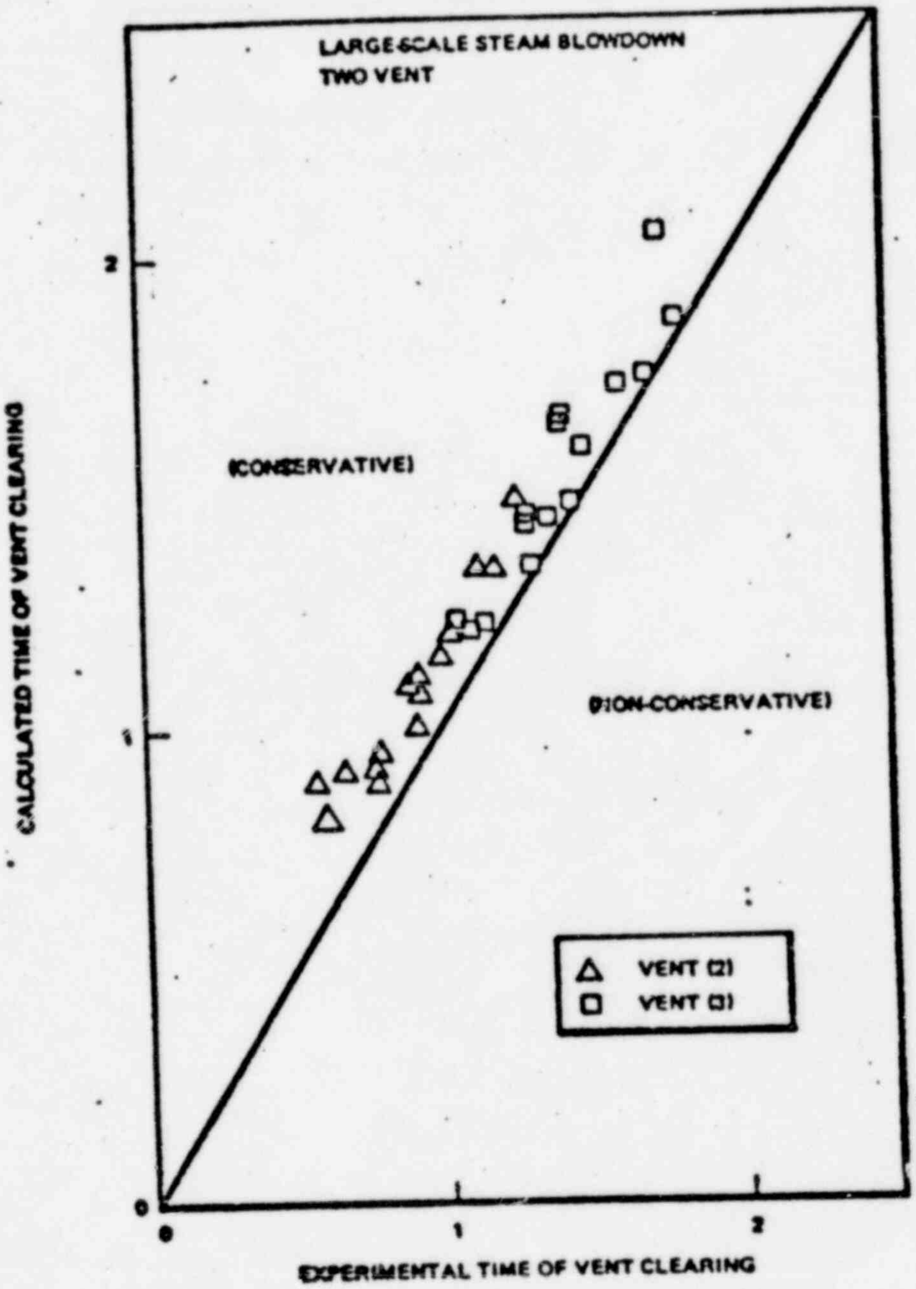
(SERIES 5701 THRU 5703)

TEST OBJECTIVES

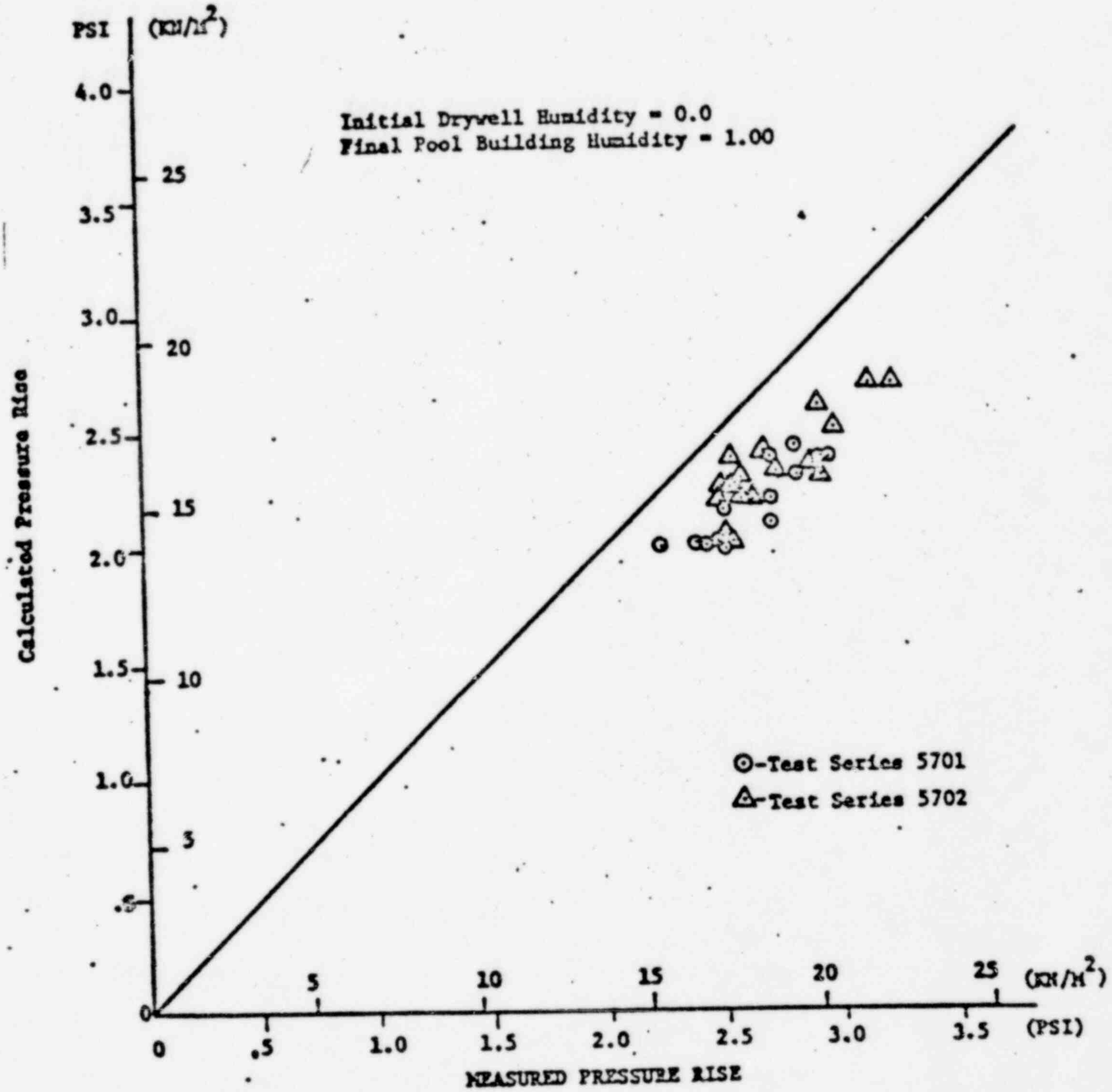
- LARGE SCALE DEMONSTRATION OF HORIZONTAL VENT SYSTEM
- DATA BASE FOR DESIGN METHODS VERIFICATION
- IDENTIFICATION OF PHENOMENA REQUIRING MODEL DEVELOPMENT

MAJOR TEST PARAMETERS

- STEAM BLOWDOWNS FROM ~1000 PSIA
- BLOWDOWN SIZE 70%, 100%, 200% DBA
- VENT SUBMERGENCE 2 FT THRU 12 FT
- NUMBER OF VENTS ONE, TWO, THREE
- NUMBER OF TESTS IN SERIES = 40



Large Scale Steam-Blowdown, Two Vent



Containment Pressure Rise Comparison.

MAJOR TEST CONCLUSIONS

- DRYWELL PEAK PRESSURE IS CONSERVATIVELY PREDICTED BY DESIGN MODEL.
- VENT CLEARING MODEL GIVES CONSERVATIVE PREDICTION OF VENT CLEARING TIME.
- SMALL AMOUNT OF STEAM RELEASED TO WETWELL AIR SPACE DURING POOL SWELL (~15 LBS.).
- POOL SWELL BREAKTHROUGH POINT IS IN THE 10 FT TO 15 FT RANGE.
- POOL SWELL MAXIMUM VELOCITY IS CONTROLLED BY AIR CHARGING RATE INTO POOL.
- AFTER VENT CLEARING POOL WAVE ACTION IS SMALL.
- WALL LOADS IN POOL ARE LOW.

LARGE SCALE AIR TESTS

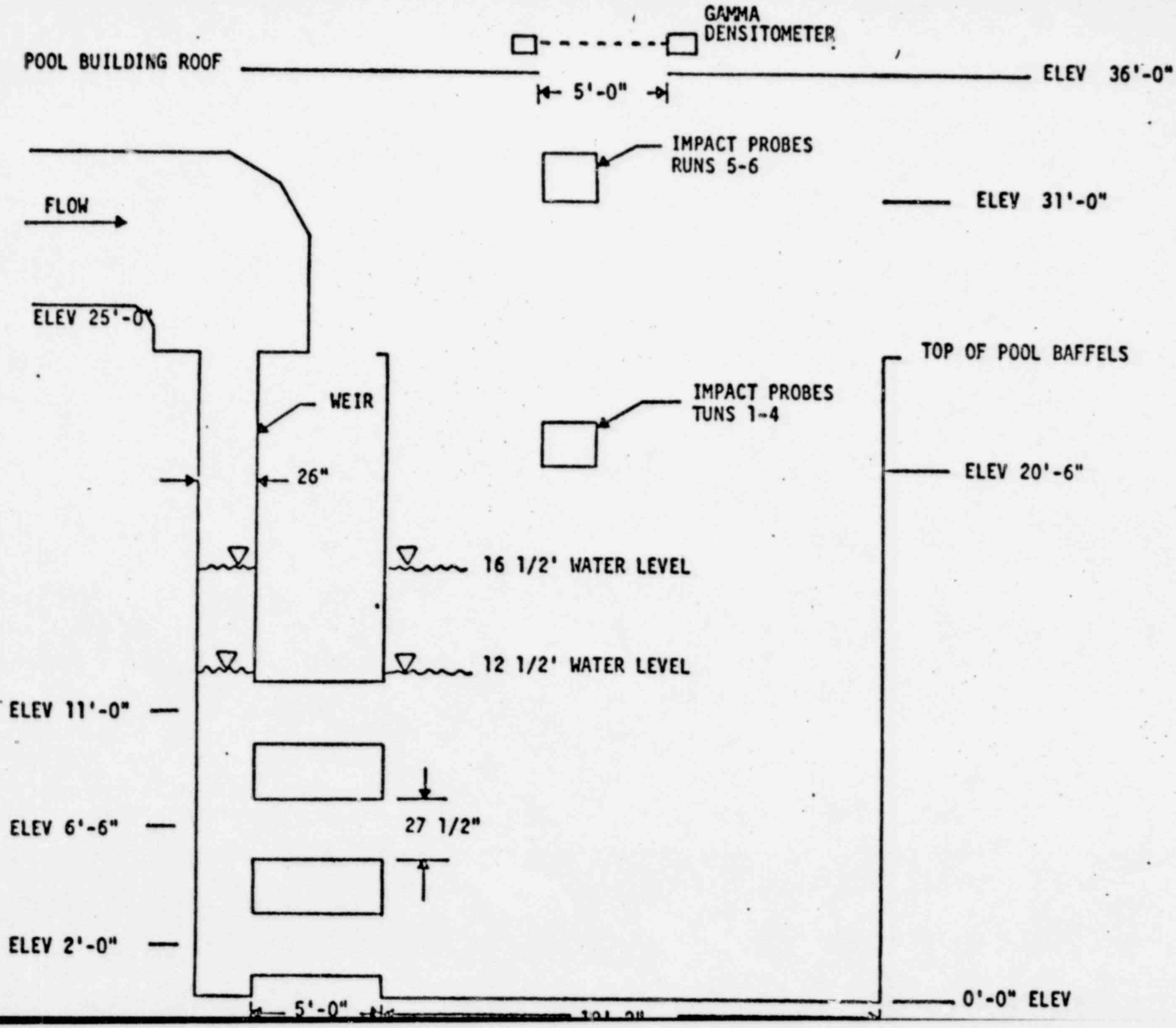
(SERIES 5706)

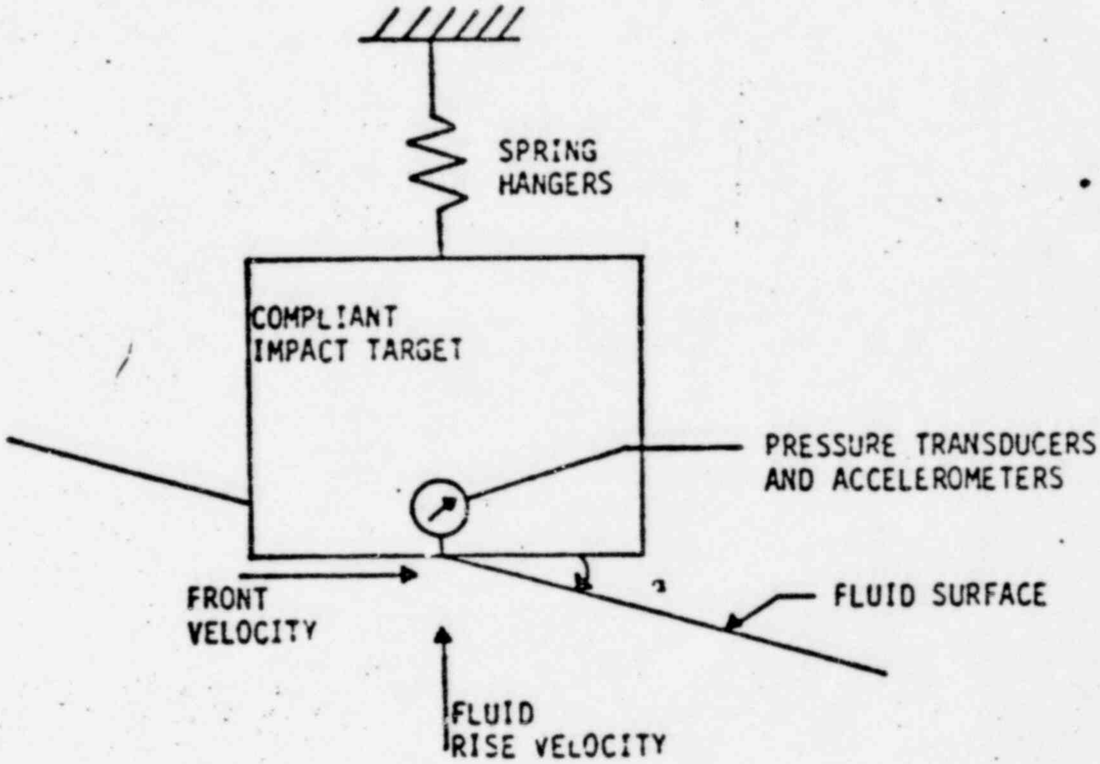
OBJECTIVES

- POOL SWELL DATA BASE WITH LARGE CHARGING RATES AND GREATER AIR FRACTION.
- MEASURE FORCES ON STRUCTURES ABOVE SUPPRESSION POOL.

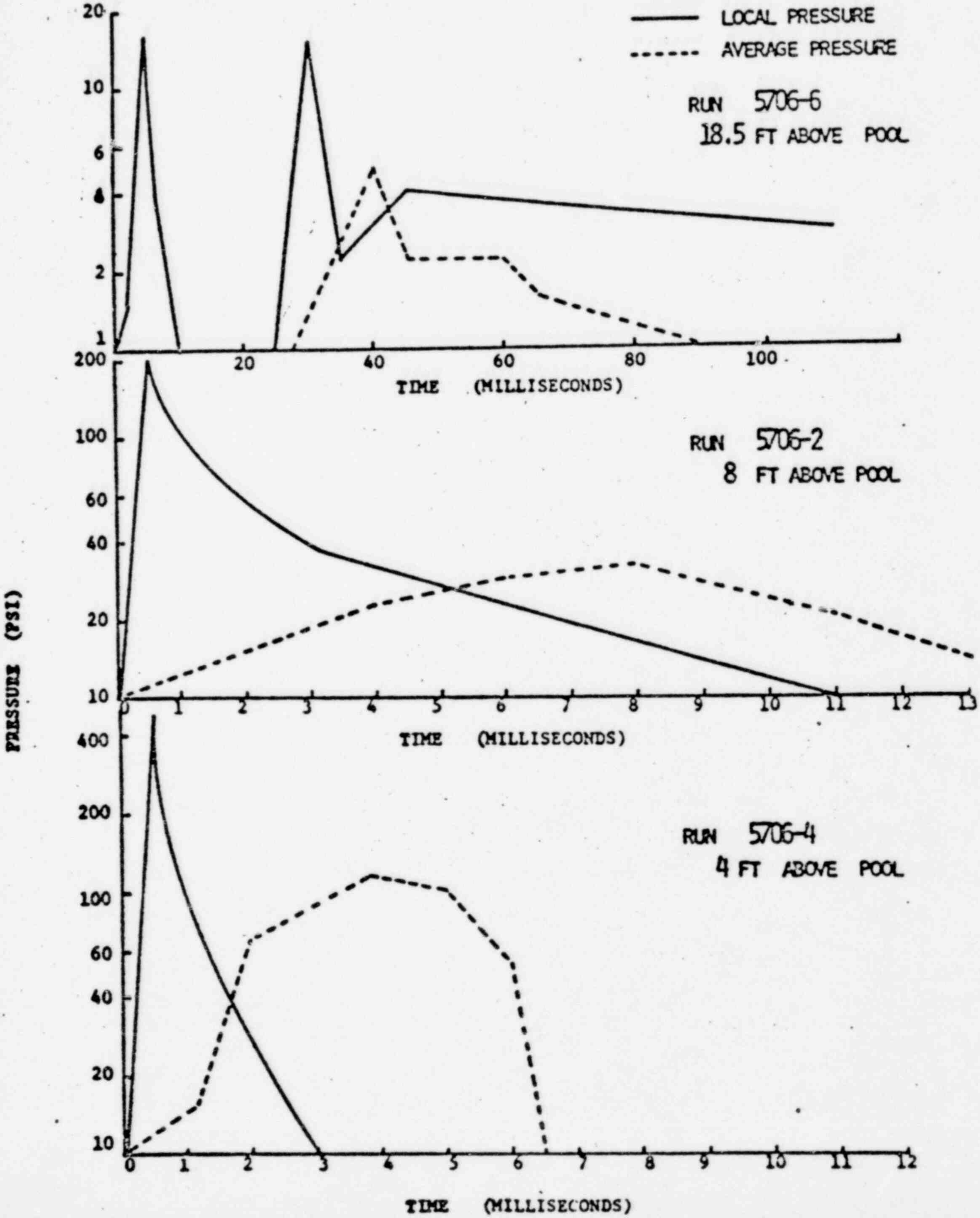
MAJOR TEST PARAMETERS

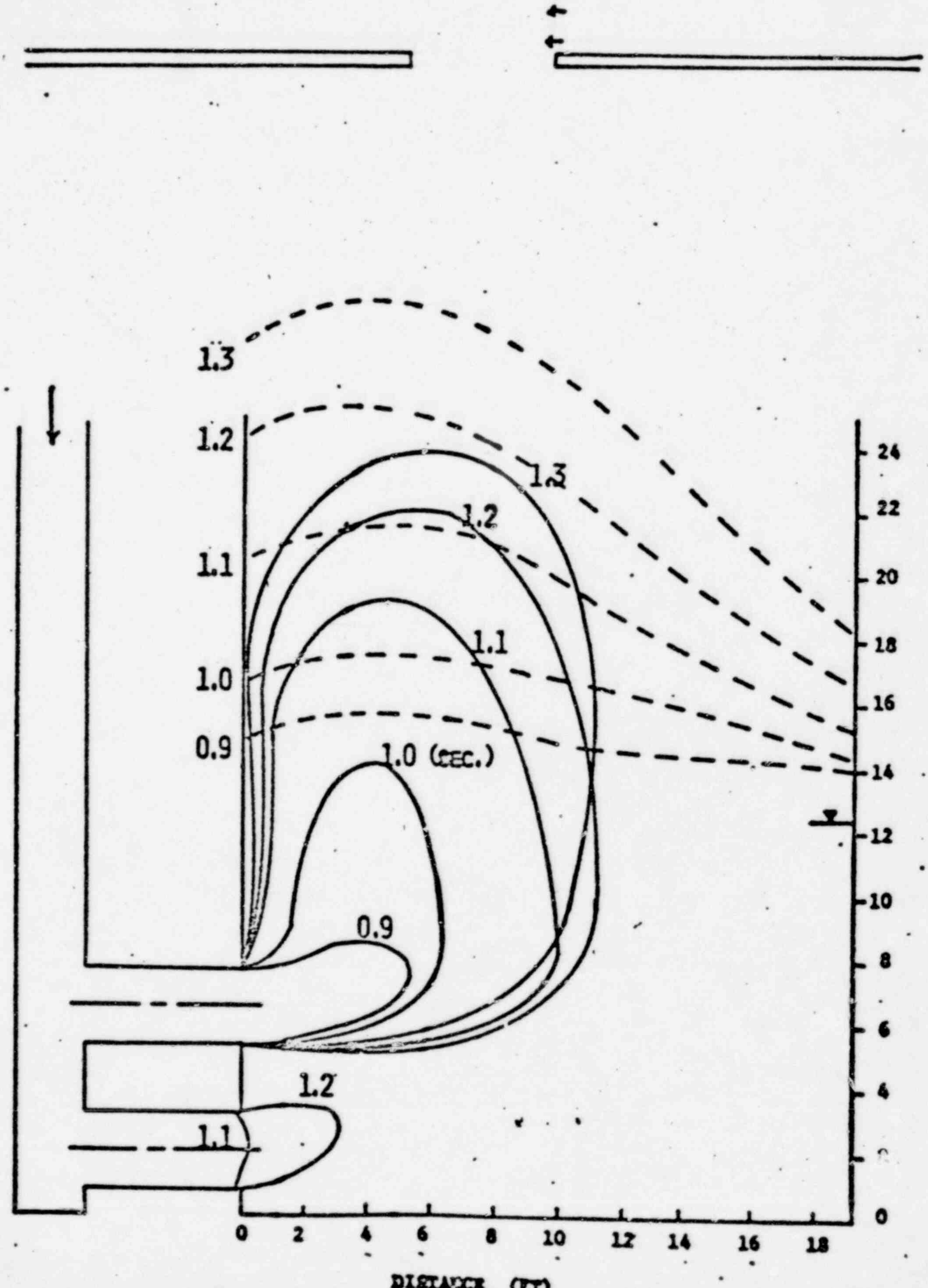
- AIR BLOWDOWN FROM 1000 PSIA.
- TWO VENTS OPEN.
- MAXIMUM SIZE BLOWDOWN FOR TEST FACILITY (4.25 INCH VENTURI).
- VENT SUBMERGENCE 6 FT AND 10 FT.
- FORCE TARGET ELEVATIONS 4 FT, 8 FT, 13½ FT.


GAMMA
DENSITOMETER
POOL BUILDING ROOF
ELEV 36'-0"
5'-0"
IMPACT PROBES
RUNS 5-6
FLOW
ELEV 31'-0"
ELEV 25'-0"
TOP OF POOL BAFFELS
WEIR
IMPACT PROBES
TUNS 1-4
26"
ELEV 20'-6"
16 1/2' WATER LEVEL
12 1/2' WATER LEVEL
ELEV 11'-0"
ELEV 6'-6"
27 1/2"
ELEV 2'-0"
0'-0" ELEV
5'-0"



TEST NO.	FLUID RISE VELOCITY (ft/sec)	IMPACT ANGLE α	FRONT VELOCITY (ft/sec)
1	38.4	13°	166
2	41.2	18.6°	121
3	28	7.6°	250
4	26.5	2.6°	210 - 271


LOCAL PRESSURE
AVERAGE PRESSURE
RUN 5706-6
18.5 FT ABOVE POOL
TIME (MILLISECONDS)
RUN 5706-2
8 FT ABOVE POOL
TIME (MILLISECONDS)
PRESSURE (PSI)
RUN 5706-4
4 FT ABOVE POOL
TIME (MILLISECONDS)


1.3
1.2
1.1
1.0
0.9
1.3
1.2
1.1
1.0 (SEC.)
0.9
1.2
1.1
0
2
4
6
8
10
12
14
16
18
DISTANCE (FT)
24
22
20
18
16
14
12
10
8
6
4
0
ELEVATION (FT)

TEST CONCLUSIONS

(SERIES 5706)

- LARGE FORCES ON STRUCTURES NEAR SUPPRESSION POOL SURFACE DURING POOL SWELL

- HCU FLOORS WILL NOT BE HIT BY SOLID LIQUID SLUGS BUT TWO PHASE MIXTURE

- MORE DATA NEEDED TO DEFINE FORCES OF STRUCTURES AND TWO PHASE PRESSURE DROP ACROSS FLOOR RESTRICTIONS

ONE-THIRD SCALE TESTS

(SERIES 5S01)

OBJECTIVES

- DETERMINE TWO PHASE PRESSURE DROP ACROSS FLOOR RESTRICTIONS
- ADDITIONAL DATA ON POOL SWELL
- ADDITIONAL DATA ON LIQUID IMPULSE ON TEST FACILITY ROOF

MAJOR TEST PARAMETERS

- STEAM BLOWDOWNS
- 1/3 AREA POOL AND VENTS
- 3 VENT TESTS
- BLOWDOWN SIZE ~70 %, 100 %, 140 %, DBA
- VENT SUBMERGENCE 5 FT, 7½ FT, 10 FT
- POOL CEILING RESTRICTION RATIO 63 %, 72 %, 81 %
- NUMBER OF TESTS = 19

RESULTS OF SERIES 5801

- FLOW THROUGH HCU FLOOR WILL BE HIGH VOID FRACTION AIR WATER MIXTURE.
- MAXIMUM PRESSURE DROP ~ 3-5 PSI.
- HCU FLOOR ΔP DID NOT INCREASE PEAK DRYWELL PRESSURE.
- HCU FLOOR VOID FRACTIONS > 80% DURING 1 TO 2 SECOND TRANSIENT.
- POOL SWELL BREAKTHROUGH AT ~2 INITIAL VENT SUBMERGENCE BASED ON COMPLETE SLUG DISINTEGRATION.

PSTF ONE-THIRD SCALE
POOL SHELL STRUCTURAL TESTING

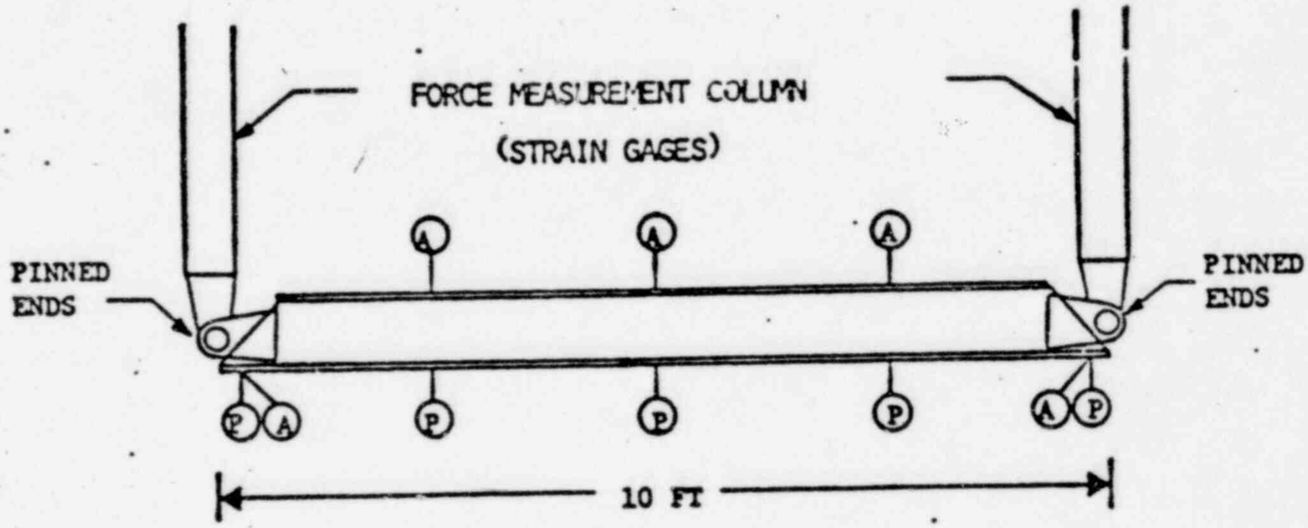
DATA ON RESPONSE OF STRUCTURES TO DYNAMIC LOADS

- TO OBTAIN LOADING INFORMATION FROM TYPICAL STRUCTURES WHICH CAN BE APPLIED TO MARK III STRUCTURES
- TO CONFIRM CONSERVATISM OF 115 PSI FORCING FUNCTION BEING USED AS A DESIGN LOAD
- TO VERIFY BEAM RESPONSE STRESS ANALYSIS METHODS
- TO CORRELATE LOADING INFORMATION IN TERMS OF KNOWN POOL DYNAMICS
- TO CHECK ASSUMPTION THAT FLOOR GRATINGS ARE SUBJECT TO DRAG LOADS ONLY

RANGE OF TEST PARAMETERS

RADIAL TARGET ORIENTATION	POOL VELOCITY (FPS)	SLUG LENGTH (FT)
10" I BEAM	22 - 30	0 - 6
5" I BEAM	10 - 29	0 - 6
10" PIPE	10 - 26	0 - 6
CIRCUMFERENTIAL TARGET		
10" I BEAM	22 - 30	0 - 6
5" I BEAM	23 - 32	0 - 6
10" PIPE	23 - 36	0 - 6
20" PIPE	23 - 36	0 - 6
GRATING	25 - 29	

TYPICAL TEST TARGET



P - PRESSURE TRANSDUCERS

A - ACCELEROMETERS

TARGETS TESTED

10" WIDE I BEAM

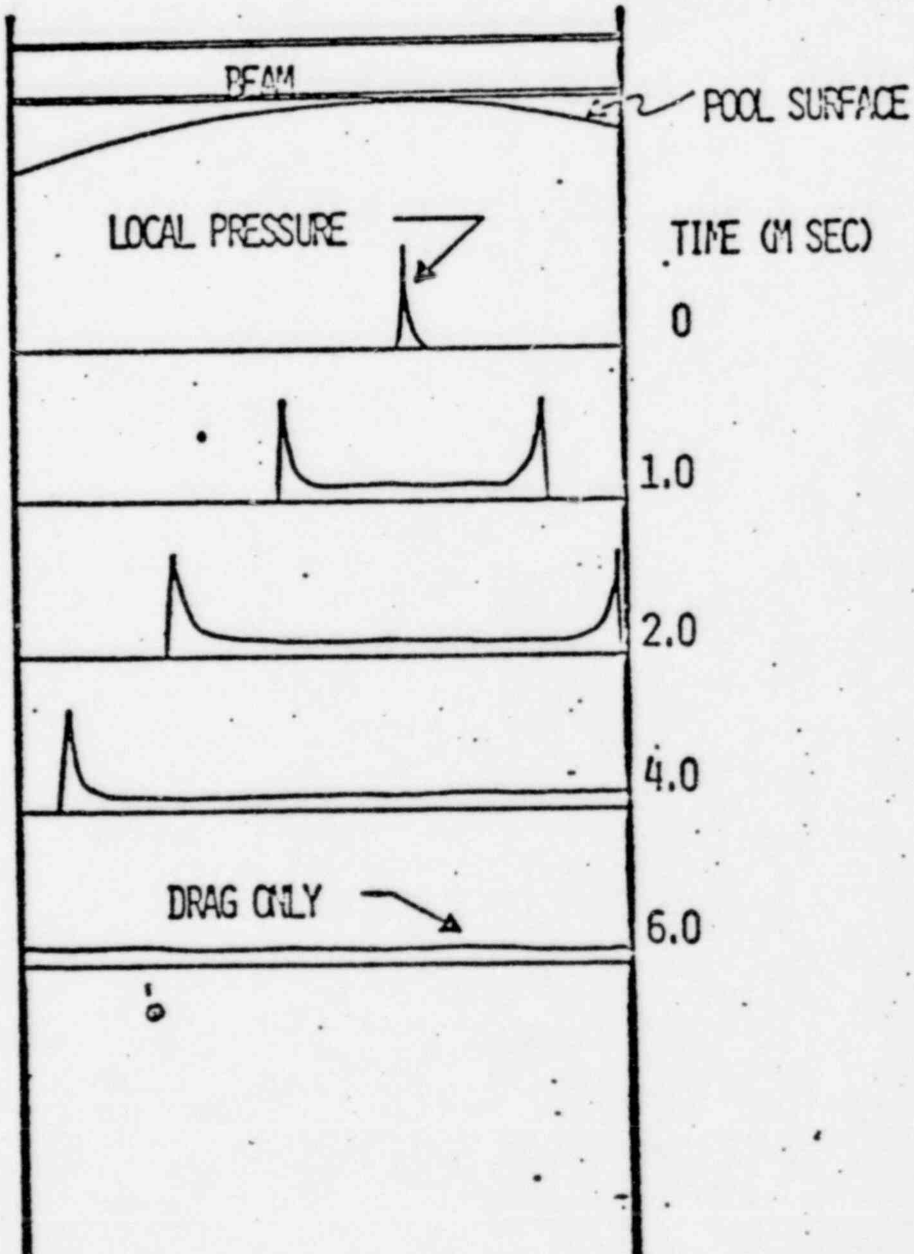
5" WIDE I BEAM

10" DIAM PIPE

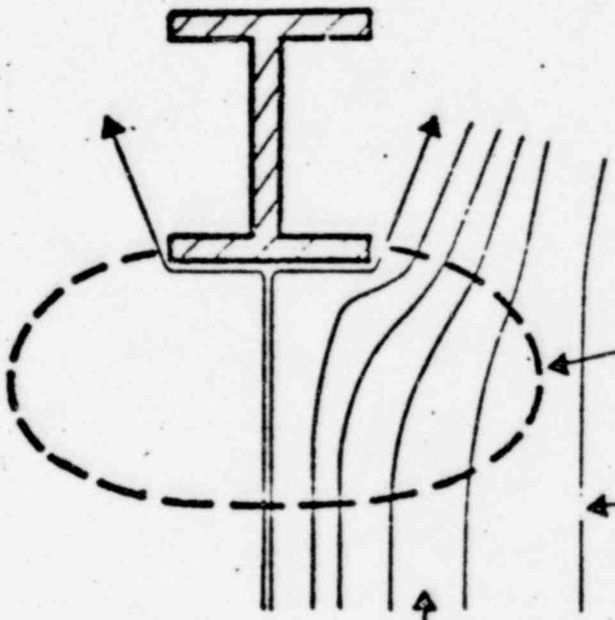
20" DIAM PIPE

GRATING

LOADING PHENOMENA



IMPULSIVE LOAD ON TARGET



FROM ONE DIMENSIONAL ANALYSIS

IMPULSE PER UNIT AREA

$$\frac{i}{A} = \frac{M_{H}gc}{A} \; \frac{V}{gc} \left(\frac{lb_f - sec}{IN^2} \right)$$

Major Test - Conclusions

TEST SERIES 5805 CONCLUSIONS

- POOL SWELL IMPACT ON STRUCTURES IS CHARACTERIZED BY AN INITIAL PRESSURE IMPULSE DECAYING TO A STEADY STATE DRAG PRESSURE.
- INITIAL IMPULSE IS A PRESSURE WAVE TRAVELING ALONG SURFACE OF IMPACTED BODY.
- MEASURED IMPULSE DURATION WAS 5 MILLISECONDS TO 20 MILLISECONDS.
- IMPULSE AMPLITUDE IS CHARACTERIZED BY A HYDRODYNAMIC MASS WHICH IS A FUNCTION OF TARGET GEOMETRY.
- FORCES ON PIPES ARE LESS THAN ONE HALF FORCES OF SAME WIDTH FLAT SURFACES.
- UPWARD FORCES ARE AT LEAST 10 TIMES GREATER THAN OTHER FORCE COMPONENTS.
- IMPULSIVE LOADS ON GRATING WERE TO SMALL TO MEASURE.

1/3 SCALE AIR TESTS

TEST SERIES 5806

TEST OBJECTIVES:

- DIRECT COMPARISON OF STEAM AND AIR DRIVEN POOL SWELL TO IDENTIFY ANY STEAM DILUTION EFFECTS.
- DIRECT SCALING COMPARISON TO FULL SCALE AIR TESTS

NUMBER OF TESTS 12

File
SRV - Ramshead

EG&G Idaho, Inc.

P. O. Box 1625
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November 24, 1976

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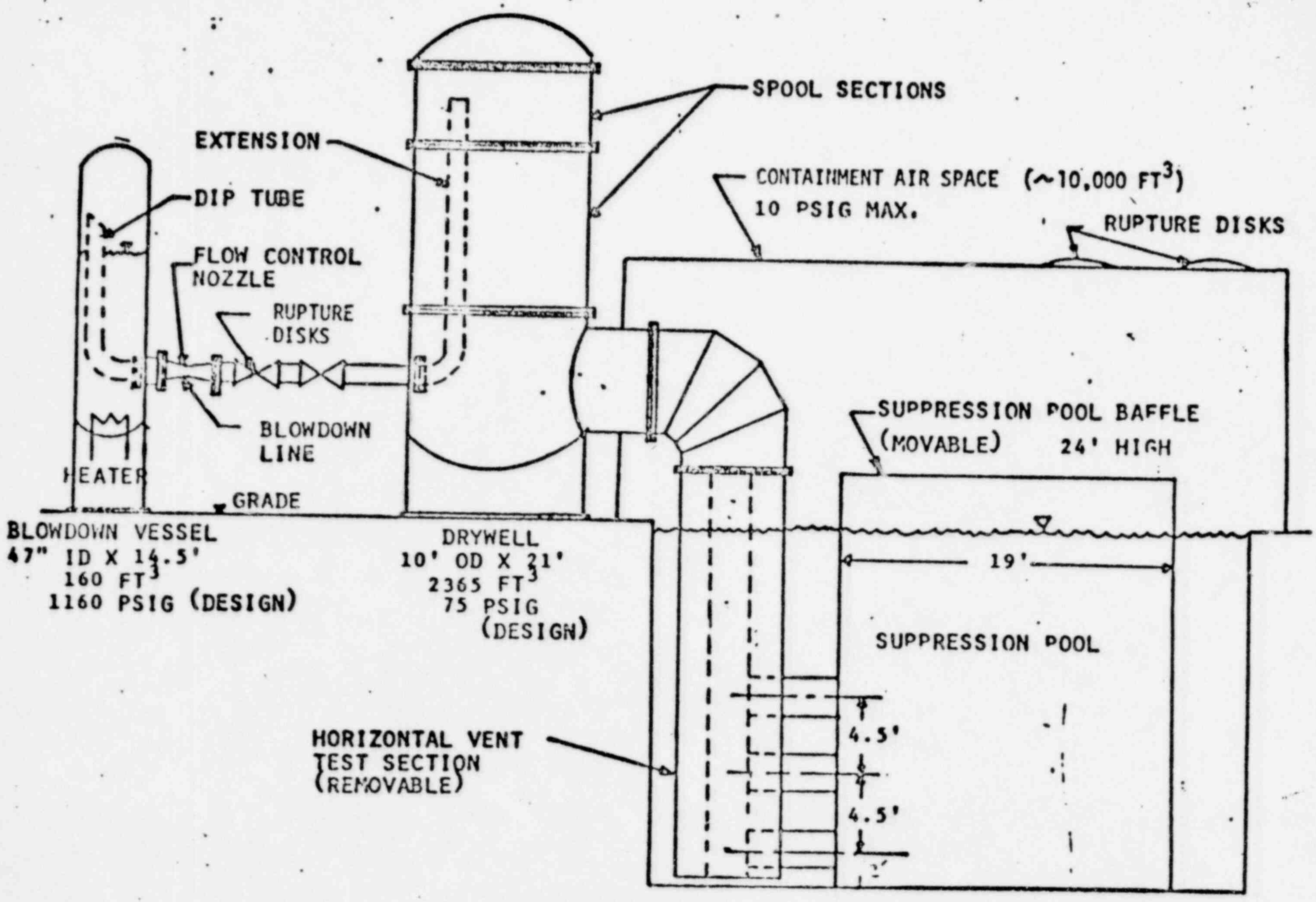


Figure 3 -- PRESSURE SUPPRESSION TEST FACILITY

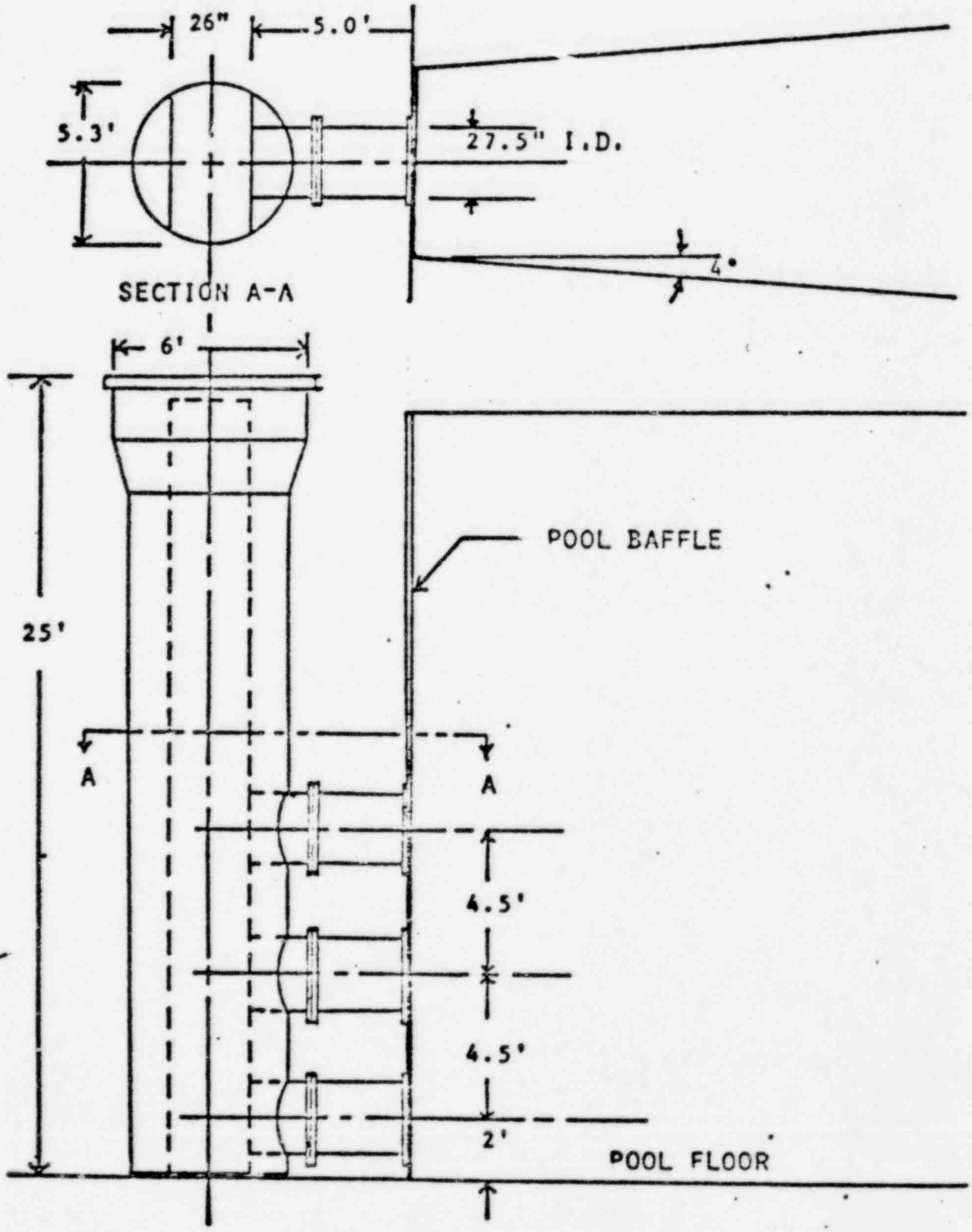
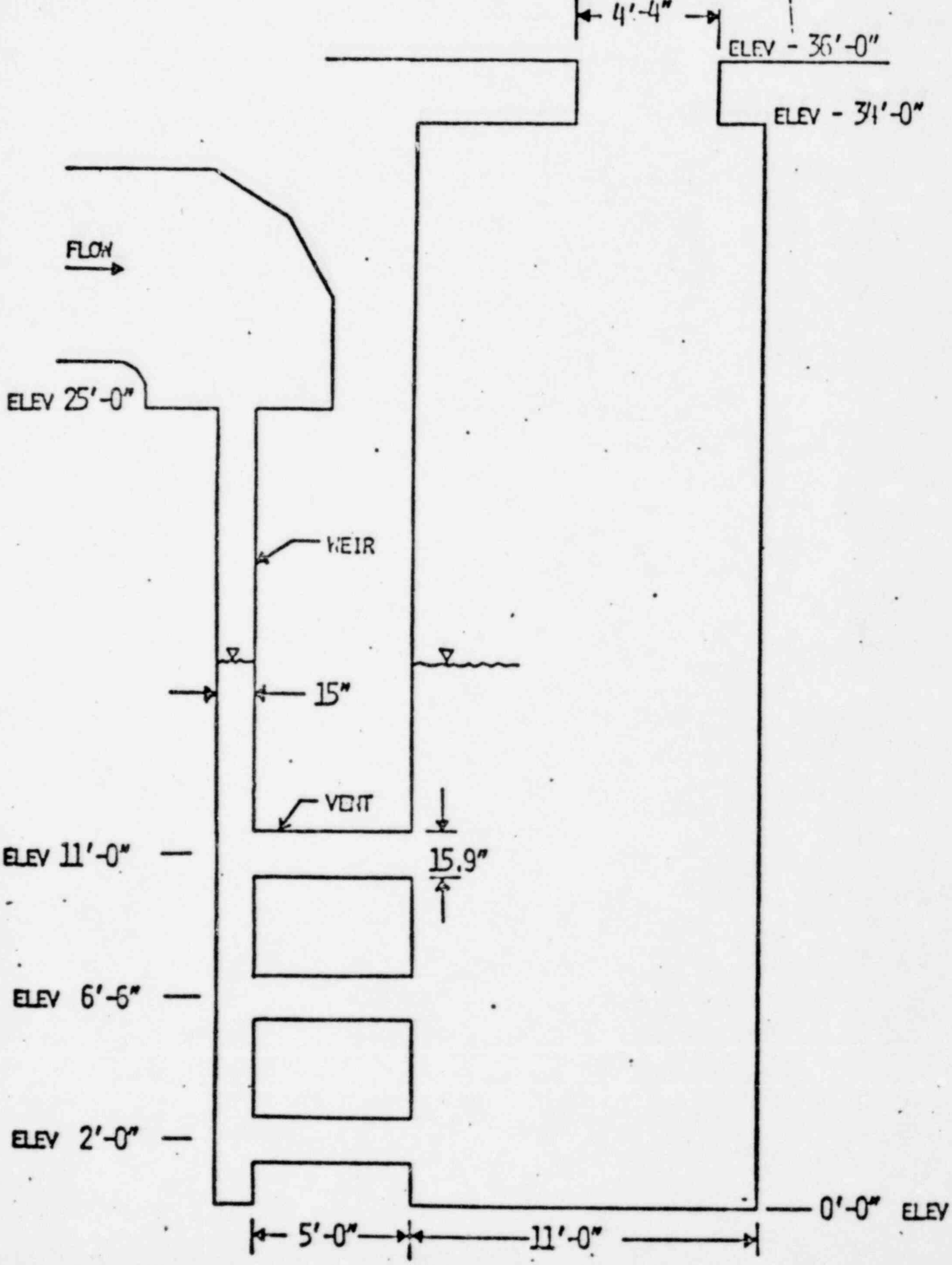


Figure 2 -- TYPICAL HORIZONTAL VENT TEST SECTION

1/3 SCALE VENT-POOL CONFIGURATION



MARK III CONFIRMATORY TEST PROGRAM

SUMMARY

FULL SIZE VENT TESTS

STEAM BLOWDOWNS

5701 5702 5703	41 TESTS	• GENERAL BLOWDOWN RESPONSE • VENT CLEARING • CONDENSATION EFFECTIVENESS • CHUGGING DATA

AIR BLOWDOWNS

5705 5706	12 TESTS	• POOL SWELL DATA • STRUCTURAL IMPACT ABOVE POOL

1/3 SCALE VENT TESTS

STEAM BLOWDOWNS

5801 5802 5803 5804	29 TESTS	• POOL SWELL DATA • ΔP AT HCU FLOOR • POOL WALL LOADS • DRYWELL AND VENT RESPONSE
5805	51 TESTS	• FLUID IMPACT ON STRUCTURES

AIR BLOWDOWNS

5806	12 TESTS	• POOL SWELL

FUTURE TEST SUMMARY

1/3 SCALE STEAM TESTS

- SMALL BLOWDOWN RESPONSE (CHUGGING)
- SUPPRESSION POOL THERMAL STRATIFICATION
- HOT POOL VIBRATIONS
- LIQUID BLOWDOWNS
- CHUGGING WALL LOADS

1/9 SCALE STEAM TESTS

- ADJACENT VENT INTERACTIONS

LARGE SCALE TESTS

(SERIES 5701 THRU 5703)

TEST OBJECTIVES

- LARGE SCALE DEMONSTRATION OF HORIZONTAL VENT SYSTEM
- DATA BASE FOR DESIGN METHODS VERIFICATION
- IDENTIFICATION OF PHENOMENA REQUIRING MODEL DEVELOPMENT

MAJOR TEST PARAMETERS

- STEAM BLOWDOWNS FROM ~1000 PSIA
- BLOWDOWN SIZE 70%, 100%, 200% DBA
- VENT SUBMERGENCE 2 FT THRU 12 FT
- NUMBER OF VENTS ONE, TWO, THREE
- NUMBER OF TESTS IN SERIES = 40

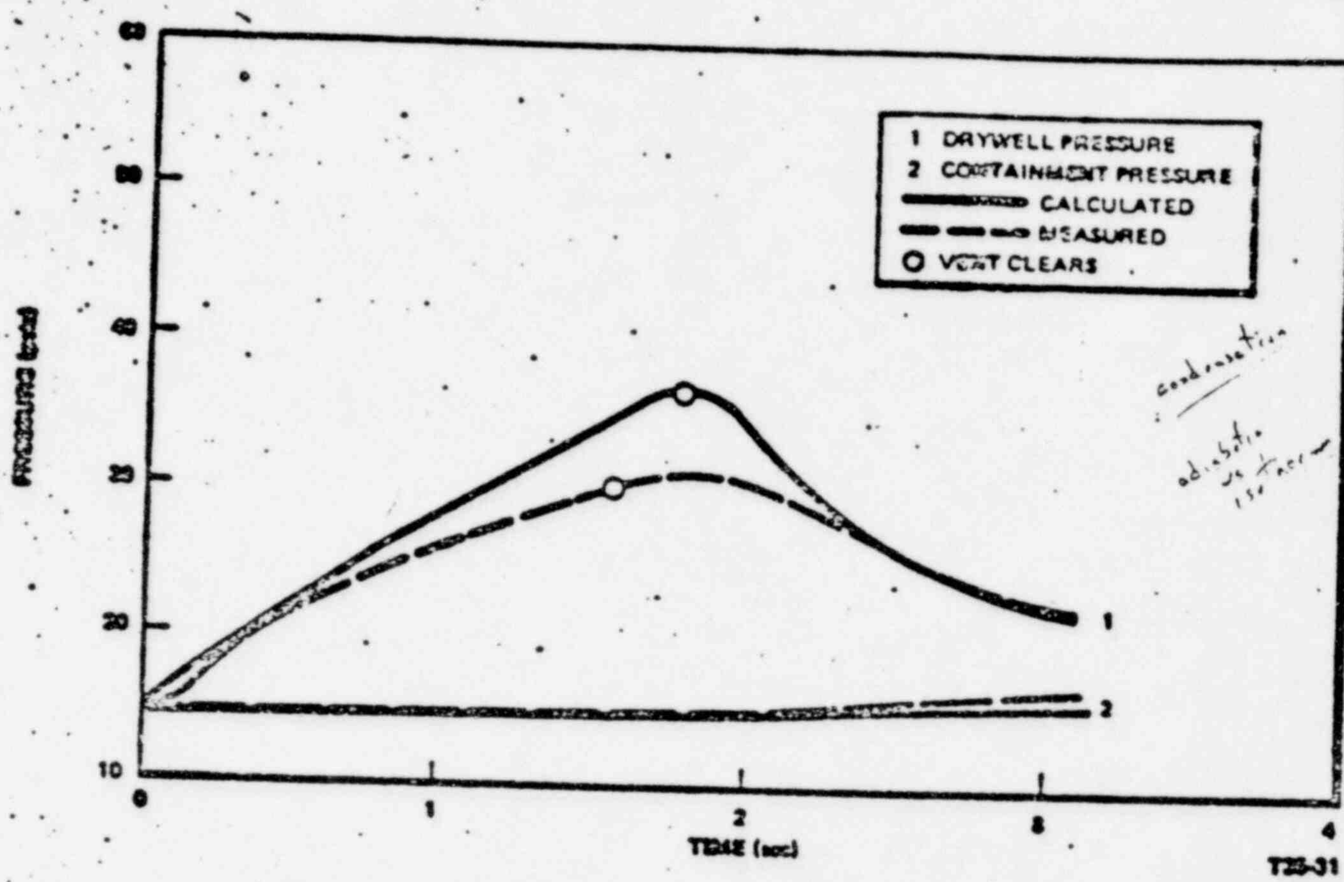


Figure A-12 Steam Blowdown, 70% BWR/6 Break Area/Vessel Volume; 1 Vent, 12-ft Submergence (With Vent Back Pressure)

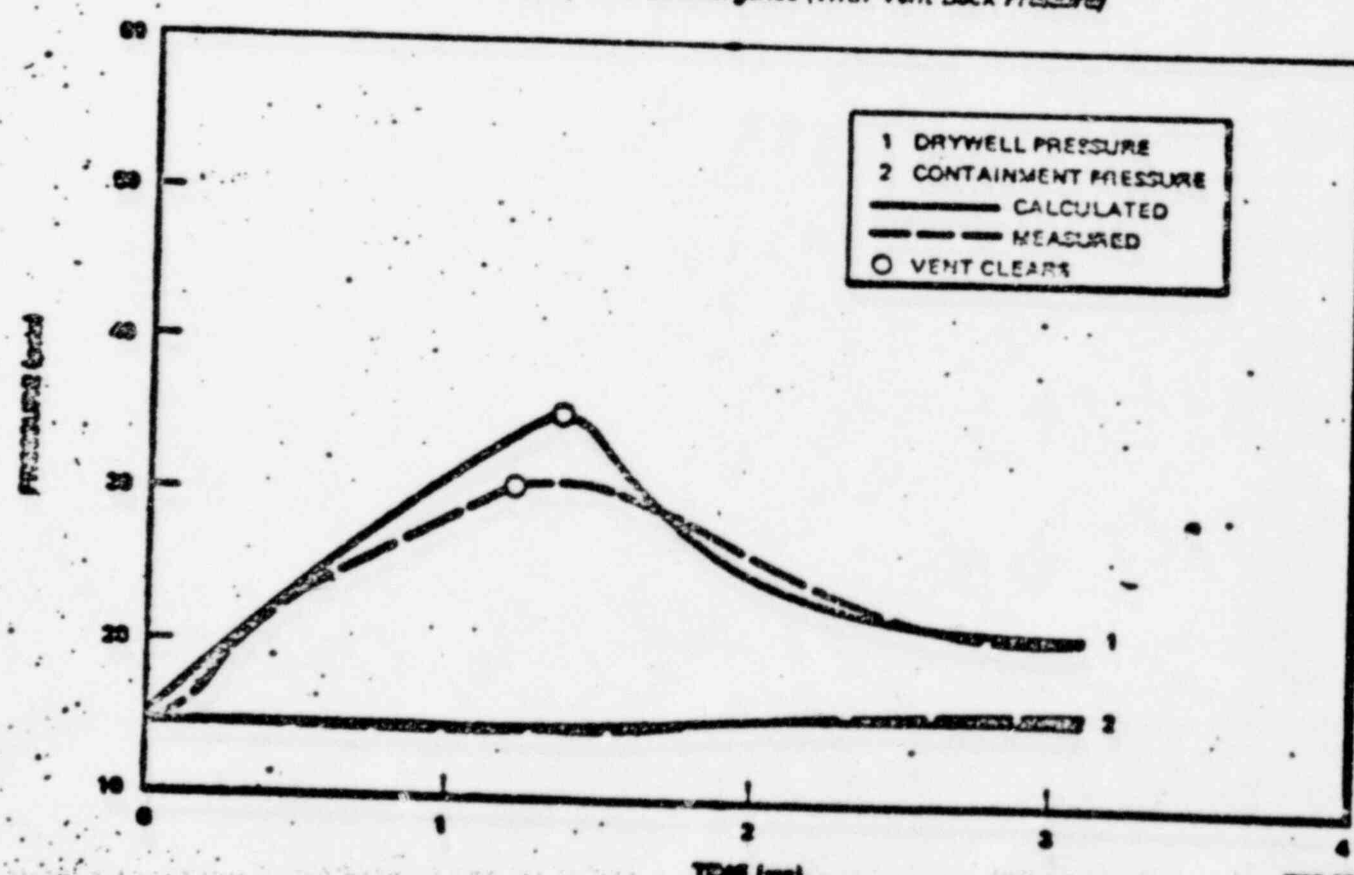
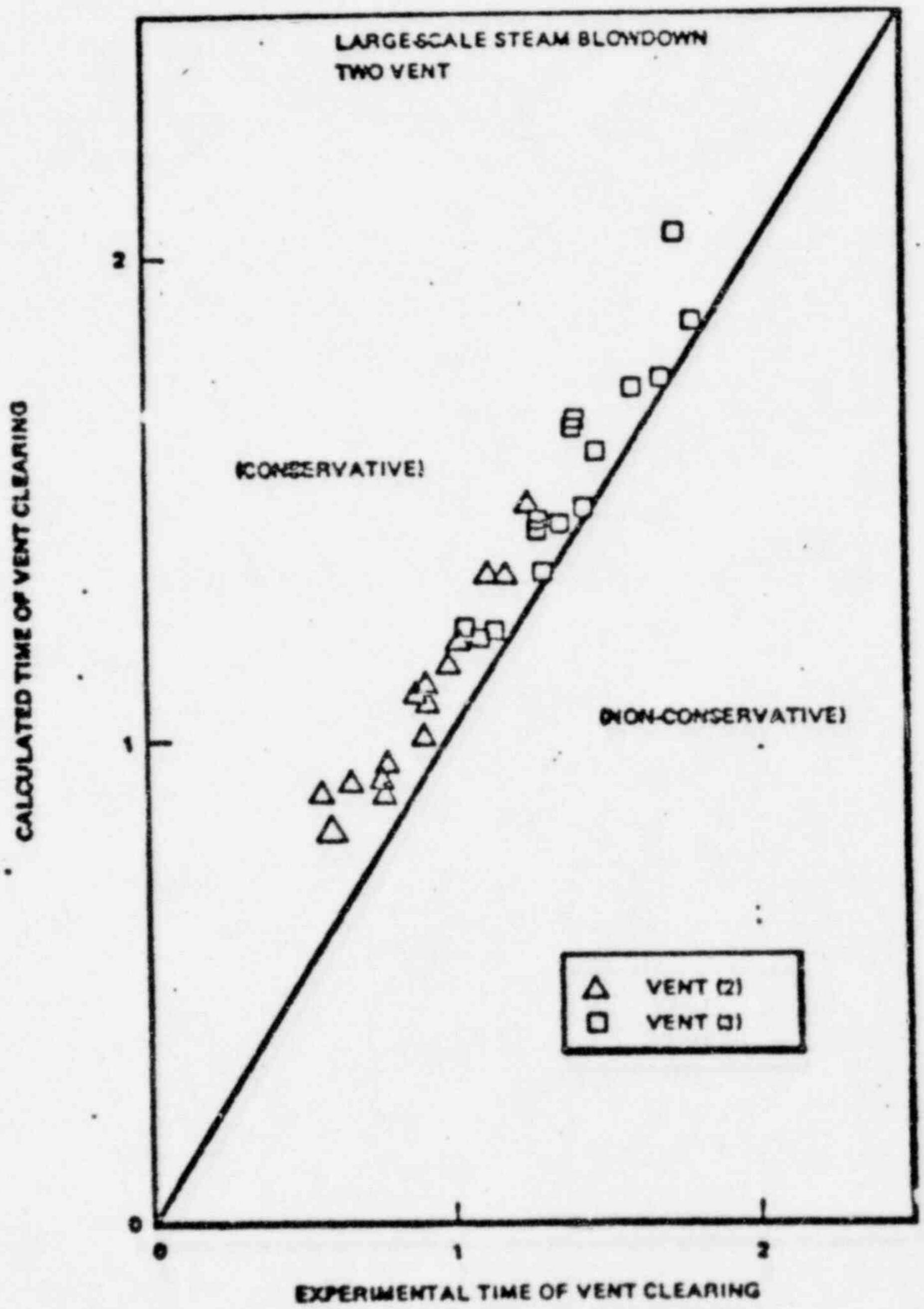
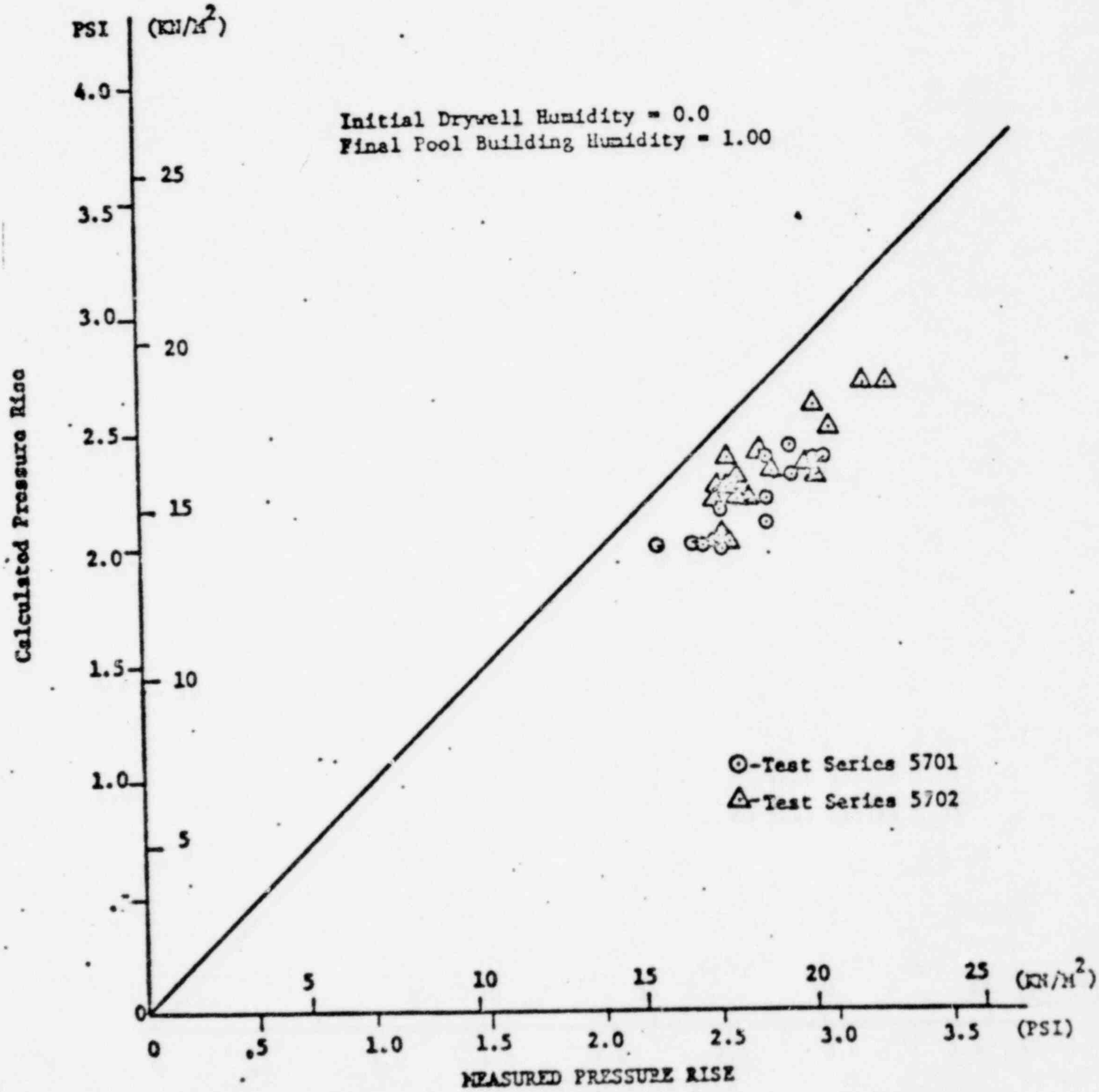


Figure A-13 Steam Blowdown, 100% BWR/6 Break Area/Vessel Volume; 1 Vent, 8-ft Submergence (With Vent Back Pressure)



Large Scale Steam-Blowdown, Two Vent



Containment Pressure Rise Comparison.

MAJOR TEST CONCLUSIONS

- DRYWELL PEAK PRESSURE IS CONSERVATIVELY PREDICTED BY DESIGN MODEL.
- VENT CLEARING MODEL GIVES CONSERVATIVE PREDICTION OF VENT CLEARING TIME.
- SMALL AMOUNT OF STEAM RELEASED TO WETWELL AIR SPACE DURING POOL SWELL (~15 LBS.).
- POOL SWELL BREAKTHROUGH POINT IS IN THE 10 FT TO 15 FT RANGE.
- POOL SWELL MAXIMUM VELOCITY IS CONTROLLED BY AIR CHARGING RATE INTO POOL.
- AFTER VENT CLEARING POOL WAVE ACTION IS SMALL.
- WALL LOADS IN POOL ARE LOW.

LARGE SCALE AIR TESTS

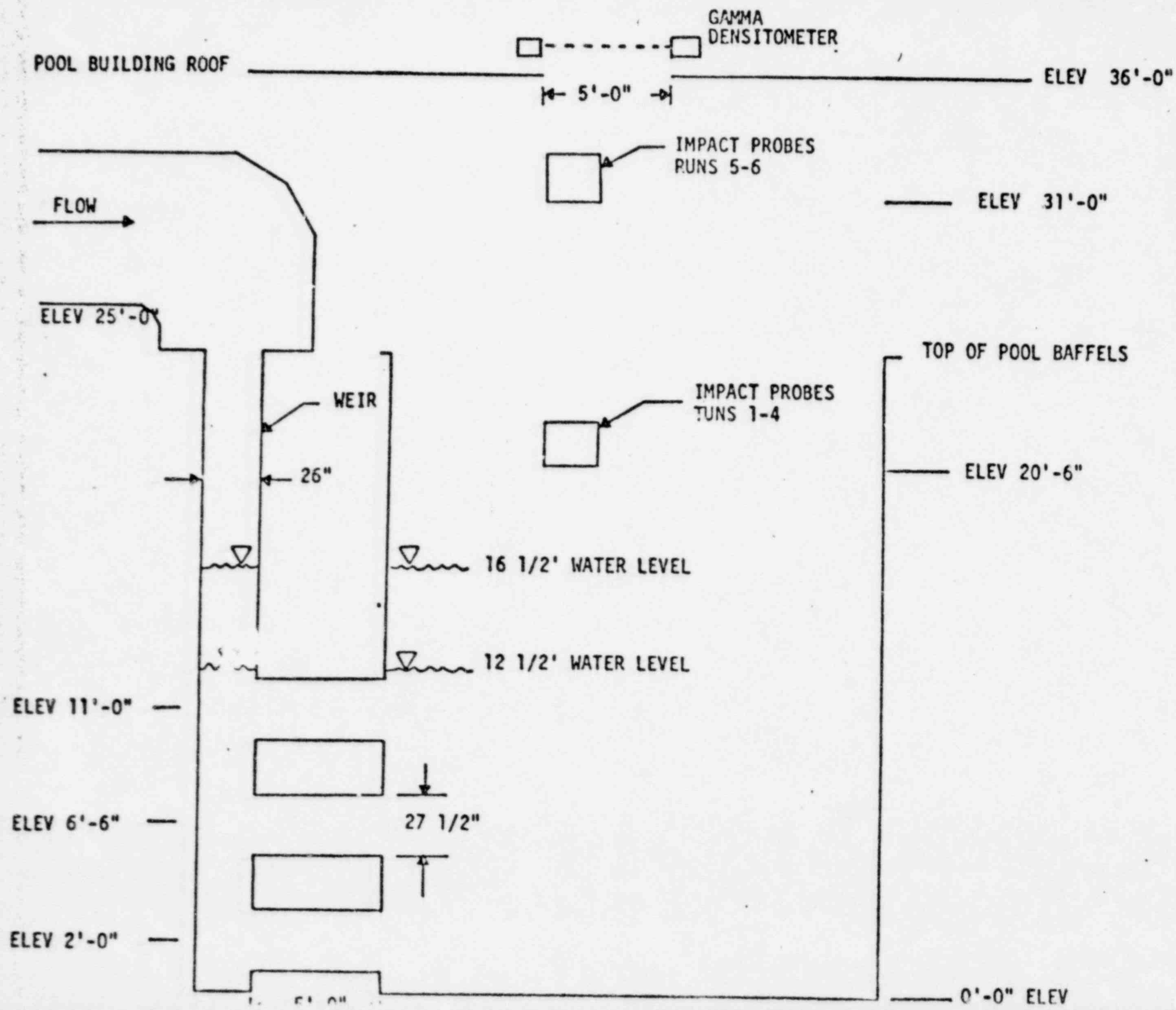
(SERIES 5706)

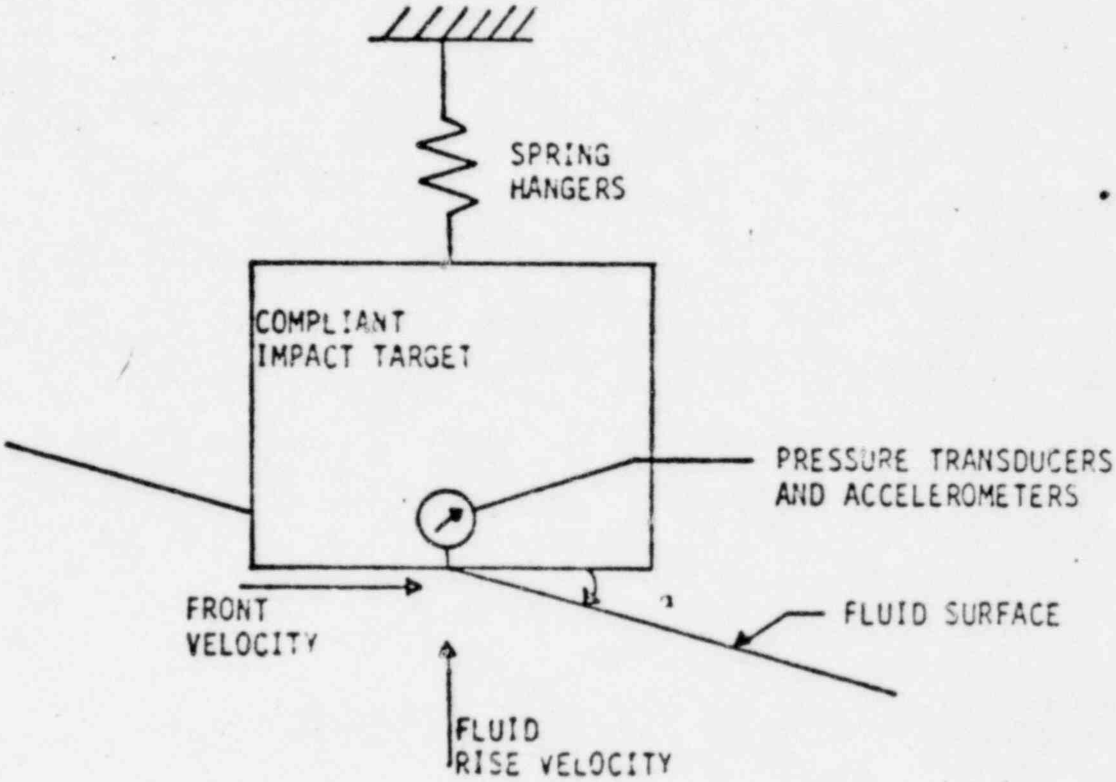
OBJECTIVES

- POOL SWELL DATA BASE WITH LARGE CHARGING RATES AND GREATER AIR FRACTION.
- MEASURE FORCES ON STRUCTURES ABOVE SUPPRESSION POOL.

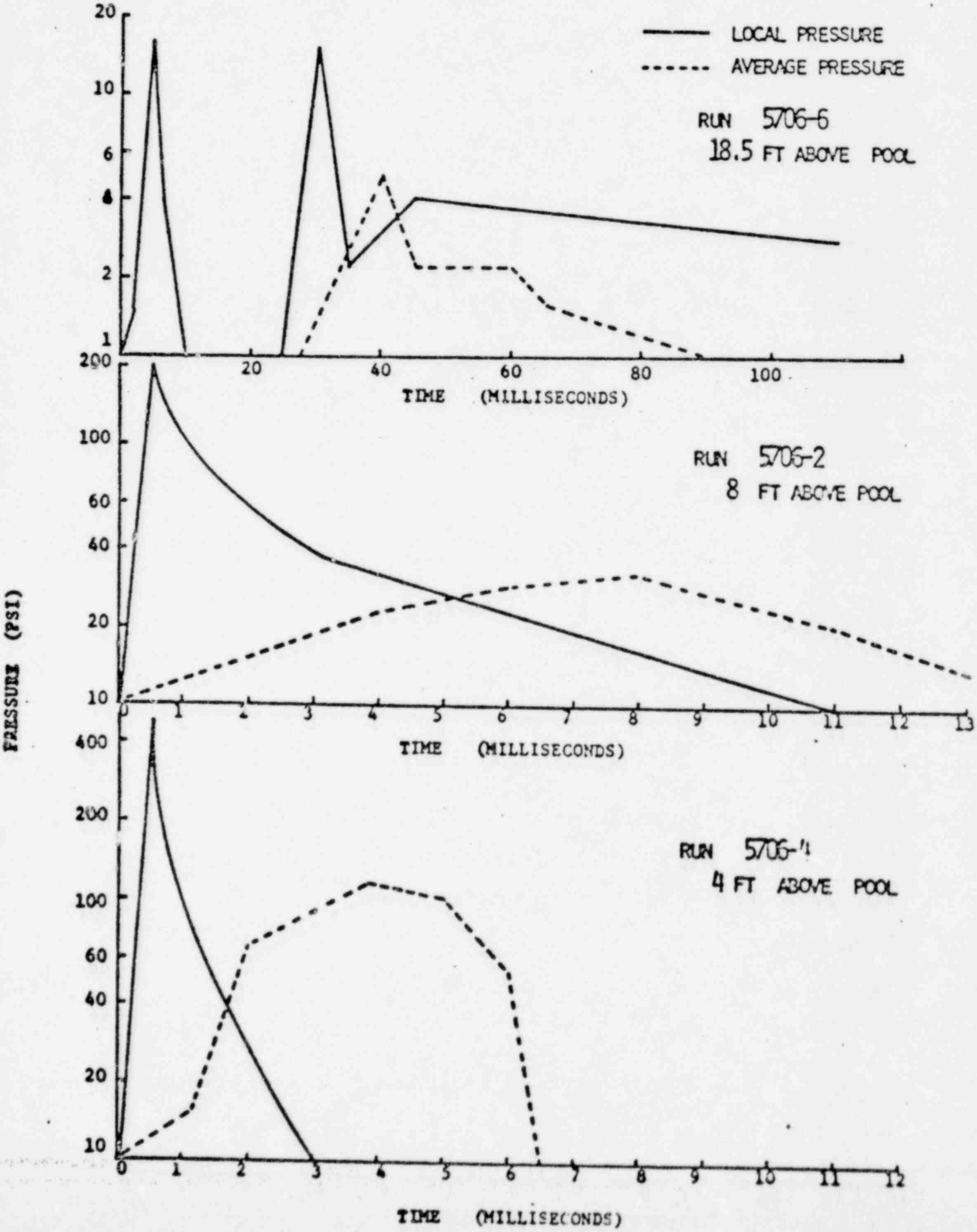
MAJOR TEST PARAMETERS

- AIR BLOWDOWN FROM 1000 PSIA.
- TWO VENTS OPEN.
- MAXIMUM SIZE BLOWDOWN FOR TEST FACILITY (4.25 INCH VENTURI).
- VENT SUBMERGENCE 6 FT AND 10 FT.
- FORCE TARGET ELEVATIONS 4 FT, 8 FT, 13½ FT.

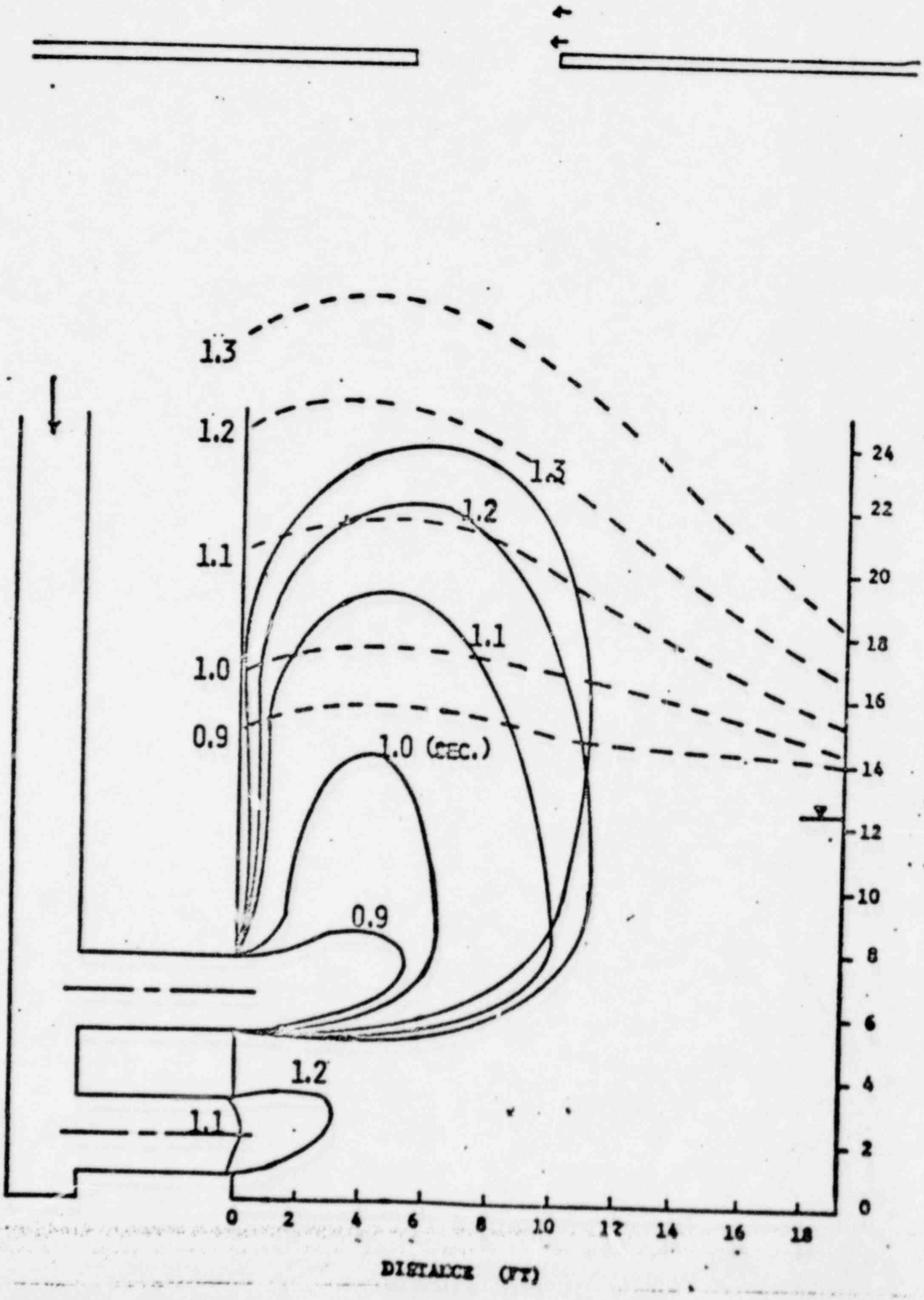

GAMMA DENSITOMETER
POOL BUILDING ROOF
ELEV 36'-0"
5'-0"
IMPACT PROBES RUNS 5-6
FLOW
ELEV 31'-0"
ELEV 25'-0"
TOP OF POOL BAFFELS
WEIR
IMPACT PROBES TUNS 1-4
26"
ELEV 20'-6"
16 1/2' WATER LEVEL
12 1/2' WATER LEVEL
ELEV 11'-0"
ELEV 6'-6"
27 1/2"
ELEV 2'-0"
0'-0" ELEV



TEST NO.	FLUID RISE VELOCITY (ft/sec)	IMPACT ANGLE a	FRONT VELOCITY (ft/sec)
1	38.4	13°	166
2	41.2	18.6°	121
3	28	7.6°	250
4	26.5	2.6°	210 - 571



LOCAL PRESSURE
AVERAGE PRESSURE
RUN 5706-6
18.5 FT ABOVE POOL
TIME (MILLISECONDS)
RUN 5706-2
8 FT ABOVE POOL
PRESSURE (PSI)
TIME (MILLISECONDS)
RUN 5706-4
4 FT ABOVE POOL
TIME (MILLISECONDS)


1.3
1.2
1.1
1.0
0.9
1.3
1.2
1.1
1.0 (SEC.)
0.9
1.2
1.1
0 2 4 6 8 10 12 14 16 18
DISTANCE (FT)
0 2 4 6 8 10 12 14 16 18 20 22 24
ELEVATION (FT)

TEST CONCLUSIONS

(SERIES 5706)

- LARGE FORCES ON STRUCTURES NEAR SUPPRESSION POOL SURFACE DURING POOL SWELL
- HCU FLOORS WILL NOT BE HIT BY SOLID LIQUID SLUGS BUT TWO PHASE MIXTURE
- MORE DATA NEEDED TO DEFINE FORCES OF STRUCTURES AND TWO PHASE PRESSURE DROP ACROSS FLOOR RESTRICTIONS

ONE-THIRD SCALE TESTS

(SERIES 5S01)

OBJECTIVES

- DETERMINE TWO PHASE PRESSURE DROP ACROSS FLOOR RESTRICTIONS
- ADDITIONAL DATA ON POOL SWELL
- ADDITIONAL DATA ON LIQUID IMPULSE ON TEST FACILITY ROOF

MAJOR TEST PARAMETERS

- STEAM BLOWDOWNS
- 1/3 AREA POOL AND VENTS
- 3 VENT TESTS
- BLOWDOWN SIZE ~70 %, 100 %, 140 %, DBA
- VENT SUBMERGENCE 5 FT, 7½ FT, 10 FT
- POOL CEILING RESTIRCTION RATIO 63 %, 72 %, 81 %
- NUMBER OF TESTS = 19

PROPRIETARY INFORMATION
GENERAL ELECTRIC COMPANY

TYPICAL ROOF PRESSURE DROP

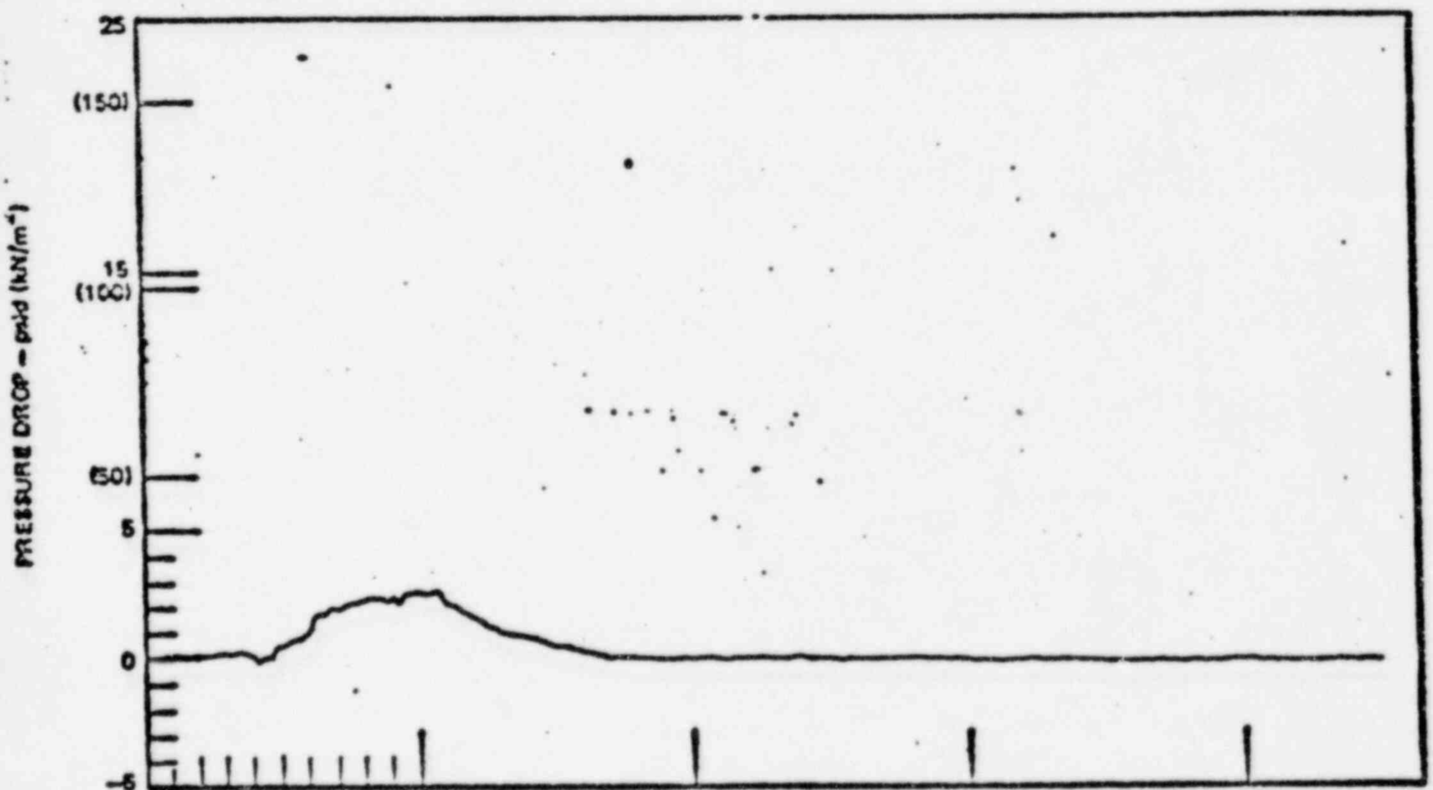


FIGURE 4-67. ROOF PRESSURE DROP (2.5 IN. 63.5 mm) VENTURI: 5.0 FT (1.52m) SUBMERGENCE: 0.28 ROOF OPENING RATIO - RUN 5801-9 (PROPRIETARY).

PROPRIETARY INFORMATION
GENERAL ELECTRIC COMPANY

POOL SWELL BREAK THROUGH

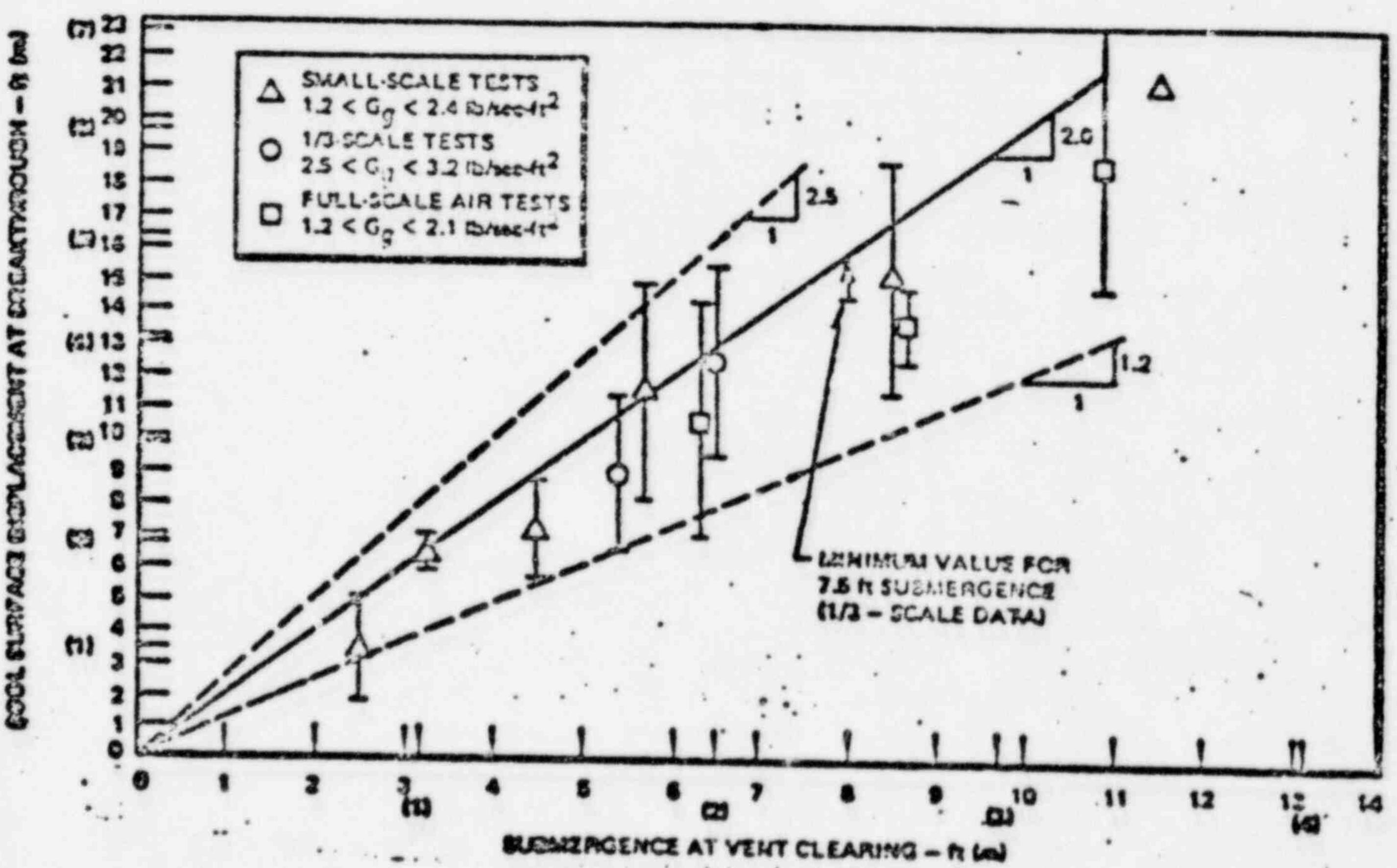


FIGURE 4-46. POOL SWELL AT BREAKTHROUGH (ZERO SLUG THICKNESS) VS. SUBMERGENCE (PROPRIETARY).

RESULTS OF SERIES 5801

- FLOW THROUGH HCU FLOOR WILL BE HIGH VOID FRACTION AIR WATER MIXTURE.
- MAXIMUM PRESSURE DROP ~ 3-5 PSI.
- HCU FLOOR ΔP DID NOT INCREASE PEAK DRYWELL PRESSURE.
- HCU FLOOR VOID FRACTIONS > 80% DURING 1 TO 2 SECOND TRANSIENT.
- POOL SWELL BREAKTHROUGH AT ~2 INITIAL VENT SUBMERGENCE BASED ON COMPLETE SLUG DISINTEGRATION.

PSTF ONE-THIRD SCALE
POOL SHELL STRUCTURAL TESTING

DATA ON RESPONSE OF STRUCTURES TO DYNAMIC LOADS

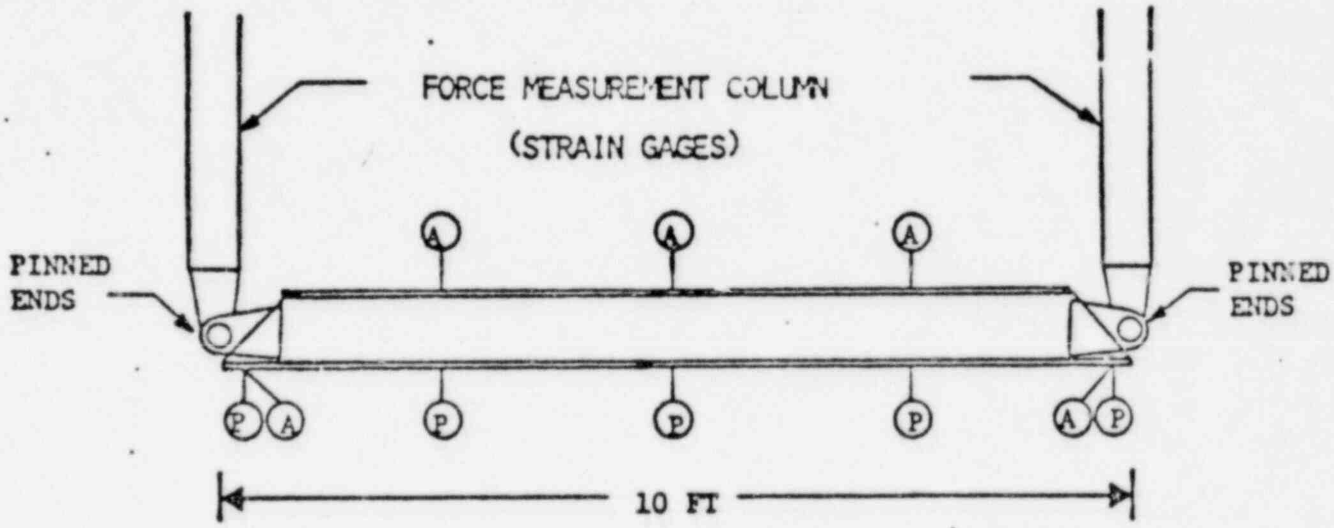
- TO OBTAIN LOADING INFORMATION FROM TYPICAL STRUCTURES WHICH CAN BE APPLIED TO MARK III STRUCTURES
- TO CONFIRM CONSERVATISM OF 115 PSI FORCING FUNCTION BEING USED AS A DESIGN LOAD
- TO VERIFY BEAM RESPONSE STRESS ANALYSIS METHODS
- TO CORRELATE LOADING INFORMATION IN TERMS OF KNOWN POOL DYNAMICS
- TO CHECK ASSUMPTION THAT FLOOR GRATINGS ARE SUBJECT TO DRAG LOADS ONLY

RANGE OF TEST PARAMETERS

RADIAL TARGET ORIENTATION	POOL VELOCITY (FPS)	SLUG LENGTH (FT)
10" I BEAM	22 - 30	0 - 6
5" I BEAM	10 - 29	0 - 6
10" PIPE	10 - 26	0 - 6

CIRCUMFERENTIAL TARGET		
10" I BEAM	22 - 30	0 - 6
5" I BEAM	23 - 32	0 - 6
10" PIPE	23 - 36	0 - 6
20" PIPE	23 - 36	0 - 6
GRATING	25 - 29	

TYPICAL TEST TARGET



P - PRESSURE TRANSDUCERS

A - ACCELEROMETERS

TARGETS TESTED

10" WIDE I BEAM

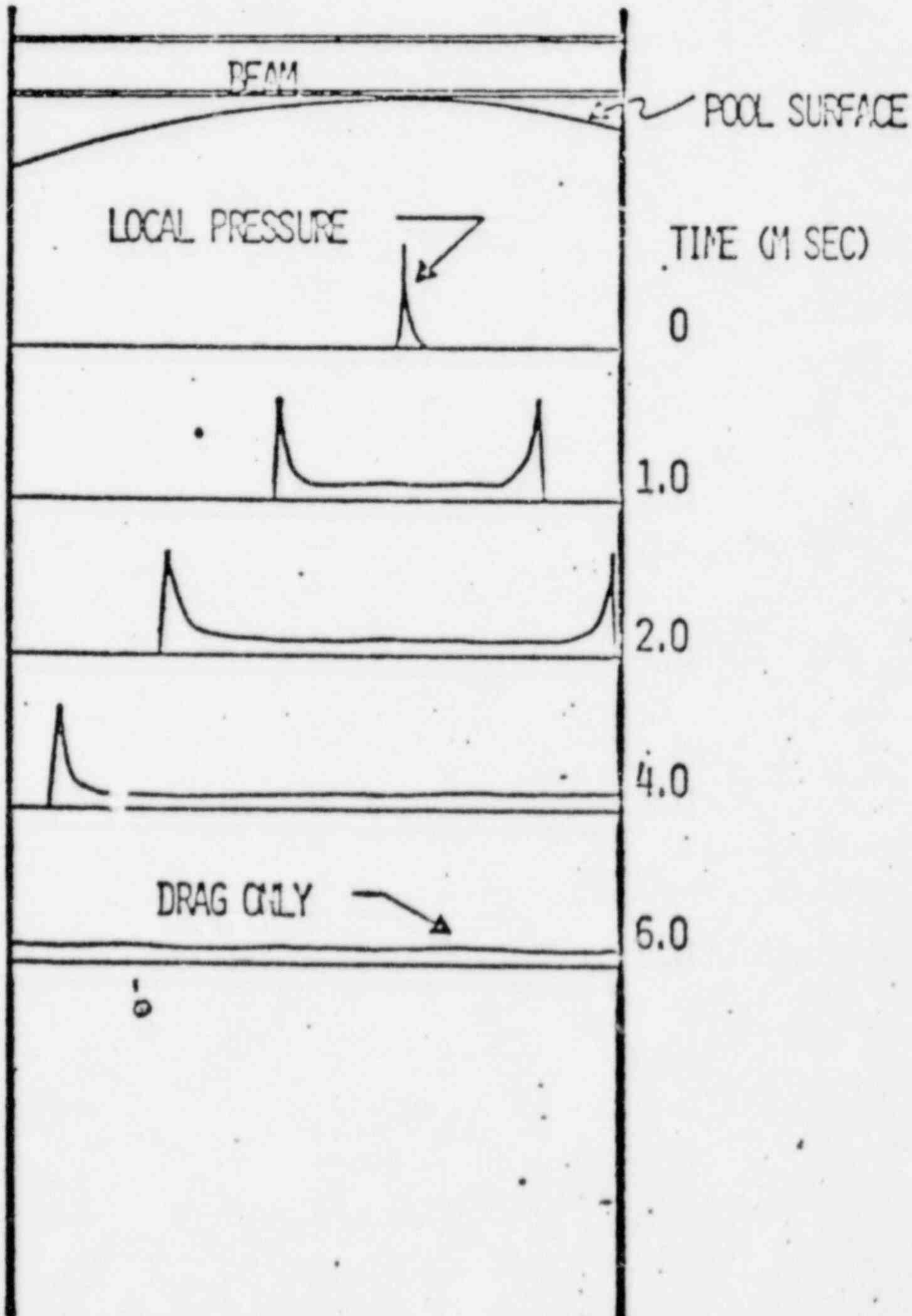
5" WIDE I BEAM

10" DIAM PIPE

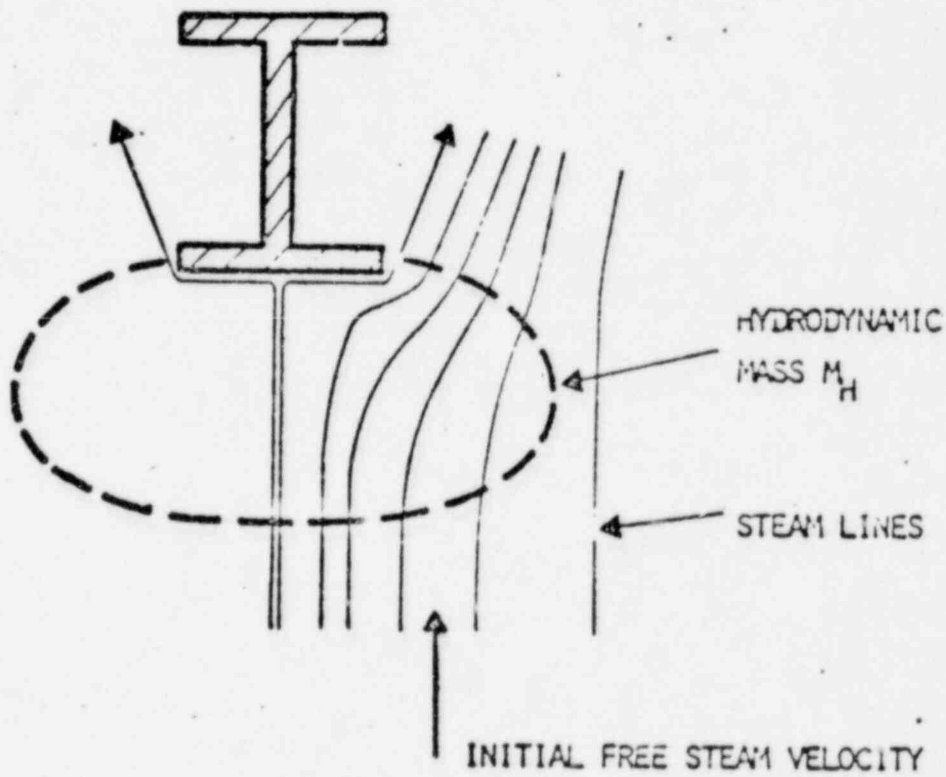
20" DIAM PIPE

GRATING

LOADING PHENOMENA



IMPULSIVE LOAD ON TARGET



FROM ONE DIMENSIONAL ANALYSIS

IMPULSE PER UNIT AREA

$$\frac{i}{A} = \frac{M_{H\,gc}}{A} \; \frac{V}{gc} \quad \left(\frac{lb_f - sec}{IN^2} \right)$$

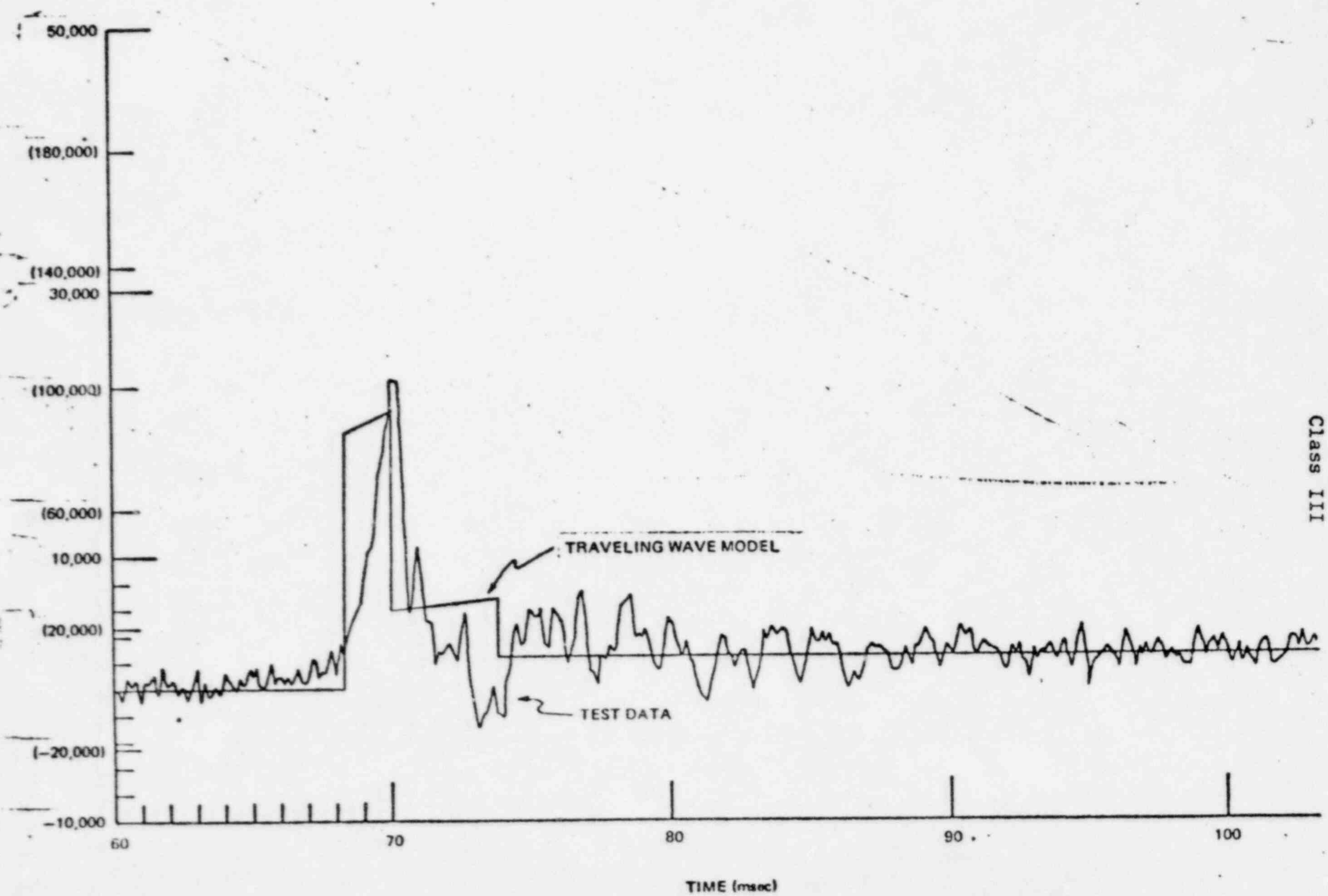


Figure 6-5. Total Applied Lift, Traveling Wave Model (Test 5805, Run 27)
(Proprietary)

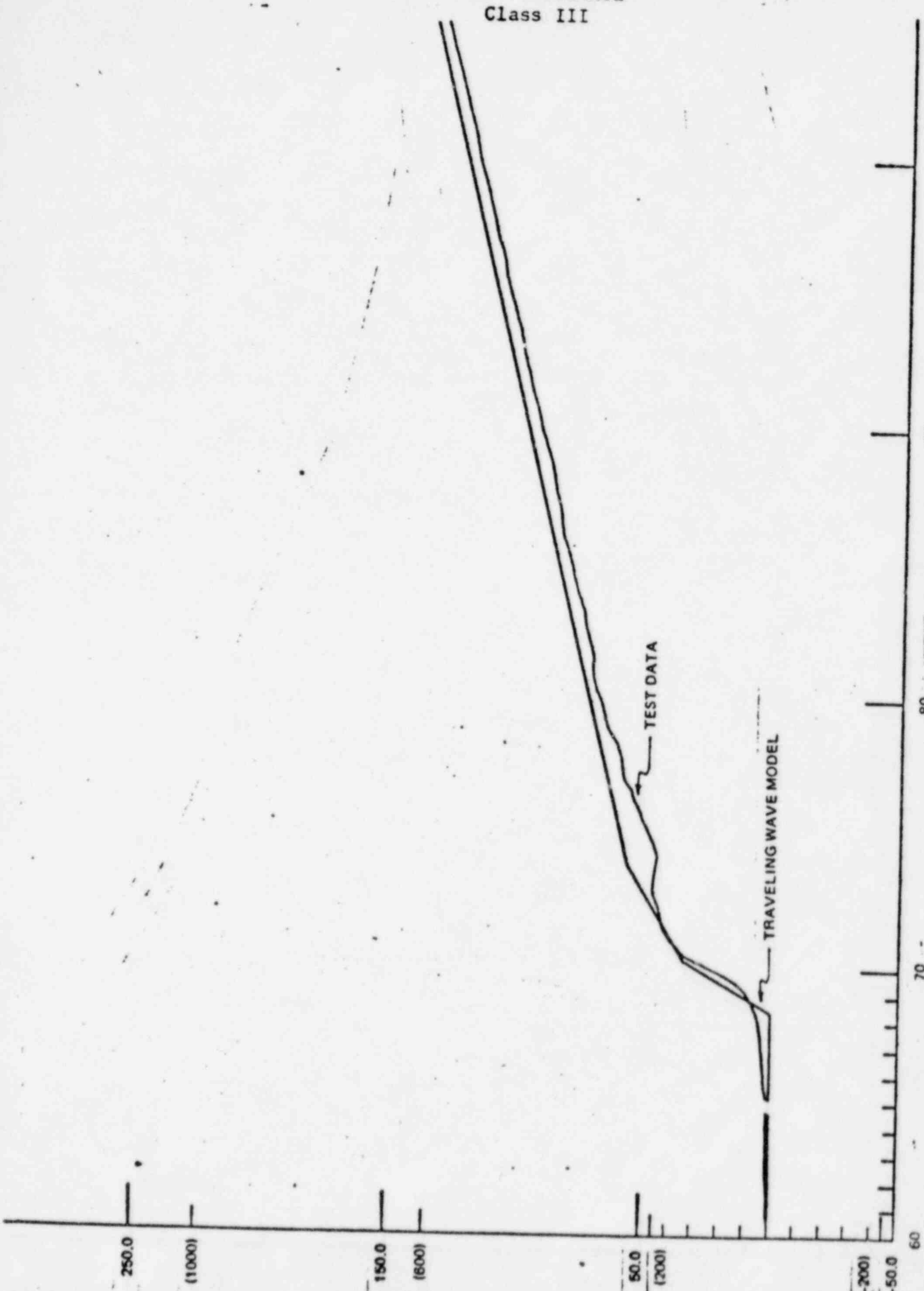


Figure 6-6. Total Impulse, Traveling Wave Model (Test 5805, Run 27)
(Proprietary)

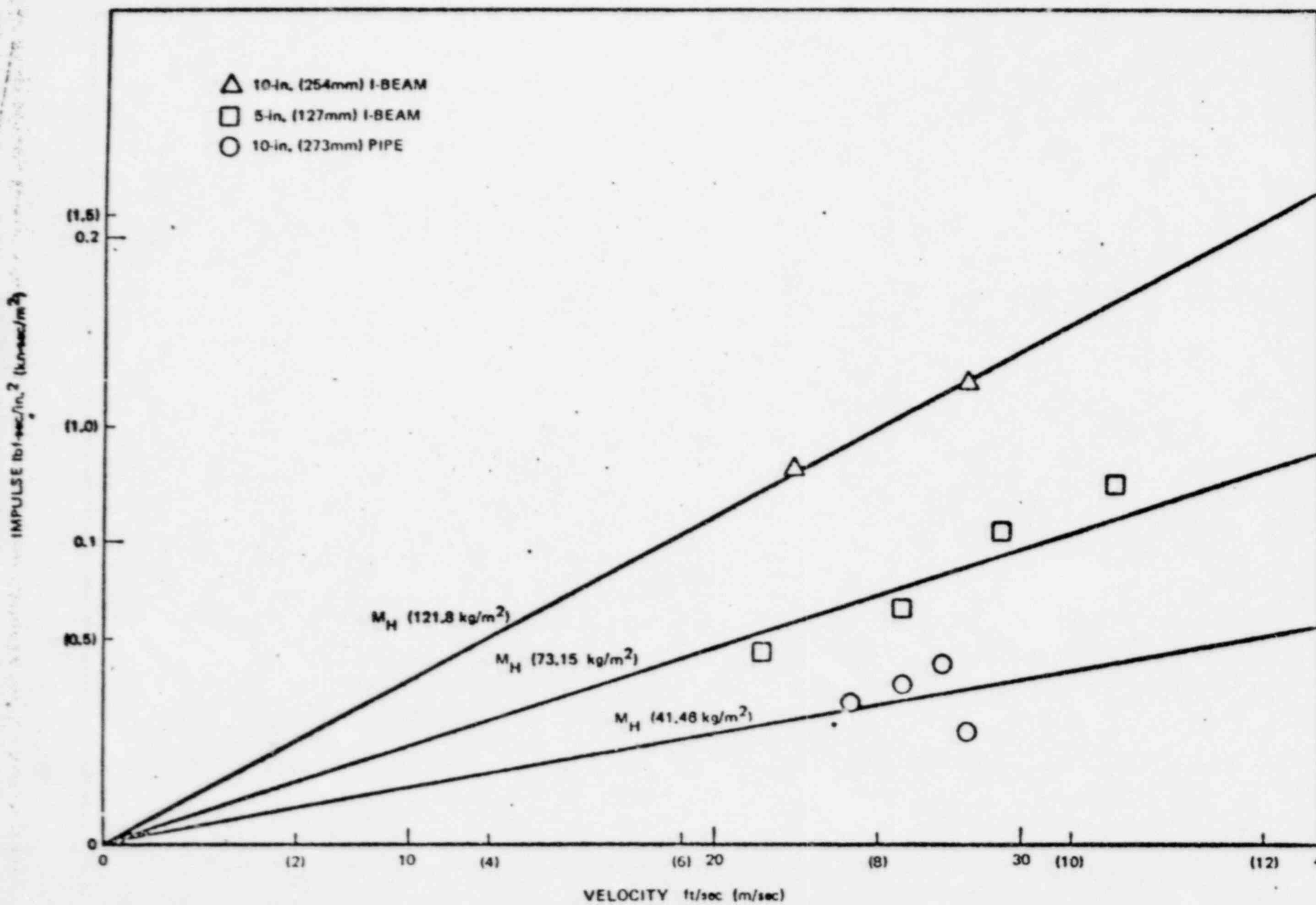


Figure 5-24. Total Impulse per Unit Area versus Impact Velocity - Radial Targets
(Proprietary)

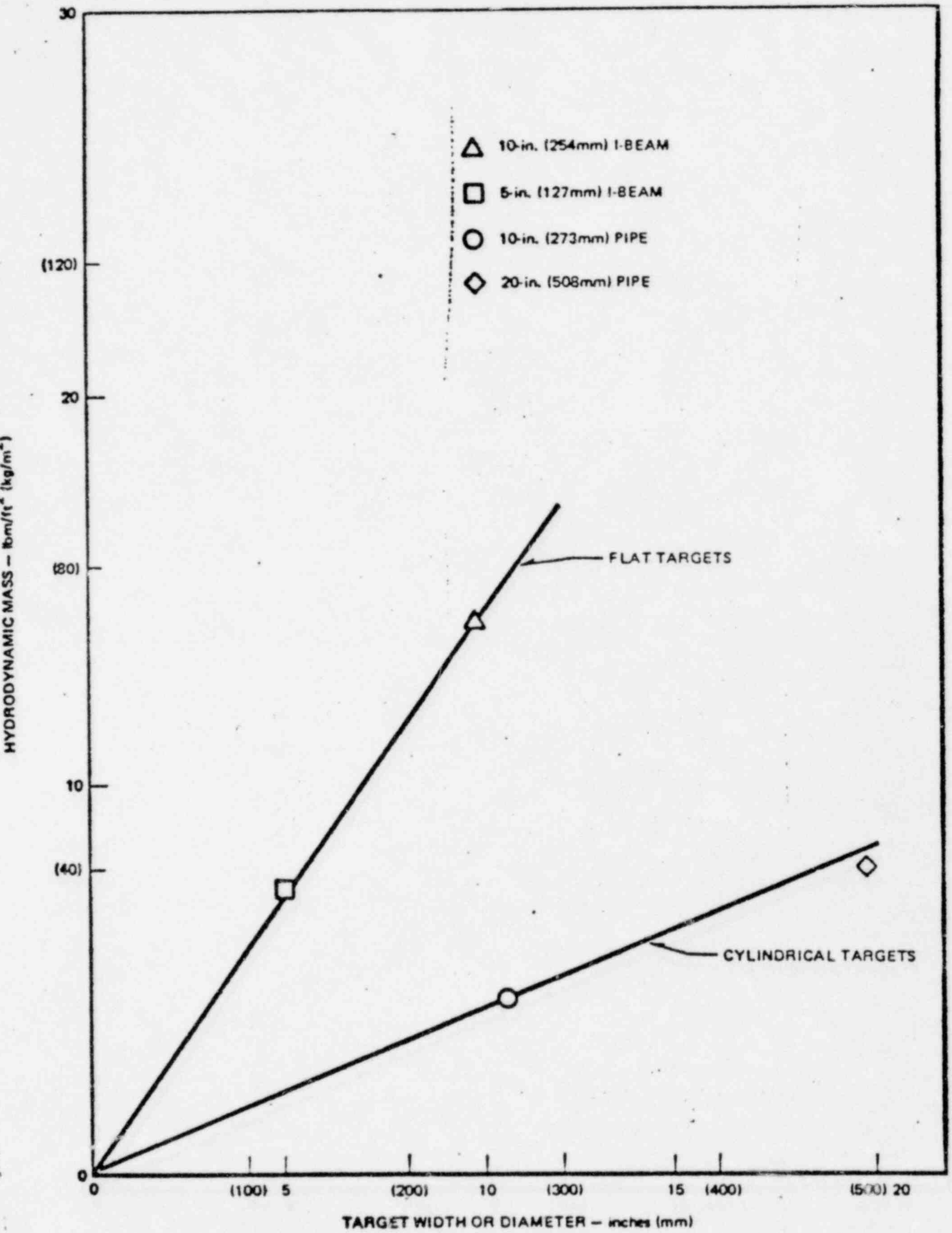


Figure 6-9. Geometry Effect - Circumferential Targets (Based on Total Impulse) (Proprietary)

Major Test - Conclusions

TEST SERIES 5805 CONCLUSIONS

- POOL SWELL IMPACT ON STRUCTURES IS CHARACTERIZED BY AN INITIAL PRESSURE IMPULSE DECAYING TO A STEADY STATE DRAG PRESSURE.
- INITIAL IMPULSE IS A PRESSURE WAVE TRAVELING ALONG SURFACE OF IMPACTED BODY.
- MEASURED IMPULSE DURATION WAS 5 MILLISECONDS TO 20 MILLISECONDS.
- IMPULSE AMPLITUDE IS CHARACTERIZED BY A HYDRODYNAMIC MASS WHICH IS A FUNCTION OF TARGET GEOMETRY.
- FORCES ON PIPES ARE LESS THAN ONE HALF FORCES OF SAME WIDTH FLAT SURFACES.
- UPWARD FORCES ARE AT LEAST 10 TIMES GREATER THAN OTHER FORCE COMPONENTS.
- IMPULSIVE LOADS ON GRATING WERE TO SMALL TO MEASURE.

1/3 SCALE AIR TESTS

TEST SERIES 5806

TEST OBJECTIVES:

- DIRECT COMPARISON OF STEAM AND AIR DRIVEN POOL SWELL TO IDENTIFY ANY STEAM DILUTION EFFECTS.

- DIRECT SCALING COMPARISON TO FULL SCALE AIR TESTS

NUMBER OF TESTS 12

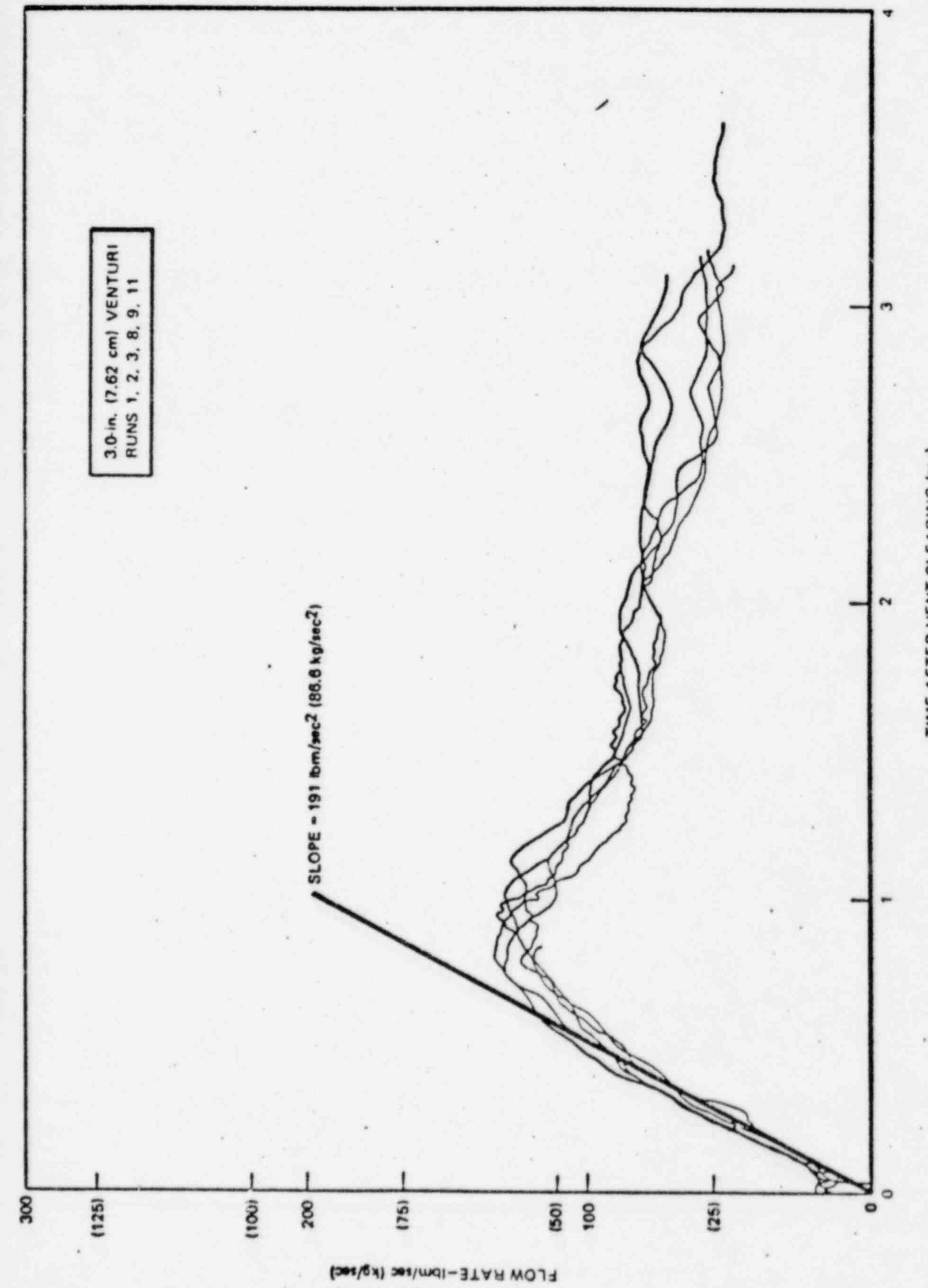
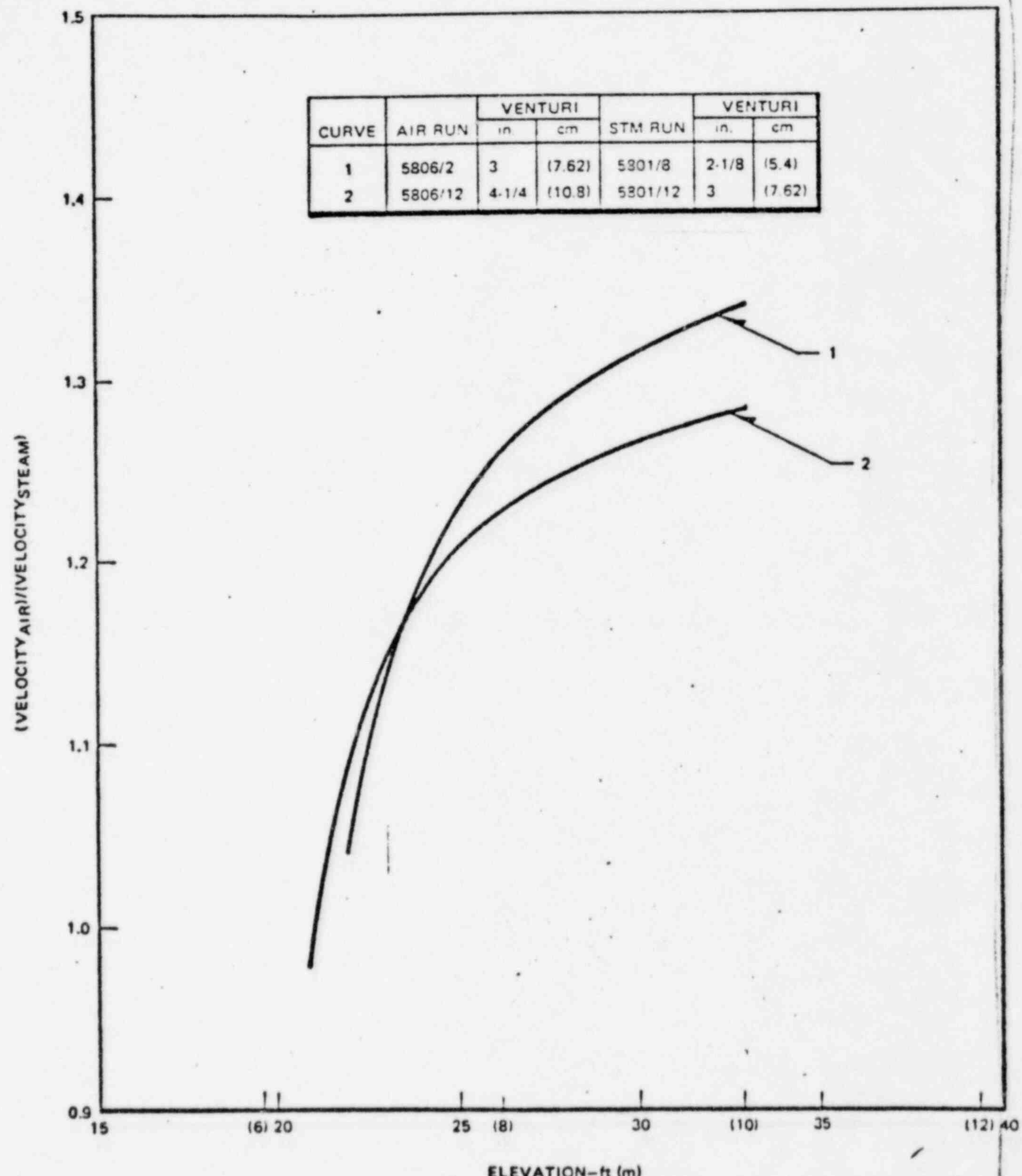


Figure 4-11. Vent Flow Transient-Air Tests (5806)
(COMPANY PROPRIETARY)



CURVE	AIR RUN	VENTURI in.	VENTURI cm	STM RUN	VENTURI in.	VENTURI cm
1	5806/2	3	(7.62)	5801/8	2-1/8	(5.4)
2	5806/12	4-1/4	(10.8)	5801/12	3	(7.62)

Figure 4-40. *Relative Velocities, Air and Steam 1/3-Scale Tests, Matching Drywell Pressure, 7.5 ft (2.29 m) Submergence*

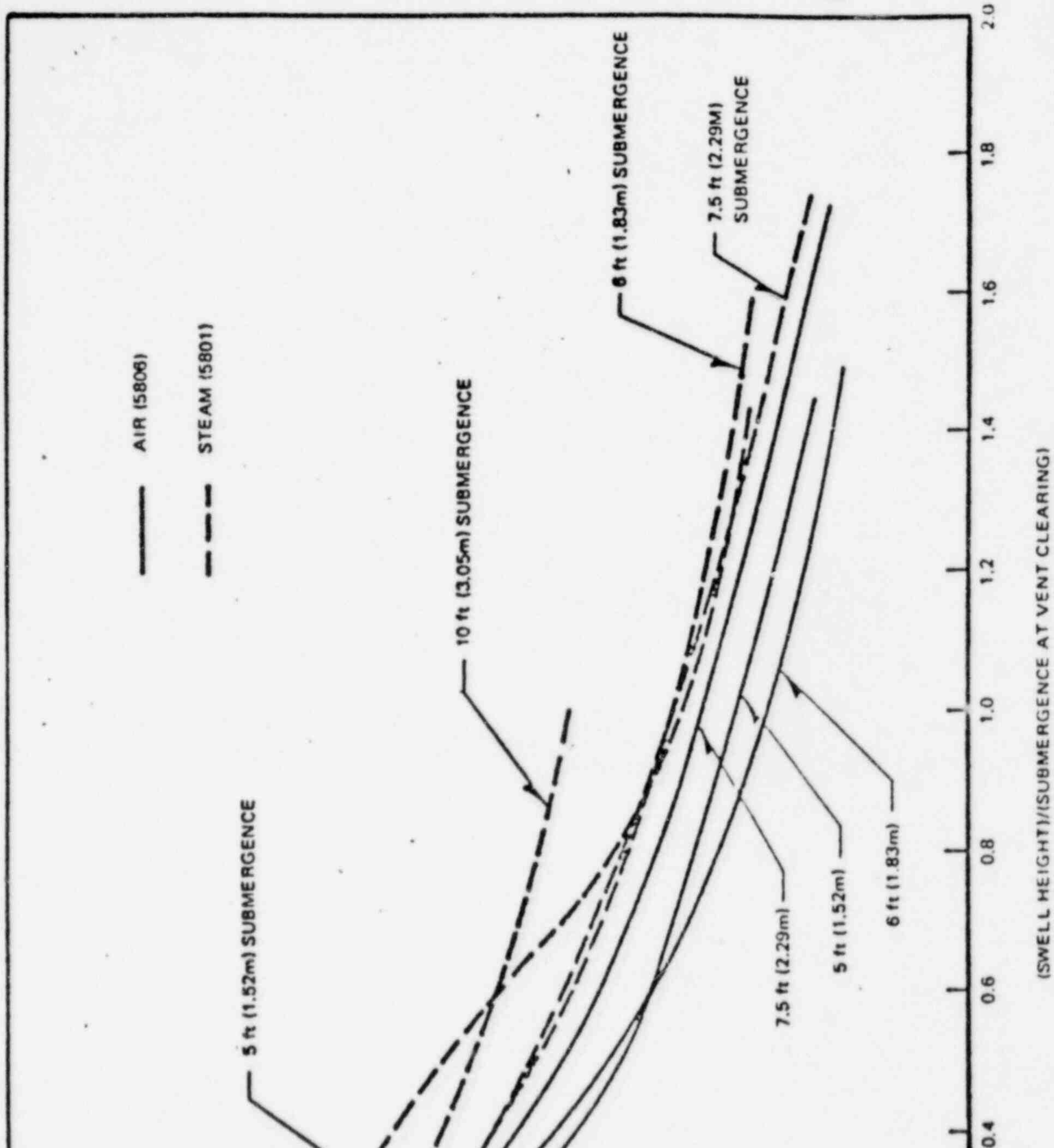


Figure 4-41. Comparison of Dimensionless Slug Length Versus Dimensionless Swell Height for 1/3-Scale Air and Steam Tests

(COMPANY PROPRIETARY)

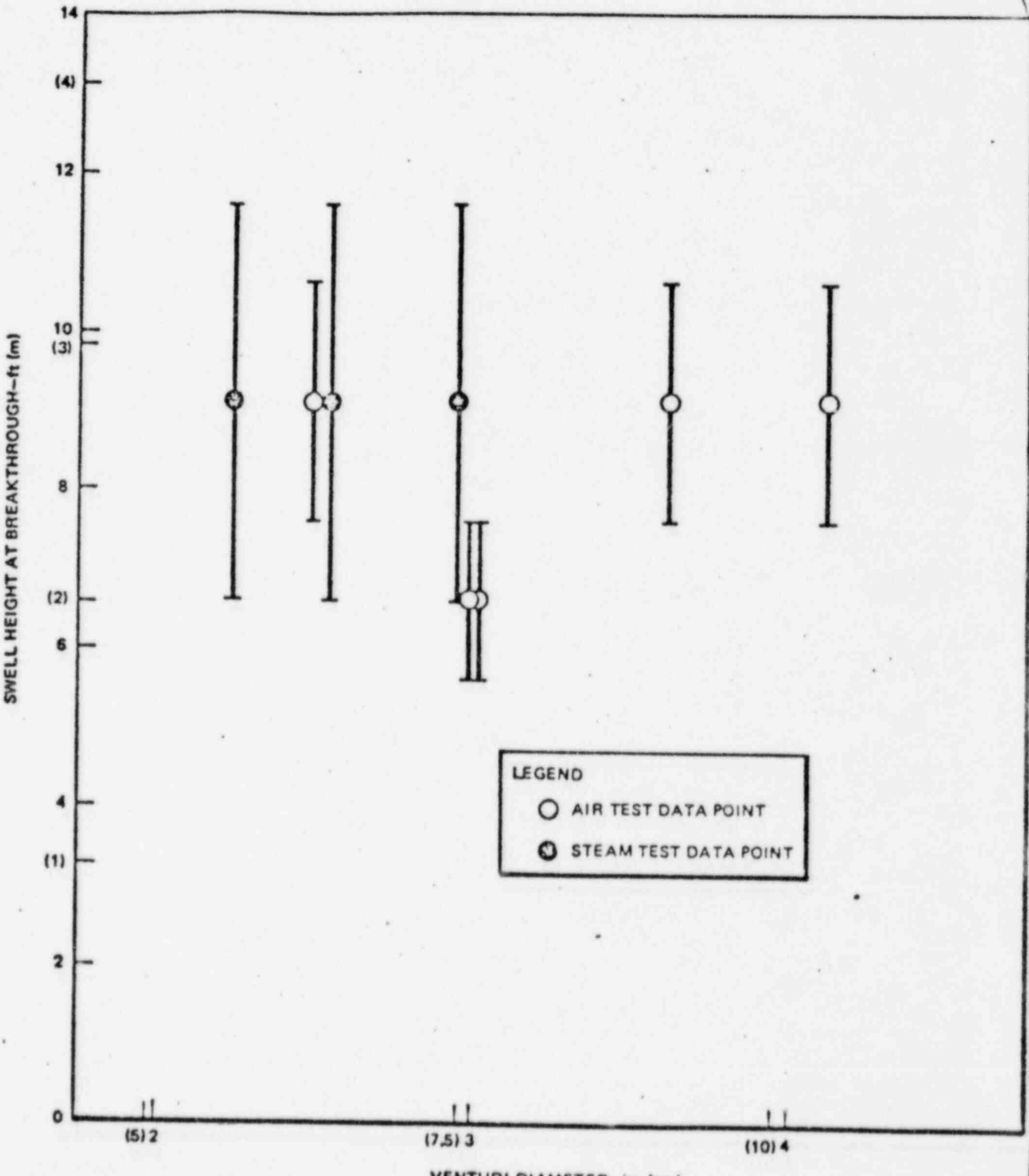


Figure 4-42. Comparison of Breakthrough Elevations, 1/3-Scale Air and Steam Tests, 5.0 ft (1.52 m) Submergence

(COMPANY PROPRIETARY)

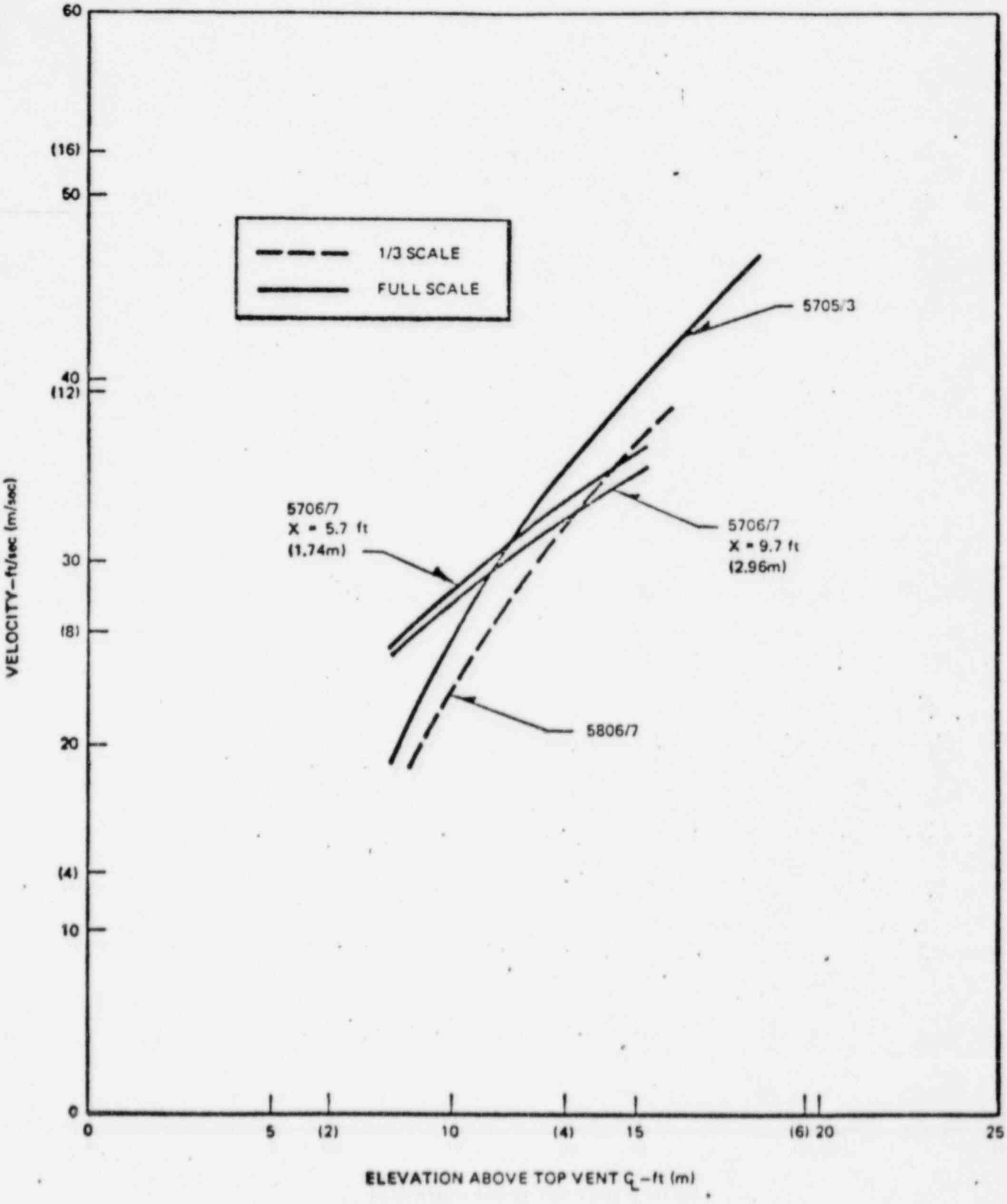


Figure 4-49. Comparison of Surface Velocity Versus Elevation, 1/3-Scale and Full-Scale Air Tests, 6 ft (1.83 m) Submergence

(COMPANY PROPRIETARY)

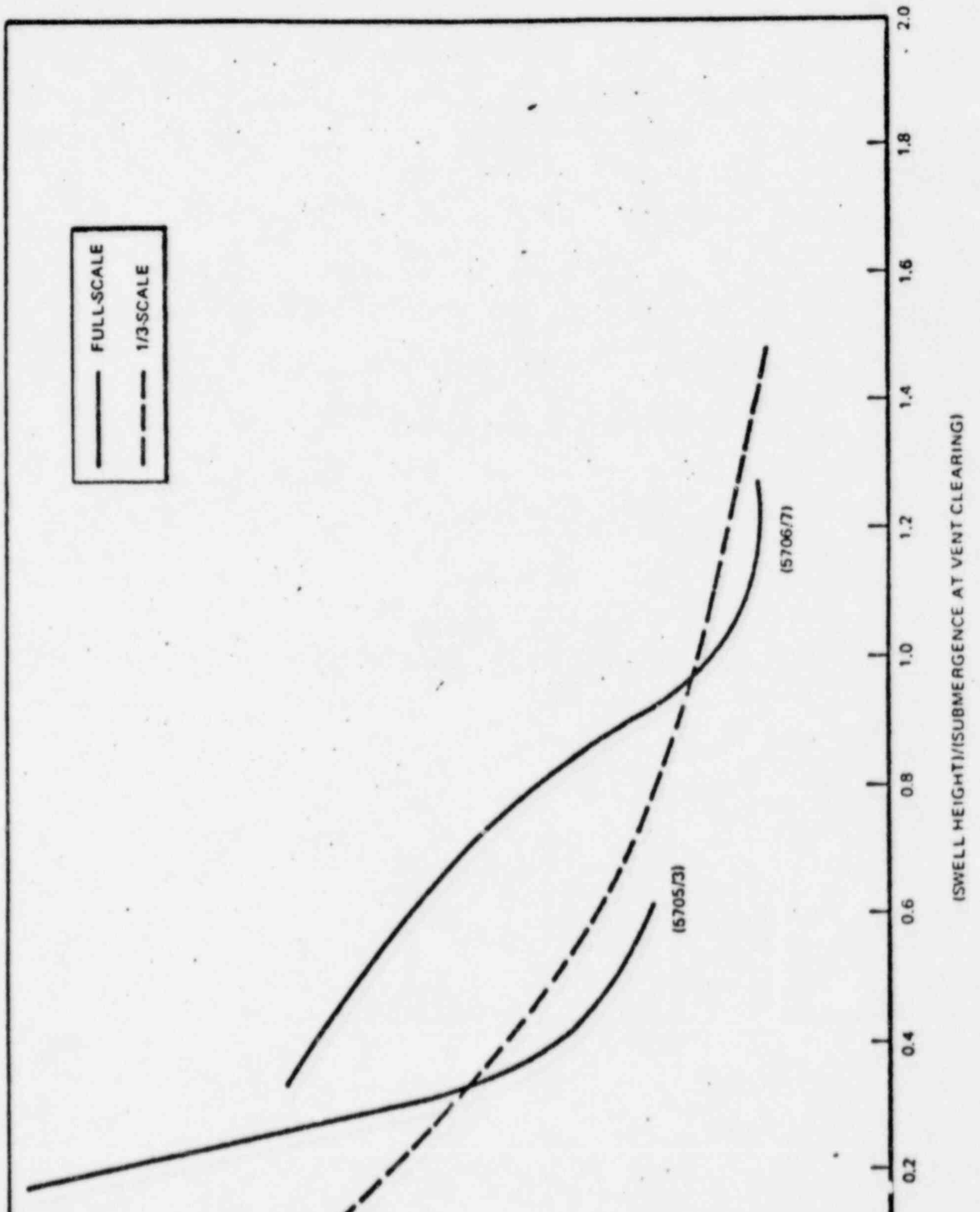


Figure 4-51. Comparison of Dimensionless Slug Length Versus Dimensionless Swell Height 1/3-Scale Air Versus Full-Scale Air, 6 ft (1.83 m) Submergence

(COMPANY PROPRIETARY)

GENERAL ELECTRIC

NUCLEAR ENERGY DIVISION

BWR PROJECTS DEPARTMENT

GENERAL ELECTRIC COMPANY, 175 CURTNER AVENUE, SAN JOSE, CALIFORNIA 95125
Mail Code 682
Phone (408) 297-3000, TWX NO. 910-338-0116

September 24, 1975

Mr. R. L. Tedesco
Assistant Director for Containment Safety
Division of Technical Review
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Tedesco:

Attached are three copies of the visual aids used in presentations to members of your staff at generic meetings held in San Jose on September 16-18, 1975. Portions of the material contain information which the General Electric Company customarily maintains in confidence and withholds from public disclosure. The information has been handled and classified proprietary by GE in accordance with the procedures and standards set forth in Attachment A to this letter; and we hereby request that the material identified as proprietary be witheld from public disclosure in accordance with the provisions of 10CFR2.790.

The proprietary information in this transmittal is necessary for our business and gives us an opportunity to obtain an advantage over competitors who do not have access to it. The data was obtained at considerable expense to General Electric or via exchange agreements with other sources which require proprietary treatment. Its release would allow competitors to confirm similar designs without incurring similar expense. Extensive measures have been employed to guard such information, and to the best of our knowledge, the information has been released outside the company only in accordance with contractual proprietary agreements.

Please call if you have any questions or comments on this material.

Sincerely,

Geza Gyorey

Geza L. Gyorey, Manager
BWR Licensing

Attachments
cc: L. S. Gifford
cb

F-2

GENERAL ELECTRIC

PROPRIETARY CLASSIFICATION SYSTEM

General Electric proprietary documents contain information and are of the type which General Electric customarily maintains in confidence and withholds from public disclosure. To the best of General Electric's knowledge and belief, such documents have consistently been maintained in confidence and no public disclosure has been made of them.

Documents are classified proprietary pursuant to standard General Electric procedures pertaining to such classification. General Electric's definition of proprietary information is similar to that used in the courts to define "trade secrets". The definition encompasses "any formula, pattern, device or compilation of information which is used in one's business and which gives him an opportunity to obtain an advantage over competitors who do not know or use it." Additionally, a substantial element of secrecy must exist, so that, except by the use of improper means, there would be difficulty in acquiring the information. Some factors to be considered in determining whether given information is proprietary are: (1) the extent to which the information is known outside the busines; (2) the extent to which it is known by employees and others involved at General Electric; (3) the extent of measures taken to guard the secrecy of the information; (4) the value of the information to General Electric and its competitors; (5) the amount of effort of money expended by General Electric in developing the information; and (6) the ease or difficulty with which the information could be properly acquired or duplicated by others. Additional information treated as confidential consists of business intelligence such as business plans, forecasts, financial data and similar information which, if obtained by competition, could compromise the interest of the Company.

"LICENSING TOPICAL REPORT"

OUTLINE:

1. INTRODUCTION
2. S/RV LOADS WITH QUENCHER
3. LATERAL LOADS ON DOWNCOMER VENT
4. TEMPERATURE THRESHOLD LIMIT FOR HIGH TEMPERATURE CONDENSATION VIBRATION.

SECTION - 1 INTRODUCTION

I. BACKGROUND:

- QUENCHER DESIGNED TO REDUCE AIR-CLEARING LOAD
- DEFINE DYNAMIC LOADS ON THE VENTS
- ESTABLISH A SUPPRESSION POOL TEMPERATURE TO AVOID STEAM CONDENSATION VIBRATIONS.

II PURPOSE:

TO PROVIDE CONTAINMENT DYNAMIC LOADS SUPPORTING DATA IN THE THREE AREAS MENTIONED ABOVE.

SECTION 2 S/RV LOADS WITH QUENCHER

1. INTRODUCTION
2. DESCRIPTION OF PHENOMENA
3. DEVELOPMENT OF MII AND III QUENCHER DESIGN LOADS

A. SMALL SCALE TEST

- LIST OF TEST PARAMETERS AFFECTING THE QUENCHER LOADS
- DESCRIPTION OF SMALL SCALE TEST SETUP
  - SKETCH OF THE TEST FACILITY SHOWING DETAILS OF
    - A. OUTLAY AND CONFIGURATION OF VARIOUS ELEMENTS OF THE TEST FACILITY
    - B. LOCATION OF PRESSURE AND TEMPERATURE TRANSDUCERS AND OTHER INSTRUMENTATION
    - C. IMPORTANT DIMENSIONS AND SIZES
- EFFECTS OF DIFFERENT PARAMETERS
  - TEST RESULTS
  - DISCUSSION
  - APPLICATION TO LARGE SCALE TEST

B. LARGE SCALE TEST:

- SKETCH SHOWING DETAILS OF
  - OUTLAY AND CONFIGURATION OF TEST FACILITY
  - LOCATION OF PRESSURE AND TEMPERATURE TRANSDUCERS
  - RELEVANT DIMENSIONS AND SIZES
- RESULTS OF THE LARGE SCALE TESTS
  - SINGLE ACTUATION TESTS
  - ACTUATION OF MULTIPLE VALVES
  - CONSECUTIVE ACTUATION OF THE SAME VALVE
- COMPARISON OF PREDICTED AND MEASURED VALUES OF LOADS.

C. MARK II AND III AIR-CLEARING LOAD PREDICTION

- DESCRIPTION OF PREDICTION METHOD USING THE SMALL AND LARGE SCALE FIRST AND SUBSEQUENT ACTUATION DATA

- STATISTICAL EVALUATION OF THE SMALL AND LARGE SCALE DATA
  - CALCULATION OF MEAN VALUE OF MEASURED LOADS AND THEIR STANDARD DEVIATION
  - CALCULATION OF QUANTITATIVE EFFECT OF VARIOUS PARAMETERS ON AIR-CLEARING LOADS

- STATISTICAL EVALUATION OF THE PREDICTION METHOD FOR M II AND III QUENCHER LOADS.

4. ATTENUATION, FREQUENCY AND WAVE SHAPE OF THE CONTAINMENT LOADS

- METHOD OF ATTENUATION OF LOADS IN THE SUPPRESSION POOL
  - JUSTIFICATION FROM FULL SCALE DATA

- LOADING OSCILLATION FREQUENCY AND WAVE SHAPE
  - JUSTIFICATION FROM FULL SCALE DATA

SECTION 3. LATERAL LOADS ON DOWNCOMER VENT :

I. INTRODUCTION

A. GENERAL — INTRODUCTION OF LOADS AND PURPOSE OF REPORT

B. PHENOMENA - DISCRIPTION OF LOAD PHENOMENA WITH ILLUSTRATIVE SKETCHES

II. TEST FACILITY AND PROCEDURE

A. FACILITY - DISCRIPTION OF FACILITY, INCLUDING FIGURES

B. INSTRUMENTATION AND CALIBRATION

- INSTRUMENTATION — LIST OF PRESSURE, TEMPERATURE AND FORCE MEASURING POINTS AND FIGURES SHOWING THEIR LOCATION
- CALIBRATION — DESCRIPTION OF CALIBRATION PROCEDURES OF STRAIN GAGES AND LONGITUDINAL DISPLACEMENT TRANSDUCERS

C. PROCEDURE - DESCRIPTION OF TEST PROCEDURE.

III TEST RESULTS AND DISCUSSION

A. PRESSURE AND LATERAL LOADS — GENERAL DESCRIPTION OF RESULTS, TABULATION OF MEASURED VALUES WITH ILLUSTRATIVE SKETCHES

B. DISCUSSION

- EFFECT OF POOL TEMPERATURE
- EFFECT OF AIR TEMPERATURE
- EFFECT OF MASS FLUX DENSITY
- REPRODUCIBILITY
- FREQUENCY DISTRIBUTION OF TRANSVERSE FORCES
- DIRECTION OF LOAD

C. SUMMARY OF RESULTS

D. APPLICABILITY OF RESULTS

- TABULATION OF MAJOR TEST PARAMETERS RELATED TO LATERAL LOADS AND G.E. BWR'S.
- DISCUSSION OF APPLICABILITY

SECTION 4. TEMPERATURE THRESHOLD LIMIT FOR HIGH TEMPERATURE CONDENSATION VIBRATION.

1. INTRODUCTION

- FUNCTION OF SUPPRESSION POOL
- POSSIBILITY OF SIGNIFICANT VIBRATIONS WITH LIMITING-CASE ASSUMPTIONS

2. FIELD EXPERIENCE

- EVENT 1. STUCK OPEN S/RV INDUCES VIBRATION ABOVE 160°F; STRUCTURAL DAMAGE OBSERVED.
- TWO OPENED S/RVS' DURING TEST INDUCE VIBRATION. CATWALK SHAKEN DOWN. INSTRUMENT LINES BROKEN.
- DOMESTIC PLANT RELIEF VALVE OPERATION:- MOST PLANTS HAVE RAMS HEAD. NO INCIDENTS OBSERVED.

3. PHENOMENA DISCUSSION

- STEAM CONDENSATION ALWAYS COMPLETE.
- G-MAP ILLUSTRATES DIFFERENT MODES OF CONDENSATION FOR STRAIGHT PIPES.

4. RAMS HEAD DISCHARGE DEVICE

- EFFECTS OF SPLITTING DISCHARGE FLOW
- DIRECTIONAL EFFECTS
- DISCUSSION OF PERFORMANCE OF DEVICES SIMILAR TO RAMS HEAD
- TEMPERATURE THRESHOLD LIMITS FOR HIGH TEMPERATURE CONDENSATION VIBRATION.

5. DEVELOPMENT OF QUENCHER

I. SMALL-SCALE MODEL TESTS, 1:100 VOLUMETRIC

- TEST STAND STRUCTURE
- INSTRUMENTATION — PRESSURE AND TEMPERATURE TRANSDUCERS' LOCATION
- TEST PROCEDURES
- TESTING WITH DIFFERENT NOZZLE CONFIGURATIONS
- EVALUATION OF PERFORMANCE OF PERFORATED PIPE NOZZLES
- PERFORATED PIPE HOLE OPTIMIZATION

II. LARGE-SCALE MODEL TESTS, 1:4 VOLUMETRIC

- TEST STAND STRUCTURE
- INSTRUMENTATION — PRESS. AND TEMPERATURE TRANSDUCERS' LOCATION
- TEST PROCEDURES
- 7 NOZZLE VERSIONS TESTED
- RESULTS - TEMPERATURE DISTRIBUTION, PRESS. AMPLITUDE AND FREQUENCY DISCUSSED. G-MAP DEVELOPED

III. Application Of Test Rig Results To Large Scale Quencher Facility

- Test With Large Scale Nozzle In A Plant
- Nozzle Geometry, Arrangement Specified
- Resulting Loads And Temperature Limits Discussed, Compared To Test Rig Values

CURRENT MASS TRANSER MODEL

MAJOR ASSUMPTIONS:

1. DROPLET TEMPERATURE IS EQUAL TO THE ADIABATIC SATURATION (WET BULB) TEMPERATURE.

2. ALL HEAT TRANSFER ENERGY IS USED TO VAPORIZE THE LIQUID.

3. THE CHANGE IN SENSIBLE ENERGY OF THE DROPLET IS NEGLIGIBLE.

4. GOOD MIXING IN THE DROPLET.

PROPOSED MODEL IMPROVEMENTS

1. INCLUSION OF DROPLET SENSIBLE ENERGY.

2. CHANGE FROM THE ENERGY METHOD OF CALCULATING MASS TRANSFER TO THE PARTIAL PRESSURE METHOD.

CURRENT MODEL

EQUATIONS:

EVAPORATION RATE:

$$\dot{m}_e = \frac{\pi D^2 h \left(T_A - T_D\right)}{\lambda}$$

WHERE: D = DROPLET DIAMETER
h = CONVECTIVE HEAT TRANSFER COEFFICIENT
T_A = AMBIENT AIR TEMPERATURE
T_D = DROPLET TEMPERATURE
λ = LATENT HEAT OF VAPORIZATION

THE HEAT TRANSFER COEFFICIENT IS DETERMINED FROM:

$$h = \frac{k \, N_u}{D}$$

WHERE: k = THERMAL CONDUCTIVITY OF AIR
[illegible] NUMBER.

AND.

$$N_u = 2.0 + 0.6 \, S_c^{1/3} R_e^{1/2}$$

GENERAL ELECTRIC CO.
Nuclear Energy Division
ENGINEERING CALCULATION SHEET

DATE September 17, 1975

SHOP ORDER NO. RELAP 3 & 4 Discussions

SUBJECT ______ BY MRW SHEET ____ OF ____

NRC/GE GENERIC MEETING

- RELAP-4 Improvements
- Review Key Assumptions
- Discussion of GE/NRC Analysis
  - Revised GE Analysis
  - Reactor Shield Wall and Reactor Skirt Pressure comparisons
  - Shear Force Comparison
- Conclusions

FORM NO. NED 87

MODELING IMPROVEMENTS INCORPORATED INTO RELAP-4

- MOMENTUM FLUX
  - AREA CHANGES
  - DENSITY CHANGES
  - HEAT ADDITION
- BRANCHING FLOW PATHS
- ADDITIONAL CHOKING OPTIONS
- ECCS IMPROVEMENTS
- NODE STATIC PRESSURE AVAILAB[illegible]

GENERAL ELECTRIC CO.
Nuclear Energy Division
ENGINEERING CALCULATION SHEET

DATE ...-7-75

SHOP ORDER NO. RELAP 3 & 4 Discussions

SUBJECT ______ BY MRW SHEET ____ OF ____

SUMMARY OF GE RELAP-4 MODEL OF RSW/RPV ANNULUS

- 30 Nodes and 55 Junctions
- One-Half the Annulus Considered
- Moody Model Used for Blowdown Flow Rate
- All The Blowdown Flow Enters the Annulus
- Accounted for FLOW Area and Form Losses* due to Pipes Crossing the Annulus
- Accounted for Turning Losses*
- Used a .6 Moody Multiplier between Nodes
- Insulation treated Conservatively
- Initial Conditions are a Homogeneous Water-Steam Mixture
- Neglected Momentum Flux and Compressibility of Flow in the Region of the Break

* I'del chik

FORM NO. NED 87

GENERAL ELECTRIC CO.
Nuclear Energy Division
ENGINEERING CALCULATION SHEET

DATE 9-17

SHOP ORDER NO. RE-AP 3 & 4 DISCUSSIONS

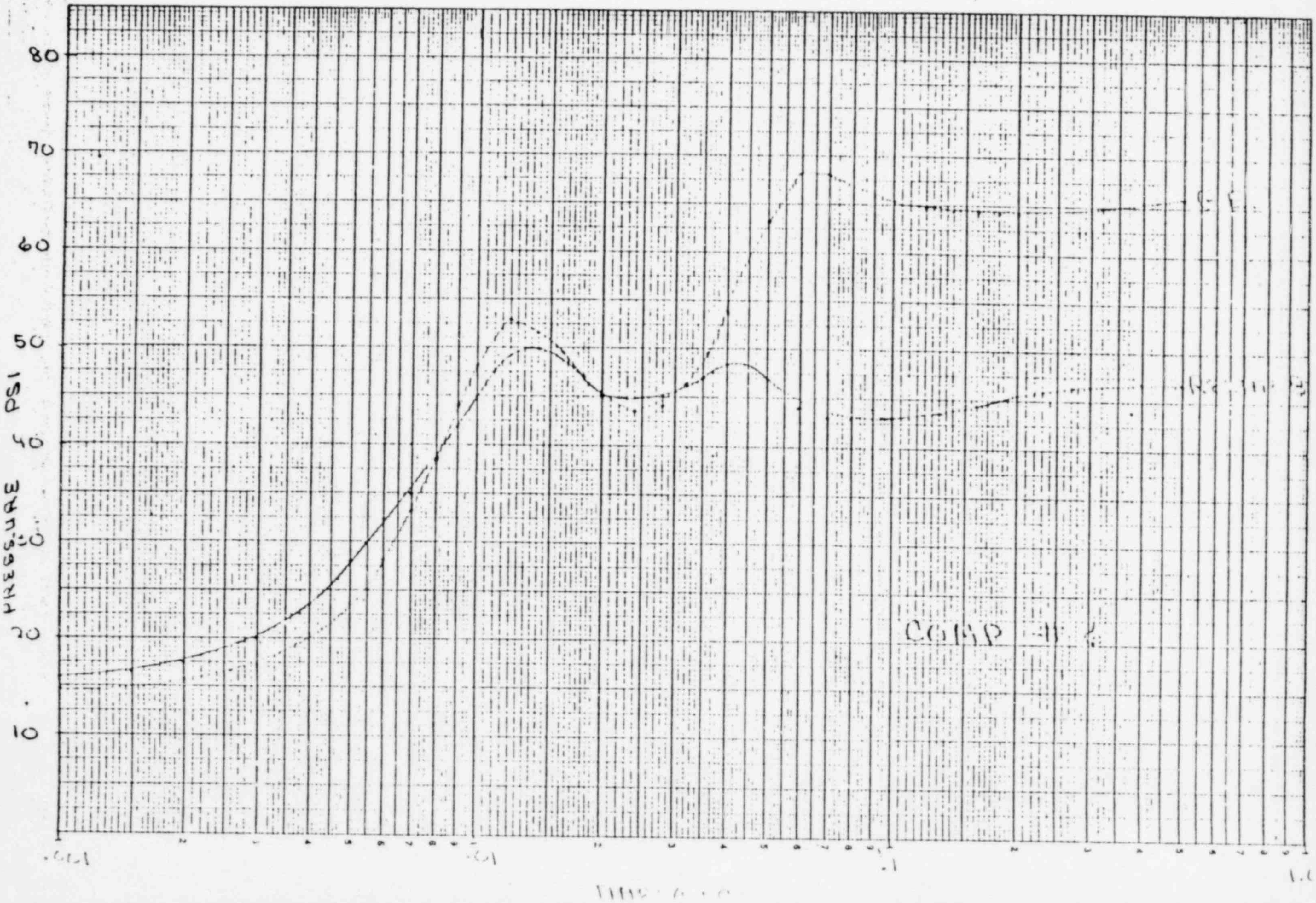
SUBJECT ______ BY MRW SHEET ____ OF ____

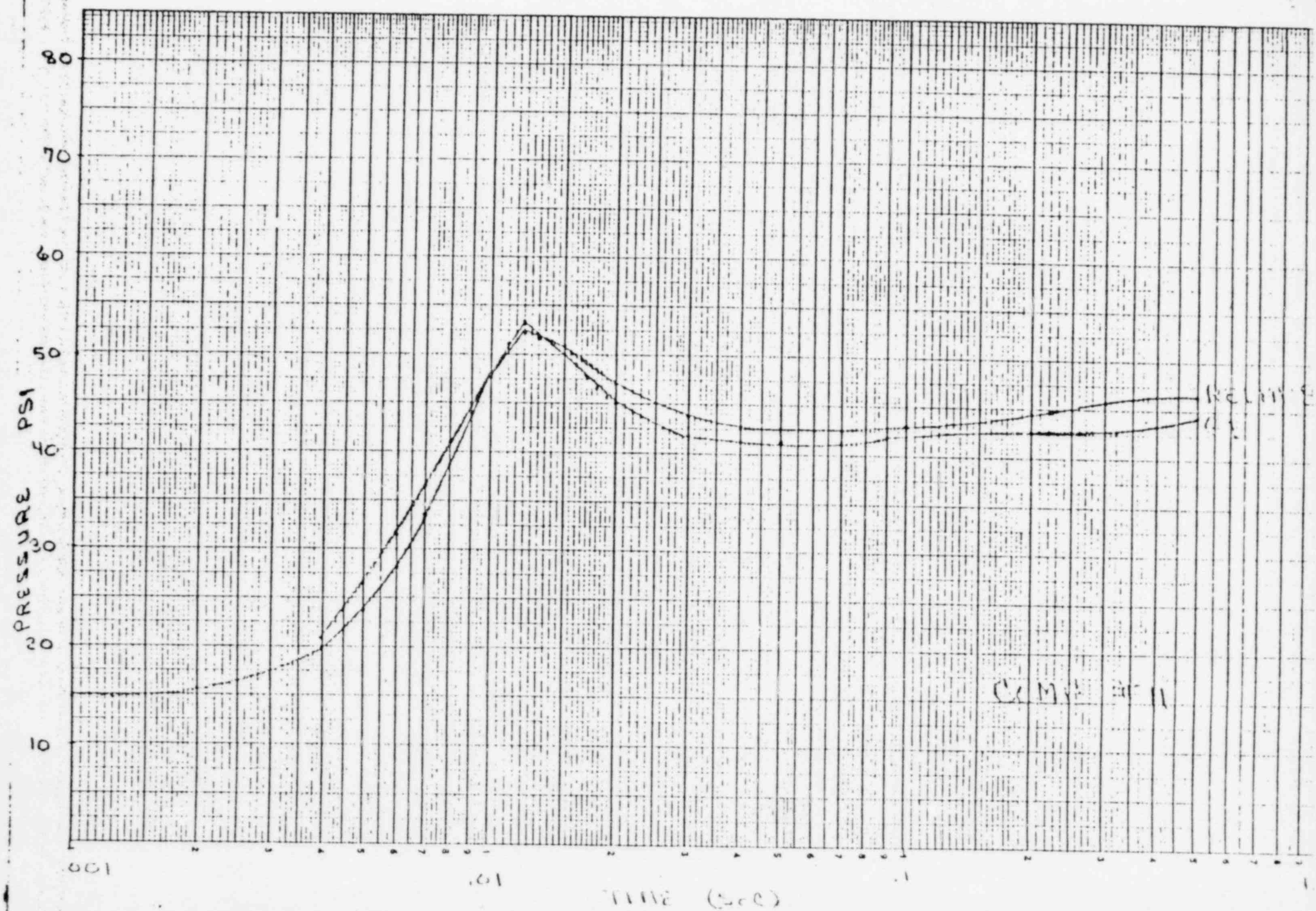
IMPROVEMENTS IN G.E. METHODS

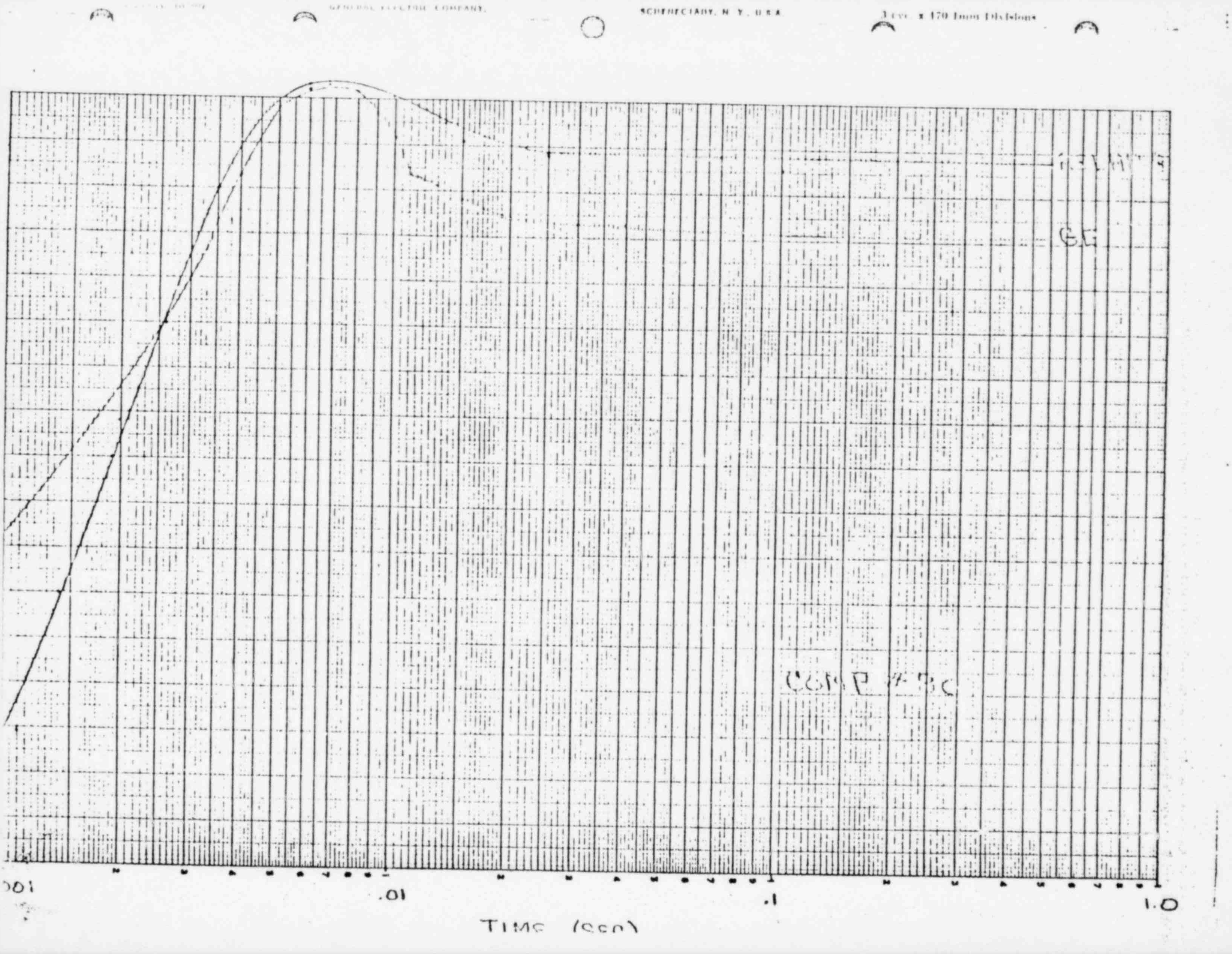
	GESSAR	NOW	EFFECT
• TIME STEP	.002	.0001	MORE ACCURATE ANALYSIS [SHEAR FORCE UP ≈ 10%]
• INITIAL CONDITIONS	15.95 PSIA X = 100%	14.95 PSIA X = 92.6%	SHEAR FORCE UP BY 5%

FORM NO. NEO 47

FN-265-A (8-50) GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., U.S.A. 3 cyc. x 170 1mm Divisions




80
70
60
50
40
30
20
10
PRESSURE PSI
.001
.01
.1
1
TIME (sec)


GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y., U.S.A.
3 cyc. x 170 1mm Divisions
GE
COMP #3C
.001
.01
.1
1.0
TIME (sec)

GENERAL ELECTRIC CO.
Nuclear Energy Division
ENGINEERING CALCULATION SHEET

DATE 4-16-75

SHOP ORDER NO. RELAP 3 & 4 Discussion

SUBJECT ______ BY MRW ______ SHEET ____ OF ____

COMPARISON OF GE AND NRC ANALYSIS

	GE	NRC	DIFFERENC
AVERAGE SKIRT PRESSURE	58.5 PSIA (@ t=.5 sec)	47.6 PSIA (MAXIMUM)	23%
AVERAGE RSW PRESSURE	46.9 PSIA (@ t=.5sec)	47.4 PSIA (MAXIMUM)	1%

FORM NO. NED 87

GESSAR
VESSEL PRESSURE DIFFERENTIAL
AT DIFFERENT LEVELS

Projected area for 30^0 segment = $\frac{\pi D*30*h}{360}$

= .262 Dh

Projected area for 45^0 segment = $\frac{\pi D*45*h}{360}$

= .393 Dh

Force = Pressure in compartment * projected area * cosine angle
horizontal component of force cancel due to symmetry.

Force per Dh

Time		Level 1	Level 2	Level 3	Level
	GESSAR	24.6	24.4	23.52	14.3
0.02	RELAP-3	23.9	23.9	23.0	18.5
	GESSAR	22.6	18.1	11.68	6.04
0.05	RELAP-3	13.8	15.6	14.5	5.8
	GESSAR	12.6	6.74	7.34	5.32
0.5	RELAP-3	13.7	13.7	13.5	13.4

GESSAR DATA SHOULD BE INCREASED 10% -15% [TIME STEP AND INITIAL CONDITIONS ADJUSTMENTS]

GENERAL ELECTRIC CO.
Nuclear Energy Division
ENGINEERING CALCULATION SHEET

DATE 7-17-75

SHOP ORDER NO. RELAP 3 & 4 DISCUSSIONS

SUBJECT ______ BY MRW SHEET ___ OF ___

SUMMARY AND CONCLUSIONS

- RELAP 4 CONTAINS IMPROVED ANALYTICAL MODELING.
- G.E. IS USING CONSERVATIVE INPUT ASSUMPTIONS
- RELAP 4 CONSERVATIVE FOR RPV SKIRT AND SHIELD WALL PRESSURE CALCULATIONS (UP TO 20% ABOVE RELAP 3)
- RELAP 4 SHEAR FORCE CALCULATIONS APPROXIMATELY 15% BELOW NRC CALCULATIONS
- RELAP 4 IS AN APPROPRIATE DESIGN TOOL.

NEDE-20942-P

- PURPOSE – TO DOCUMENT RECENT MODEL DEVELOPMENT AND REFINEMENTS

- MODELS :

  PIPE CLEARING TRANSIENT
  BUBBLE DYNAMICS
  PRESSURE DISTRIBUTION IN POOL

- RECENT DEVELOPMENTS :

  INITIAL BUBBLE POSITION
  EFFICENCY OF BUBBLE FORMATION PROCESS
  BOUNDARY EFFECTS
    RIGID BOUNDARIES
    FREE SURFACE
  MOTION OF C.G. OF BUBBLE

- RESULTS :

  BETTER AGREEMENT WITH DATA
  BOUNDARY CONDITIONS SATISFIED
  BETTER REPRESENTATION OF PHENOMENA

- UNDER STUDY :

  SECOND POP PHENOMENON (DATA NEEDED)

PIPE CLEARING MODEL

MAX. PIPE PRESSURE DEPENDS ON:

1) WATER LEG
2) fL/D for COMPRESSIBLE FLOW
3) INITIAL CONDITIONS IN PIPE AND POOL

BACK PRESSURE SIMPLY ADDS TO MAX. PIPE PRESSURE
SAME THING WITH FRICTIONAL EFFECTS FOR WATER.

MAX. PIPE PRESSURE WILL BE CACULATED USING:

MAX. WATER LEG (SECOND POP)

MAX. POOL WATER LEVEL

WORST ENVIRONMENTAL CONDITIONS

CONSERVATIVE fL/D, flow rate and set POINT

LOCAL PRESSURE CALCULATION

Assuming Bubbles all in phase:

$$P - P_\infty = (P_B - P_\infty) R_B \sum \frac{1}{r_i}$$ will not satisfy B.C. on Bubble surface.

$$\therefore \; P - P_\infty = X \sum \frac{1}{r_i}$$

Such that, on bubble surface:

$$P_B - P_\infty = X \sum \frac{1}{r_i'}$$ where r_i' = distance from point on bubble surface to bubble # i

$$X = \frac{P_B - P_\infty}{\sum \frac{1}{r_i'}}$$

and $\therefore$

$$P - P_\infty = \frac{P_B - P_\infty}{\sum \frac{1}{r_i'}} \sum \frac{1}{r_i} \qquad (1)$$

Method used by G.E. is:

$$P - P_\infty = (P_B - P_\infty) R_B \sqrt{\left(\sum \frac{1}{r_i}\right)_1^2 + \left(\sum \frac{1}{r_i}\right)_2^2 + \cdots} \qquad (2)$$

where subscripts 1, 2, ... refer to actual bubbles.

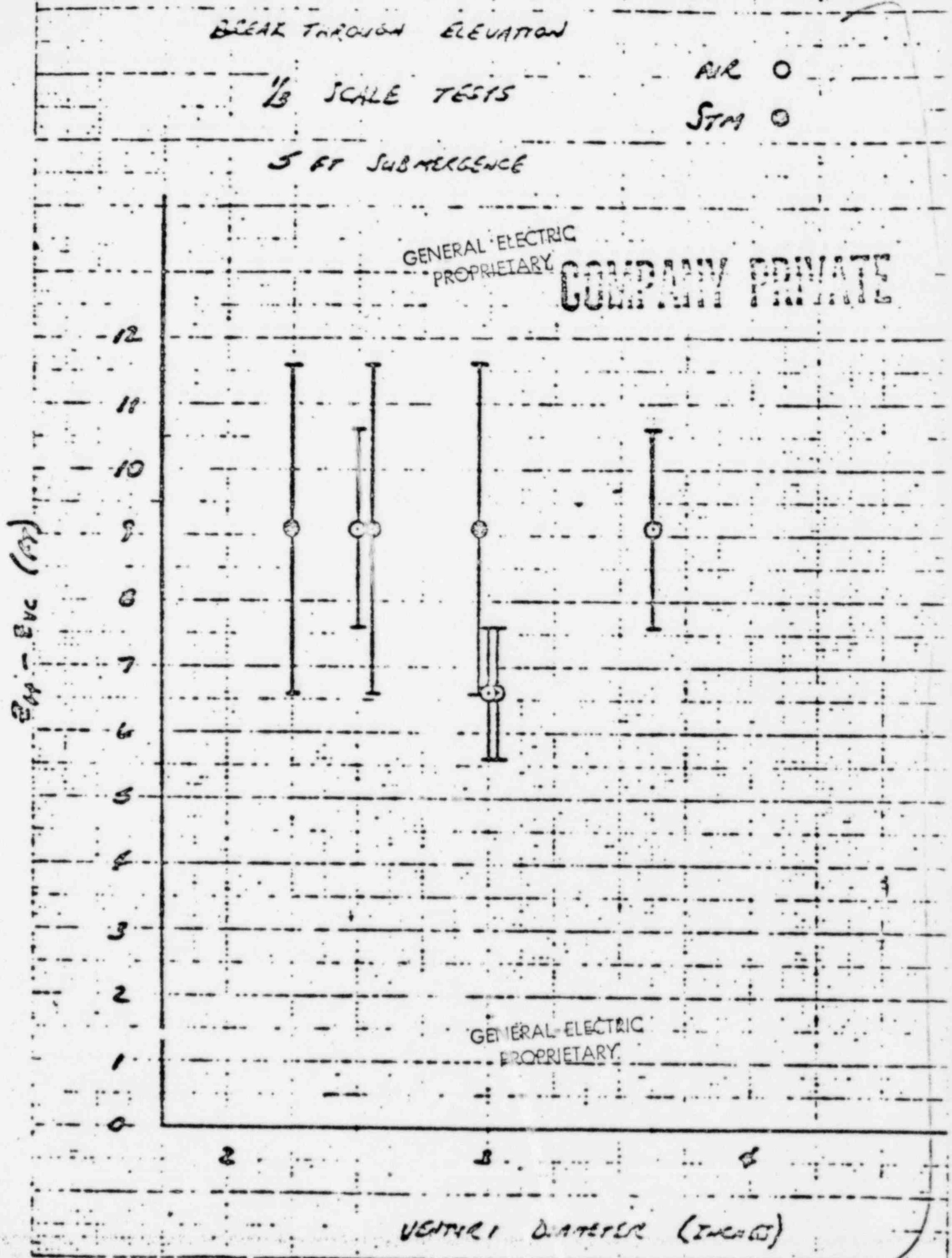
Eq. (1) results in $P_B - P_\infty$ on the bubble

Eq. (2) " " $P - P_\infty > P_B - P_\infty$ on the bubble

In general, Eq. (2) is more conservative

TEST SERIES 5006 INTERPRETATION

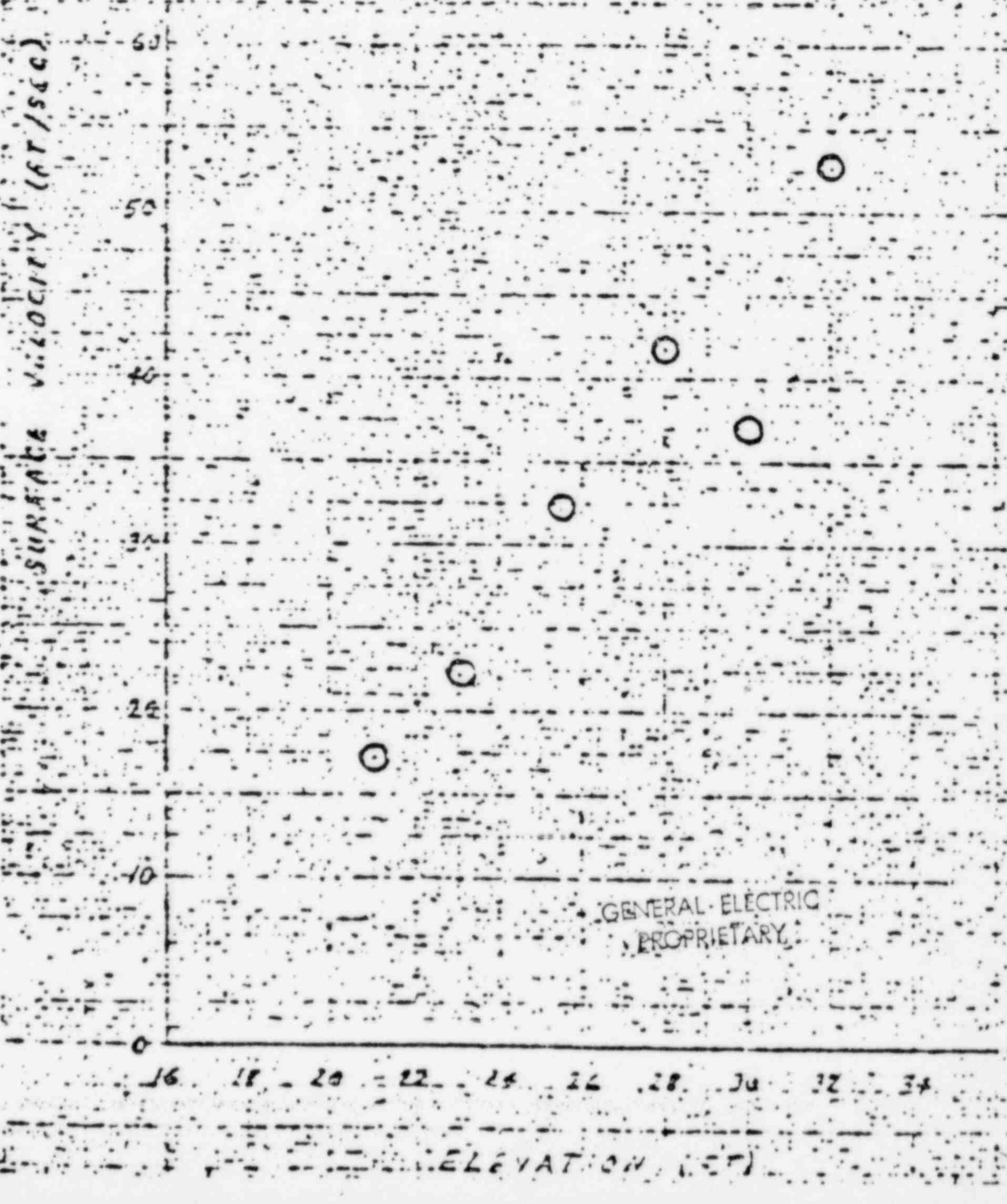
- TWELVE 1/3 SCALE AIR TESTS (JUNE-JULY 1975)
- OBJECTIVES
  - IDENTIFY INFLUENCE OF VENT FLOW COMPOSITION ON POOL SWELL VELOCITY AND LIGAMENT THICKNESS PROFILES.
  - PROVIDE ADDITIONAL DATA FOR POOL SWELL SCALING STUDIES AND ANALYTICAL MODEL VERIFICATION.
- PRELIMINARY TEST RESULTS REVIEWED BY NRC JUNE 1975.
- PRELIMINARY CONCLUSIONS (AUGUST 1975)
- CONCLUSIONS
  - FOR COMPARABLE TEST CONDITIONS, SWELL VELOCITIES ARE 20% HIGHER FOR AIR.
  - BREAK THROUGH ELEVATION INDEPENDENT OF CHARGING RATE.
- DOCUMENTATION - REPORT, OCTOBER 31, 1975


BREAK THROUGH ELEVATION
1/8 SCALE TESTS
5 FT SUBMERGENCE
AIR ○
STM ○
GENERAL ELECTRIC PROPRIETARY
COMPANY PRIVATE
12
11
10
8
7
6
5
4
3
2
1
0
2
8
VENTURI DIAMETER (INCHES)
GENERAL ELECTRIC PROPRIETARY

5806/12 X=5

Company Private

GENERAL ELECTRIC PROPRIETARY



GENERAL ELECTRIC PROPRIETARY

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PROPRIETARY.

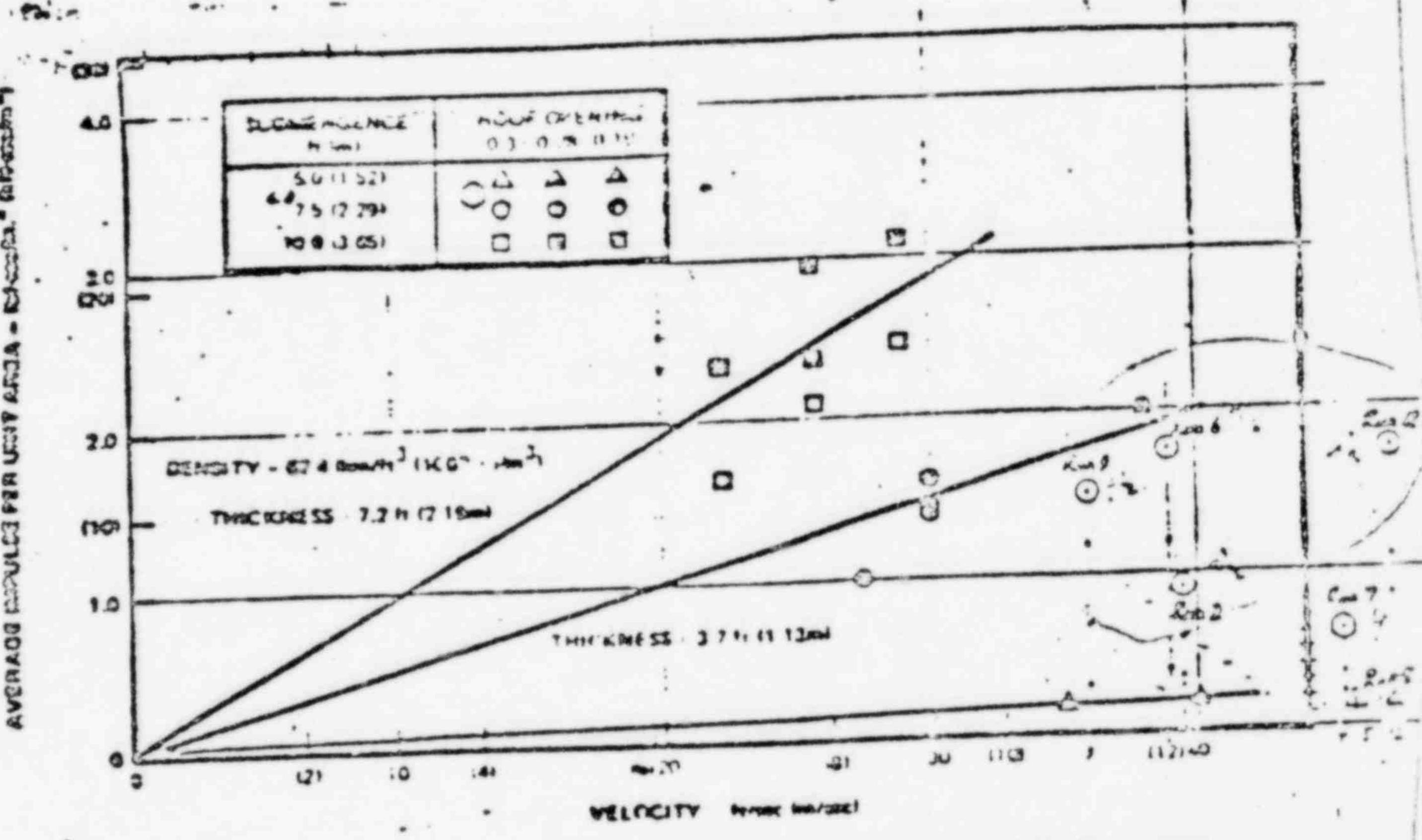

Figure 4-63 Average Impulse per Unit Area vs Water Velocity — Test Series 5801 (Proprietary)

FIGURE 3: COMPARISON TO TEST 5801

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MARK III LOADS PERSPECTIVE

1. PIPES
2. BEAMS
3. HCU FLOOR ΔP
4. TOTAL MARGINS AVAILABLE
5. PRACTICAL PROBLEMS
6. SUMMARY

PRACTICAL PROBLEMS IN DESIGNING FOR HIGH LOADS

I. SUPPORTS AND HANGERS COMPLEX

A. MANY SUPPORTS AND HANGERS EVERY 3-4 FEET

B. LONG DISTANCES TO ANCHORING STRUCTURE

C. SUPPORT STRUCTURE TO PIPE INCREASES LOAD

D. SUPPORT STRUCTURE TO PIPE ITSELF BECOMES A MAJOR STRUCTURE

2. THERMAL DESIGN PROBLEMS

A. STIFFER PIPE INCOMPATIBLE WITH THERMAL REQUIREMENTS

B. MAY HAVE TO WELD STIFFENERS TO PIPE ITSELF TO ACCOMMODATE LOADS

3. OTHER CRITERIA DIFFICULT TO MEET

A. I.S.I. LESS EFFECTIVE

B. SEPARATION CRITERIA LESS EASILY MET

4. ANCHOR LOADS HIGH

A. INTEGRATED LOADS VERY HIGH TO STRUCTURE

B. MANY PIPES ARE INVOLVED

MARGIN IDENTIFICATION

DESIGN CONDITION : DBA LOCA

PIPES

B 31.1 CODE

TYPICAL MATERIAL : A155, CL 2 KC 70

- ALLOW STRESS : 15.75 15.75
- YIELD STRENGTH : 35 KSI
- ULT STRENGTH : 70 KSI

FOR ONE-TIME LOAD, MARGIN ON ULT:

$$\text{FACTOR} = \frac{70}{15.75} = 4.4$$

BEAMS

AISC

TYPICAL MAT'L : A 36 STEEL

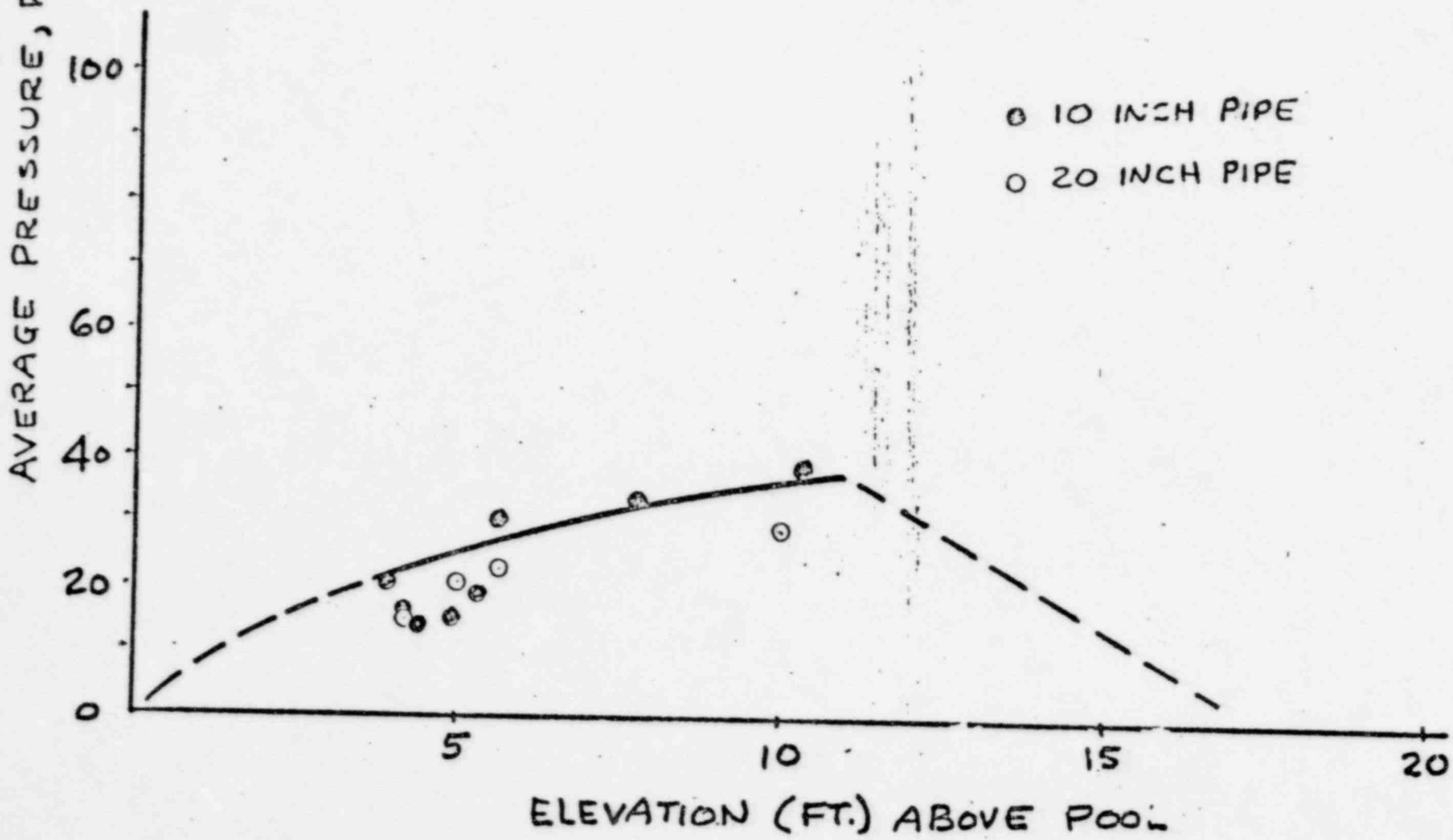
- ALLOW STRESS : 0.9 YIELD = 32.4 KSI
- ULT STRENGTH : 58-80 KSI

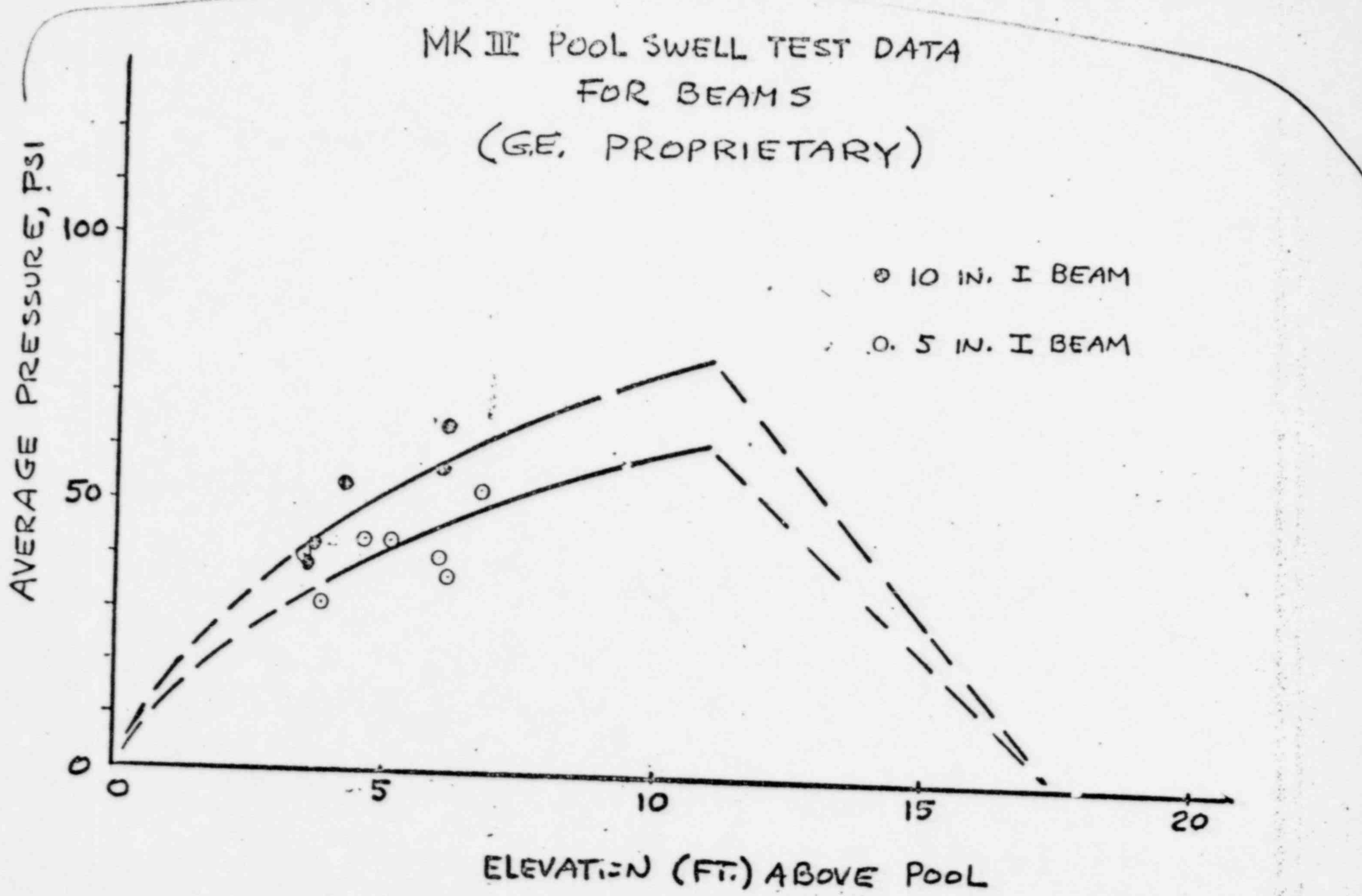
FOR ONE-TIME LOAD, MARGIN ON ULT :

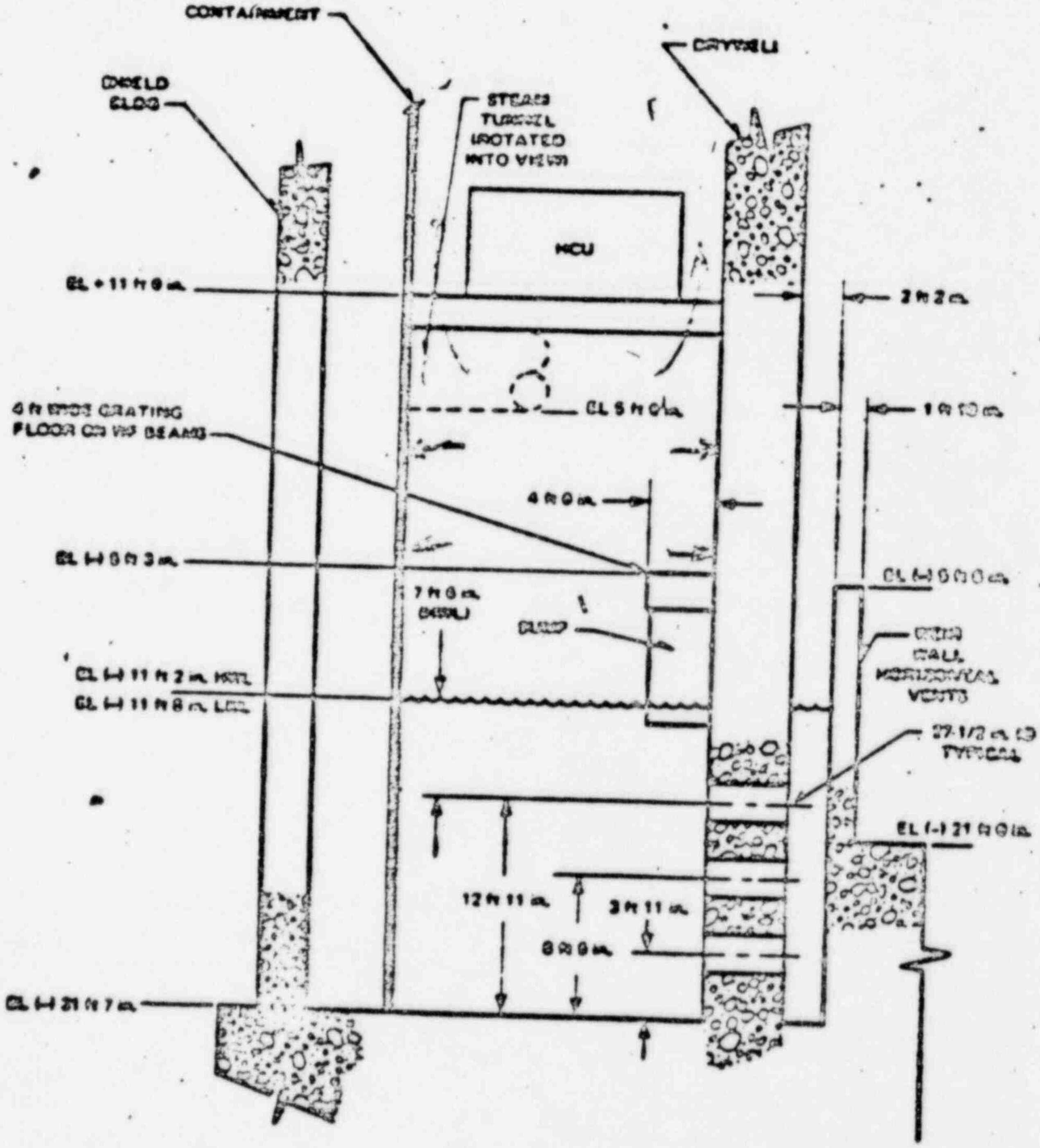
$$\text{FACTOR} = \frac{58}{32.4} = 1.8$$

9-15-75

MK III Pool Swell Test Data for Pipes (G.E. Proprietary)




MK III POOL SWELL TEST DATA
FOR BEAMS
(G.E. PROPRIETARY)
AVERAGE PRESSURE, PSI
100
50
0
10 IN. I BEAM
5 IN. I BEAM
0
5
10
15
20
ELEVATION (FT.) ABOVE POOL


CONTAINMENT
DRYWELL
STEAM
TUNNEL
(ROTATED
INTO VIEW)
HCU
27-1/2 in. ID
TYPICAL

SUMMARY

- TESTS THEMSELVES ARE REPRESENTATIVE OF REAL STRUCTURES AND ARE CONSERVATIVE
- LARGE UNCERTAINTY FACTORS NOT NEEDED ON LOADS
- LARGE MARGINS ON LOADS THEMSELVES ARE UNCALLED FOR
- THERE IS AMPLE CONSERVATISM IN STRUCTURAL DESIGN
- LOAD SPECS WITH A REASONABLE MARGIN WOULD BE

PIPES	30 PSI X 1.30 = ≈40 PSI
BEAMS	60 PSI X 1.30 = ≈80 PSI
HCU FLOOR	3.3 PSI X 1.30 = ≈4.5 PSI Δ P

- LOADS MUCH IN EXCESS OF ABOVE MAKE THE TECHNICAL VIABILITY QUESTIONABLE
- G.E. CURRENT SPECS ARE SPECIFIED AS FOLLOWS IN ATTEMPT TO BE VERY CONSERVATIVE:

PIPES	60 PSI
BEAMS	115 PSI
HCU	11 PSI

- G.E. SPECS ARE OVER CONSERVATIVE AND NRC SHOULD CONSIDER LOWER VALUES, NOT HIGHER ONES TO ACHIEVE BOTH AN OVERALL SAFER DESIGN AND ONE THAT IS POSSIBLE.

PREDICTION OF M III CONTAINMENT AIR-CLEARING LOADS WITH QUENCHER

I. SMALL SCALE TEST DATA

- IMPORTANT PARAMETERS AFFECTING LOADS
- SENSITIVITY OF LOADS TO IMPORTANT PARAMETERS

II. LARGE SCALE TEST AND VERIFICATION OF PREDICTION METHOD

- LARGE SCALE TEST SCALING FACTORS
- PREDICTION OF LARGE SCALE TEST 1st ACTUATION LOADS
- COMPARISON OF PREDICTED AND MEASURED LARGE SCALE RESULTS FOR 1st ACTUATION.
- LARGE SCALE TEST DATA FOR SUBSEQUENT ACTUATION.

III PREDICTION OF M. III CONTAINMENT LOADS

- SCALING FACTORS ; LARGE SCALE → M. III
- M. III LOAD PREDICTION INCLUDING SUBSEQUENT ACTUATION

Scr.

I SMALL SCALE TEST:

- IMPORTANT PARAMETERS AFFECTING AIR CLEARING LOADS:
  1. AIR VOLUME IN PIPE / QUENCHER CROSS SECTION AREA
  2. FREE WATER SURFACE AREA / QUENCHER CROSS SECTION AREA
  3. TOTAL AIR VOLUME AT TIME OF BLOWOUT / TOTAL QUENCHER HOLE OPENING AREA
  4. POOL TEMPERATURE
- PARAMETERS WITH NO SIGNIFICANT INFLUENCE ON LOADS:
  1. VALVE OPENING TIME
  2. SUBMERGENCE DEPTH BETWEEN 4 m TO 6 m
  3. WETWELL PRESSURE
  4. BLOWOUT PRESSURE
- SENSITIVITY OF LOADS TO VARIOUS PARAMETERS
  - STATISTICAL ANALYSIS OF TEST DATA.

include fig. showing the effect of the time

" " " " " " Submergence

 COMPANY PRIVATE

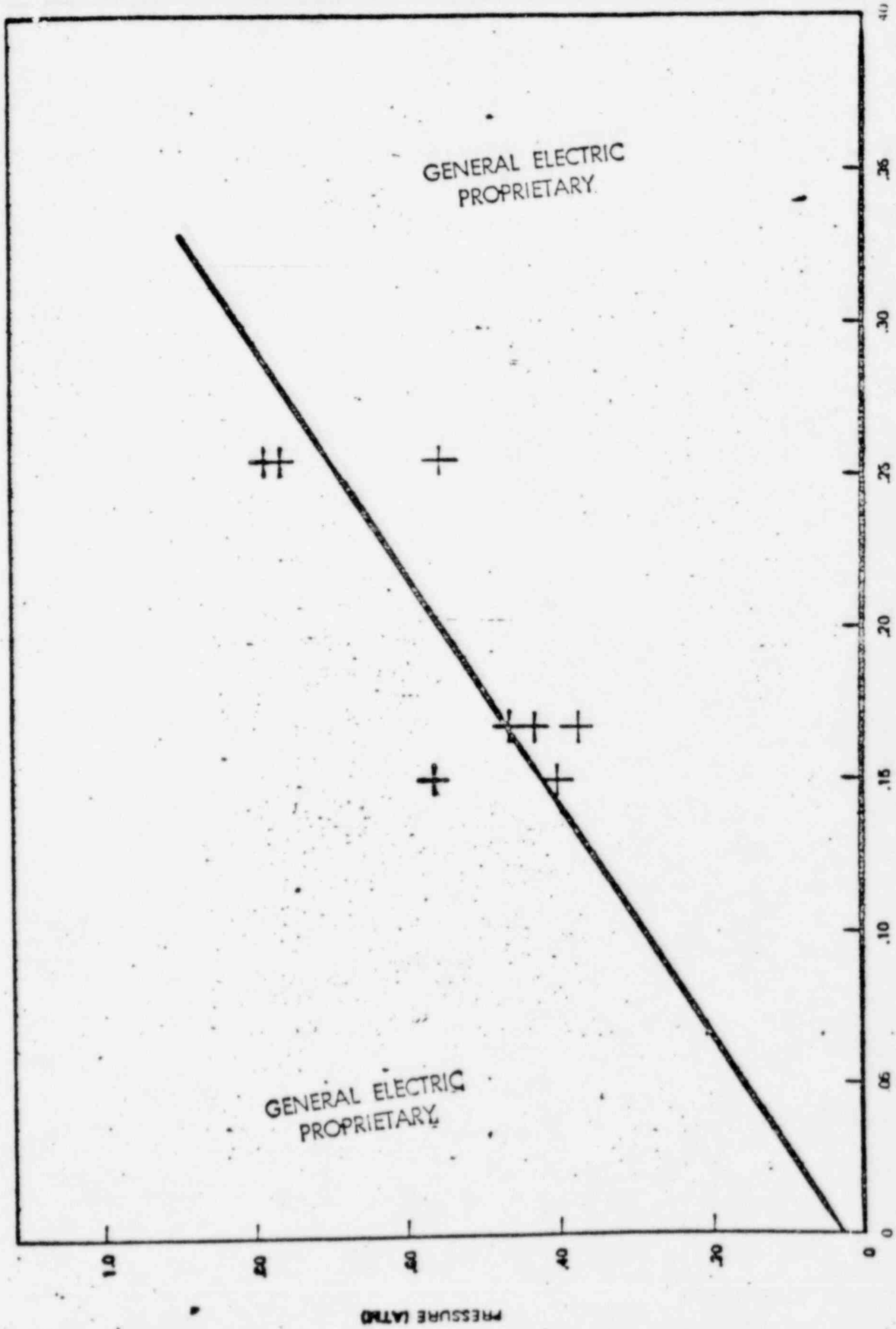


Figure A12.15. Floor Pressure Versus Air Volume/Nozzle Cross Section

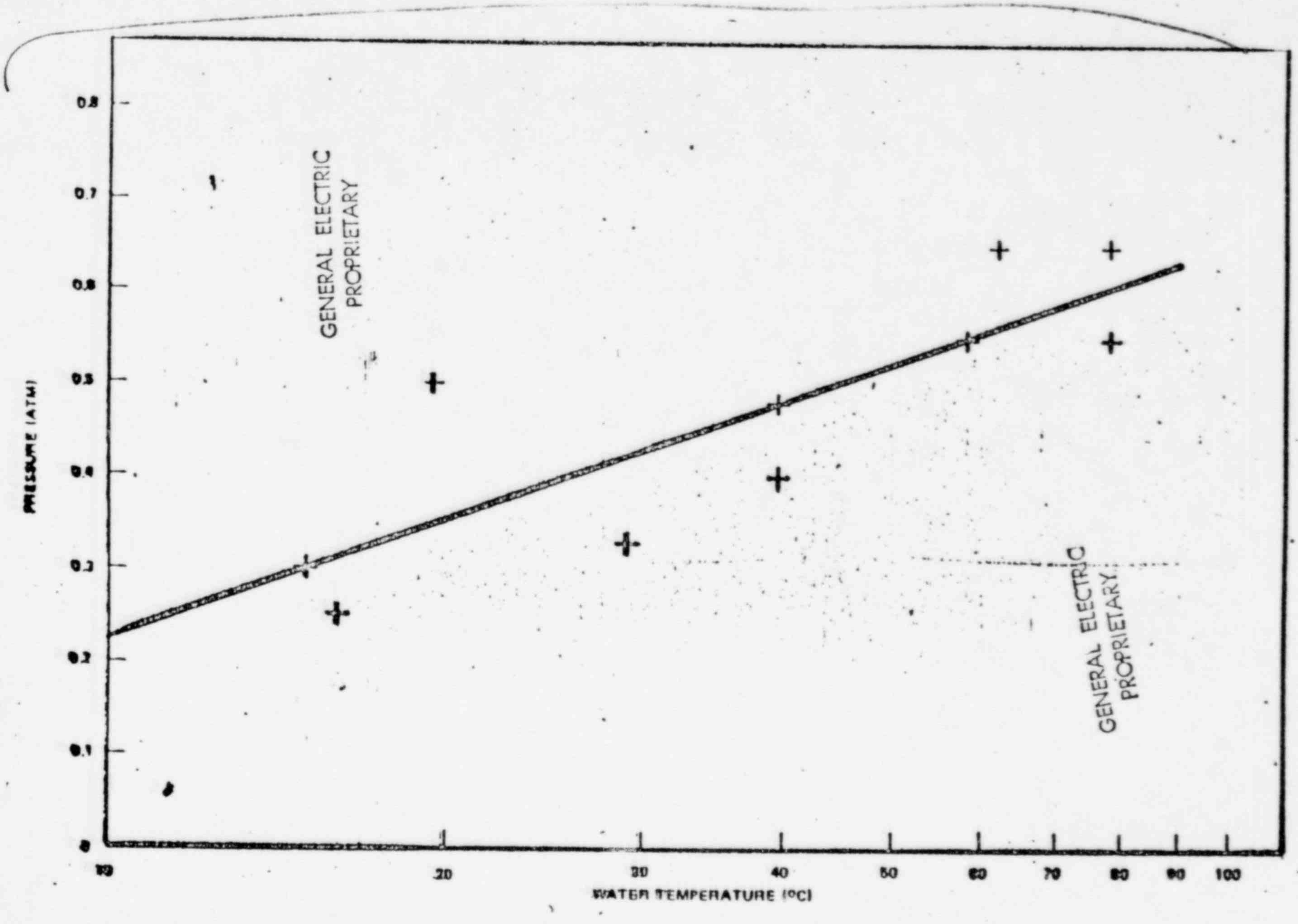


Figure A12.16. Positive Floor Pressure Versus Water Temperature

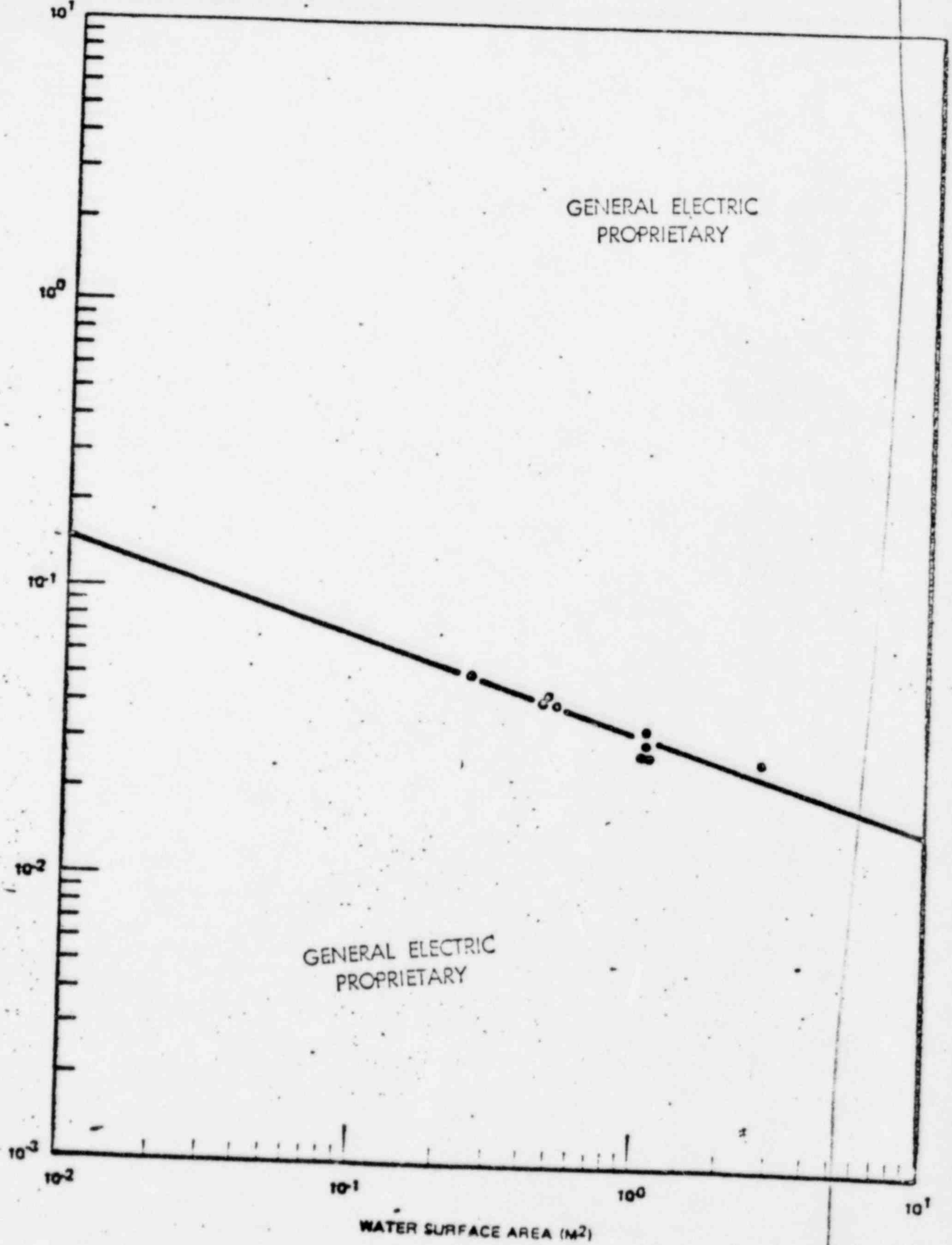


Figure A12.18. Floor Pressure Versus Water Surface Area

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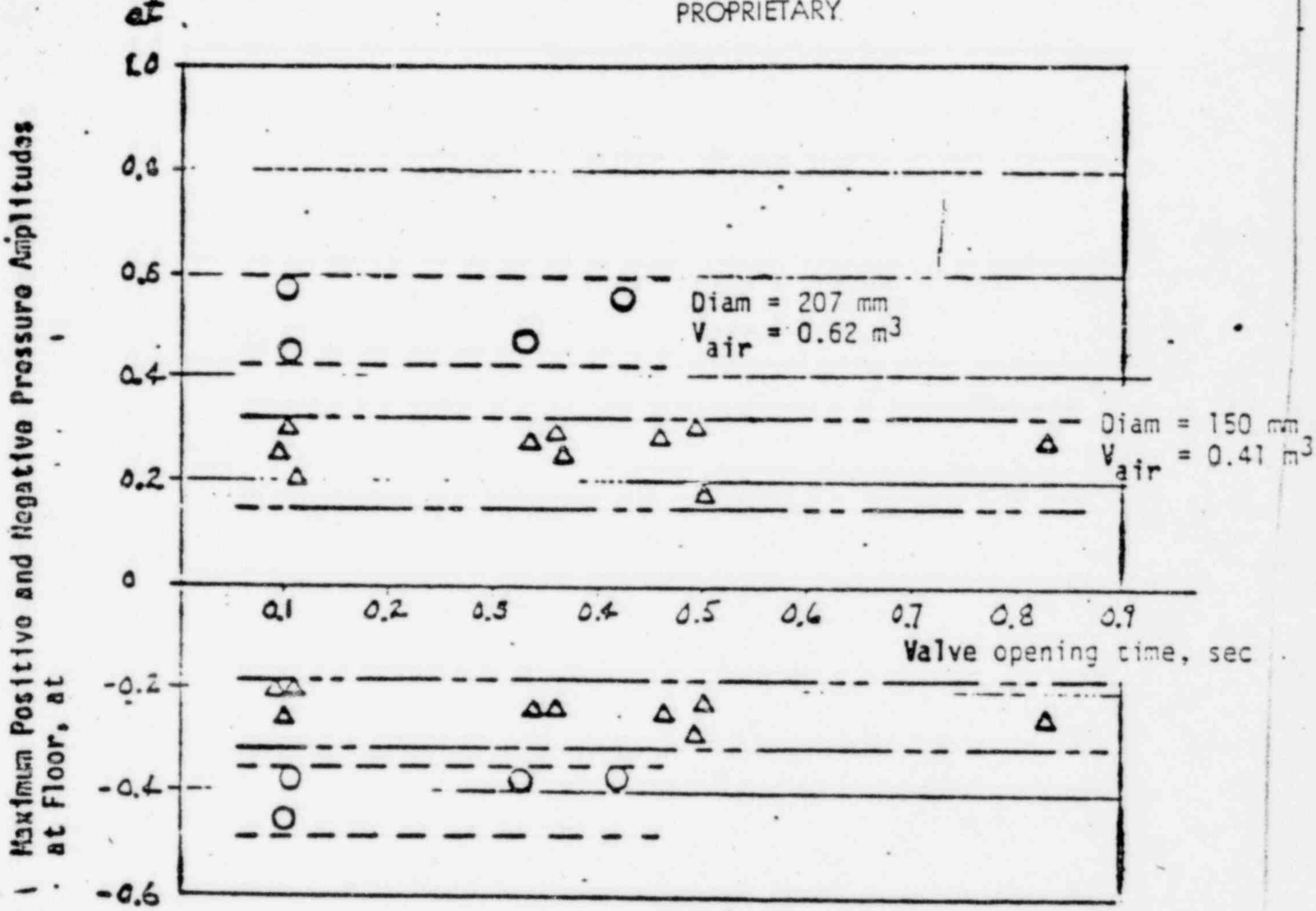

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Fig. B.2.2-2 FLOOR PRESSURES DURING SMALL SCALE BLOWOUT TRIALS WITH QUENCHER, SUBMERSION DEPTH = 2 m.

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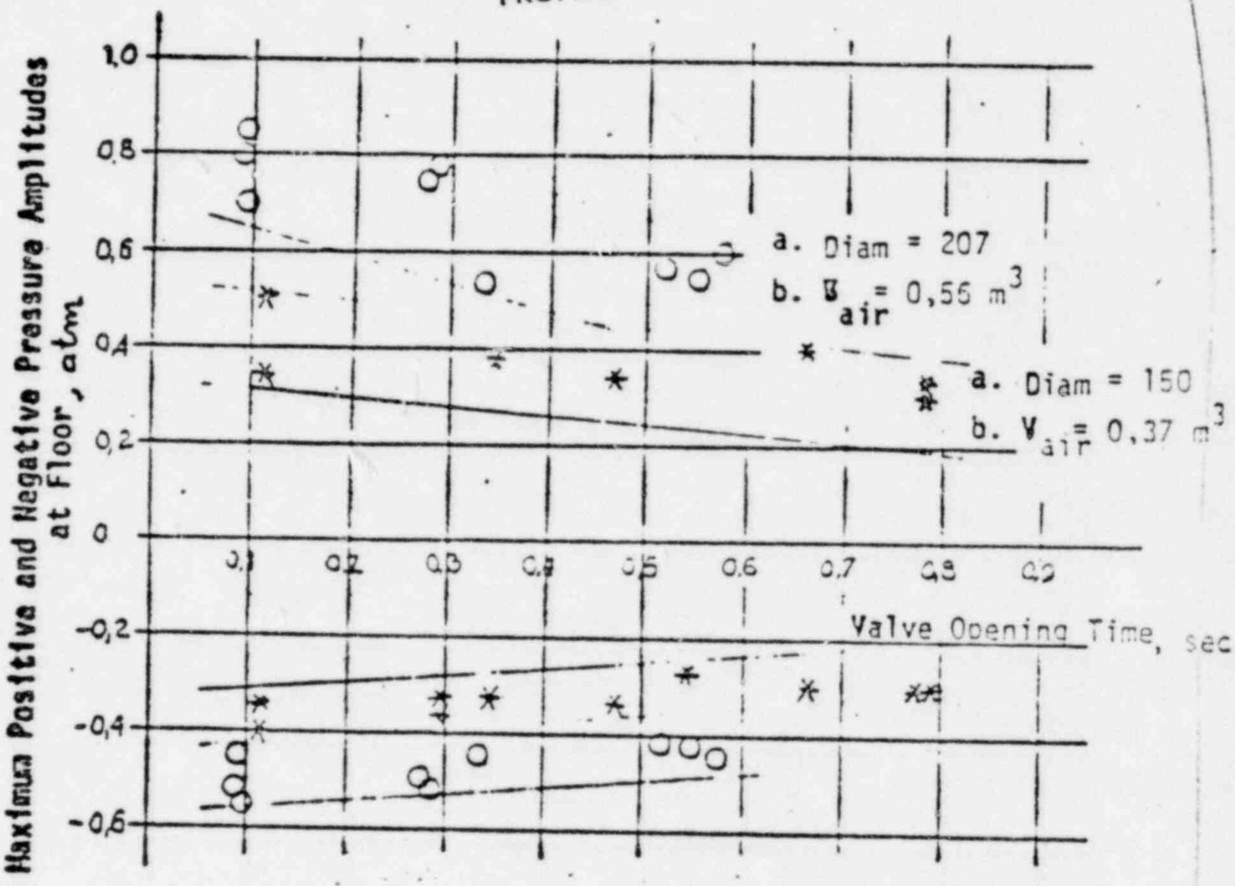

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Fig. B.2.2-3 FLOOR PRESSURES DURING BLOWOUT, SMALL SCALE TEST BLOWOUT TRIALS WITH HS1, 4 PIERCED PIPE NOZZLE, SUBMERSION DEPTH 4 m

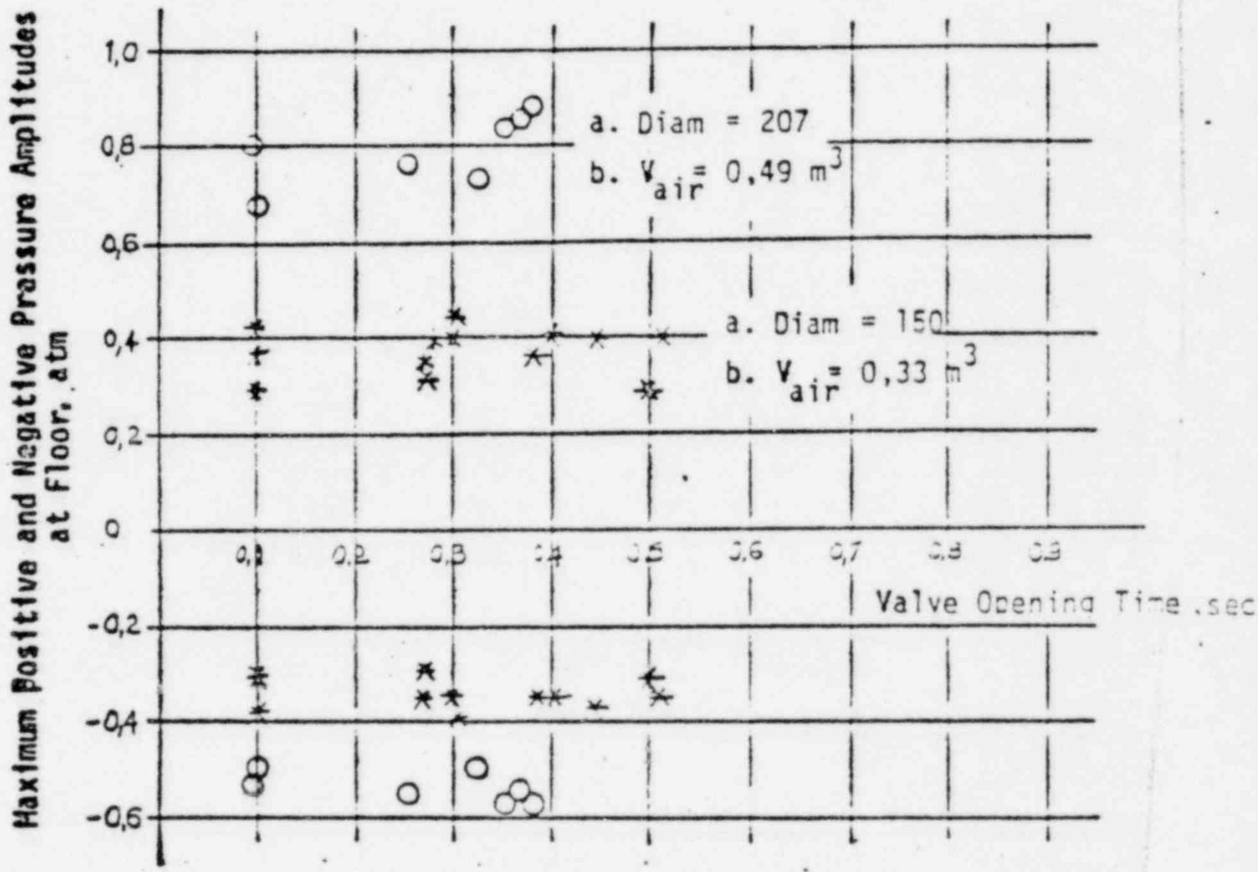

Fig. B.2.2-4 FLOOR PRESSURES DURING BLOWOUT, SMALL SCALE BLOWOUT TRIALS WITH HS1, 4 PIERCED PIPE NOZZLE, SUBMERSION DEPTH = 6 m

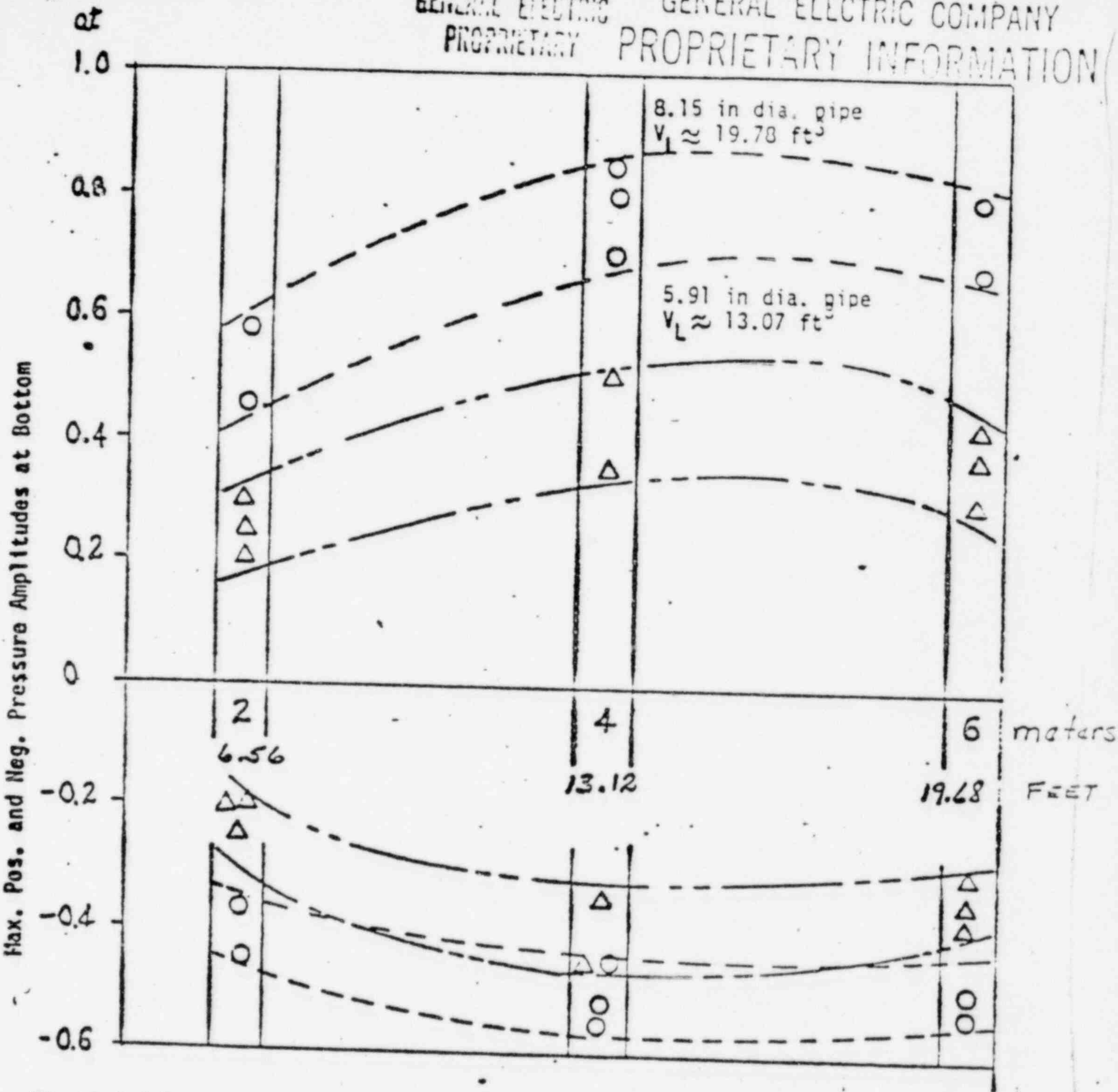

Fig. B.2.4-1 Maximum pressure amplitude at bottom , air clearing test with quencher design
Valve opening time ≈ 100 msec

SMALL SCALE TEST

II LARGE SCALE TEST

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- SCALING PARAMETERS:

	PARAMETER	SPECIFIC VALUES: SMALL SCALE TEST	SPECIFIC VALUES: LARGE SCALE TEST	TRANSFER FACTOR
1.	VOL. OF AIR / QUENCHER C.S. AREA	0.168 m	0.17 m	1.01
2.	FREE WATER AREA / QUENCHER C.S. AREA	3.2	3.3	1.03
3.	VOLUME AT BLOWOUT / QUENCHER HOLE AREA	14.3 m	13.5 m	0.95

- PREDICTION OF LARGE SCALE INITIAL ACTUATION LOADS:

SMALL SCALE LOAD → SCALING FACTORS S.SCALE → L.SCALE → PREDICTED LARGE SCALE LOADS

- COMPARISON OF PREDICTED AND MEASURED LOADS:

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	PRESSURE AMPLITUDE: POSITIVE	PRESSURE AMPLITUDE: NEGATIVE
PREDICTED (MEAN)	6.8 psid	5.4 psid
MEASURED (MEAN)	6.2 psid	4.5 psid

- LARGE SCALE TEST SUBSEQUENT ACTUATION DATA
  - OBSERVED INCREASE IN LOAD OVER INITIAL VALVE OPENING LOAD

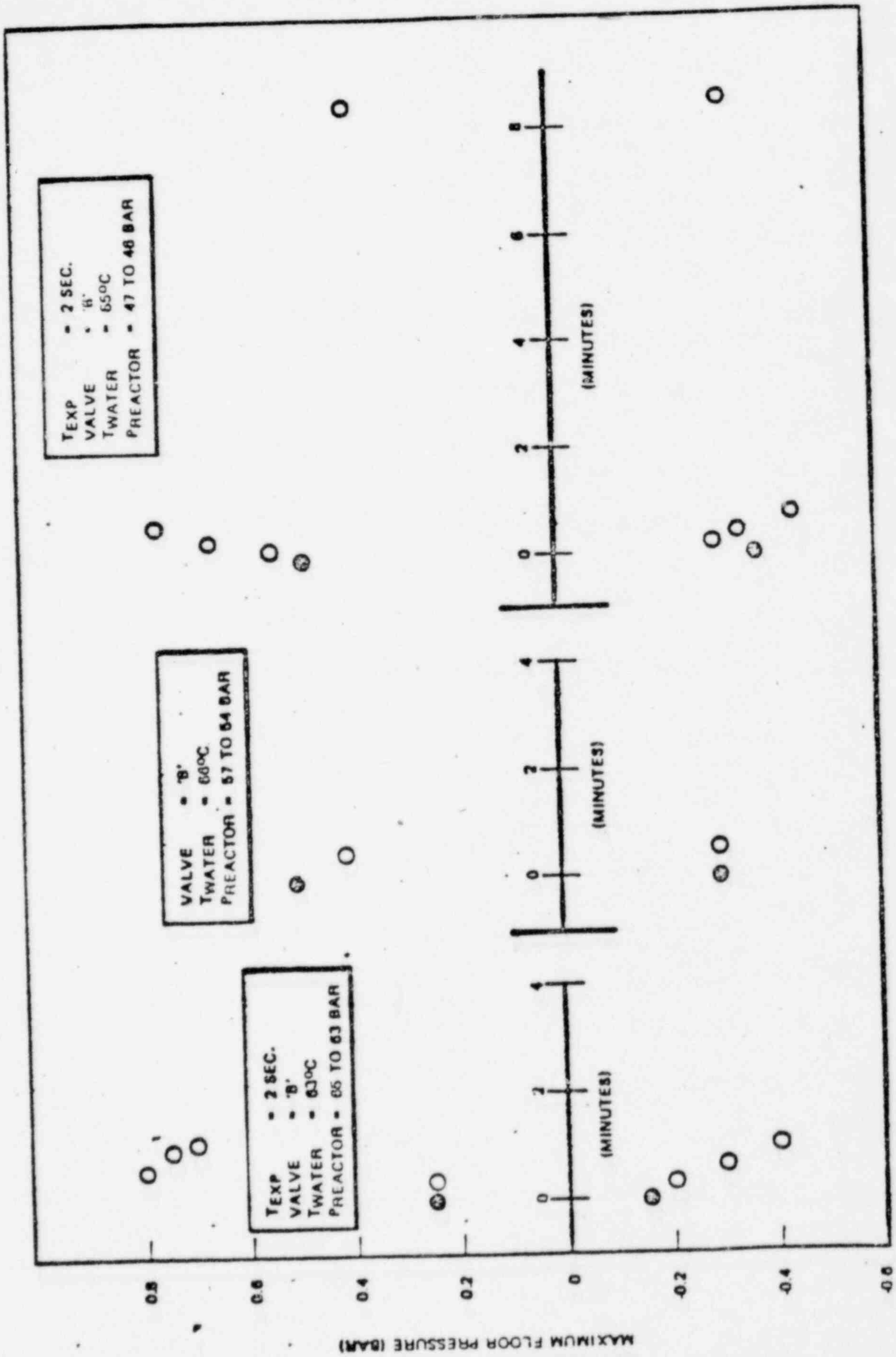

Figure A12.10. Maximum Floor Pressure Versus Subsequent Actuation

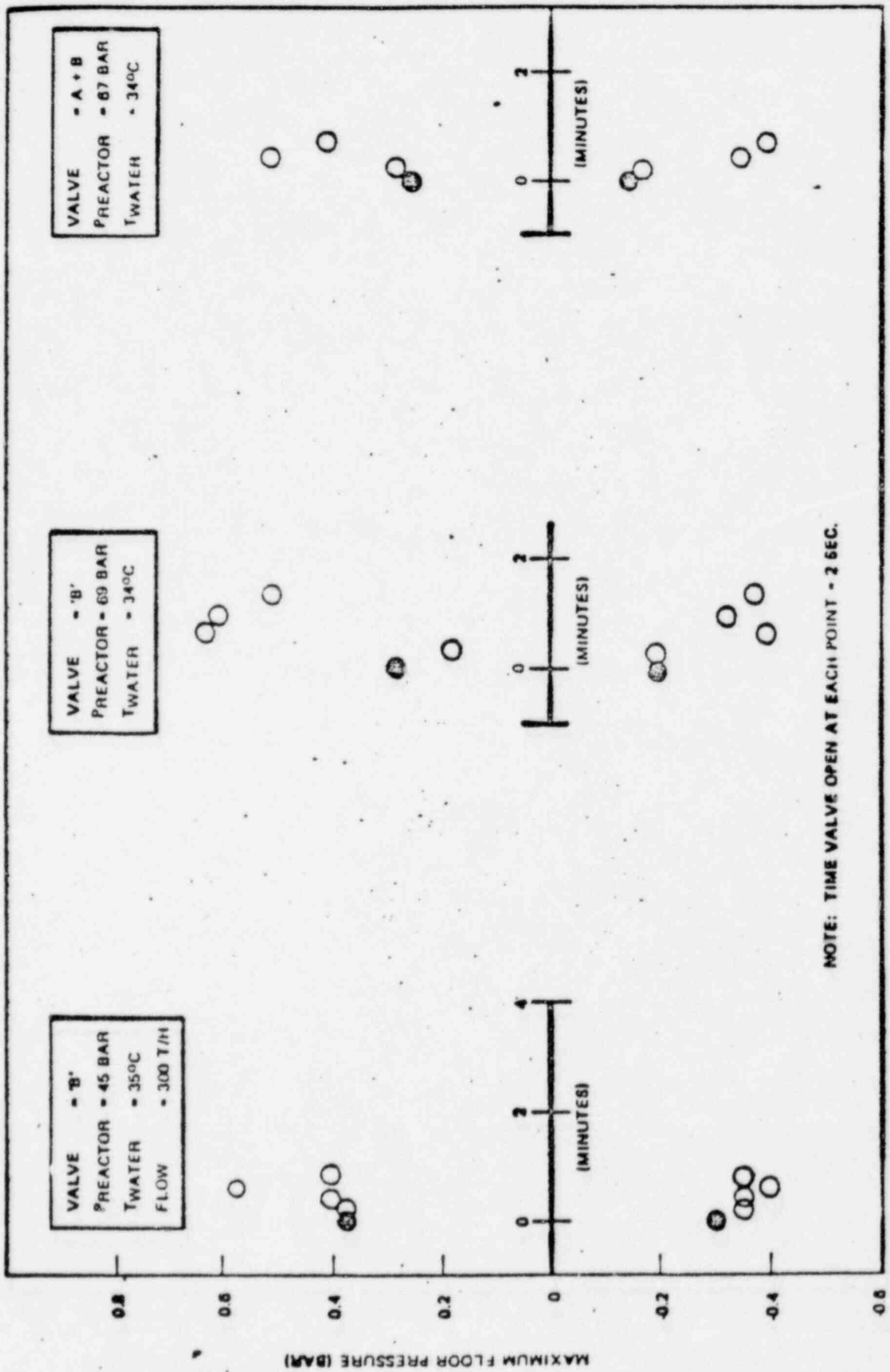

Figure A12.9 Maximum Floor Pressure Versus Subsequent Actuation

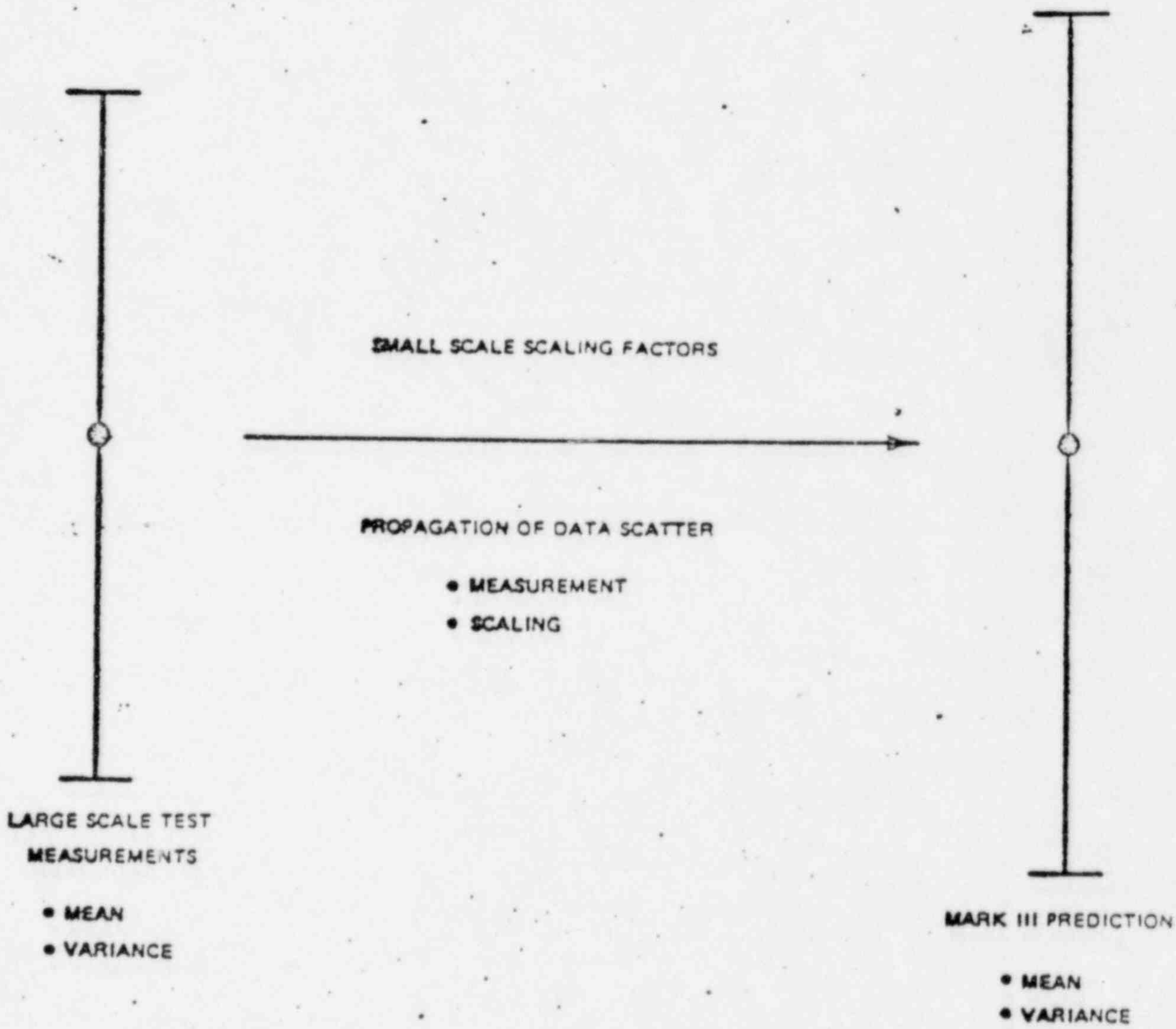

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Figure A12.13. Prediction of Mark III Containment Pressure Load - Relief Valve

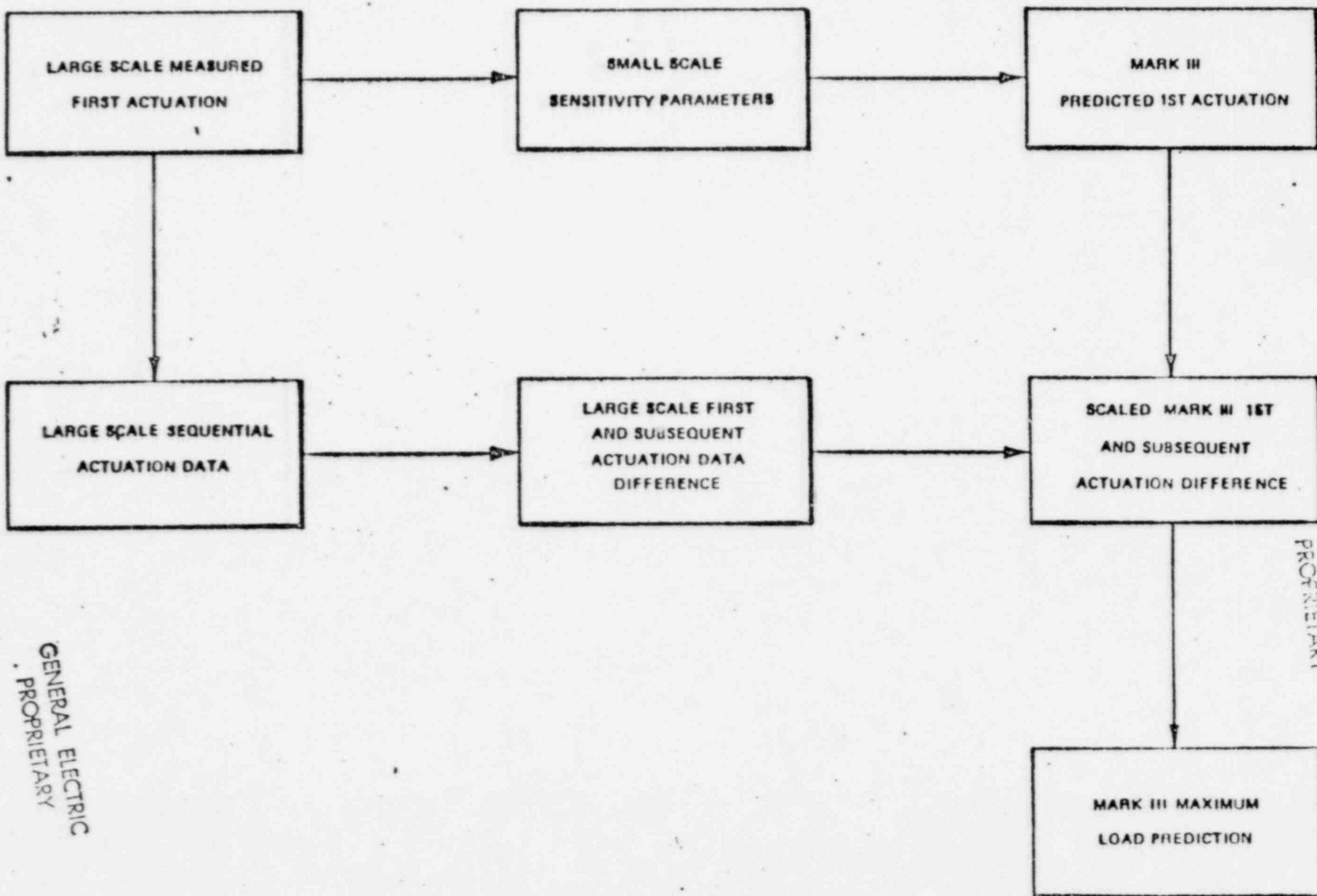


Figure A12.12. Mark III Air Clearing Load Prediction

PREDICTED M III LOADS (FOR 238 STND. PLANT)

DATA FOR:

REACTOR PRESSURE (POS. LOADS) = 1161 psia

REATOR PRESSURE (NEG. LOADS) = 1150 psia

WATER SURFACE AREA = 294.9 ft^2

WATER TEMP = 100° F

S/RV OPENING TIME = 20 MSEC

AIR VOLUME ≃ 55 ft^3

[illegible] PRESSURE AMPLITUDE	POSITIVE LOAD psid	NEGATIVE LOAD psid
MEAN VALUE	11.01	− 6.78
STND. DEVIATION	3.78	− 1.98
75%-75% LOADS	14.828	− 8.770
90%-90% LOADS	19.401	− 11.164
95%-95% LOADS	23.066	− 13.093

GE-NRC MEETING

ASEA ATOM, MARK II, MARK I TEST STATUS

I. ASEA ATOM COOPERATIVE TEST PROGRAM

- OBJECTIVES
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS AND RESULTS

II. MARK II POOL SWELL TESTS - FIRST PHASE

- OBJECTIVES
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS - TENTATIVE SCHEDULE

III. MARK I POOL SWELL 1/12-SCALE TESTS

- OBJECTIVES
- SCALING STUDY
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS AND RESULTS - INCLUDING MOVIE

I. ASEA ATOM COOPERATIVE TEST PROGRAM

- OBJECTIVES
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS AND RESULTS

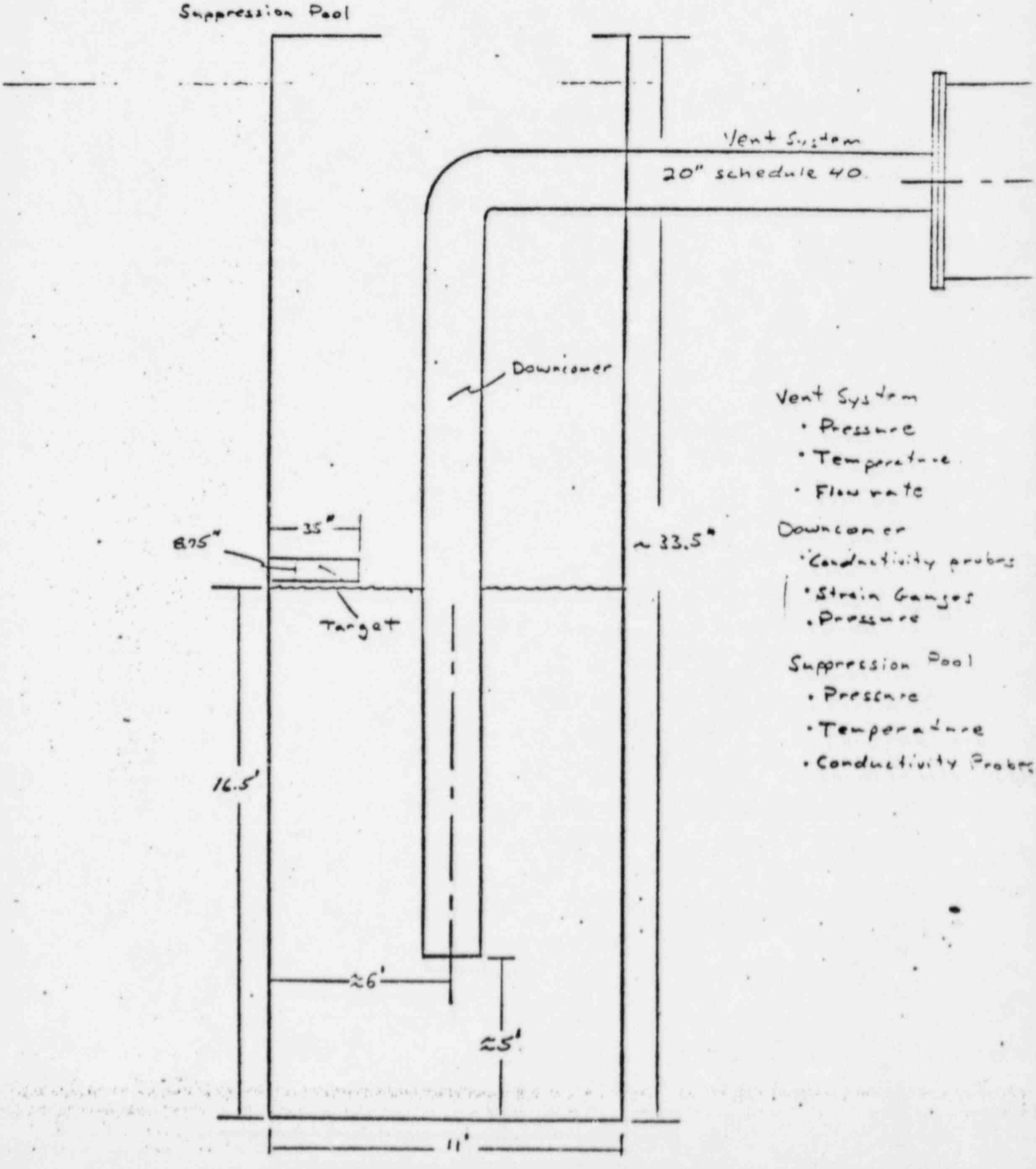
ASEA ATOM COOPERATIVE TEST PROGRAM

OBJECTIVES

- TEST TO CONFIRM DESIGN OF AIR CUSHION DAMPER FOR STRUCTURE LOCATED ABOVE SUPPRESSION POOL
- DETERMINE AIR CUSHION DAMPER VS FLAT STRUCTURE EFFECT

MSCH HICH Test

Facility Design and Instrumentation

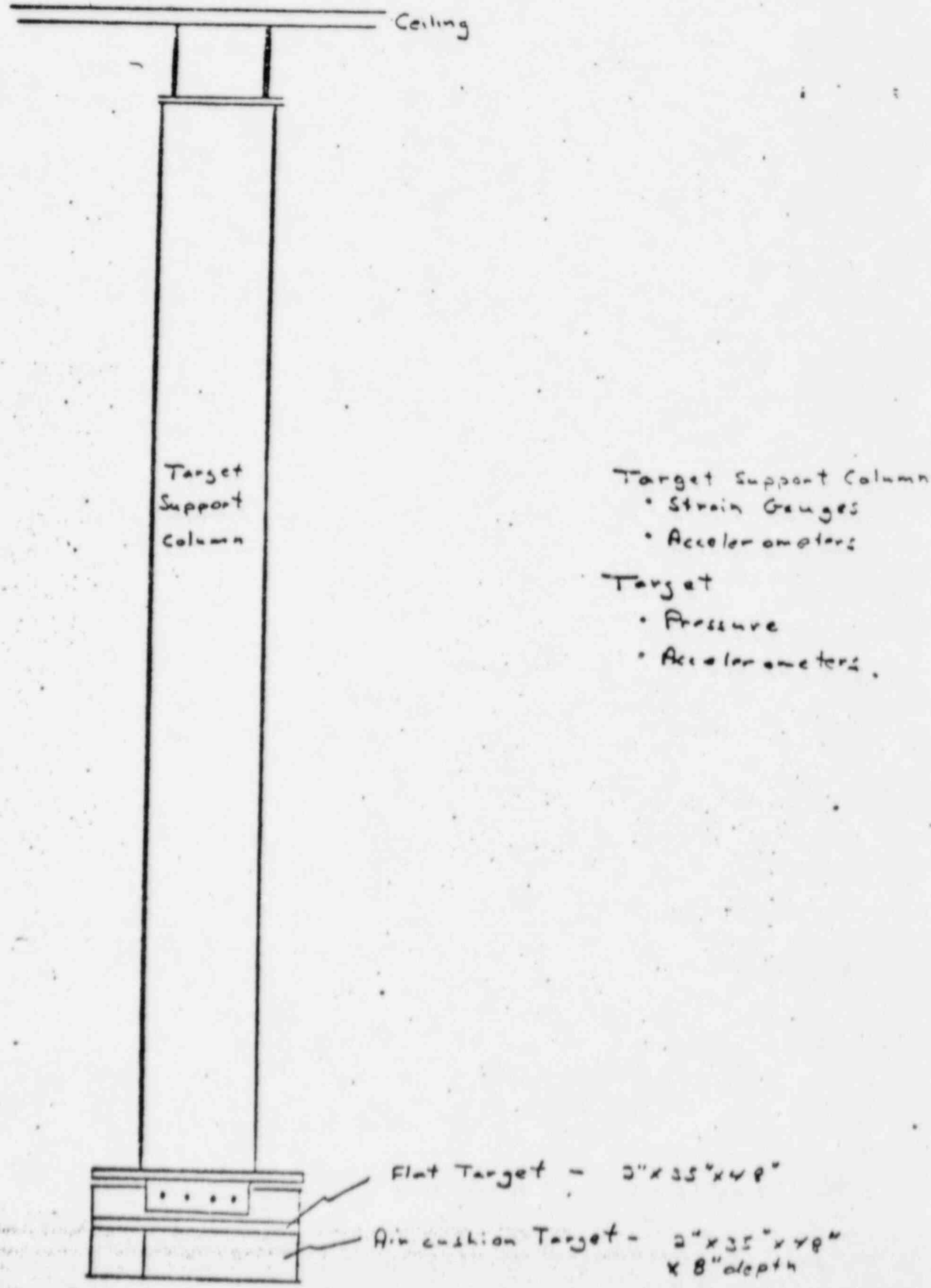


Vent System
- Pressure
- Temperature
- Flow rate

Downcomer
- Conductivity probes
- Strain Gauges
- Pressure

Suppression Pool
- Pressure
- Temperature
- Conductivity Probes

Facility, Design and Instrumentation



ASEA ATOM COOPERATIVE TEST PROGRAM

TEST MATRIX

- FLAT PLATE TARGET - 6 TESTS
  - 2 BLOWDOWN FLOW RESTRICTOR SIZES
  - 3 INITIAL TARGET CLEARANCES

- AIR DAMPER TARGET - 10 TESTS
  - 3 BLOWDOWN FLOW RESTRICTOR SIZES
  - 6 INITIAL SUBMERGENCES

ASEA ATOM COOPERATIVE TEST PROGRAM

TEST STATUS

- TESTS COMPLETED
- DATA REDUCED
- ANALYSIS UNDERWAY
- REPORT IN PROGRESS

ASEA ATOM COOPERATIVE TEST PROGRAM

PRELIMINARY RESULTS

- POOL SURFACE FLAT AT ELEVATION OF TARGET IMPACT
- IMPACT ON FLAT PLATE CHARACTERIZED BY HIGH NARROW PEAK
- AIR DAMPER REDUCED LOCAL IMPACT PRESSURE BY FACTOR OF ~3
- TEST REPEATABILITY WAS WITHIN ±10%
- IMPACT MEASUREMENTS SUPPORTED DESIGN CALCULATIONS

II. MARK II POOL SWELL TEST
(FIRST PHASE)

- OBJECTIVES
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS - TENTATIVE SCHEDULE

MARK II POOL SWELL TEST

OBJECTIVES

1. A. MEASURE AND EVALUATE VELOCITY, SLUG THICKNESS, AND HEIGHT OF LIQUID SWELL OVER A RANGE OF BLOWDOWN CONDITIONS IN ORDER TO PROVIDE DATA BASE THAT CAN BE USED TO SUPPORT ANALYSES OF THE MARK II POOL SWELL TRANSIENT

   B. MEASURE BUBBLE BREAKTHROUGH HEIGHT

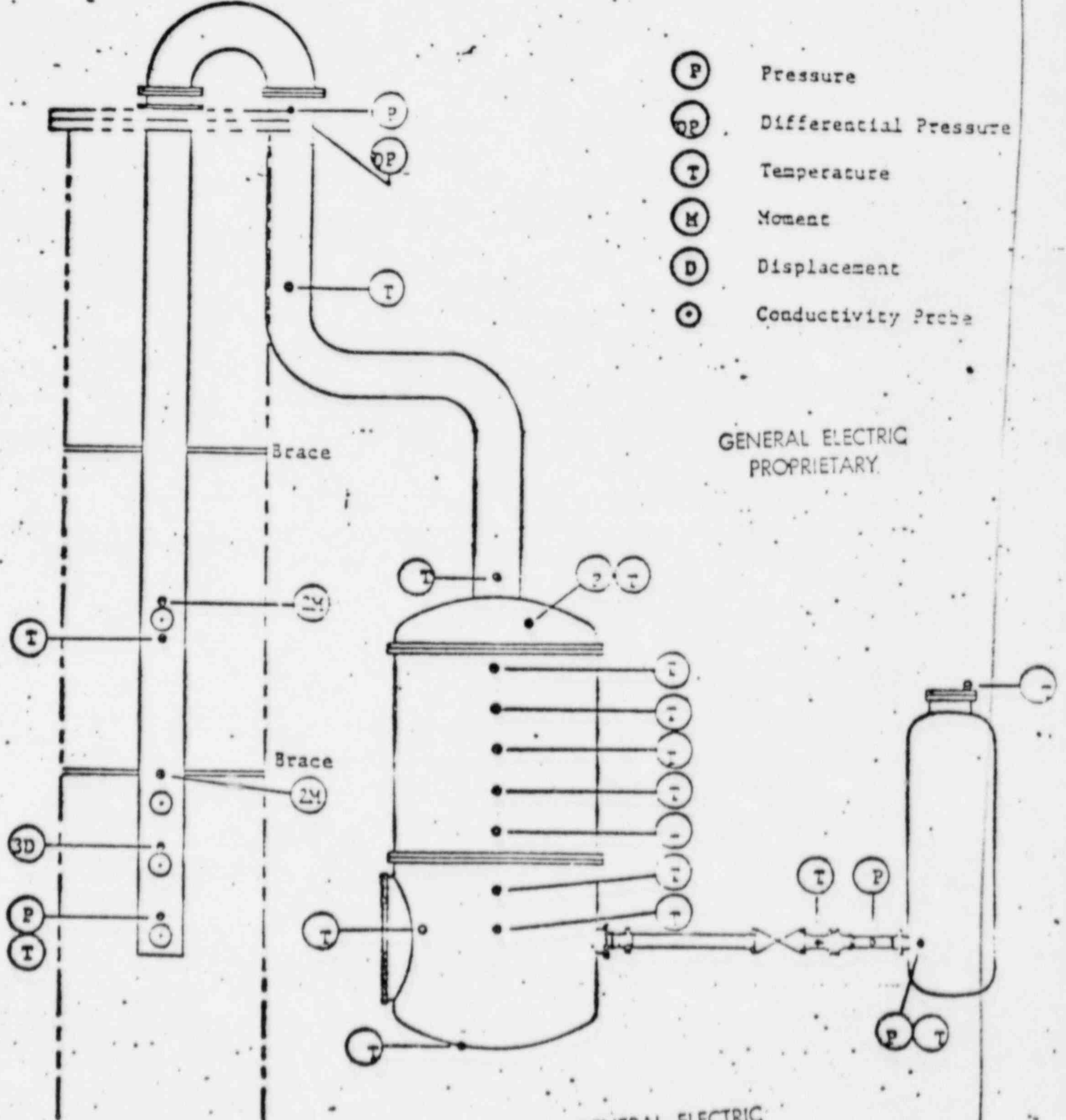
2. EVALUATE THE EFFECT OF WETWELL BACK PRESSURE ON POOL SWELL

3. MEASURE WETWELL PRESSURE DURING POOL SWELL TO CHECK ASSUMPTIONS ON WETWELL TO DRYWELL DIAPHRAGM FLOOR LOADING

4. MEASURE FLUID/FROTH INTERACTION PRESSURE AT THE POOL CEILING, IF ANY

5. MEASUREMENT OF LATERAL LOADING ON VENT PIPING

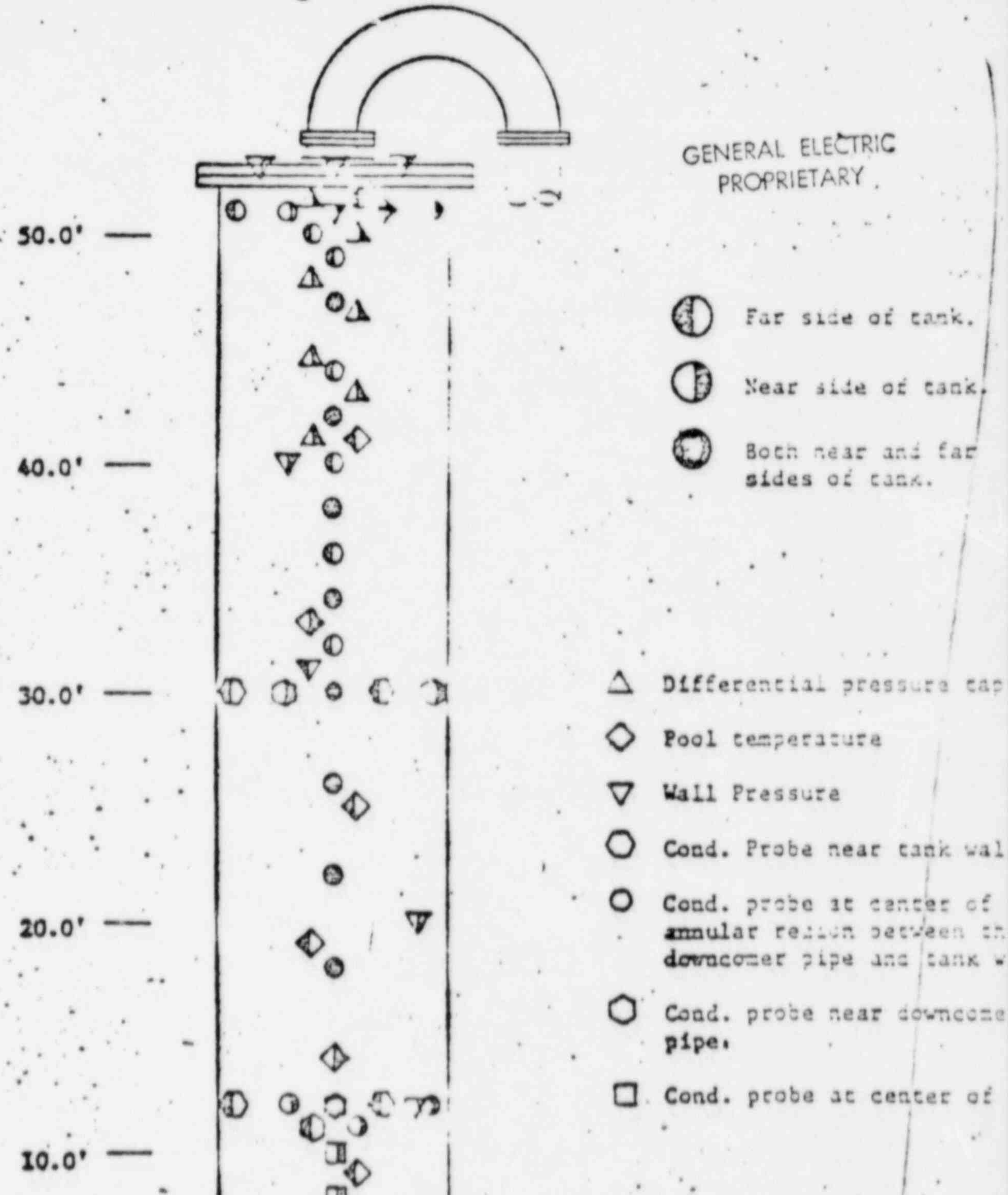
Mark II Pool Swell Test
Facility Design and Instrumentation



Steam Generator, Drywell & Vent System

Facility Design and Instrumentation

GENERAL ELECTRIC PROPRIETARY



GENERAL ELECTRIC PROPRIETARY

Suppression Pool

TENTATIVE MARK II POOL SWELL TEST MATRIX

For 2 1/2" Diameter Blowdown Venturi

Submergence (ft)	24" Downcomer		20" Downcomer	
	Open Pool	Closed Pool	Open Pool	Closed Pool
9'	x	x	x	x
11'	x	x	x	x
13.5'	x	x	x	x

For 3" Diameter Blowdown Venturi

9'	x	x	x	x
11'	x	x	x	x
13.5'	x	x	x	x

Total number of tests = 24

III. MARK II POOL SWELL 1/12 SCALE TESTS

- OBJECTIVES
- SCALING RELATIONSHIPS
- FACILITY DESIGN AND INSTRUMENTATION
- TEST MATRIX
- TEST STATUS AND RESULTS INCLUDING MOVIE

MARK I 1/12 SCALE TEST
OBJECTIVES

- VISUALLY OBSERVE POOL SWELL BEHAVIOR FOR A RANGE OF SCALED LOCA CONDITIONS.
- MEASURE POOL SWELL VELOCITY AT RING HEADER.
- ESTIMATE BREAK THROUGH LOCATION
- MEASURE NET UPWARD AND DOWNWARD TORUS FORCES DURING POOL SWELL PHASE OF BLOWDOWN.

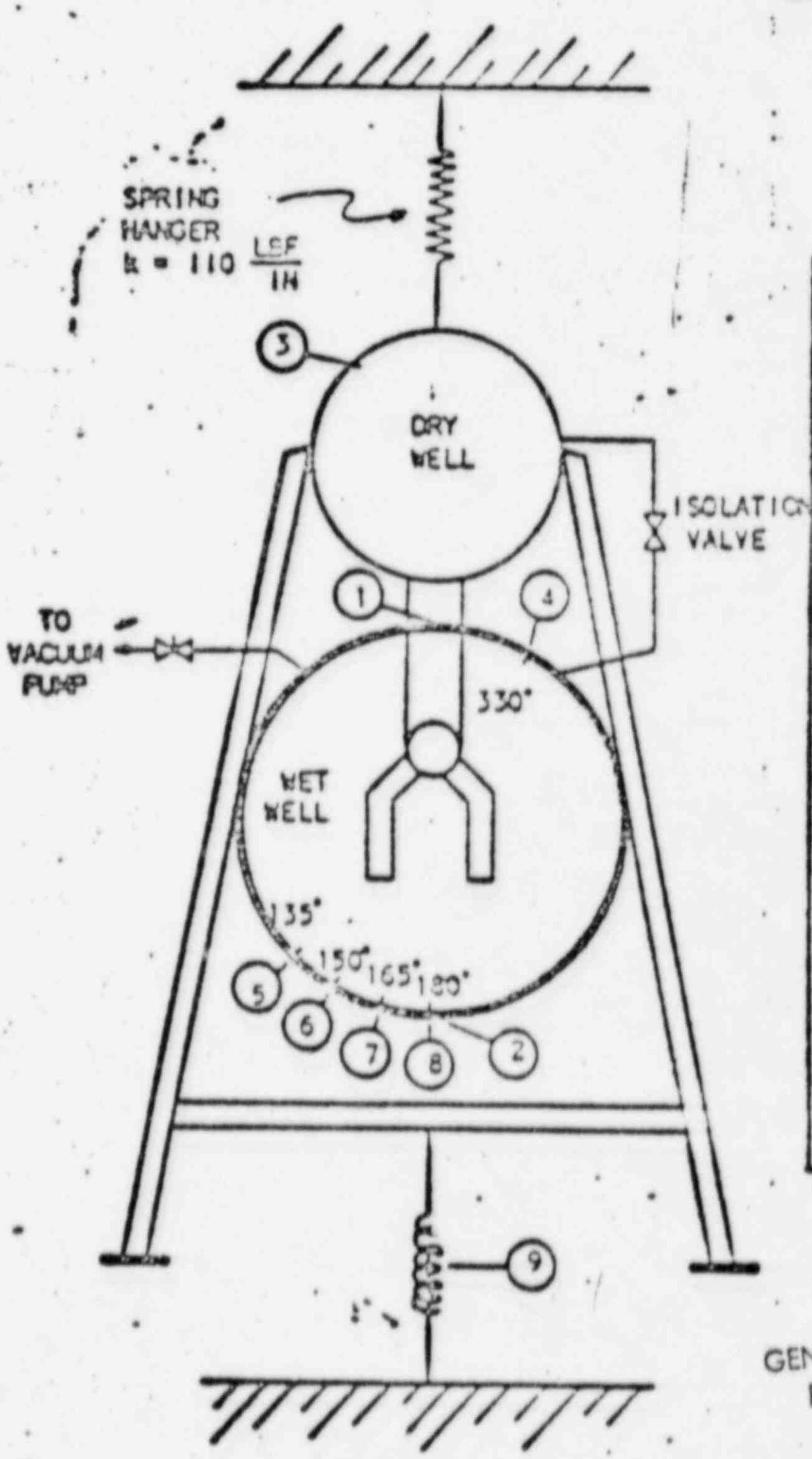
MARK I 1/12 SCALE TEST

SCALING RELATIONSHIPS

- VELOCITY $\frac{V_{SCALE}}{V_{FULL\ SCALE}} = \sqrt{\frac{L_{SCALE}}{L_{FULL\ SCALE}}}$
- PRESSURE $\frac{P_{SCALE}}{P_{FULL\ SCALE}} = \frac{L_{SCALE}}{L_{FULL\ SCALE}}$
- TIME $\frac{T_{SCALE}}{T_{FULL\ SCALE}} = \sqrt{\frac{L_{SCALE}}{L_{FULL\ SCALE}}}$
- $\frac{L_{SCALE}}{L_{FULL\ SCALE}}$ SCALE FACTOR = 1/12

SCHEMATIC OF 1/12 SCALE MARK I
TEST SECTION AND INSTRUMENTATION

GENERAL ELECTRIC
PROPRIETARY



INSTRUMENTATION

LOCATION	MEASUREMENT DESCRIPTION
1	ACCELERATION
2	ACCELERATION
3	DRY WELL PRESSURE
4	WET WELL PRESSURE (330°)
5	WET WELL PRESSURE (135°)
6	WET WELL PRESSURE (150°)
7	WET WELL PRESSURE (165°)
8	WET WELL PRESSURE (180°)
9	DISPLACEMENT

GENERAL ELECTRIC
PROPRIETARY

GENERAL ELECTRIC PROPRIETARY

MARK I 1/12 SCALE TEST MATRIX

RUN	DATE	INITIAL [illegible] (IN)	NOZZLE [illegible] (IN)	INITIAL PRESSURE (PSIA)	CAMERA SPEED (FRAMES/SEC)	CAMERA POSITION (FT)
3002-1	SHAKE DOWN TEST					
3002-2	8/4/75	4	0.622	1.2	1000	22
3		6				
4		3				
5		4			2000	12
6		6				
7		3				
8*	8/5/75	4	0.811		1000	22
9*						
10						
11					2000	12
12			0.468			
13					1000	22

*WITH SUPPORTS TO PREVENT DOWNWARD MOTION.

GENERAL ELECTRIC PROPRIETARY

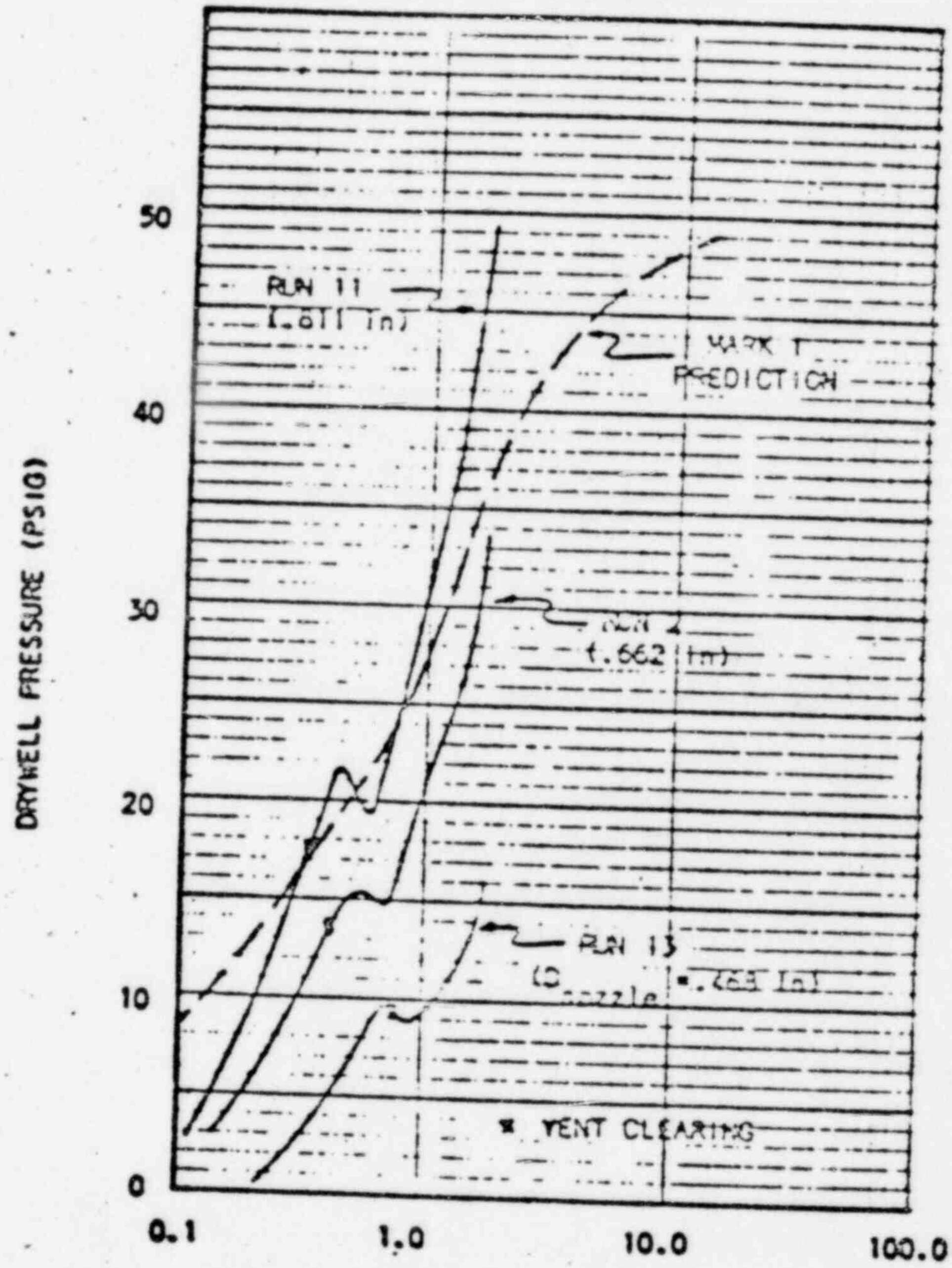
MARK I 1/12 SCALE TEST
STATUS

- TESTS COMPLETE
- DATA REDUCED
- ANALYSIS, INTERPRETATION AND APPLICATION UNDERWAY

TEST UNCERTAINTIES

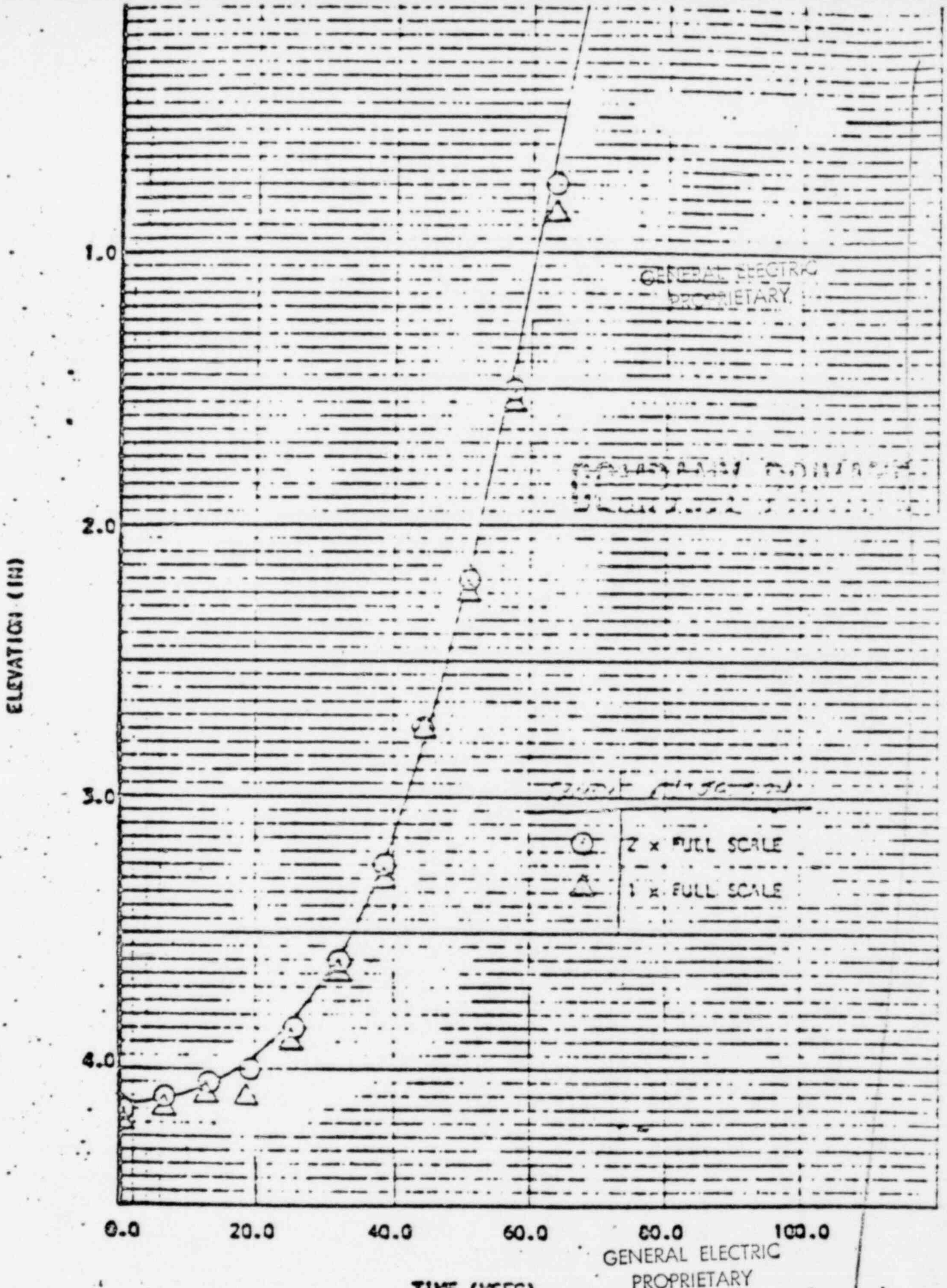
1. DRYWELL PRESSURE (INITIAL AND TRANSIENT)
2. VENT RESISTANCE
3. HIGH WATER LEVEL IN VENTS

GENERAL ELECTRIC
PROPRIETARY



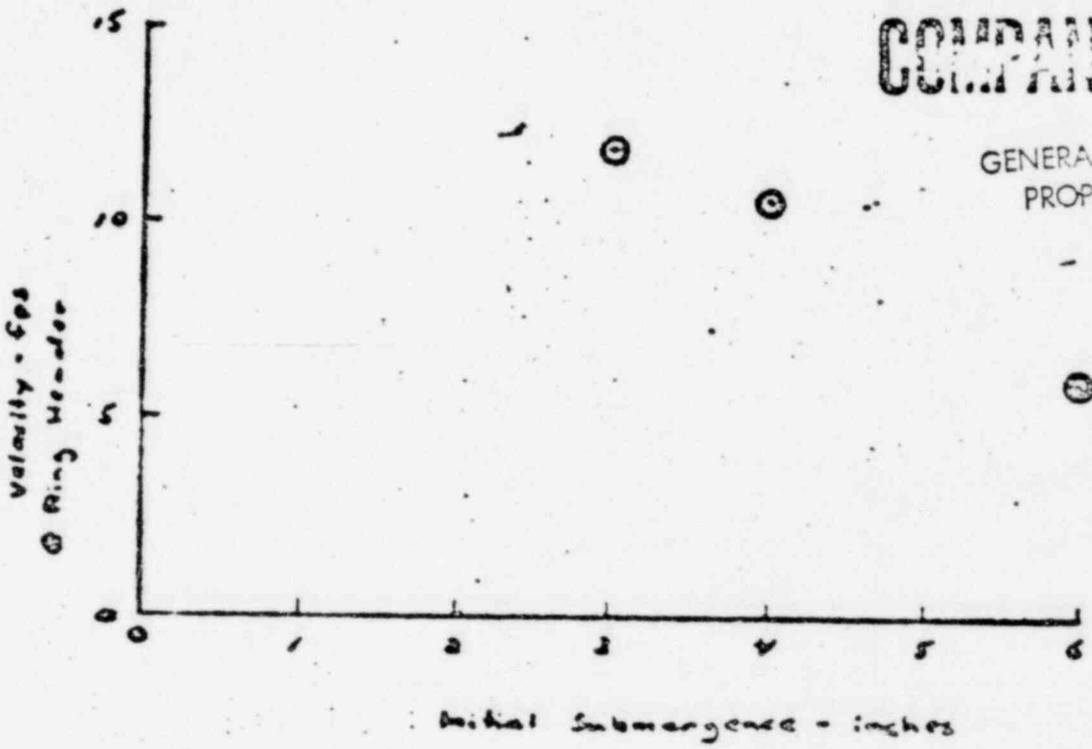
GENERAL ELECTRIC
PROPRIETARY

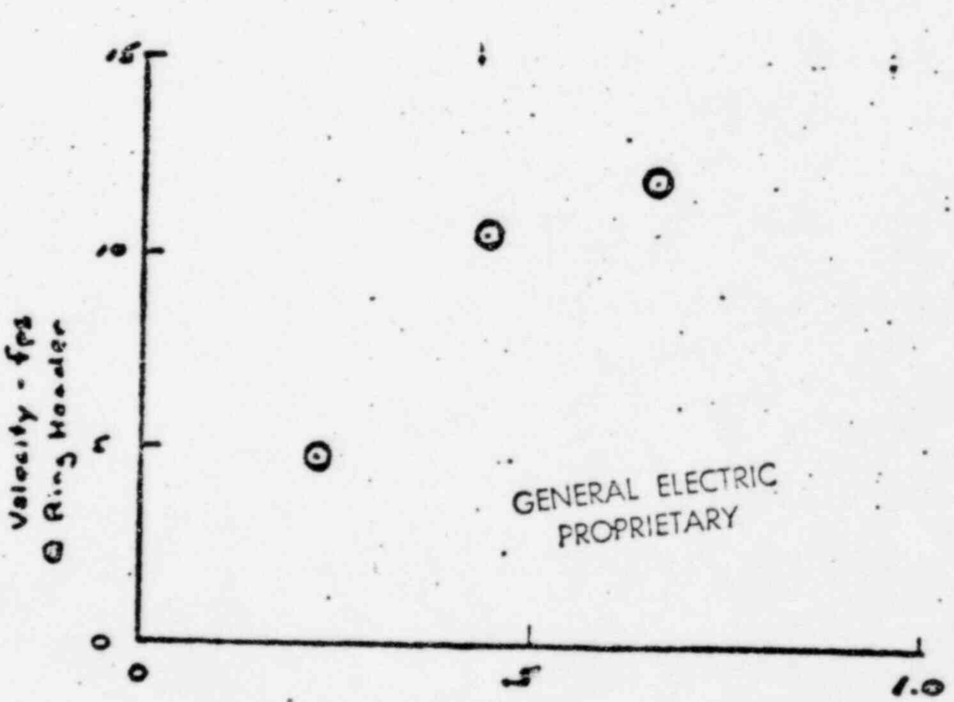
TIME (SEC)



POOL SURFACE DISPLACEMENT VS. TIME
(Not Corrected For Test Uncertainities)

Mark I 1/12 Scale Test
Velocity

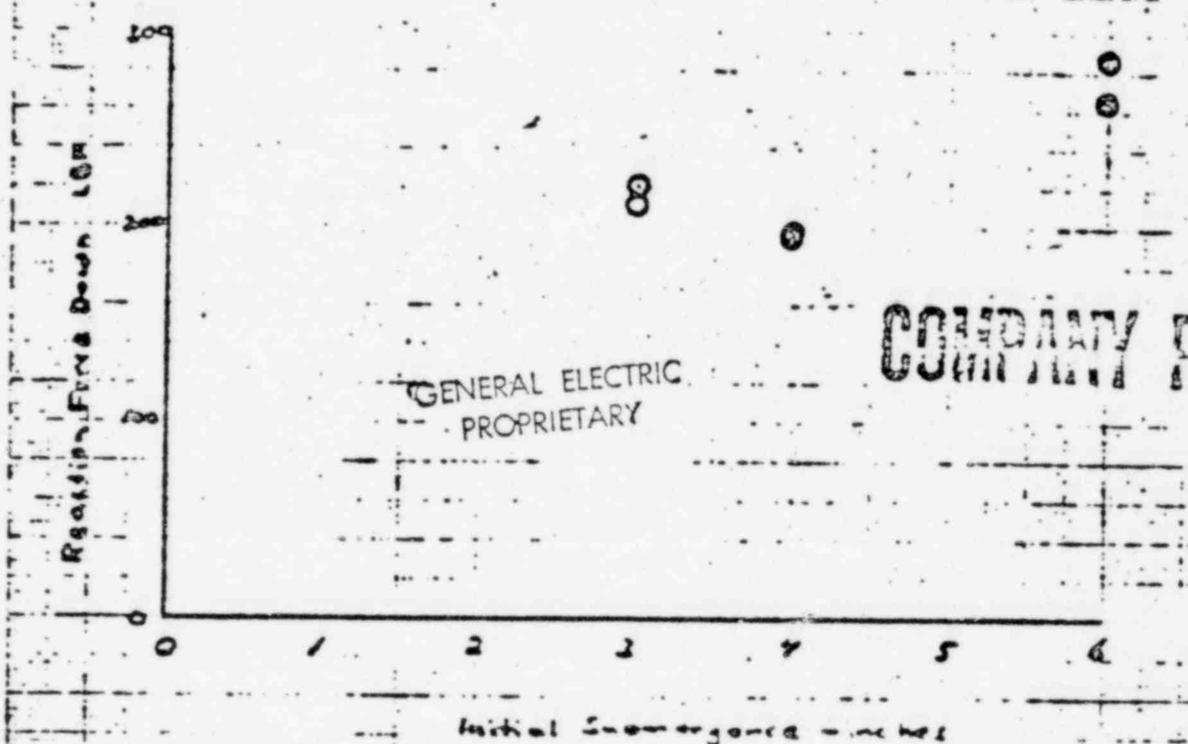


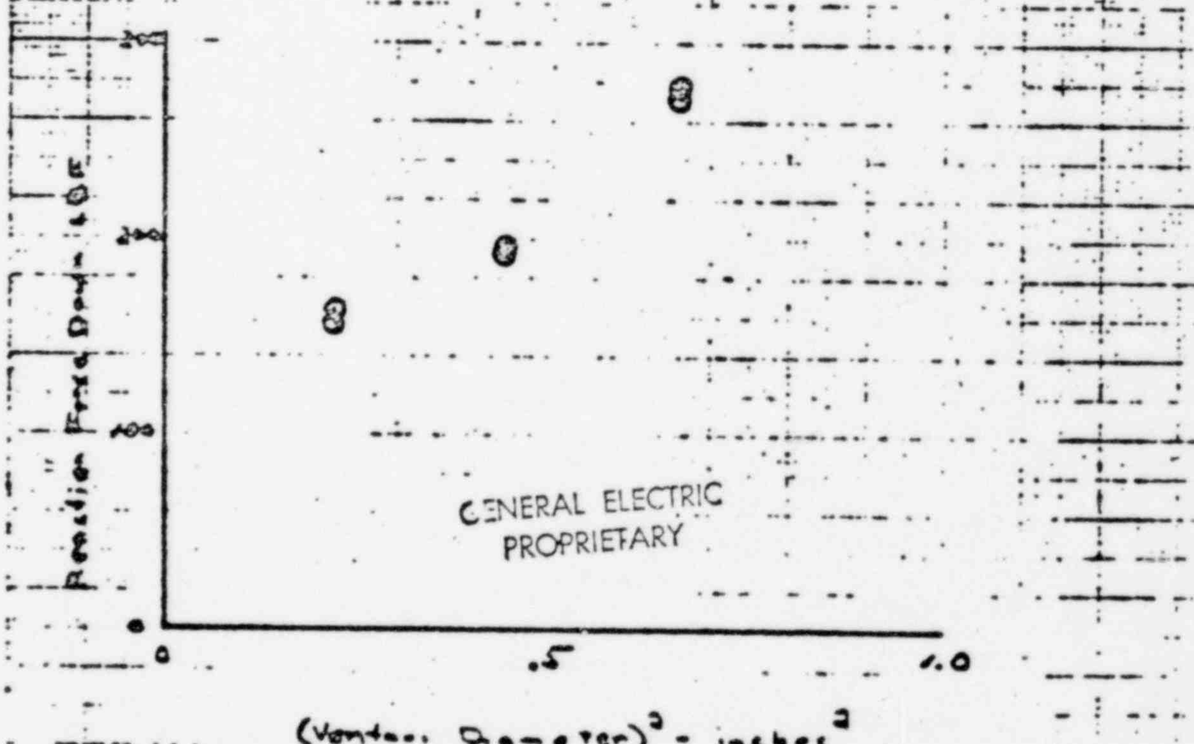


GENERAL ELECTRIC PROPRIETARY

(Not corrected for test uncertainities)

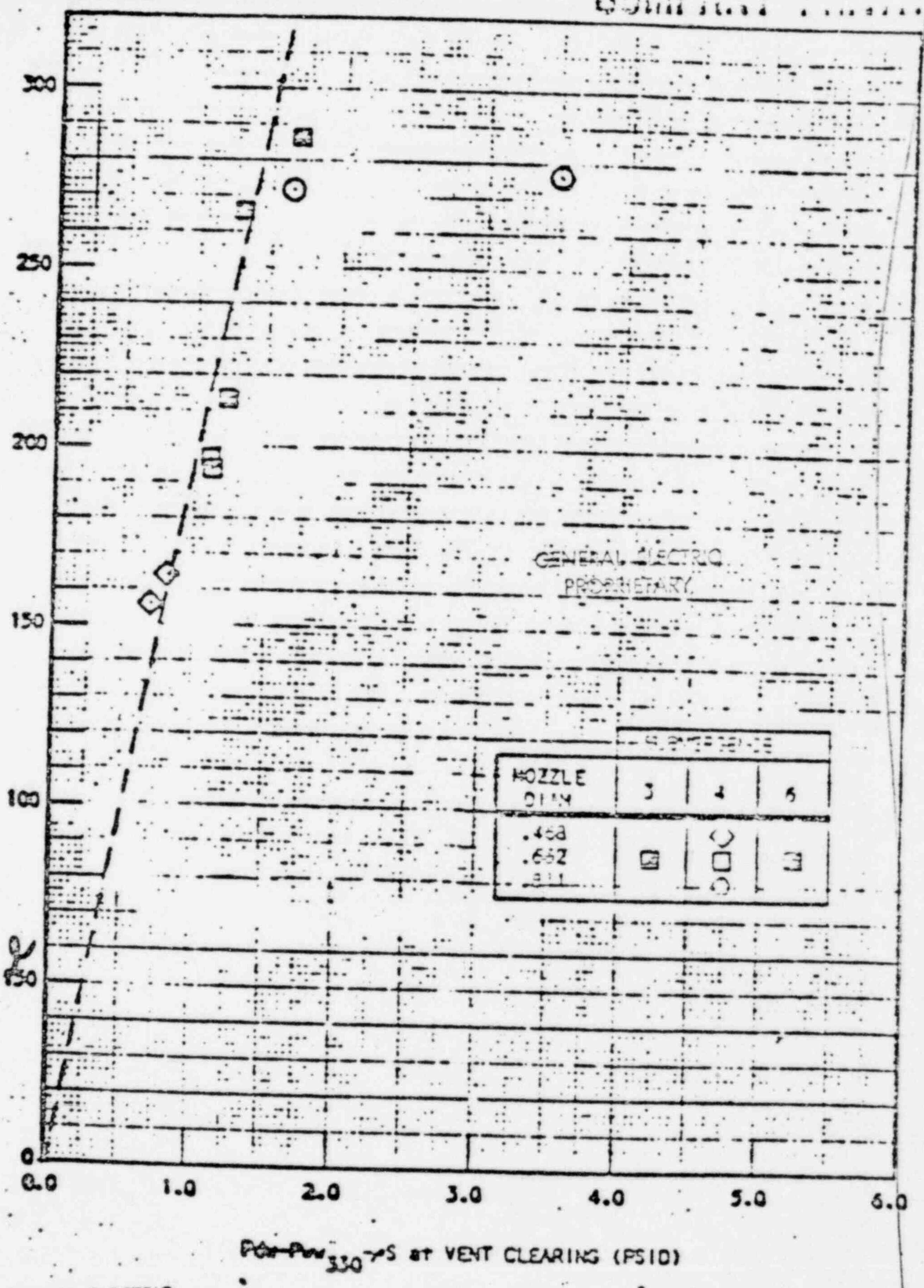
Mark I 1/2 Scale Test
Reaction Force Down





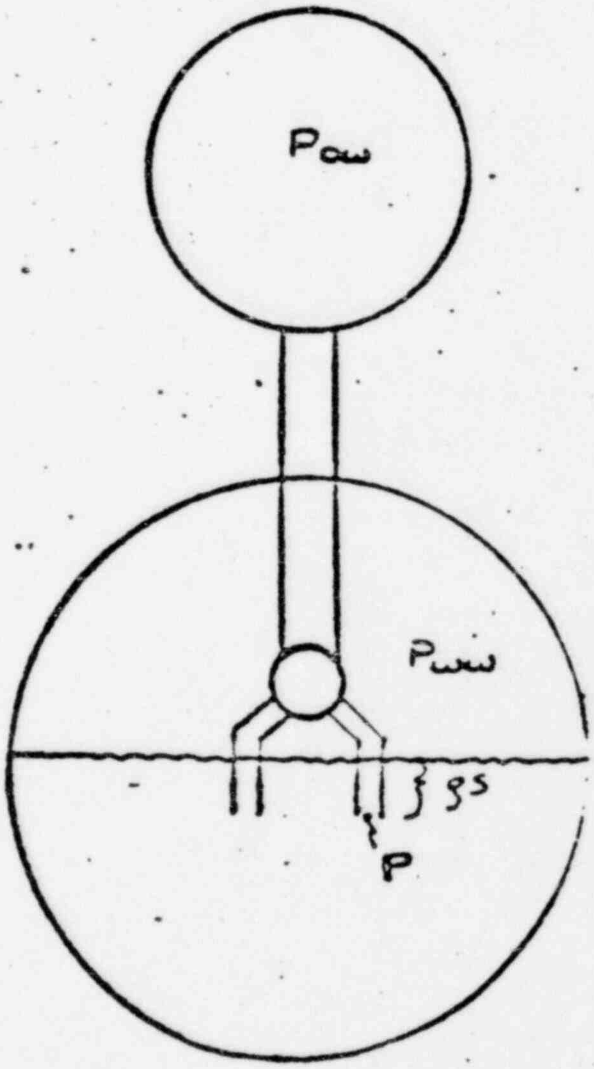
Reaction Force Down

COMPANY PRIVATE



GENERAL ELECTRIC
PROPRIETARY

Mark I 1/12 Scale Test

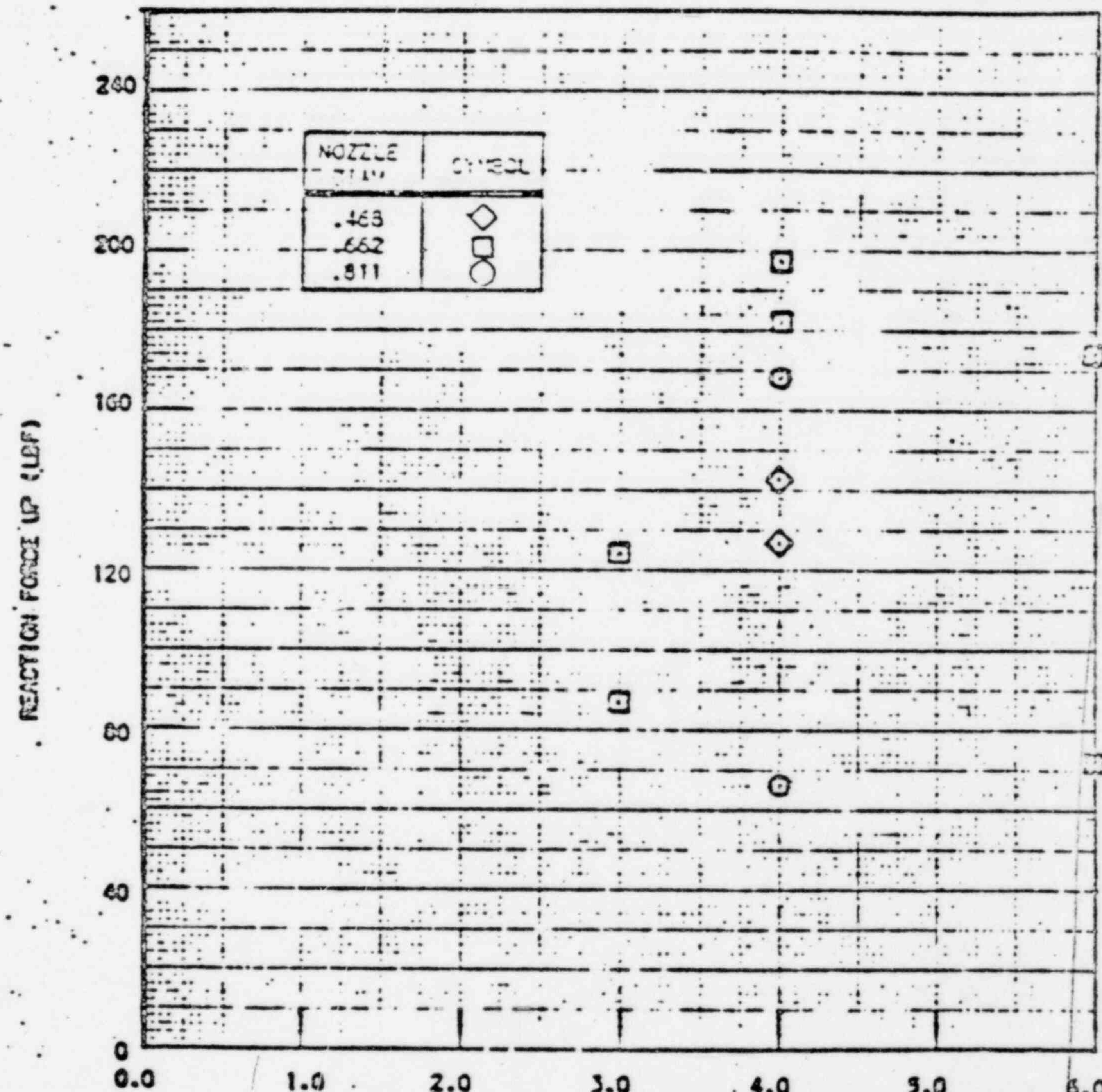


$P = P_{DW} - P_{WW} - \rho s$ = ΔP @ vent exit

Mark I 1/12 Scale Test
Reaction Force UP

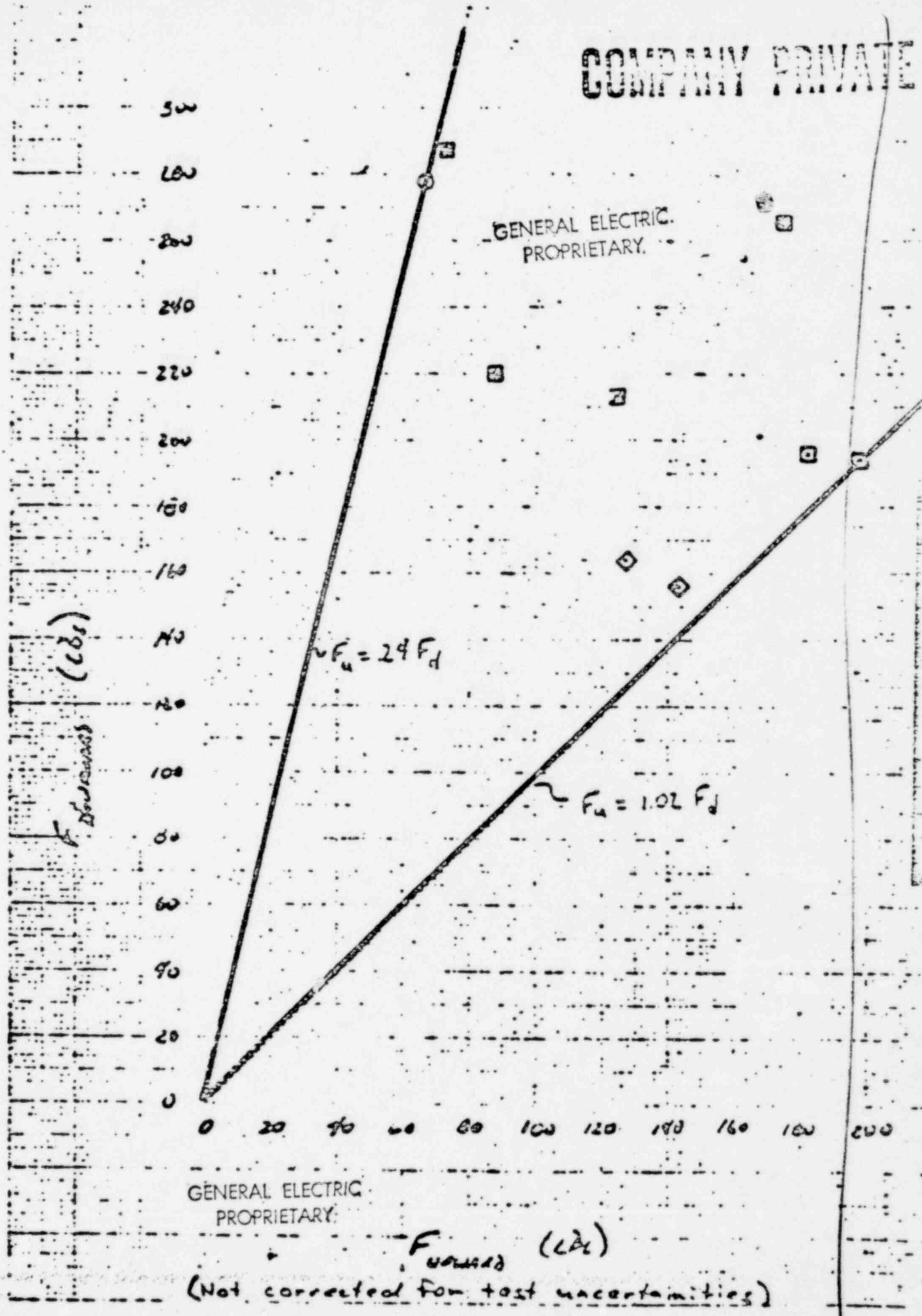
GENERAL ELECTRIC
PROPRIETARY

COMPANY PRIVATE



(Not corrected for test uncertainities)

GENERAL ELECTRIC
PROPRIETARY


GENERAL ELECTRIC PROPRIETARY
$F_u = 2.9 F_d$
$F_u = 1.02 F_d$
$F_{downward}$ (lbs)
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
0 20 40 60 80 100 120 140 160 180 200
GENERAL ELECTRIC PROPRIETARY
F_{upward} (lbs)
(Not corrected for test uncertainties)

WORK TO BE DONE

FURTHER ANALYSIS OF DATA

MODELING CONSIDERATIONS

COMPARISON OF GE AND SRI TEST RESULTS

MODELING

A POWERFUL SOLUTION METHOD

* OFTEN ECONOMICAL
* SOMETIMES THE ONLY WAY

PURPOSE :

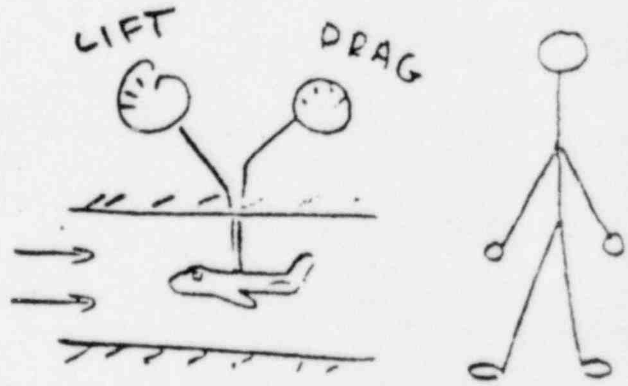
* TO SUMMARIZE WHAT MODELING INVOLVES
* TO DESCRIBE TECHNIQUES FOR DETERMINING MODELING LAWS
* TO APPLY MODELING METHODS IN A SOLUTION OF CONTAINMENT POOL MOTION CAUSED BY DBA.

DEFINITION OF MODELING:

MODELING IS THE PROCESS OF SPECIFYING A SMALL SCALE TEST THAT WILL PROVIDE MEASURABLE BEHAVIOR, WHICH WILL DUPLICATE EXPECTED FULL SCALE BEHAVIOR IF LENGTH, TIME, AND OTHER MEASURABLES ARE MULTIPLIED BY APPROPRIATE SCALE FACTORS.

FOR EXAMPLE:

FULL SCALE

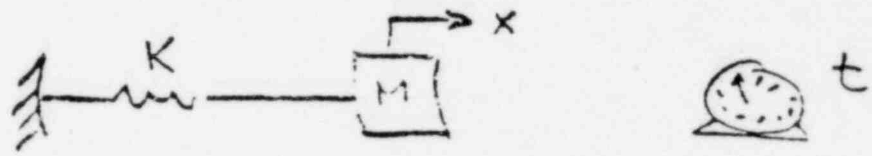


SMALL SCALE

WHEN MODELING IS NOT NEEDED

THE PROBLEM PHENOMENA CAN BE FORMULATED AND A SATISFACTORY ANALYTICAL SOLUTION CAN BE OBTAINED FOR THE VARIABLES REQUIRED

EXAMPLE :



GOVERNING EQUATION

$$\frac{d^2 x}{dt^2} + \frac{K}{M} x = 0$$

INITIAL CONDITIONS

$$t = 0$$

$$x = x_o$$

$$\frac{dx}{dt} = V_o$$

SOLUTION

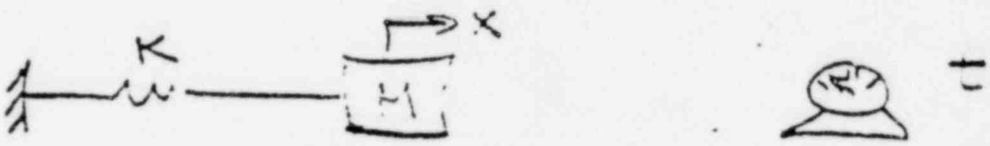
$$\underline{X} = X_o \cos\sqrt{\frac{K}{M}}\, t + V_o\sqrt{\frac{M}{K}}\, \sin\sqrt{\frac{K}{M}}\, t$$

MODELING **NOT** NEEDED

WHEN MODELING IS USEFUL

① PROBLEM PHENOMENA CAN BE FORMULATED, BUT A SATISFACTORY ANALYTICAL SOLUTION CANNOT BE OBTAINED FOR THE REQUIRED VARIABLES.

EXAMPLE:



FORMULATION:

GOVERNING EQUATION

$$\frac{d^2x}{dt^2} + \frac{K}{M}x = 0$$

INITIAL CONDITIONS

$$t = 0$$
$$x = x_0$$
$$\frac{dx}{dt} = V_0$$

SUPPOSE CANNOT SOLVE ANALYTICALLY.

NON-DIMENSIONALIZE THE GOVERNING EQUATION AND INITIAL CONDITIONS

$$X^* = \frac{X}{X_0} \quad , \quad t^* = t\sqrt{\frac{K}{M}}$$

G.EQ. $$\frac{d^2X^*}{dt^{*2}} + X^* = 0$$

I.C. $$t^* = 0$$

$$X^* = 1$$

$$\frac{dX^*}{dt^*} = \frac{V_0}{X_0}\sqrt{\frac{M}{K}}$$

WITHOUT SOLVING, CONCLUDE THAT ANY TWO SYSTEMS WILL GIVE THE SAME NON-DIMENSIONAL SOLUTION

$$X^* = f(t^*)$$

IF THE MODELING PARAMETER $\frac{V_0}{X_0}\sqrt{\frac{M}{K}}$ IS IDENTICAL IN EACH.

THEN . . .

$$X^* = \frac{X_{MODEL}}{X_{0\,MODEL}} = \frac{X_{FULL}}{X_{0\,FULL}}$$

$$t^* = t_{MODEL}\sqrt{\frac{K_{MODEL}}{M_{MODEL}}} = t_{FULL}\sqrt{\frac{K_{FULL}}{M_{FULL}}}$$

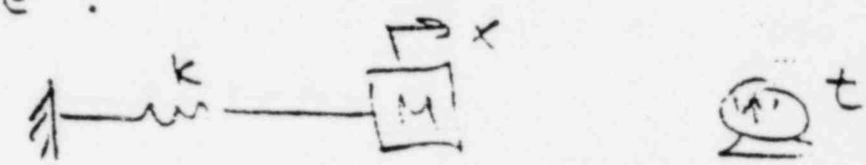
$$X_{FULL} = X_{MODEL}\left(\frac{X_{0\,FULL}}{X_{0\,MODEL}}\right)$$

$$t_{FULL} = t_{MODEL}\sqrt{\frac{M_{FULL}}{M_{MODEL}} \cdot \frac{K_{MODEL}}{K_{FULL}}}$$

ALSO, MODELING IS USEFUL IF

(2) PROBLEM PHENOMENA CANNOT EVEN BE FORMULATED

EXAMPLE:



LIST VARIABLES & PARAMETERS WHICH PROBABLY AFFECT BEHAVIOR

x
t
K
M
x_0
V_0

BUCKINGHAM π-THEOREM LEADS TO:

$$\frac{x}{x_0}, \quad t\sqrt{\frac{K}{M}}, \quad \frac{V_0}{x_0}\sqrt{\frac{M}{K}}$$

NON-DIMENSIONAL GROUPS

DISADVANTAGES OF π-THEOREM:

* MAY INCLUDE TOO FEW OR TOO MANY EFFECTS.
* EFFECTIVENESS DEPENDS ON USER.
* DOES NOT SHOW WHICH MODELING PARAMETERS ARE IMPORTANT AND WHICH ARE NOT.

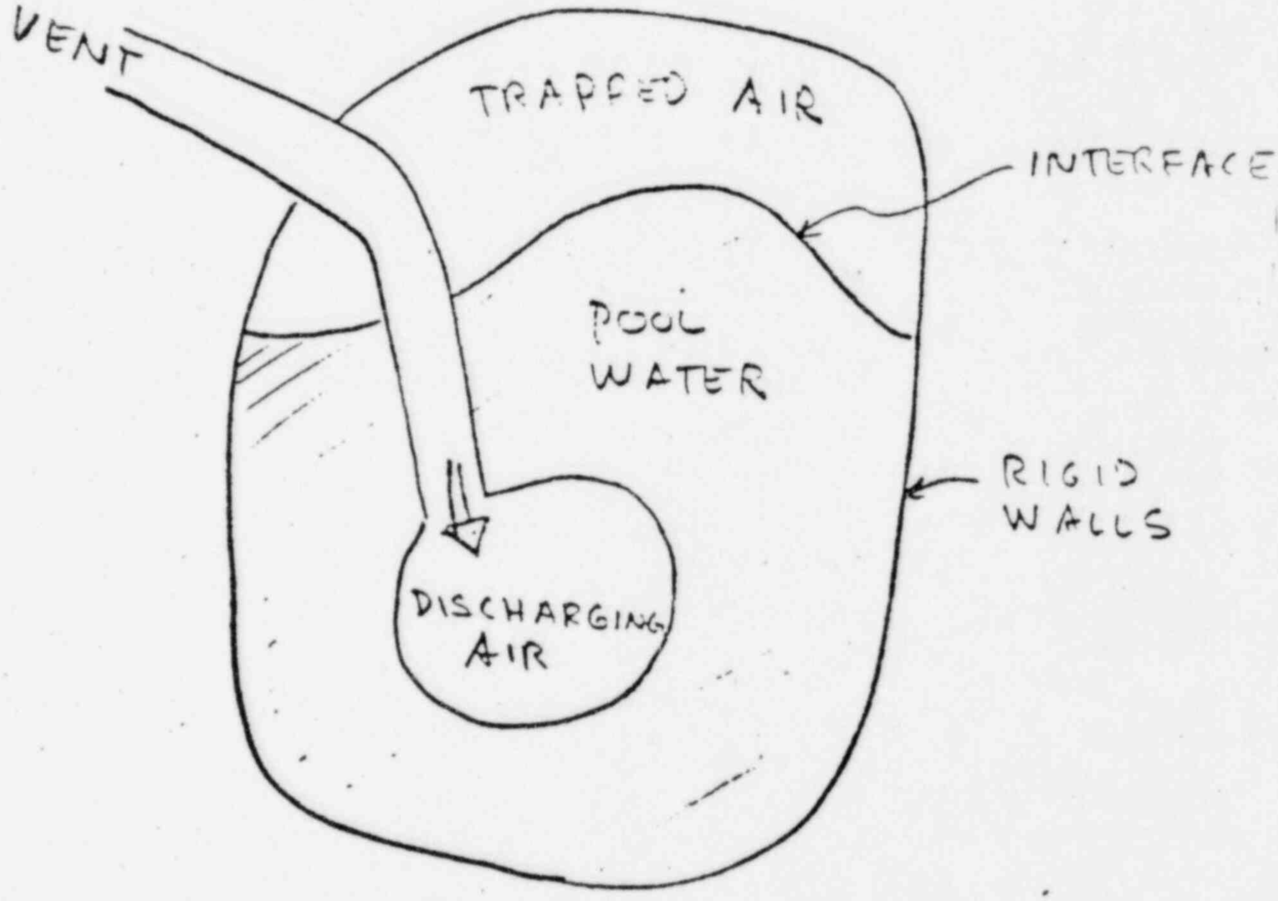
∴ MODELING WORKS BEST WHEN THE PHENOMENA CAN BE FORMULATED BUT NOT SATISFACTORILY SOLVED BY ANALYTICAL METHODS.

METHOD

* FORMULATE THE GOVERNING EQUATIONS, BOUNDARY CONDITIONS, INITIAL CONDITIONS
* NON-DIMENSIONALIZE SO THAT THE INDEPENDENT VARIABLES AND THEIR DERIVATIVES BECOME $O(1)$ IN MAGNITUDE.
* EXTRACT MODELING PARAMETERS
* EXCLUDE OBVIOUSLY SMALL EFFECTS
* SPECIFY SMALL SCALE TEST

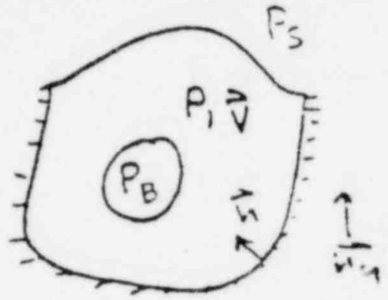
APPLICATION

POOL MOTION DURING VENT WATER EXPULSION AND AIR DISCHARGE



GOVERNING EQUATIONS

POOL MOTION:



MASS CONSERVATION

$$\nabla \cdot \vec{V} = 0$$

MOMENTUM CONSERVATION

$$\left(\frac{\partial}{\partial t} + \vec{V}\cdot\nabla\right)\vec{V} + \frac{1}{\rho}\nabla P + g\vec{i}_y = \nu\nabla^2\vec{V}$$

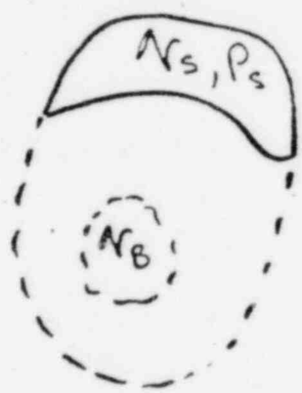
WALLS

$$\vec{V}\cdot\vec{n} = 0$$

INTERFACE

$$P_1 - P_s = T\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

TRAPPED AIR:



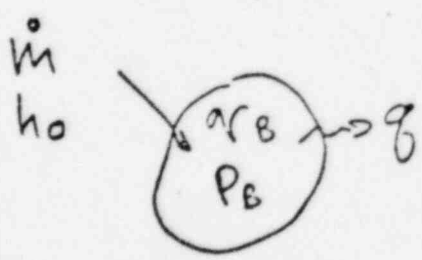
ADIABATIC COMPRESSION

$$P_s V_s^{\gamma} = P_{si} V_{si}^{\gamma}$$

$$V_s + V_B = V_{si}$$

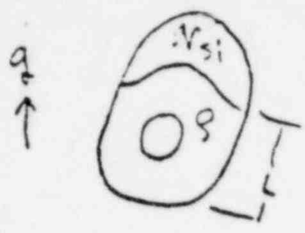
$$P_s = P_{si}\left(1 - \frac{V_B}{V_{si}}\right)^{-\gamma}$$

SUBMERGED AIR:



$$(\gamma-1)q + \gamma P_B \frac{dV_B}{dt} + V_B \frac{dP_B}{dt} = (\gamma-1)h_o\dot{m}$$

NON-DIMENSIONALIZE



$$\ell^* = \frac{\ell}{L} \qquad \vec{V}^* = \frac{\vec{V}}{\sqrt{gL}}$$

$$t^* = t\sqrt{\frac{g}{L}} \qquad \mathcal{V}^* = \frac{\mathcal{V}}{\mathcal{V}_{si}}$$

$$p^* = \frac{p}{\rho g L} \qquad \dot{q}^* = \frac{\dot{q}}{\dot{q}_R}$$

GOVERNING EQUATIONS BECOME:

$$\nabla^* \cdot \vec{V}^* = 0$$

$$\left(\frac{\partial}{\partial t^*} + \vec{V}^* \cdot \nabla^*\right)\vec{V}^* + \nabla^* p^* + \vec{n}_y = \underbrace{\left(\nu\sqrt{\frac{1}{gL^3}}\right)}_{< 10^{-7}} \nabla^{*2}\vec{V}^*$$

$< 10^{-7}$ VISCOUS EFFECT

$$\vec{V}^* \cdot \vec{n} = 0$$

$$p^* - p_s^* = \underbrace{\left(\frac{\sigma}{\rho g L^2}\right)}_{10^{-6}}\left(\frac{1}{r_1^*} + \frac{1}{r_2^*}\right)$$

10^{-6} SURFACE TENSION EFFECT

$$p_s^* = \left(\frac{p_{si}}{\rho g L}\right)\left(1 - \mathcal{V}_B^*\right)^{-\gamma} \qquad \text{TRAPPED AIR}$$

$$(\gamma-1)\underbrace{\left(\frac{\dot{q}_R\sqrt{\frac{L}{g}}}{p_{si}\mathcal{V}_{si}}\right)}_{< 0.01}\dot{q}^* + \gamma p_s^* \frac{d\mathcal{V}_s^*}{dt^*} + \mathcal{V}_B^* \frac{dp_B^*}{dt^*} = \frac{(\gamma-1)h_o\dot{m}}{p_{si}\mathcal{V}_{si}}\sqrt{\frac{L}{g}}$$

< 0.01

FOR ACCURATE MODELING, MUST HAVE

$$\boxed{\frac{p_{si}}{\rho g L}} \quad \text{and} \quad \boxed{\frac{h_o \dot{m}\sqrt{\frac{L}{g}}}{p_{si}\mathcal{V}_{si}}}$$

The same

THE MODELING PARAMETER $\frac{P_{si}}{\rho g L}$ IS MADE IDENTICAL IN FULL SCALE AND THE SMALL SCALE MODEL :

$$\left(\frac{P_{si}}{\rho g L}\right)_M = \left(\frac{P_{si}}{\rho g L}\right)_F$$

BUT BOTH FULL AND SMALL SCALE USE WATER IN A GRAVITY FIELD. THEREFORE

$$\rho_M = \rho_F$$

$$g_M = g_F$$

SO,

$$\boxed{P_{si\,M} = P_{si\,F}\,\frac{L_M}{L_F}}$$

I.e., PRESSURES IN SCALE MODEL MUST BE REDUCED FROM FULL SCALE VALUES BY THE SCALING FACTOR $\frac{L_M}{L_F}$

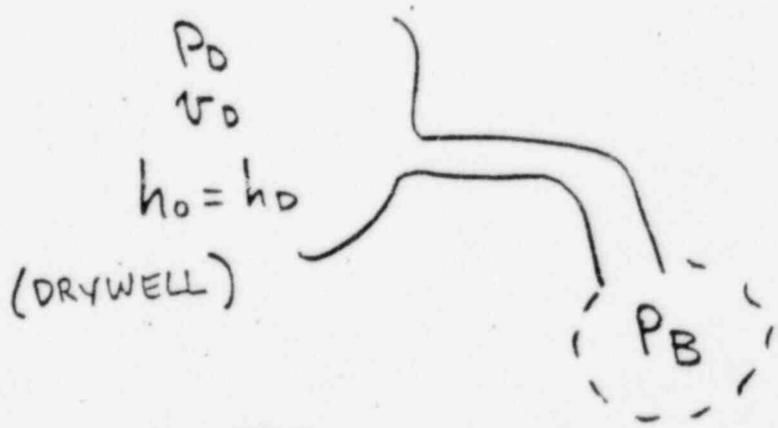
THE MODELING PARAMETER $\dfrac{h_o \dot{m} \sqrt{\frac{L}{g}}}{P_{si}\, V_{si}}$

MUST BE THE SAME IN FULL SCALE AND THE SCALE MODEL :

$$\left(\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{P_{si} V_{si}} \right)_M = \left(\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{P_{si} V_{si}} \right)_F$$

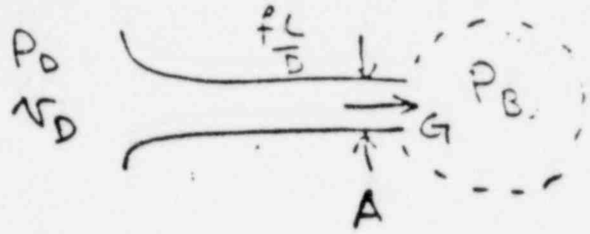
$$\boxed{\frac{h_{oM} \dot{m}_M}{h_{oF} \dot{m}_F} = \sqrt{\frac{L_F}{L_M}} \; \underbrace{\frac{P_{si\,M}}{P_{si\,F}}}_{\frac{L_M}{L_F}} \; \underbrace{\frac{V_{si\,M}}{V_{si\,F}}}_{\frac{L_M^3}{L_F^3}} = \left(\frac{L_M}{L_F} \right)^{\frac{7}{2}}}$$

STAGNATION ENTHALPY h_o IS DETERMINED FROM DRYWELL PROPERTIES :



$$\boxed{h_o = \frac{\gamma}{\gamma - 1} P_D v_D}$$

AIR FLOW RATE IN VENT IS OBTAINED FROM



$$\dot{m} = A\,G$$

$$G = \sqrt{\gamma g_c \frac{P_D}{v_D}}\; \mathcal{Y}\left(\frac{P_B}{P_D}, \frac{fL}{D} \right)$$

THEN

$$\frac{h_{OM}\,\dot{m}_M}{h_{OF}\,\dot{m}_F} = \frac{P_{DM}\, v_{DM}\, A_M \sqrt{\frac{P_{DM}}{v_{DM}}}\; \mathcal{Y}\left(\frac{P_{BM}}{P_{DM}}, \left(\frac{fL}{D}\right)_M \right)}{P_{DF}\, v_{DF}\, A_F \sqrt{\frac{P_{DF}}{v_{DF}}}\; \mathcal{Y}\left(\frac{P_{BF}}{P_{DF}}, \left(\frac{fL}{D}\right)_F \right)} = \left(\frac{L_M}{L_F}\right)^{\frac{7}{2}}$$

$$\frac{v_{DM}\sqrt{\frac{P_{DM}}{v_{DM}}}}{v_{DF}\sqrt{\frac{P_{DF}}{v_{DF}}}} = \frac{\sqrt{\gamma g_c P_{DM} v_{DM}}}{\sqrt{\gamma g_c P_{DF} v_{DF}}} = \underbrace{\frac{C_M}{C_F}}_{\text{SONIC SPEED}} \approx 1.0$$

IF ALL PRESSURES WERE SCALED,

$$\frac{P_{DM}}{P_{DF}} = \frac{L_M}{L_F}$$

$$\frac{P_{BM}}{P_{DM}} = \frac{P_{BF}}{P_{DF}}$$

AND IF $\left(\frac{fL}{D}\right)_M \approx \left(\frac{fL}{D}\right)_F$,

THEN $\mathcal{Y}\left(\frac{P_{BM}}{P_{DM}}, \left(\frac{fL}{D}\right)_M \right) \approx \mathcal{Y}\left(\frac{P_{BF}}{P_{DF}}, \left(\frac{fL}{D}\right)_F \right)$

AND

$$\frac{h_{oM}\dot{m}_M}{h_{oF}\dot{m}_F} = \frac{L_M}{L_F}\frac{A_M}{A_F} = \left(\frac{L_M}{L_F}\right)^{7/2}$$

WHICH REQUIRES

$$\boxed{\frac{A_M}{A_F} = \left(\frac{L_M}{L_F}\right)^{5/2}}$$

TO OBTAIN IDENTICAL VALUES OF THE AIR DISCHARGE PARAMETER $\dfrac{h_o \dot{m}\sqrt{\frac{L}{g}}}{P_{si}\,\forall_{si}}$.

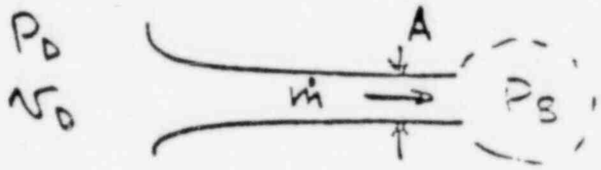
BUT FROM GEOMETRIC SCALING,

WE HAVE $\boxed{\dfrac{A_M}{A_F} = \left(\dfrac{L_M}{L_F}\right)^{2}}$

THEREFORE, IT IS IMPOSSIBLE TO HAVE EXACTLY SCALED <u>DRYWELL</u> PRESSURE AND SATISFY THE $\boxed{\dfrac{h_o \dot{m}\sqrt{\frac{L}{g}}}{P_{si}\,\forall_{si}}}$ AIR DISCHARGE PARAMETER UNLESS THE VENT AREA SUDDENLY DECREASED AFTER FULL WATER EXPULSION. A RESTRICTION IN THE VENT PERHAPS COULD APPROXIMATELY SATISFY THIS.

THERE IS ANOTHER METHOD TO SATISFY MODELING REQUIREMENTS OF THE AIR DISCHARGE PARAMETER $\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{P_{si} v_{si}}$ WHICH INVOLVES DRYWELL PRESSURE.

TO IDENTIFY REQUIREMENTS OF DRYWELL PRESSURE, NEGLECT VENT FRICTION, AND NOTE THAT CORRESPONDING AIR FLOW RATE IS



$$\dot{m} = A \sqrt{\frac{2 \gamma g_c}{(\gamma - 1)} \frac{P_D}{v_D}} \left(\frac{P_S}{P_D}\right)^{\frac{1}{\gamma}} \left[1 - \left(\frac{P_S}{P_D}\right)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{1}{2}}$$

MAINTAIN GEOMETRIC SIMILARITY OF WETWELL, POOL, AND VENTS SO THAT

$$\frac{A_M}{A_F} = \left(\frac{L_M}{L_F}\right)^2$$

THEN REQUIRING

$$\left(\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{P_{si} v_{si}}\right)_M = \left(\frac{h_o \dot{m} \sqrt{\frac{L}{g}}}{P_{si} v_{si}}\right)_F$$

IT FOLLOWS THAT

$$\sqrt{\frac{L_F}{L_M}}\left(\frac{P_D}{P_{si}}\right)_M^{\frac{\gamma-1}{2\gamma}}\sqrt{\left(\frac{P_D}{P_{si}}\right)_M^{\frac{\gamma-1}{\gamma}}-\left(\frac{P_B}{P_{si}}\right)_M^{\frac{\gamma-1}{\gamma}}} = \left(\frac{P_D}{P_{si}}\right)_F^{\frac{\gamma-1}{2\gamma}}\sqrt{\left(\frac{P_D}{P_{si}}\right)_F^{\frac{\gamma-1}{\gamma}}-\left(\frac{P_B}{P_{si}}\right)_F^{\frac{\gamma-1}{\gamma}}}$$

WHICH RELATES PRESSURE IN MODEL DRYWELL TO FULL SCALE DRYWELL PRESSURE.

SINCE IN THE SUPPRESSION CHAMBER WE HAVE PRESSURES SCALED,

$$\left(\frac{P_B}{P_{si}}\right)_M = \left(\frac{P_B}{P_{si}}\right)_F$$

COMPUTATIONS SHOW THAT IF DRYWELL PRESSURE IN THE MODEL IS ABOUT $\boxed{0.7\,\frac{L_{MODEL}}{L_{FULL}}}$ OF FULL SCALE DRYWELL PRESSURE, THE AIR DISCHARGE PARAMETER $\dfrac{h_o \dot{m}\sqrt{\frac{L}{g}}}{P_{si}\,V_{si}}$ WILL BE CLOSELY MODELED.

CONCLUSIONS

MODELING LAWS FOR POOL MOTION ARE:

$$\frac{P_{MODEL}}{P_{FULL}} = \frac{L_{MODEL}}{L_{FULL}}$$ DURING WATER EXPULSION

$$\frac{A_{MODEL}}{A_{FULL}} = \left(\frac{L_{MODEL}}{L_{FULL}}\right)^2$$

$$\frac{V_{MODEL}}{V_{FULL}} = \left(\frac{L_{MODEL}}{L_{FULL}}\right)^3$$

SATISFIED BY GEOMETRIC SCALING

AND $\frac{h_{OM}\dot{m}_M}{h_{OF}\dot{m}_F} = \left(\frac{L_{MODEL}}{L_{FULL}}\right)^{7/2}$, WHICH IS

APPROXIMATED EITHER BY HAVING

$$\frac{P_{DRYWELL,MODEL}}{P_{DRYWELL,FULL}} \approx 0.7 \frac{L_{MODEL}}{L_{FULL}}$$

DURING AIR DISCHARGE; OR BY HAVING THE DRYWELL PRESSURE MODELED, AND VENT AREAS

$$\frac{A_{VENT,MODEL}}{A_{VENT,FULL}} = \left(\frac{L_{MODEL}}{L_{FULL}}\right)^{5/2}$$

THIS MIGHT BE ACCOMODATED BY AN ORIFICE OR NOZZLE IN THE VENT WHICH RESTRICTS THE MODEL AREA TO $\sqrt{\frac{L_M}{L_F}}$ OF ITS UNRESTRICTED VALUE, IF IT DOES NOT STRONGLY AFFECT THE WATER EXPULSION PHENOMENA.

Aerojet Nuclear Company

Interoffice Correspondence

October 10, 1975

J. H. Ramsthaler
Rogers 220

BWR DYNAMICS POSITION LETTER - LLW-61-75

This letter documents informal transmittal of an ANC summary position letter on General Electric (GE) analyses and experiments related to the GE Pressure Suppression Test Facility (PSTF). The attached report: "PSTF Scaling, Test Repeatability, and HCU Froth Loading", SSRD-14-76 is authored by B. A. Bush and B. S. Anderson. The report presents conclusions and recommendations based on available data, and qualifies certain conclusions based on future receipt of confirmatory data from GE. The scaling analysis and conclusions are directed toward BWR pool motion parameters, and not toward other indirect phenomena such as air bubble shape, formation, structural pressure loads, etc.

By copy of this letter, the reference report is being sent to NRC-TR (R.L. Tedesco and J.A. Kudrick) and ERDA-ID (T.D. Knight).

L. L. Wheat, Manager
Containment Systems Project
Reactor Behavior Program

dp

Attachment as stated

cc: BSAnderson
BABush
EPEales
IAEngen
WHLe?
WJMings
CLNalezny
DCSlaughterbeck
RRStiger
File C2.0

Report No. SSRD-14-76

Date October, 1975

PROPRIETARY INFORMATION

PSTF Scaling, Test Repeatability, and HCU Froth Loading

BY

B. A. BUSH B.A. Bush

B. S. ANDERSON B.S. Anderson

Approved: L. J. Wheat Supervisor

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SYSTEMS SAFETY RESEARCH DIVISION

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PROPRIETARY INFORMATION

I. INTRODUCTION

This report presents the current Aerojet Nuclear Company (ANC) position on the scaling,hydraulic control unit (HCU) floor froth loading, and test repeatability of the General Electric (GE) one-third scale Pressure Suppression Test Facility (PSTF) program. Review of the scaling of the PSTF facility involved an independent dimensional analysis of the pool motion and breakthrough phenomena and verification of the resulting scaling factors using air test data. One-third scale steam test results were studied to determine the adequacy of the data for obtaining HCU floor froth loads and for indicating test repeatability.

The following text is divided into three sections: conclusion, discussion, and recommendations. The discussion section, divided into the three work subsections mentioned above, explains the bases for the conclusion and what data and comparisons were used.

II. CONCLUSIONS

For easy reference, the conclusions are summarized below. Many of these conclusions are based on limited data and will require further verification as more tests are performed and results are obtained.

1. The scaling factors obtained by ANC agree with GE's.
2. Most of the 1/3 scale PSTF facility dimensions are scaled satisfactorily. The effects of vent spacing, vent length, and any difference in blowdown pressure traces on conservatism remain to be reviewed.
3. Application of the scaling factors to 1/3 scale PSTF air test data produces results which are in good agreement with similar full scale PSTF air test results.
4. Comparison of non-scaled 1/3 scale PSTF air test results with full scale air PSTF test results, for similar submergence and break size, shows poor agreement.
5. For tests of the same scale, submergence, and break size but different blowdown composition, the test with the greater pool rise velocity will result in breakthrough occurring at a lower elevation.
6. Preliminary calculations of HCU floor impact pressure using 1/3 scale PSTF steam test data indicate that the HCU floor froth loading will be less than the design load of 15 psig.
7. Based on limited data, good repeatability of pool swell velocity and position to a given blowdown venturi size and vent submergence is supported by the 1/3 scale steam tests. The slug thickness is not accurately reproducible.

III. DISCUSSION

1. DIMENSIONAL ANALYSIS

A dimensional analysis was performed by applying two techniques to equations or parameters describing pool motion and breakthrough. For pool motion, Euler's equation for a continuous, incompressible, frictionless fluid was used. Both the differential equation method and several variations of a method producing the number of dimensionless groups indicated by application of the Buckingham Π Theorem resulted in the same scaling factors. For the breakthrough phenomenon, a dimensional analysis was performed using buoyancy and instability parameters. Whether these analyses were based on bubble dimensions and properties or PSTF dimensions and bubble formation variables, the scaling factors, when reduced to PSTF dimensions, were the same for those variables in common with pool motion.

The scaling factors obtained are in general terms and will apply to any reasonable scale model for pool behavior. For the 1/3 scale facility, the following scaling factor values apply. Breakthrough height, vent submergence, slug thickness, vent diameter, vent spacing, other containment dimensions, and air bubble pressure all have a $1/\sqrt{3}$ scale factor to apply to a properly scaled facility to predict or specify prototype results or size. Bubble area, pool area (or wetwell area), and vent area all have a 1/3 scale factor. Volumes then must have a $1/(3\sqrt{3})$ scale factor. Pool velocity, bubble velocity, and time are scaled by $1/\sqrt[4]{3}$. These scaling factors apply and dictate that all dimensions must be scaled the same.

Because of the variations in the 1/3 scale facility dimensions, area, and volumes, a determination of which dimensons were in error and of these, which were crucial, was necessary. Both the areas and volumes involving the wetwell and vents are scaled by one-third. Fortunately, most of the dimensions

forming volumes from the area do not play an important role in the tests since they are larger than what their scaled size should be. These are the wetwell height, wetwell height above the top vent, air space height, and pool depth below the top vent. The effect of vent spacing and vent length, both of which were unscaled, is uncertain and requires further investigation. The concern with vent length is its effect on conservatism associated with the resulting bubble area and location. In general the PSTF facility dimensions are satisfactory.

Due to current unavailability of some air test data, only the 4¼ inch break, six (6) and eight (8) foot submergence, full scale air tests and the 2½, 3 5/8, and 4¼ inch break, five (5) and seven and one-half (7.5) foot submergence, 1/3 scale air tests were compared in verifying the scaling factors. The full scale test most closely representing a Mark III was test 5705/4. This had a 4¼ inch break, eight (8) foot submergence, and a 32 psia drywell pressure at vent clearing. Using the bubble pressure scaling factor by assuming bubble pressure is the same as the drywell pressure at vent clearing, then the scaled test most similar to the full scale test is 5806/4. This test had a 2.5 inch break, five (5) foot submergence, and a 22 psia drywell pressure. The scaled value for submergence and pressure from the full scale test were 4.62 feet and 18.5 psia.

The scale factors were then applied to the 1/3 scale test results to predict full scale breakthrough, and pool velocity and slug thickness vs elevation. Plots of both predicted and full scale test results were in very good agreement both in curve shape and magnitude. Breakthrough for the full scale tests was five (5) feet below the level predicted. This is probably because the baffles did not extend to the ceiling. The results of 1/3 scale air test 5806/8, which differed from 5806/4 in break size (3.0 inch vs 2.5 inch), were

also scaled up and plotted. The six (6) foot submergence, 4¼ inch break full scale test results were plotted too. These showed no inconsistencies in expected trends.

In comparing non-scaled, 1/3 scale air tests with full scale air tests of similar submergence (7.5 ft vs 8 ft) and break size (4¼ inch), poor agreement was found in curve behavior or magnitude.

Full scale and 1/3 scale steam tests were not compared for two reasons. First, the full scale break sizes were too small. A comparable 1/3 scale test could not be found. Second, detailed full scale test results are not readily available or applicable for elevations above the baffle level.

For both air and steam tests (different blowdown compositions) with the same submergence and break size, the test with the greater pool velocity (air test) resulted in breakthrough at a lower elevation. This was shown in a comparison of tests with 7.5 ft submergences and 3 inch breaks. The steam test produced a slug of water hitting the HCU floor, the air test did not, although breakthrough was close to that elevation. It is difficult to try to make the same comparison on five (5) foot submergence tests because the recording instrument placement and scan time allows too great a span in the breakthrough measurement. Spans of three to five feet typically are reported.

2. HCU IMPACT FROTH LOADING

The test data presented for 1/3 scale steam tests, General Electric Report NEDM-13407P (May 1975), indicates that froth impact loading on the HCU floor will be less than the design load of 15 psig. The formula used to calculate impact pressure is:

$$P = \frac{\rho L V}{144 g_c t}$$

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where:

P = average impact pressure (psi)

ρ = average froth density (lbm/ft^3)

L = average froth thickness (ft)

V = average froth velocity (ft/sec)

t = impact duration (sec)

$g_c = 32.2 \frac{lbm\text{-}ft}{lbf\text{-}sec^2}$

Adequate data for froth velocity, froth thickness, and froth density exist in the report, however, there is no data for froth impact duration. Conservative values were choosen for each of the parameters as follows:

Froth Velocity - The highest froth velocity indicated at the HCU floor by any figure in the report is 40 ft/sec, so this value was used.

Froth Thickness - At the HCU floor the figures in the report show the froth thickness to be less than 2 ft. thick, so a value of 2 ft. was used.

Froth Density - The froth void fraction remains above 80 percent most of the time, so using a conservative value for void fraction of 80 percent the froth density is 12.5 lbm/ft^3.

Impact Duration - The report indicates that for impact of a water slug the impact duration is ~40 msec. The same duration was assumed for froth impact. This time should be a lower bound for froth impact since the froth slug will require time to collapse against the HCU floor due to the cushioning effect of the air trying to escape from the froth slug.

Using the conservative values above the HCU impact load is 5.4 psig.

3. REPEATABILITY OF POOL SWELL

The available 1/3 scale steam data are limited, and comparison of individual tests is impossible with available data. The pool swall results for tests with a 2.5 inch break, five (5) foot submergence, and various roof openings were compared. The scatter in the data is large, especially for slug thickness. Based on a curve of slug thickness vs. elevation, the scatter can be approximately ±20% at six feet above the original pool level, ±64% at twelve feet, and ±40% at sixteen feet. A different curve fit might change the scatter picture somewhat but not enough to overcome this kind of scatter. The tests are not repeatable enough to accurately predict what slug thickness will result from a given blowdown.

Comparing the scatter for a curve of velocity vs. elevation, the scatter is less severe in terms of percentages. Most of the scatter was within ±11% of the fit curve. At an elevation near seven feet above the original pool level, there was some ±20% scatter in the data.

How much of the scatter can be attributed to the different roof openings is not known. In general, overall trends in curve magnitude and behavior are repeatable, however the repeatability of actual slug thickness is still uncertain. A review of identical tests will be necessary.

IV. RECOMMENDATIONS

Continue verification of conclusions 3 through 7 as more test data, both for completed and future tests, becomes available.

Study the effect of vent spacing and vent length on bubble formation, pool response, and drywell pressure to determine their significance for scaled tests.

Review the blowdown drywell pressure traces for full scale and 1/3 scale tests fo· similarity and duration.

Instrument future tests more heavily in locations of concern, such as breakthrough, now that results have shown where various phenomena will occur, so that more accurate data can be obtained.

Place error bands on 1/3 scale steam test pool swell data and calculate impact based on the bounding data. Compare impact data, from subsequent tests where pool swell is not measured, with the calculated values to see whether the new data is bounded by the calculated results.

G. Lainas, DSS

Aerojet Nuclear Company

Interoffice Correspondence

April 19, 1976

J. H. RAMSTHALER
ROGERS 220

CRITIQUE OF GENERAL ELECTRIC SAFETY-RELIEF VALVE ANALYTICAL MODELS - LLW-18-76

References: (1) JIMills, "Analysis of the General Electric Safety-Relief Valve Discharge Analytical Models", SRD-71-76, April 1976.
(2) SCChang, "Critique of the General Electric Safety-Relief Valve Discharge Analytical Models", SRD-79-76, April 1976.

This letter informally transmits Reference (1), authored by Dr. Jim Mills, an ANC consultant, and Reference (2), authored by Dr. Sin Chung Chang, completing the laboratory's initial review of documented General Electric Safety-Relief (S/R) valve analytical models. A recently received General Electric amendment to their model report is currently being reviewed on a part time basis, and will be critiqued in a later report.

The conclusions provided in the two references raise several questions about the General Electric models and conclusions. Until satisfactory resolution of the main concerns is obtained, the INEL staff position is that the General Electric models and General Electric conclusions about those models are not technically substantiated.

This work is a partial fulfillment of the level of effort task entitled "BWR Dynamic Phenomena Investigations" of the I-214 Containment Analysis project.

Copies of the two proprietary referenced reports are being informally sent to:

NRC:	DHKShum	JAKudrick (3)
	WLJensen	RLTedesco
	PENorian	LSlegers
	ZRRosztoczy	DFRoss
ERDA-ID:	PELitteneker	TDKnight

L L Wheat

L. L. Wheat, Manager
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Attachment as stated

F-4