APPLICATION OF PELE-IC TO BWR CONTAINMENT ISSUES

C. S. Landram, LLL

The PELE-IC computer code couples an incompressible Eulerian fluid algorithm to a Langrangian finite-element shell module. The code was developed to assess fluid-structure interaction problems in BWR pressure-suppression systems. In these systems steam is forced down large pipes and is condensed in a water pool contained in a steel or concrete structure. Loads occur on the structure both during the air and steam jetting into the water and later during oscillatory condensation of the steam bubbles at lower mass-flow rates. The computer code calculates the loads and the structural response.

Previous documentation(1) has included a description of the computer program and some verification problems (drainage tanks, a Rayleigh bubble growth, and a submerged vibrating disk) possessing known solutions. Presented here are our most recent code studies which include verification of the fluid-structure coupling algorithm for a curved surface, qualification by comparison with MIT air blowdown experimental results and applications relative to experiments modeling Mark I and Mark II BWR pressure-suppression systems.(2) In application to the Mark I design, we simulated tests done at Lawrence Livermore Laboratory on the 90 and 7.5 degree torus sectors. Calculations were performed to investigate the influence of torus stiffness and flexible supports on observed uploads, and through these calculations we identified the controlling mechanisms for the uploads. Uploads are caused by bubble growth toward the free surface with a higher pressure region in the upper portion of the torus. The movement of the structure and support contribute a relatively small high frequency component to this main load profile. The computed pressure contours show that the geometry of the structure plays an important role in the magnitude of these loads and careful design can reduce them.

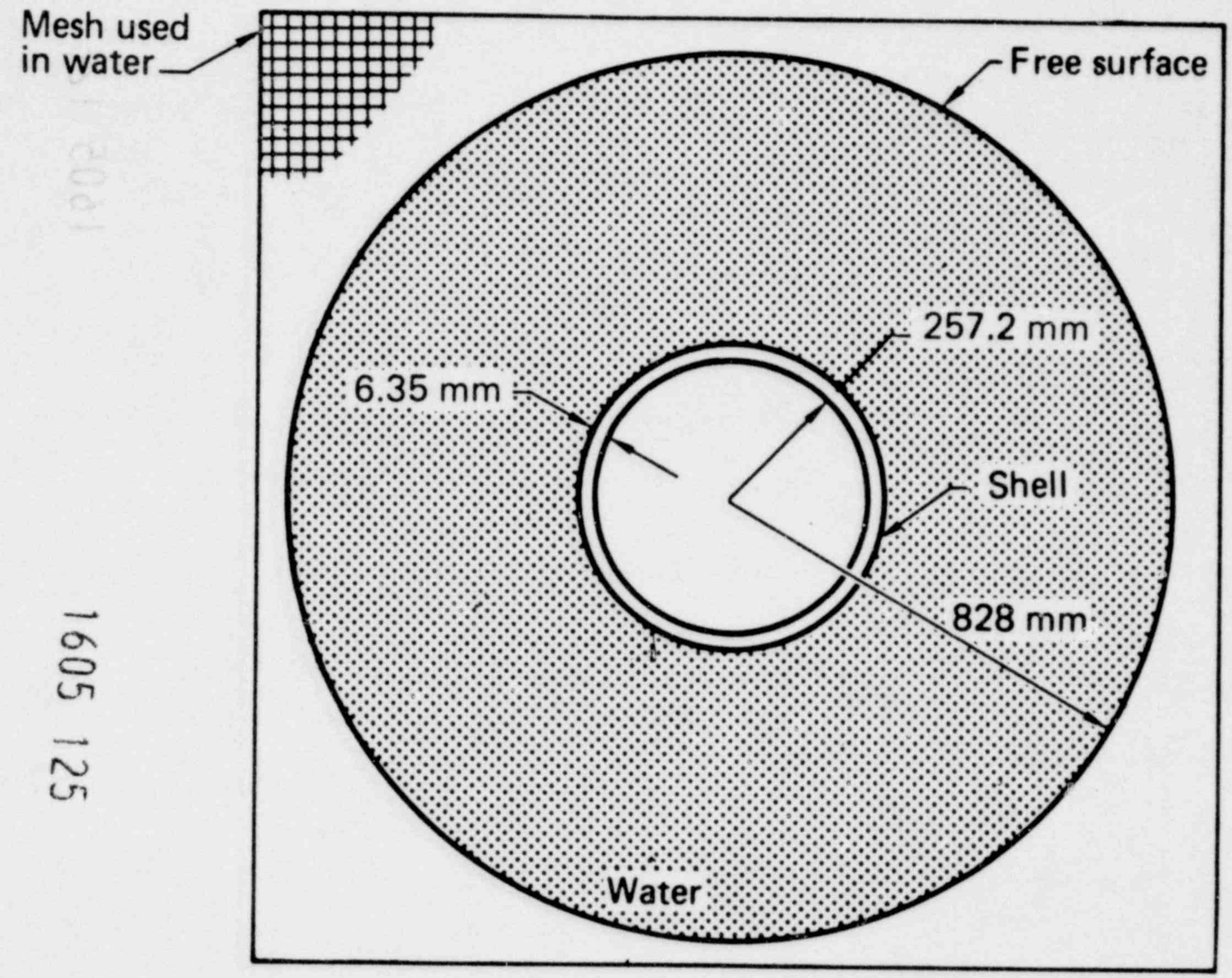
For the Mark II design, the tank used in the GE4T experiments was analyzed (1) holding either the bottom plate or the side walls fixed, and (2) allowing both to be unconstrained. In all cases a representative pressure signature at the exit of the downcomer was prescribed and permitted to propogate as an acoustic wave back and forth along the downcomer, reflecting at both ends. For the bottom center calculated pressure histories, the dominant fluid-structure frequency content (calculated at 38 Hz) was seen to be insensitive to GE4T vent acoustic effects. The fluid effective mass appears to have the effect of reducing the bottom plate natural frequency from 42 Hz to 38 Hz. For the somewhat less important frequency contents vent acoustic effects (via pulse reflection every 114 ms) excite end plate movement (at about 42 Hz) whereas in absence of vent acoustics, such lessor frequency content is associated with radial side wall motion (at about 63 Hz).

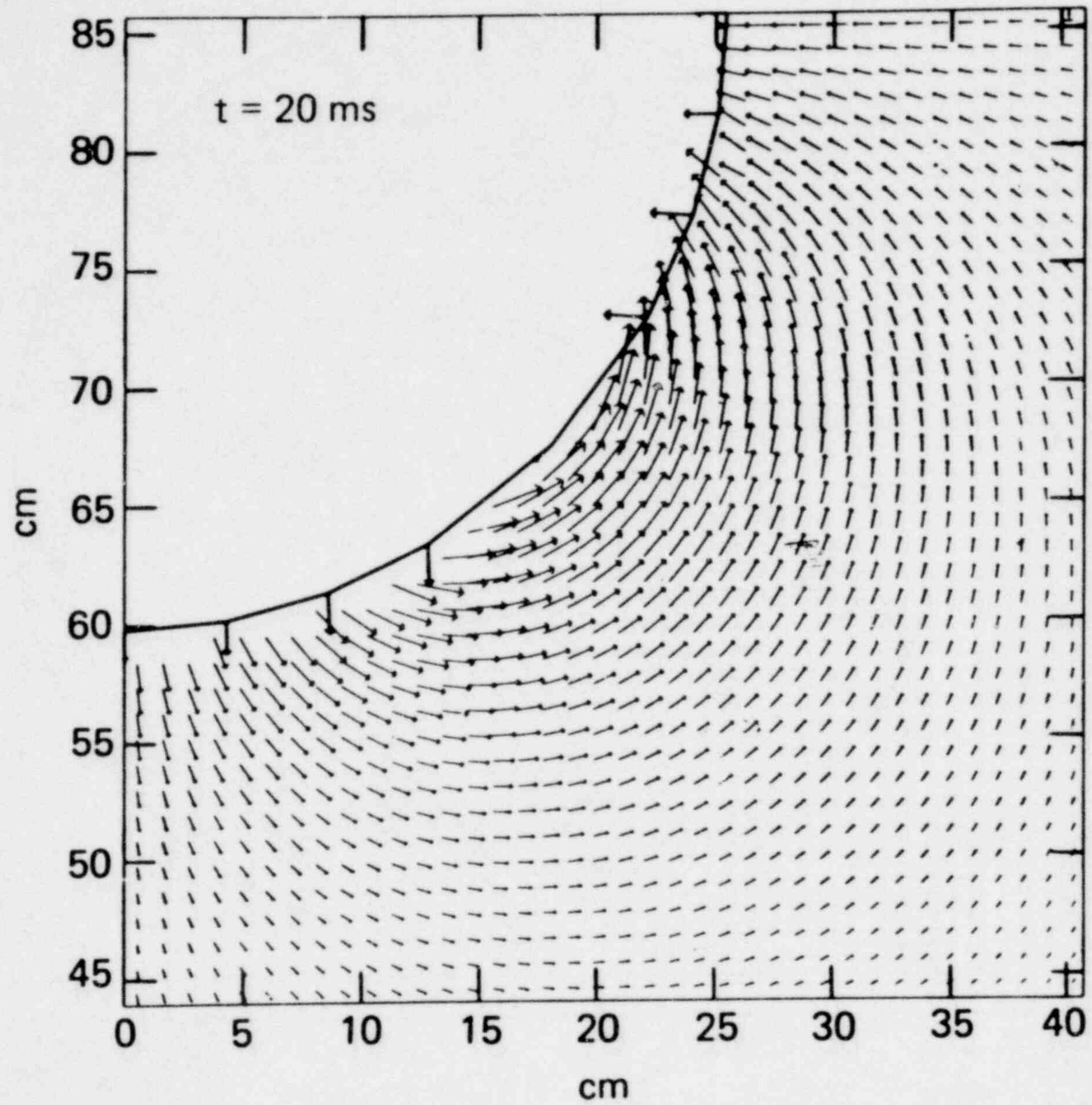
REFERENCES

1. W. H. McMaster, D. M. Norris, Jr., G. L. Goudreau, D. F. Quiñones, E. Y. Gong, B. Moran and N. A. Macken, "Coupled Fluid-Structure Method for Pressure Suppression Analysis," U. S. Nuclear Regulatory Commission NUREG/CR-0607 (February 1979).

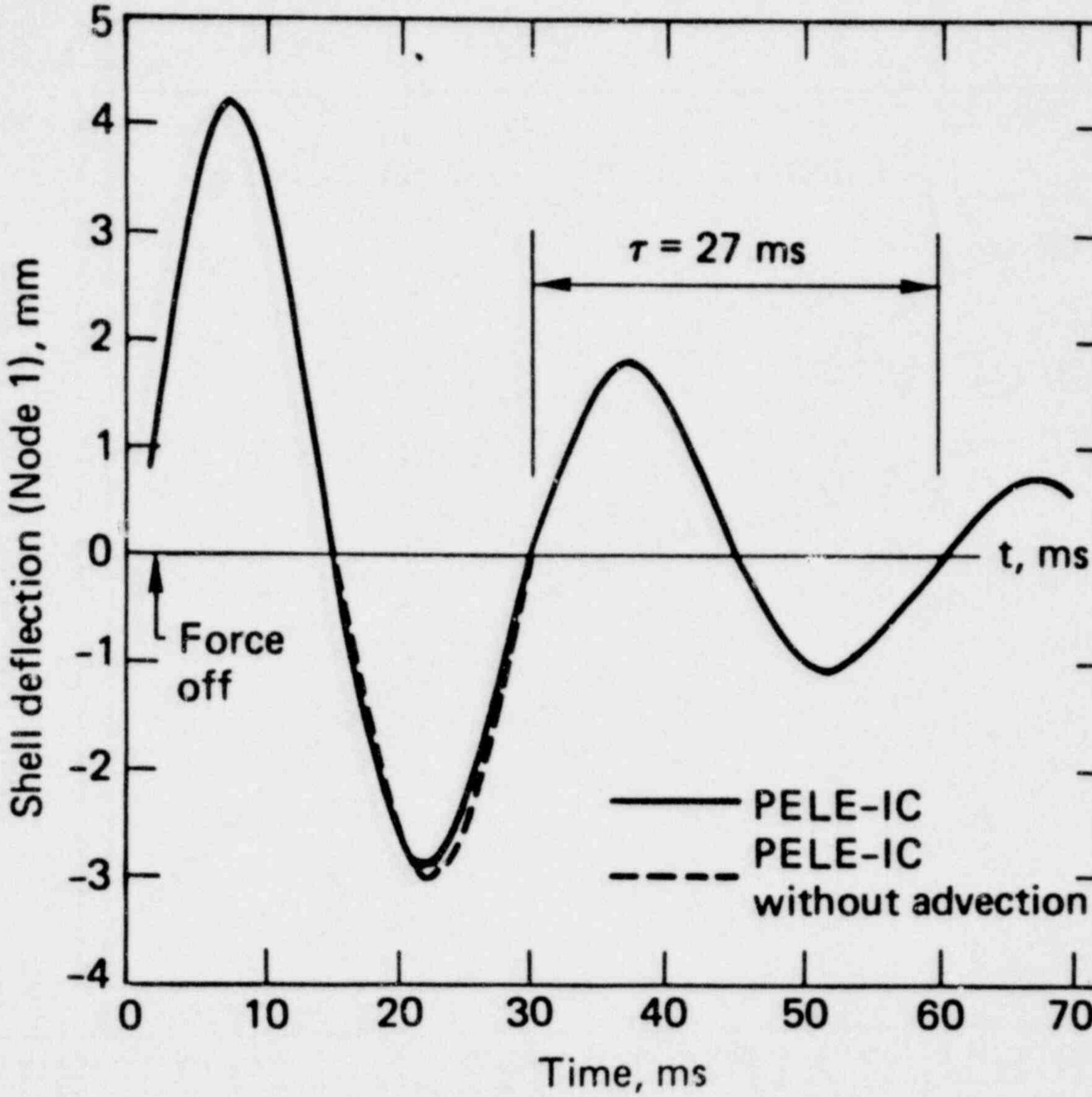
2. C. S. Landram et al, "Coupled Fluid-Structure Method for Pressure Suppression Analysis," 2nd Annual Report to the U. S. Nuclear Regulatory Commission, Lawrence Livermore Laboratory Contract A0116, December 1979, in press.

GEOMETRY OF SUBMERGED CYLINDRICAL SHELL




t = 20 ms
85
80
75
70
65
60
55
50
45
cm
0
5
10
15
20
25
30
35
40
cm

SUBMERGED CYLINDER-SHELL NODAL RESPONSE



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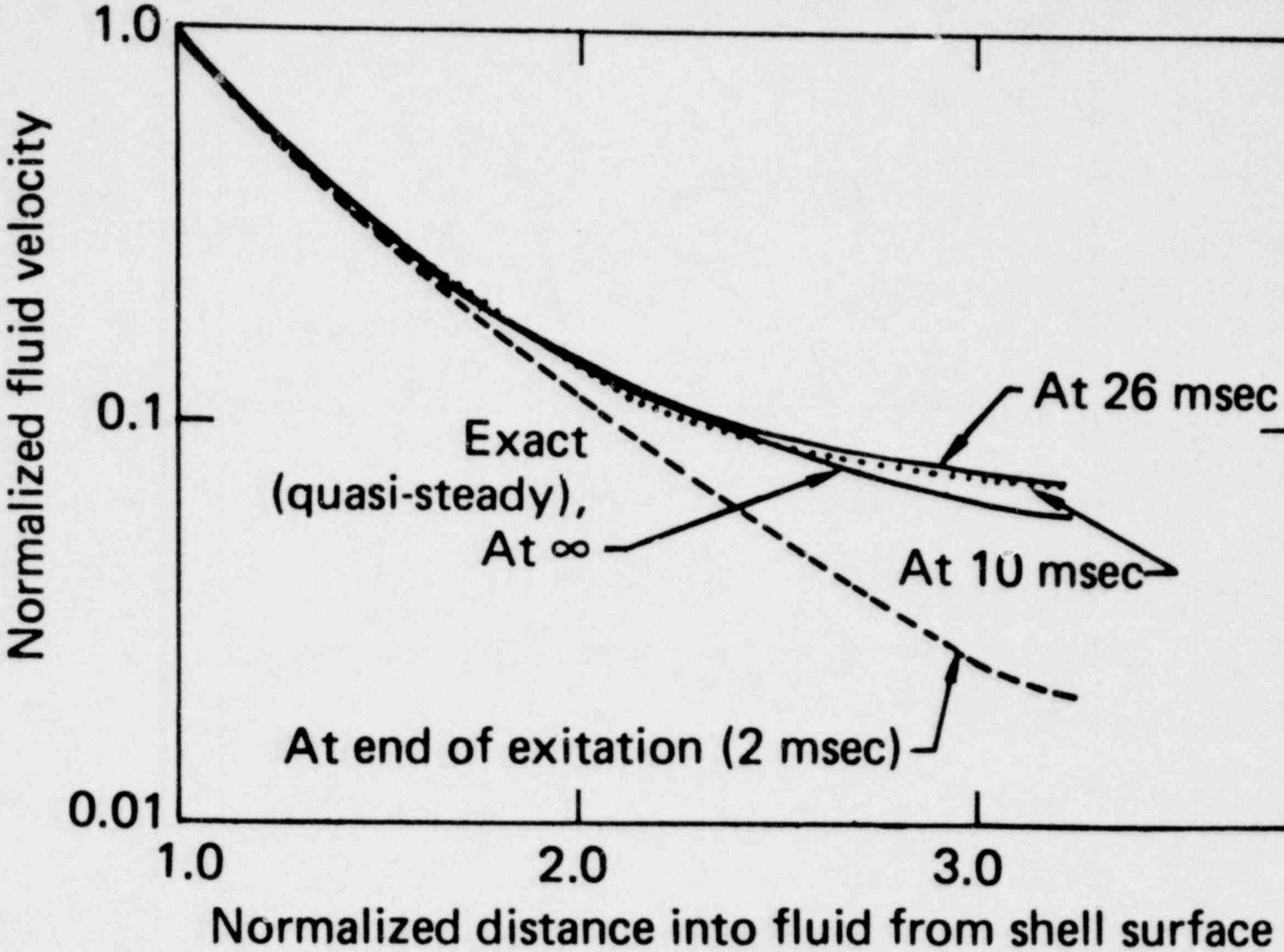
SUBMERGED CYLINDER VELOCITY DISTRIBUTION



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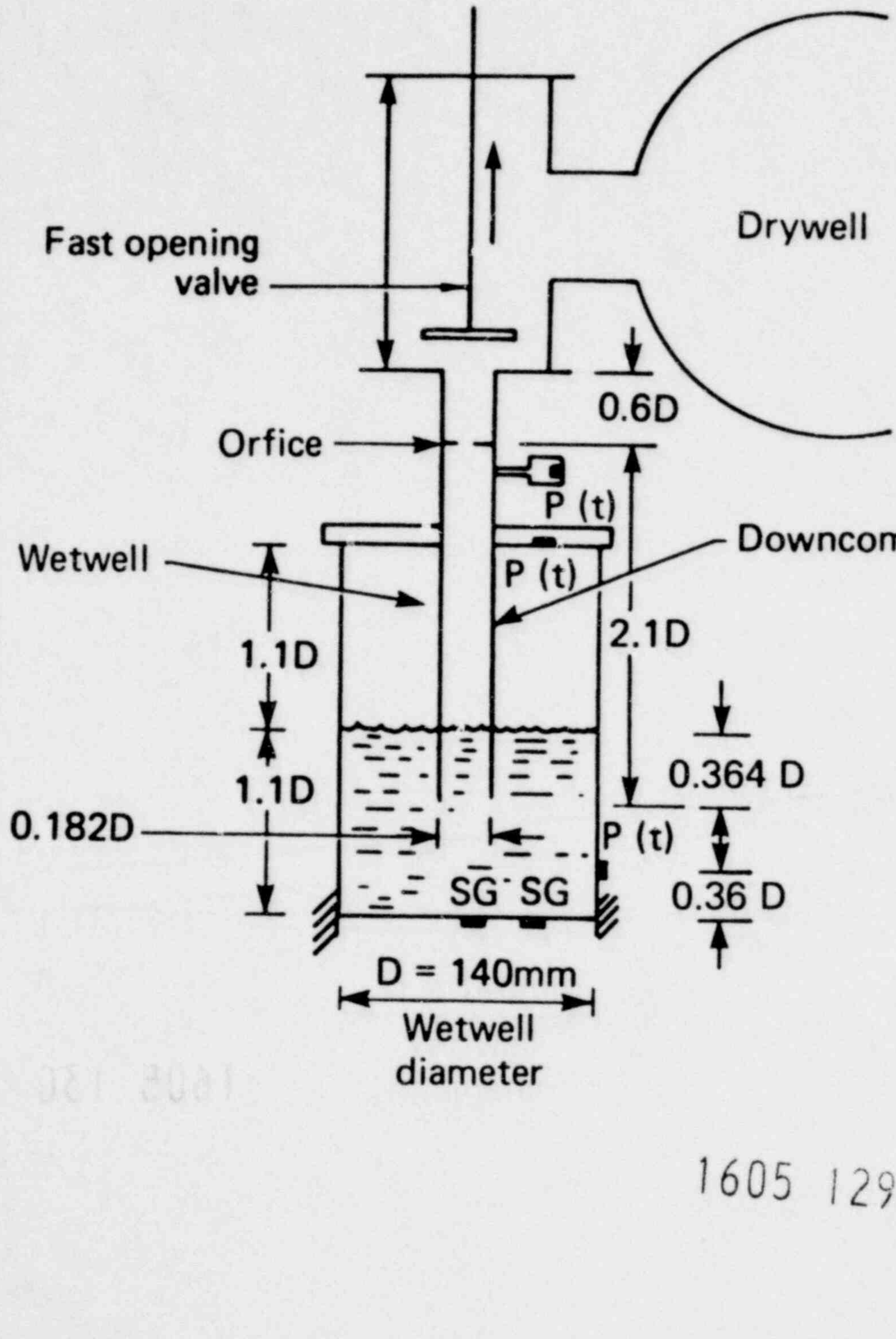
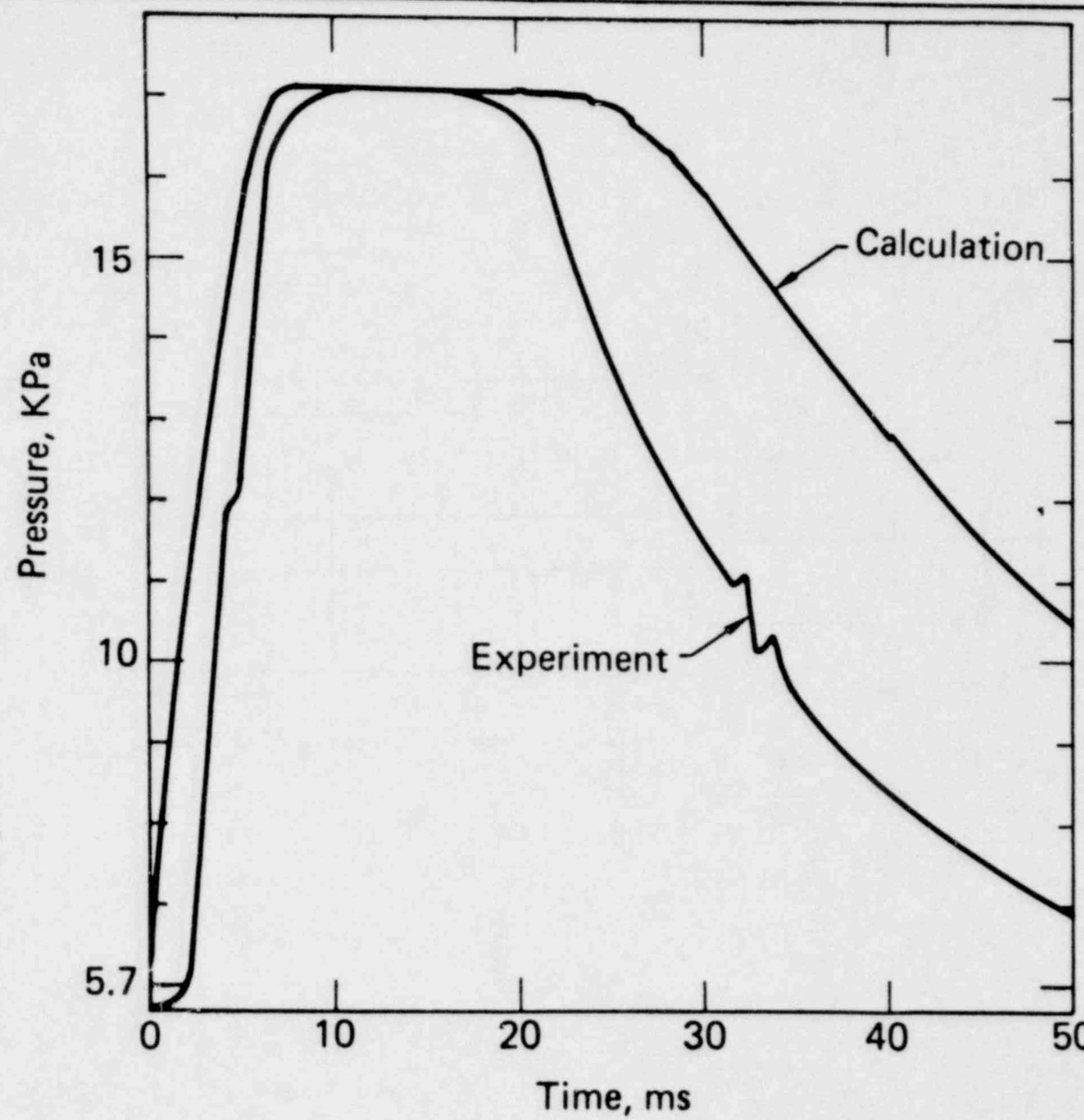


Fast opening valve
Drywell
Orfice
0.6D
P (t)
Wetwell
P (t)
Downcomer
1.1D
2.1D
1.1D
0.364 D
0.182D
P (t)
SG SG
0.36 D
D = 140mm
Wetwell diameter

MIT TANK DOWNCOMER PRESSURE



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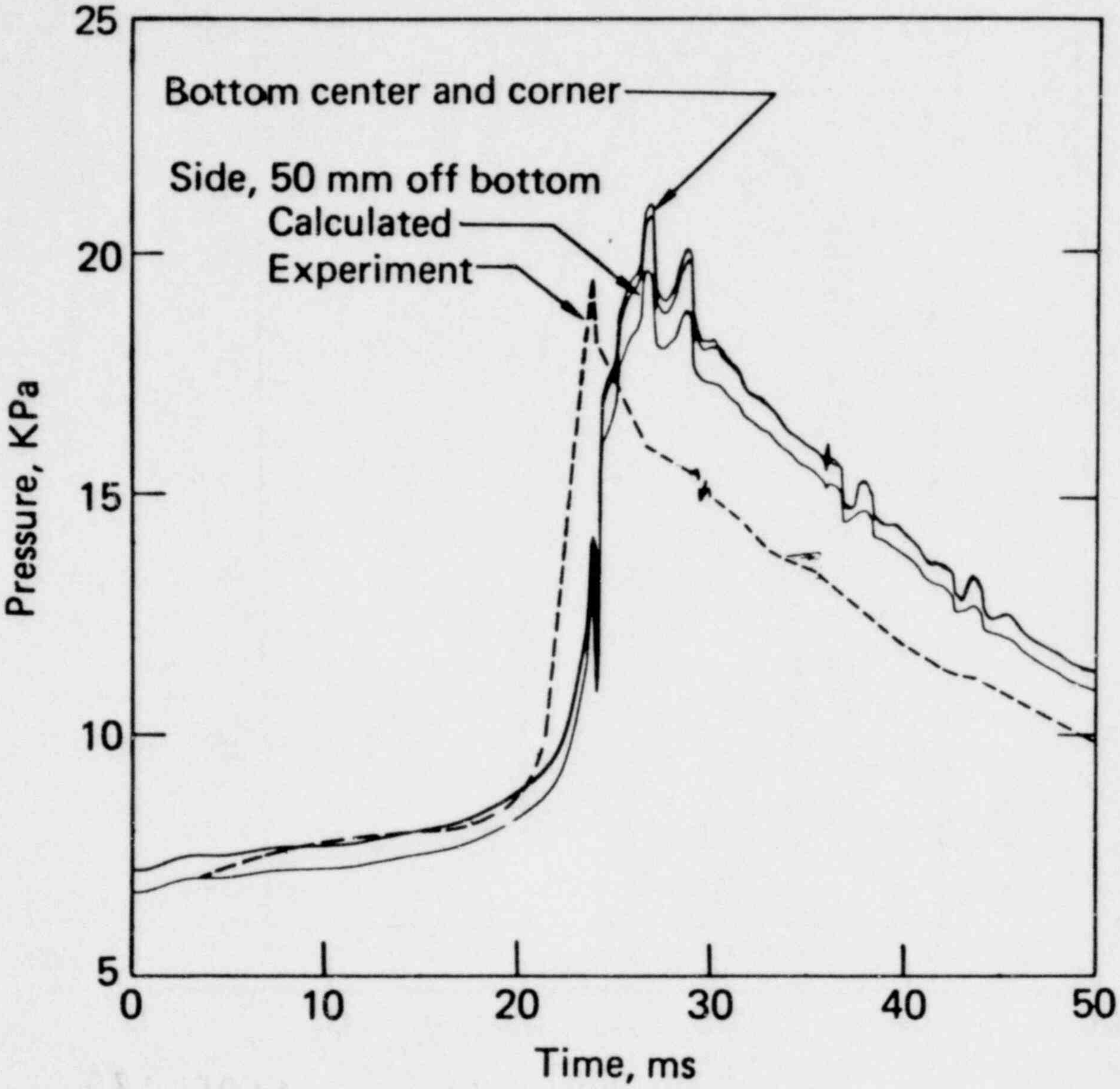
MIT TANK PRESSURE TIME HISTORIES – RIGID BOTTOM



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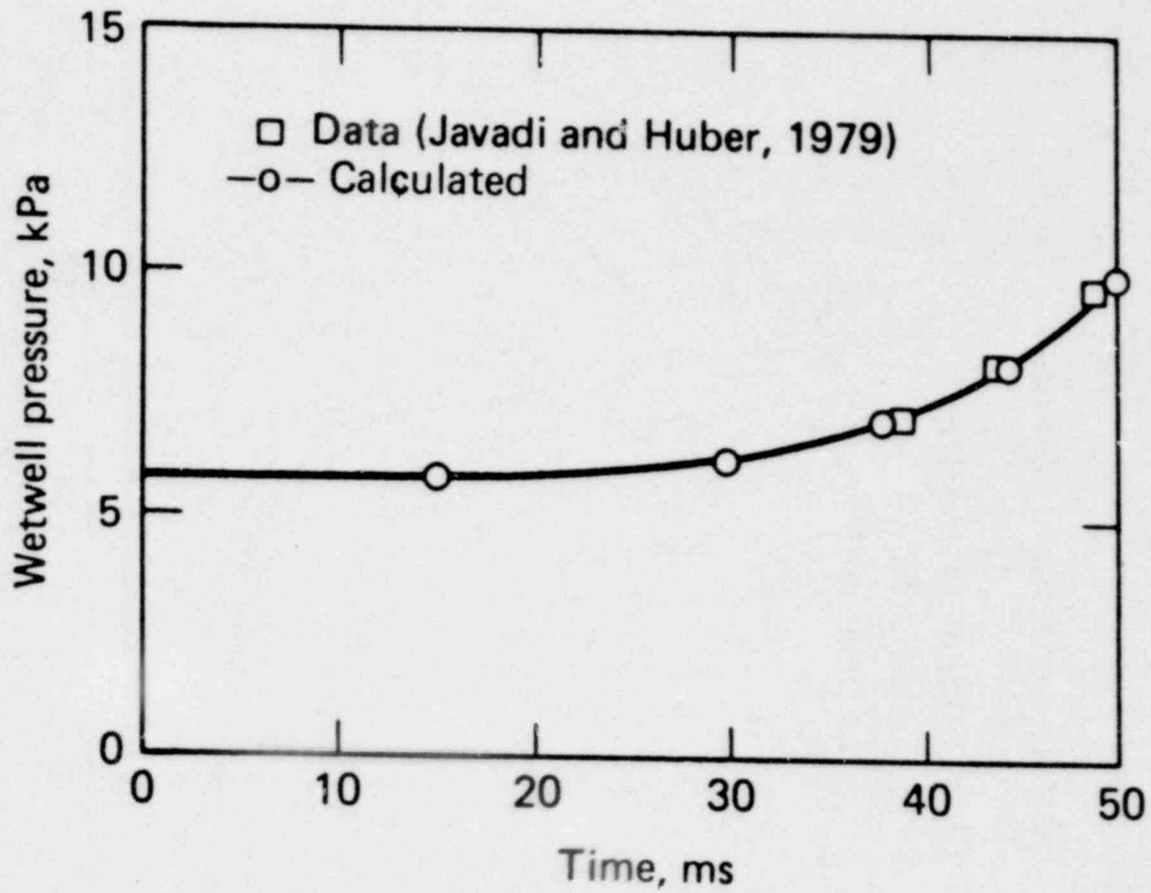
MIT TANK WETWELL PRESSURE



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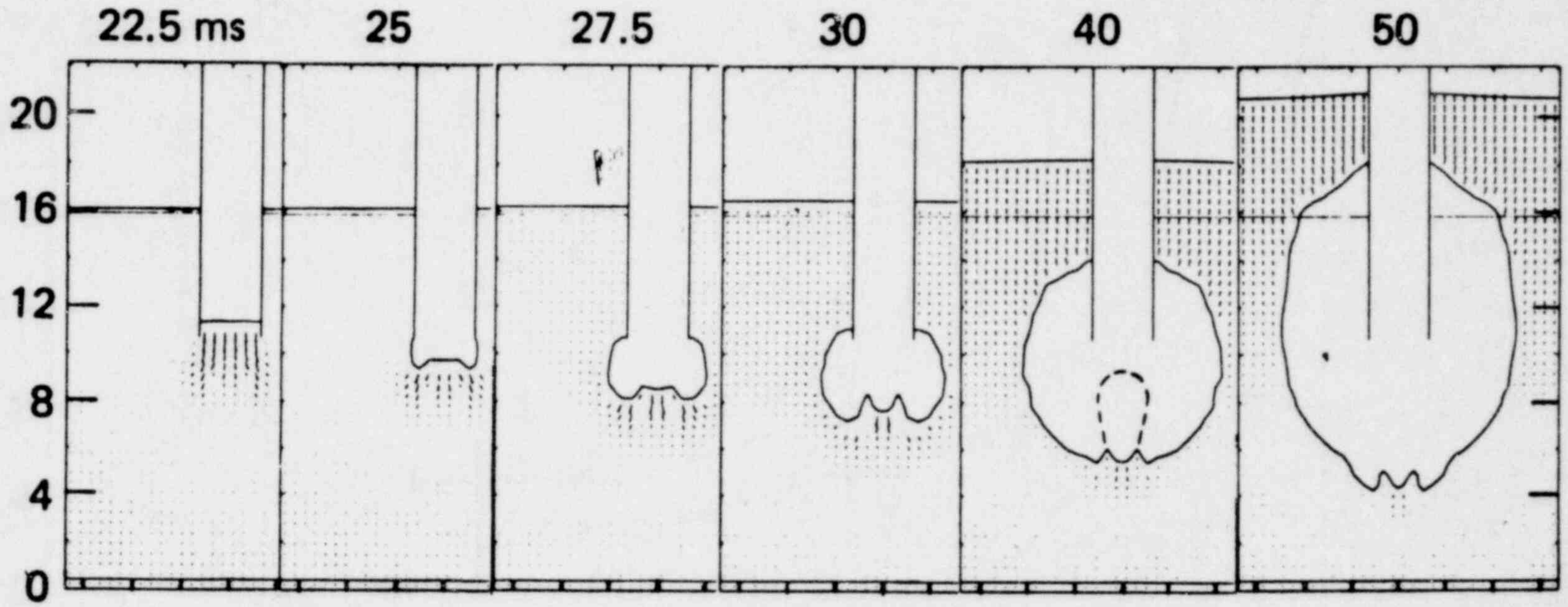
POOR ORIGINAL

MIT TANK CALCULATED BUBBLE SHAPES



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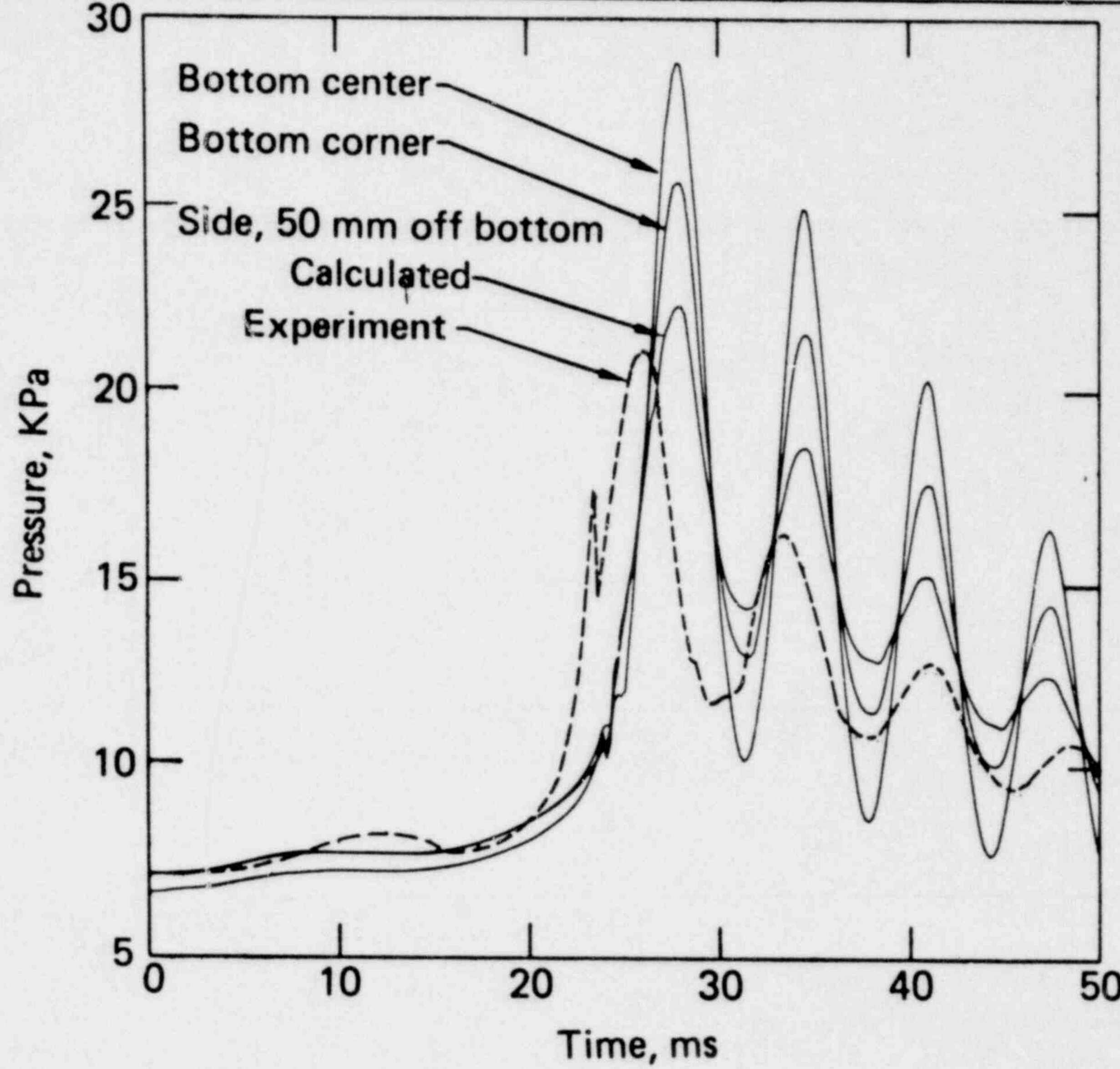
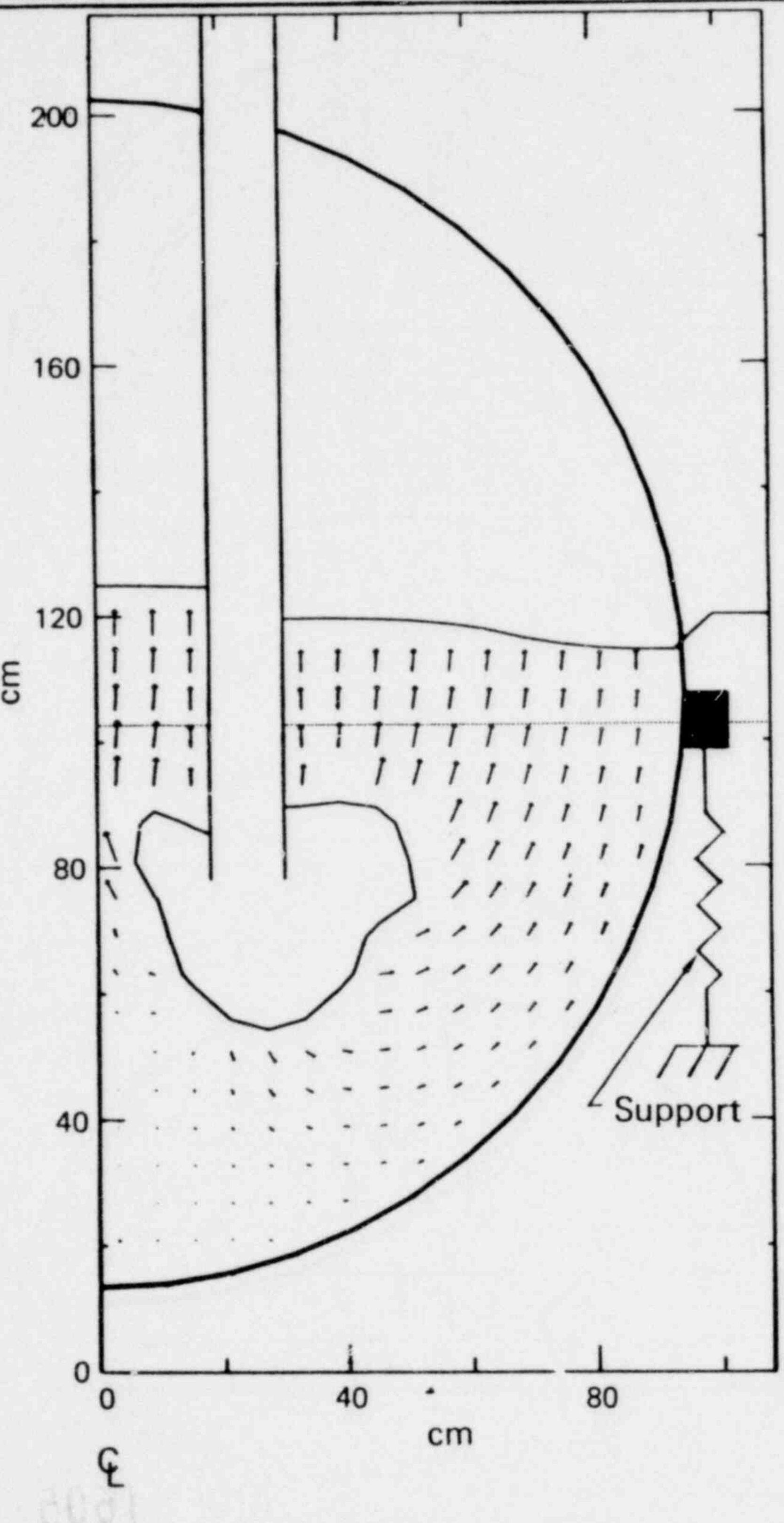
MIT PRESSURE TIME HISTORY – FLEXIBLE BOTTOM



FIFTH-SCALE CALCULATED GEOMETRY



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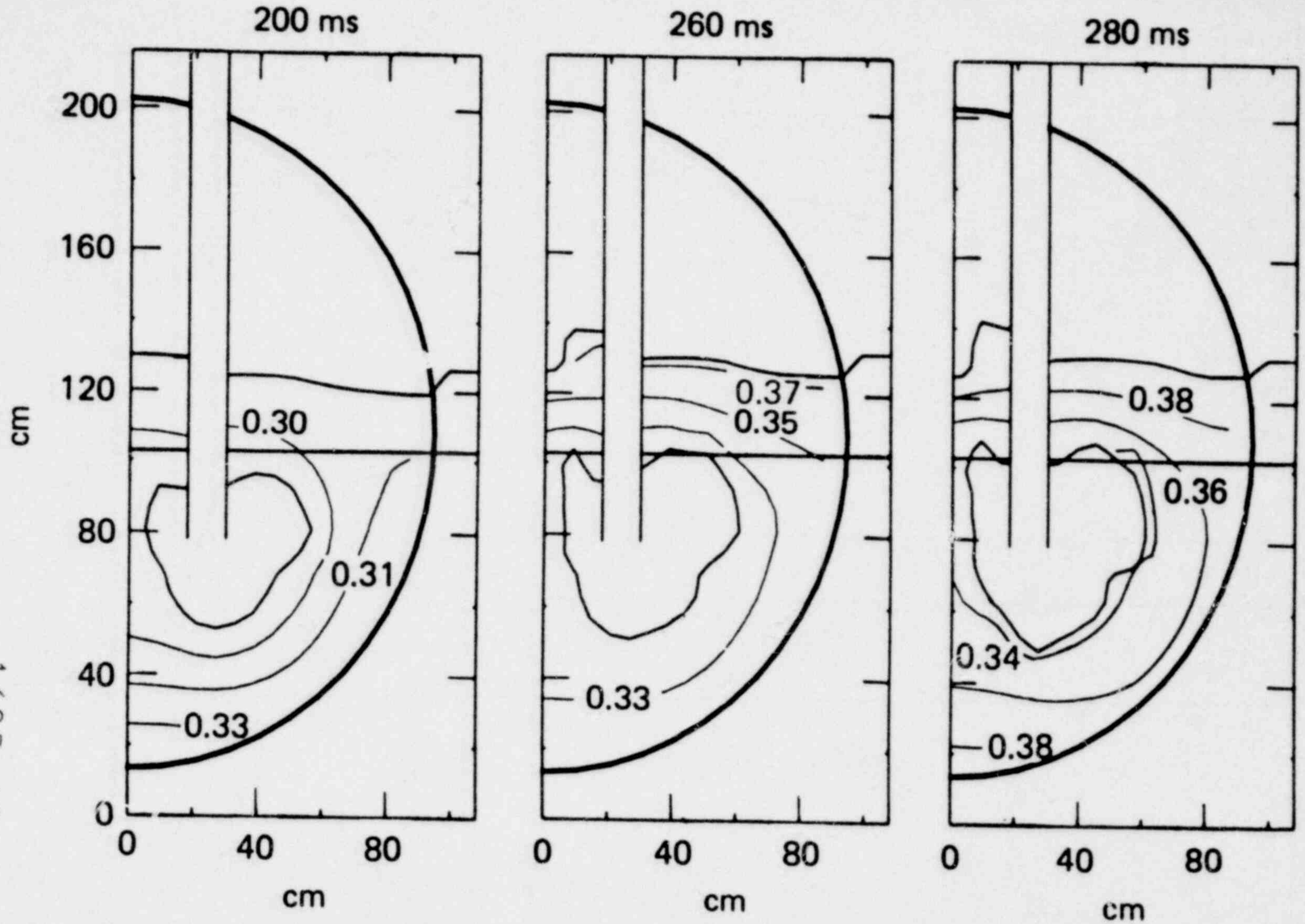
FIFTH-SCALE PRESSURE CONTOURS



Note: Pressure on contours in bars

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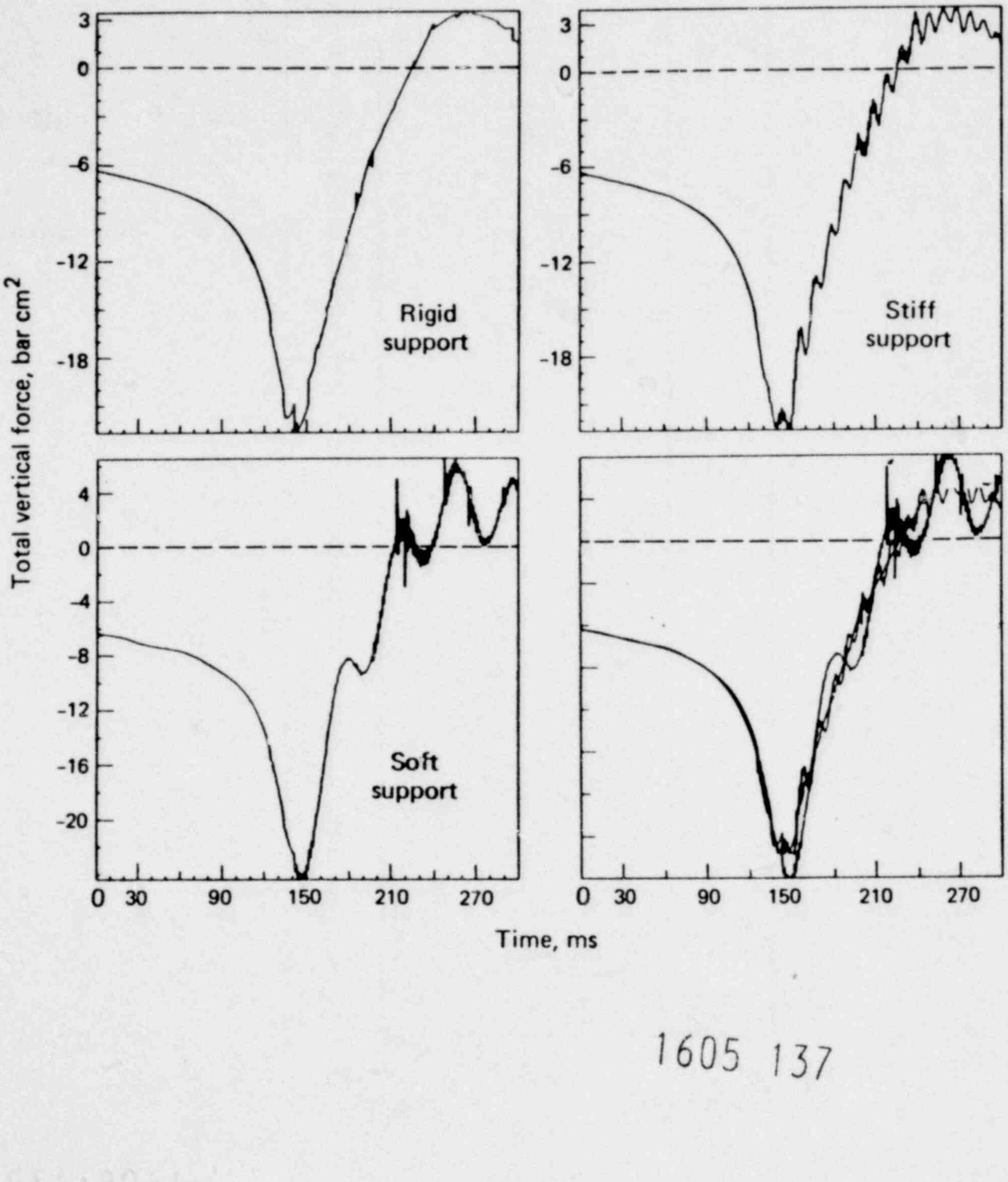
FIFTH-SCALE UPLOAD CALCULATIONS



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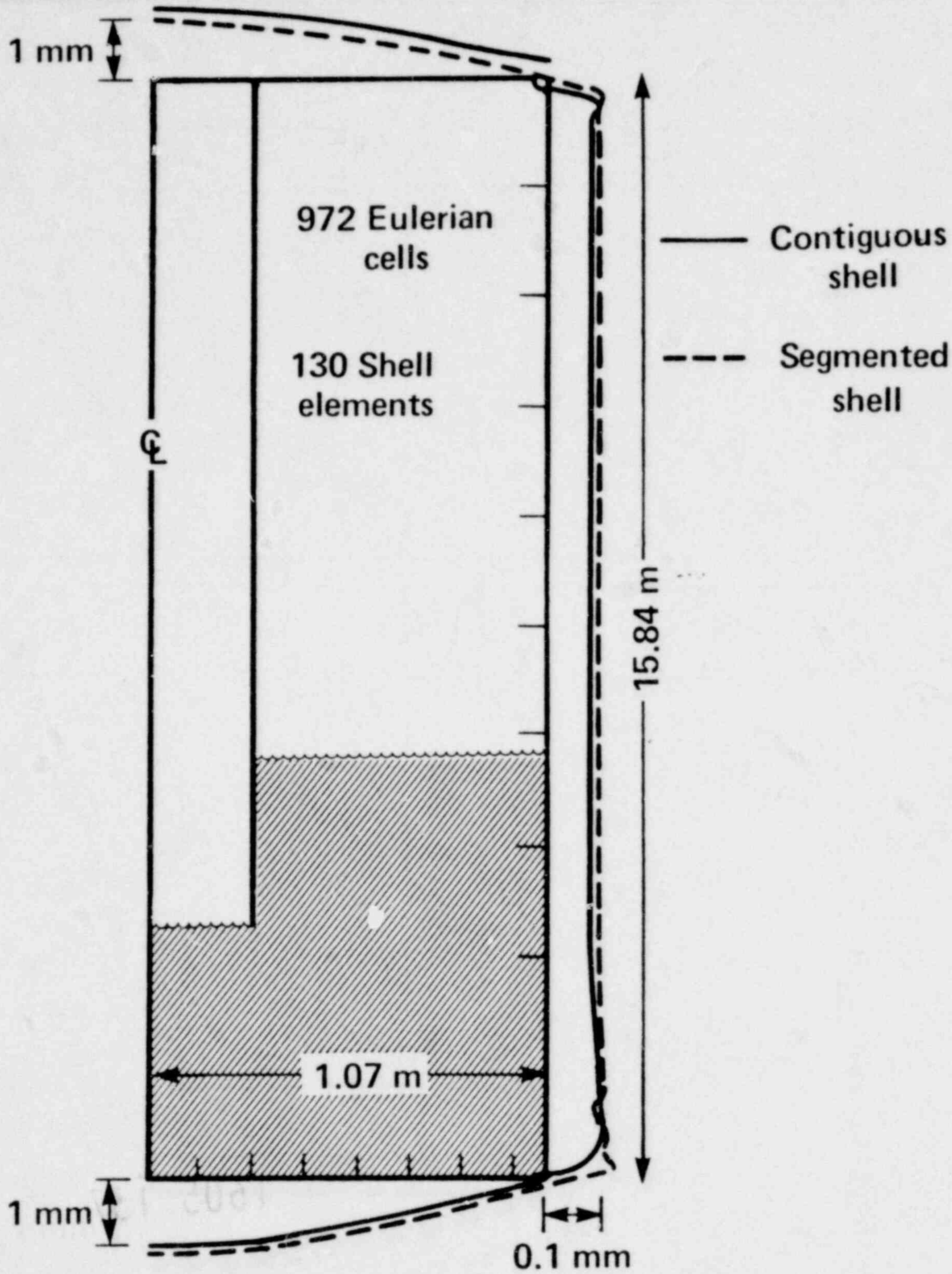
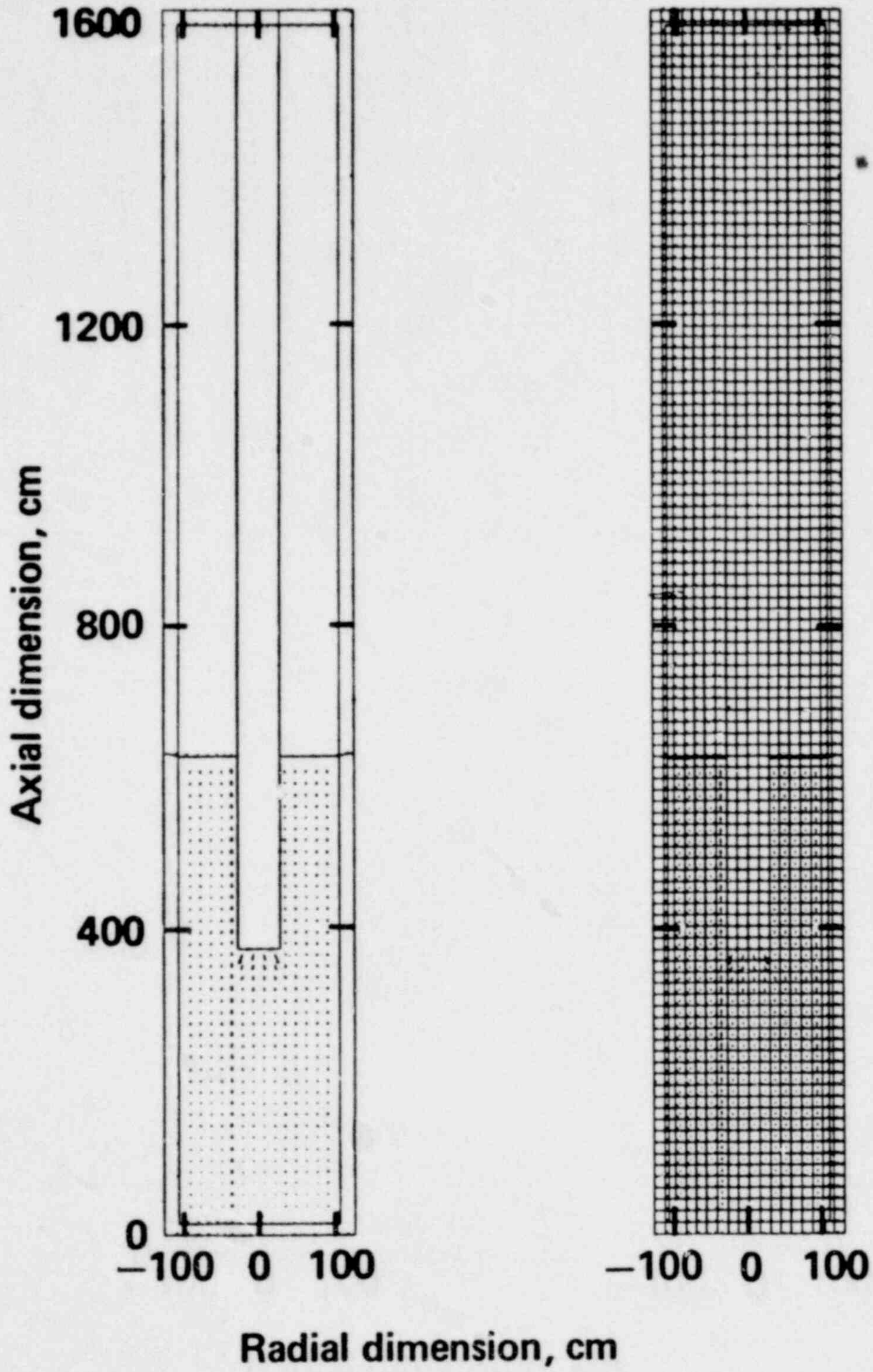
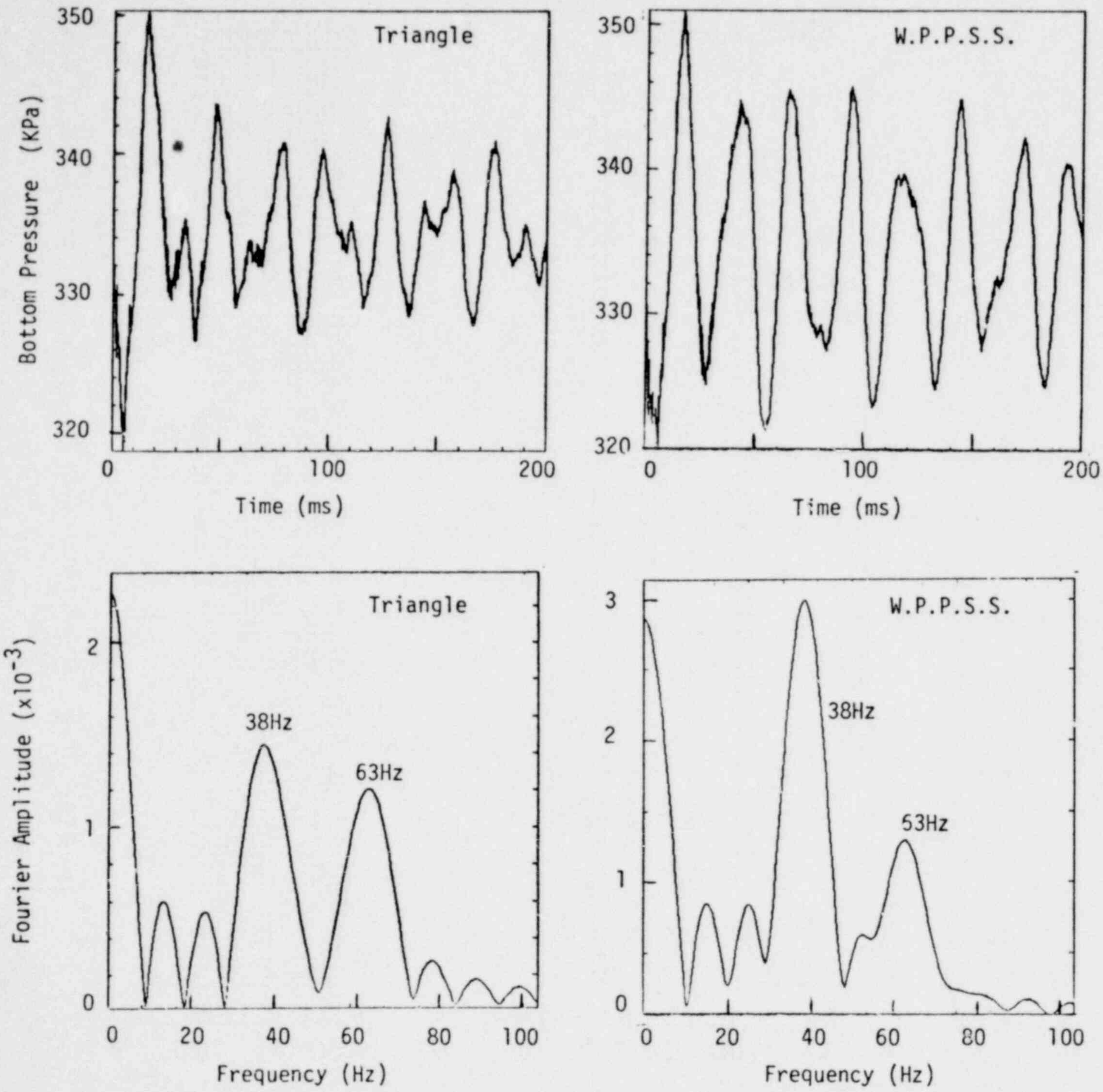
GE4T STATIC DISPLACEMENT

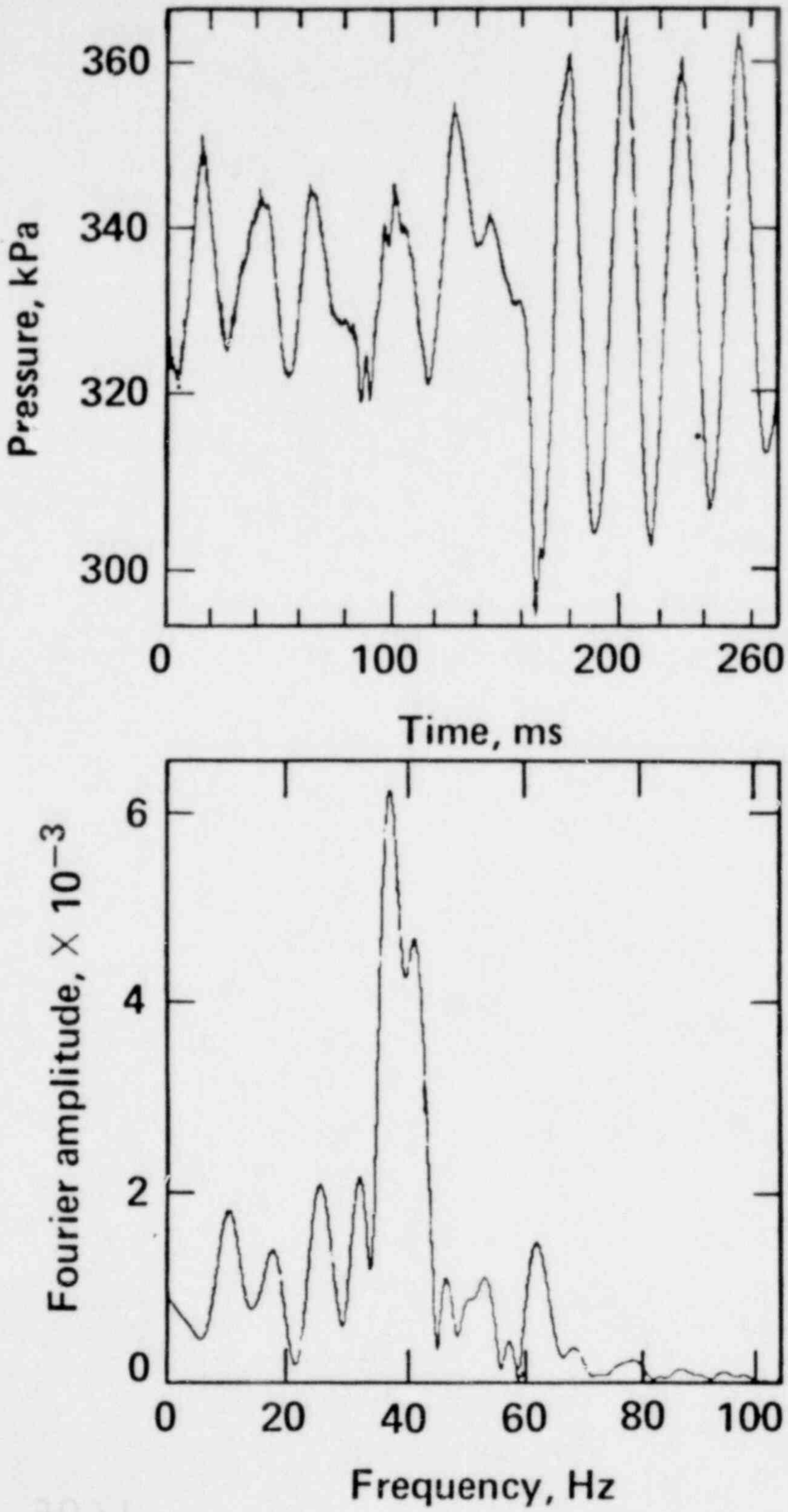


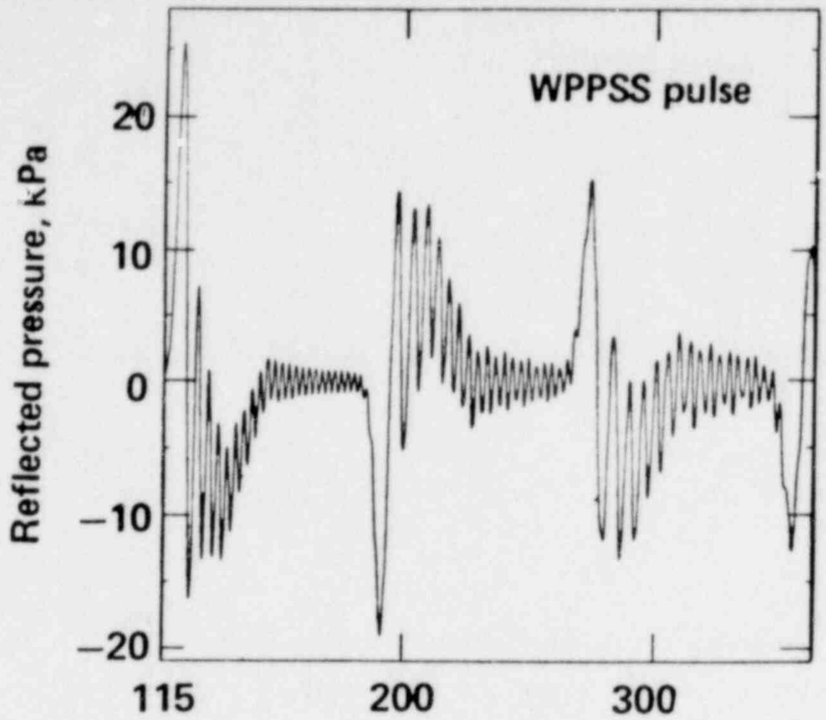
GRID FOR GE4T TANK



GE4T COMPARISON OF INPUT PULSES — LLL




360
340
320
300
Pressure, kPa
0
100
200
260
Time, ms
6
4
2
0
Fourier amplitude, × 10⁻³
0
20
40
60
80
100
Frequency, Hz


WPPSS pulse
Reflected pressure, kPa
20
10
0
−10
−20
115
200
300

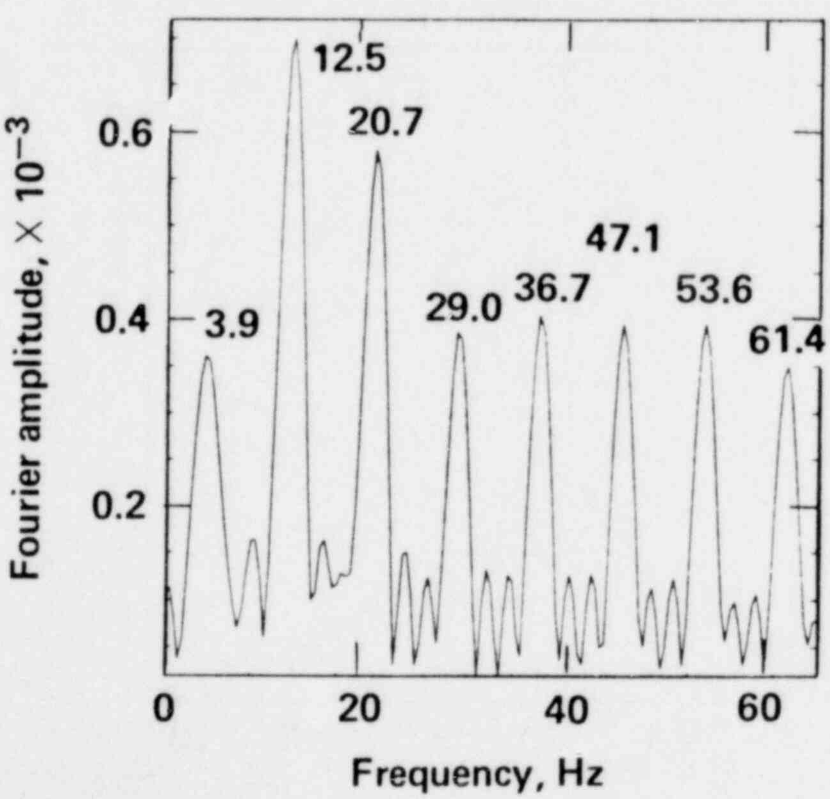

Fourier amplitude, × 10^{-3}
0.6
0.4
0.2
12.5
20.7
3.9
29.0
36.7
47.1
53.6
61.4
0
20
40
60
Frequency, Hz

TABLE I

GE4T FLUID-STRUCTURE FREQUENCIES (Hz) FROM FOURIER TRANSFORM*

Calculation 1 - No axial motion allowed at bottom plate

bottom center	67.6	56.6	14.2	24.2
side wall	67.6	57.2	14.2	24.2

Calculation 2 - No radial motion allowed on cylinder wall

bottom center	41.8	15.4	26.7	41.8
side wall	42.4	27.6	16.3	57.2

* Frequencies associated with amplitudes are progressively listed from left to right. Those having the largest amplitudes appear on the left with those having the smallest on the right.

TABLE II

GE4T FREQUENCY COMPONENTS - TRANSFORM OF PRESSURE PULSES*

Column	a	b	c	d	e
W.P.P.S.S. Pulse Alone	13.5	53.4	38.7		
Reflected W.P.P.S.S. Pulse Alone (Vent Acoustics)	12.5	20.7	37.2	29.0	3.9
PELE-IC Bottom Pressure For W.P.P.S.S. Pulse (no reflection) (100-200 ms)	38.4	62.6	15.2	25.5	52.6
PELE-IC Bottom Pressure For W.P.P.S.S. Pulse With Its Acoustic Reflection (100 - 273 ms)	39.1	25.4	18.7	53.0	11.5
(0 - 273 ms)	37.6	25.8	10.5	63.0	18.0

* Frequencies associated with amplitudes are progressively listed from left to right. Those having the largest amplitudes appear on the left with those having the smallest on the right.

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