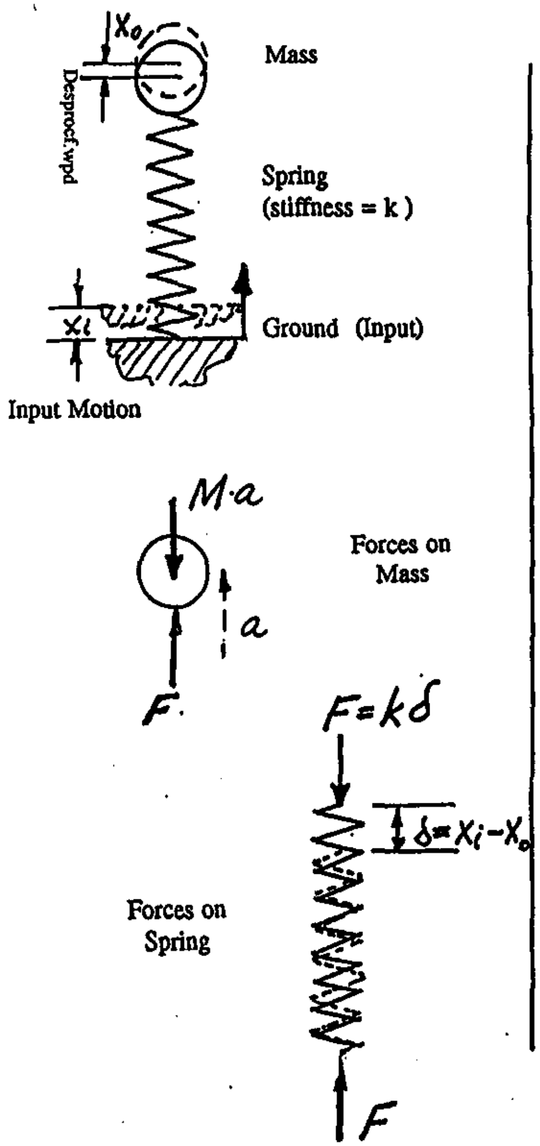
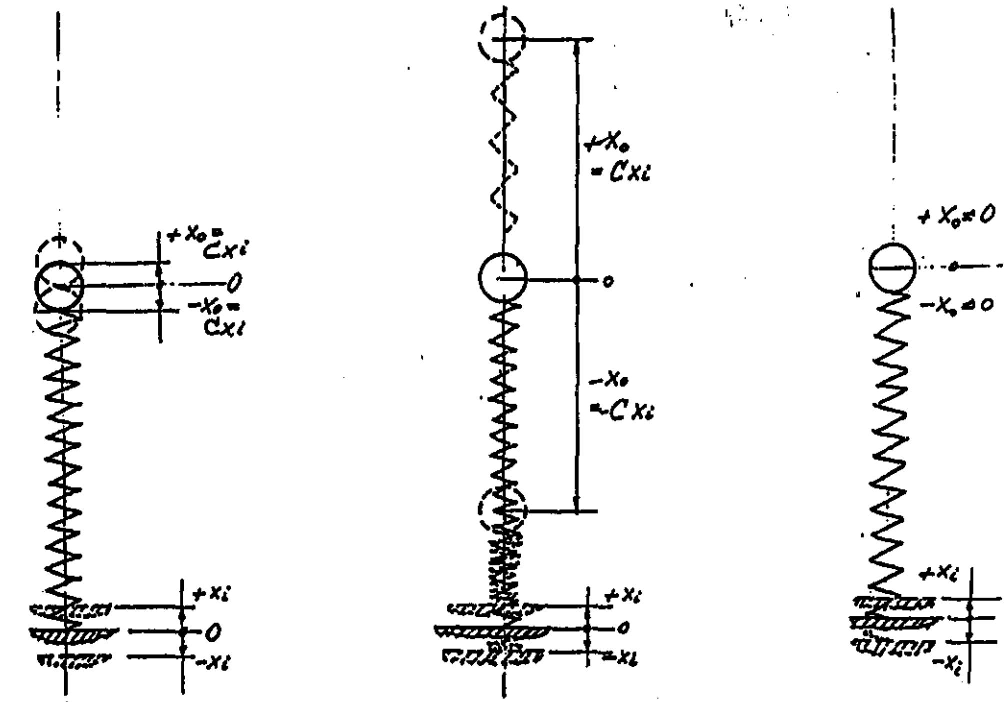


Displacements and Forces



(a) At Very Low Frequency :

- $\nu/\omega \approx 0$
- Output = Input: $x_o = x_i$
- Amplification $C = x_o / x_i = 1$
- Change in spring length = δ
  $= (x_o - x_i) = 0$
- Change of Force in spring
  due to vibration $\Delta F = 0$

(b) At Resonance :

- $\nu/\omega = 1$
- Output › Input: $x_o = C\,x_i$
- Amplification $C = x_o / x_i = 1/2\beta$
  at $\beta = 5\ \%$, $C_5 = 10$)
  at $\beta = 3\ \%$, $C_3 = 16.67$)
- Change in spring length = δ
  $= (x_o - x_i) = (C - 1)\,x_i$
- Change of Force in spring
  due to vibration $\Delta F = k\,\delta$
  $= k \cdot (C - 1)\,x_i$

(c) At Very High Frequency :

- $\nu/\omega › 10$
- Output = $x_o \approx 0$
- Amplification $C = x_o / x_i \approx 0$
- Change in spring length = $\delta = (x_o - x_i)$
  $\delta = (C - 1) \cdot x_i = (0 - 1) \cdot x_i = -x_i$
- Change of Force in spring
  due to vibration $\Delta F = k \cdot \delta$
  $\Delta F = k\,x_i$

Response for Varied Frequency at Unifom Input Displacement

Figure 4-1 Vibration Behaviour of a Simple Spring-Mass System

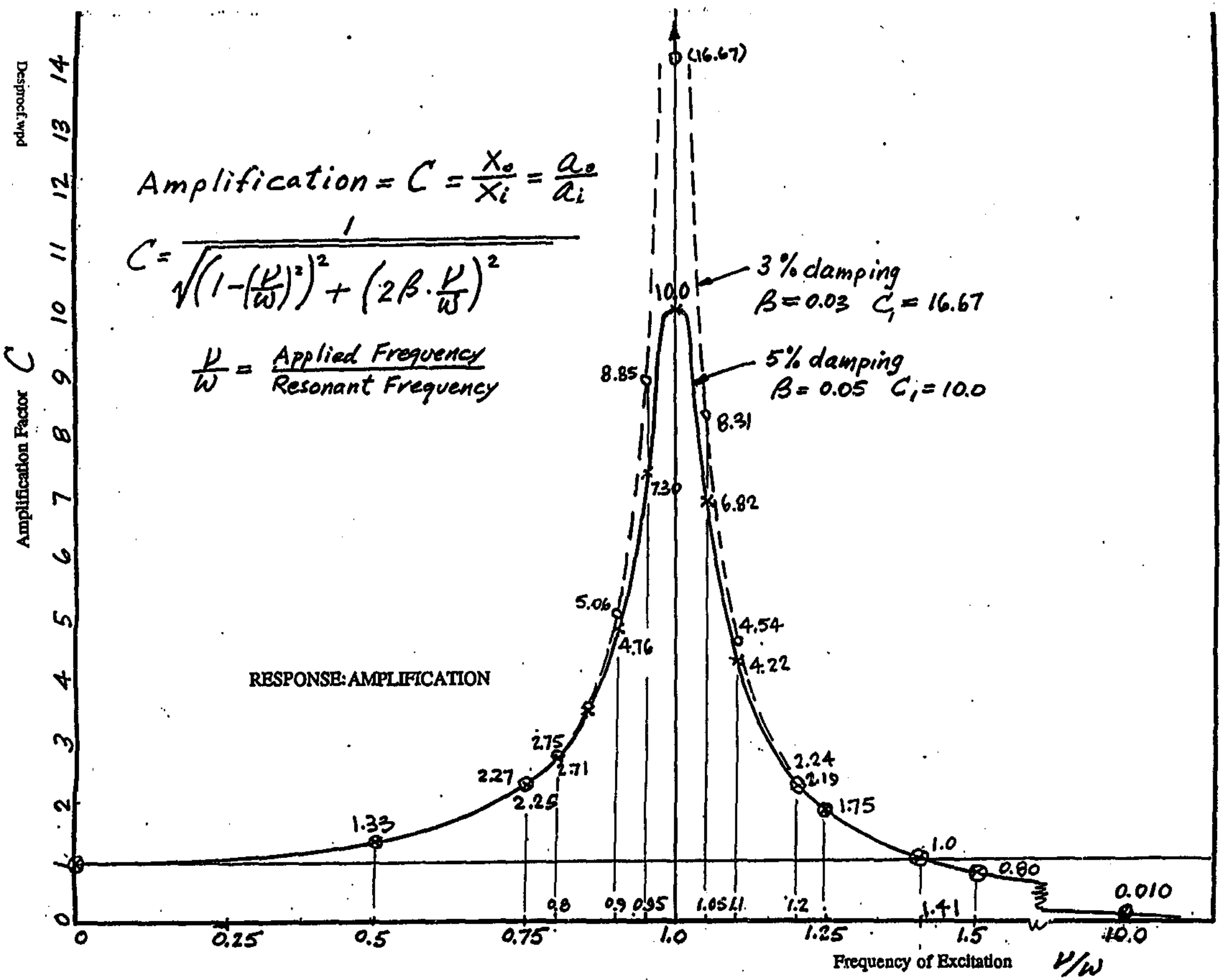


Figure 4.2 Response Amplitude for a Vibrating System

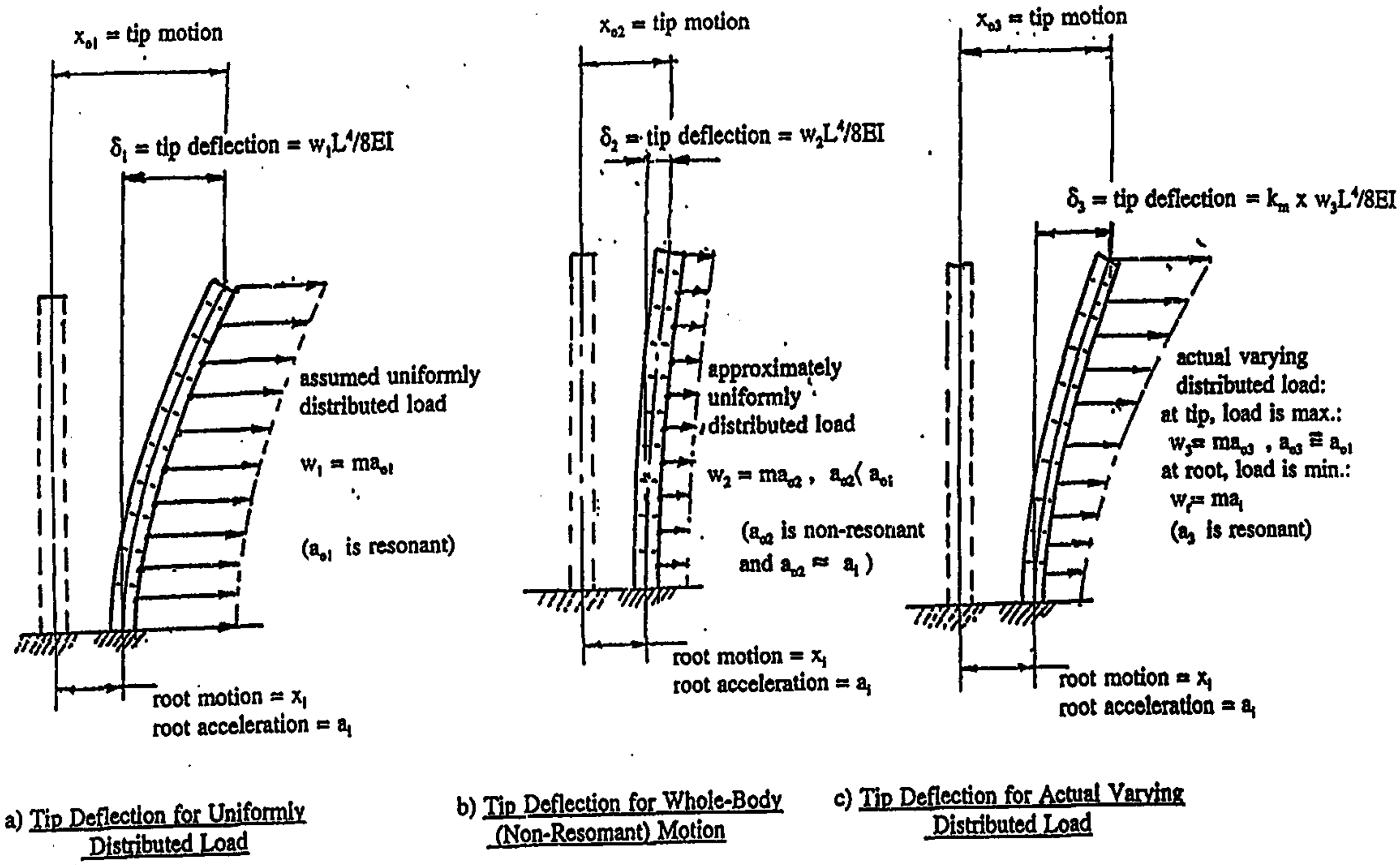
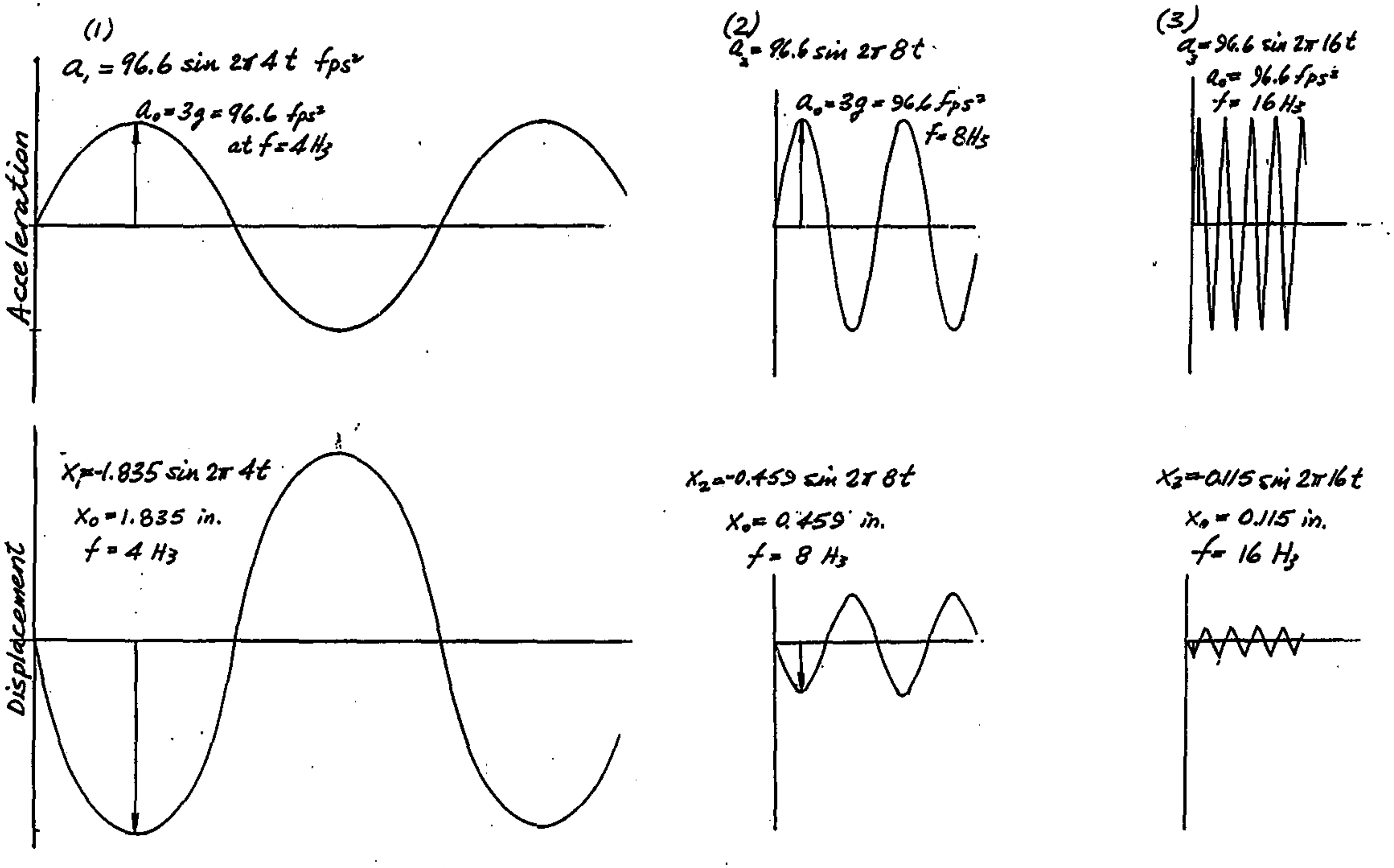


Figure 4-3 Response of a Vibrating Cantilever Beam

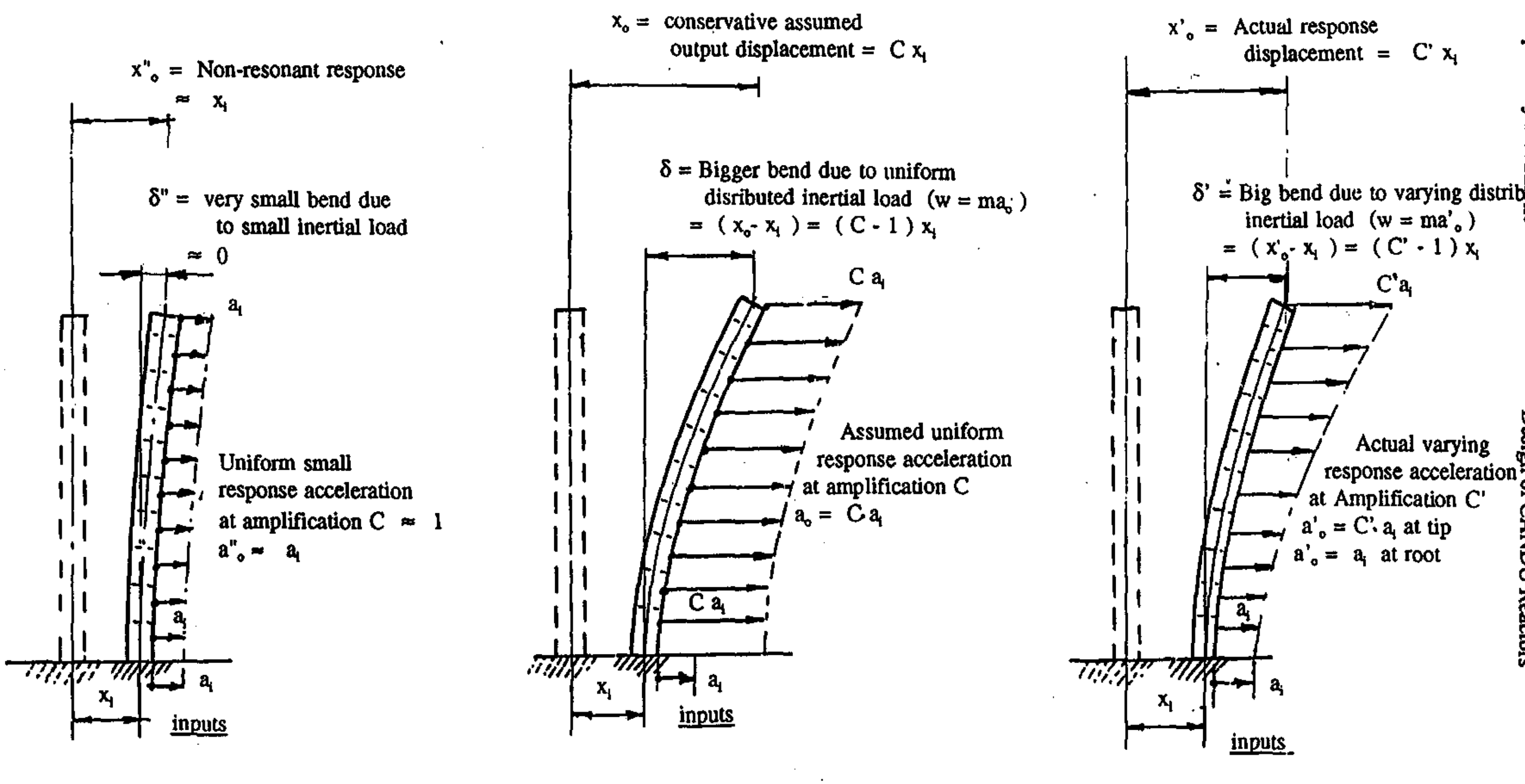


(1) $f_1 = 4$ Hz & $a_o = 3$ g = 96.6 f/s^2 (2) $f_2 = 8$ Hz & $a_o = 3$ g = 96.6 f/s^2 (3) $f_3 = 16$ Hz & $a_o = 3$ g = 96.6 f/s^2

Displacement Generated by Sinusoidal Motion at Different Frequencies at Constant Acceleration

$x = x_0 \sin 2\pi ft$ $a = x'' = -a_0 \sin 2\pi ft$ $a_o = 4\pi^2 f^2 x_0$ or $x_0 = a_0/4\pi^2 f^2$

Figure 4-4 Simple Harmonic Motion



(1) Non-Resonant Response

(2) Amplified Response for Assumed Uniform Response Acceleration

(3) Amplified Response for Actual Varied Response Acceleration

Figure 4-5 Displacement and Deflection on a Vibration Cantilever Beam

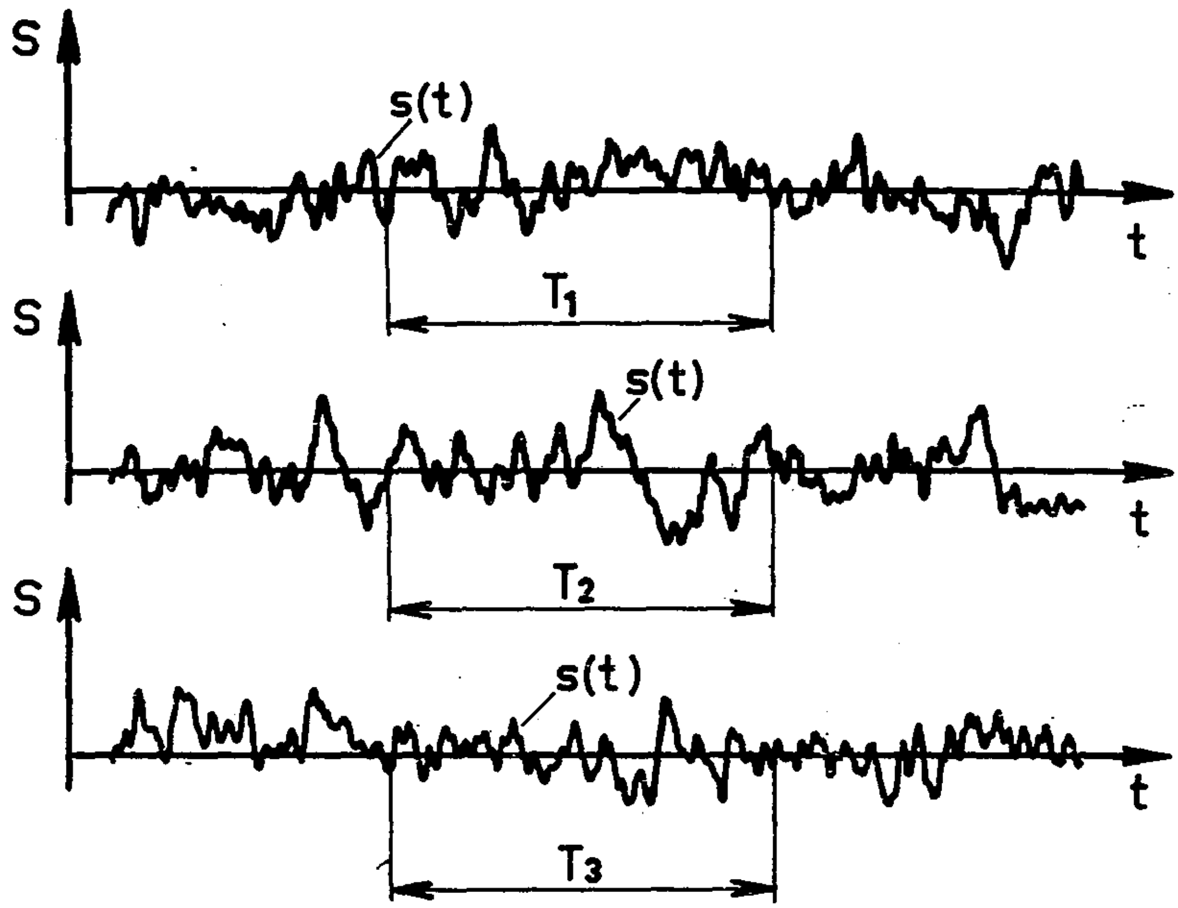


Figure 4-6 Time-History of Typical Complex Vibration

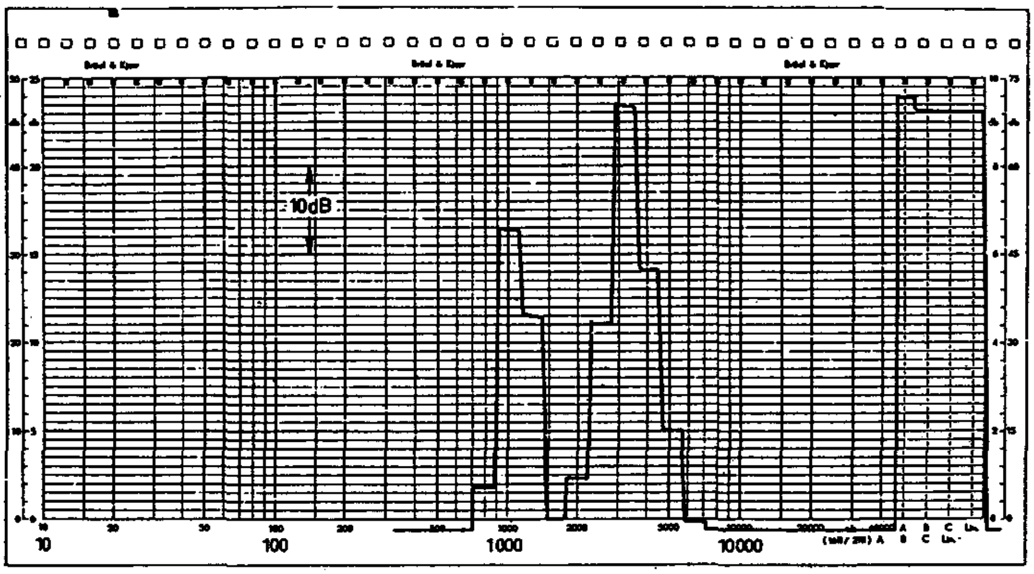
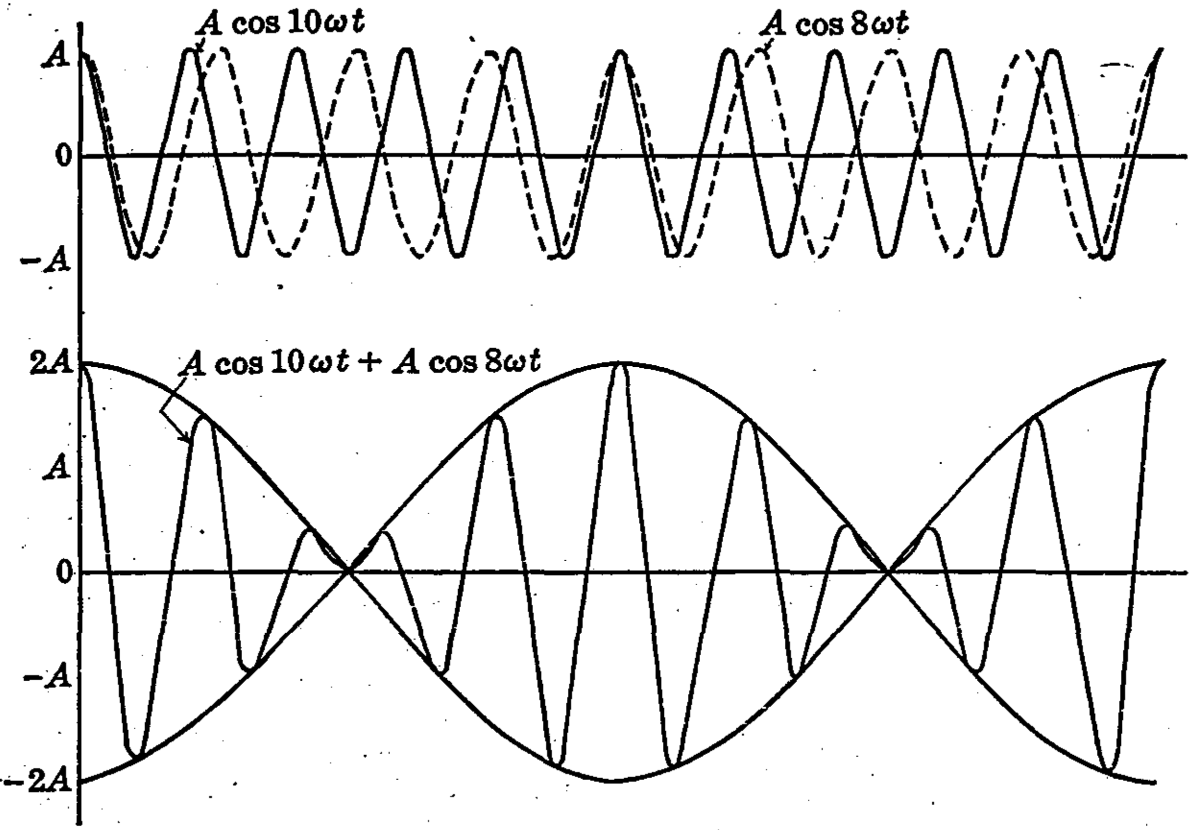
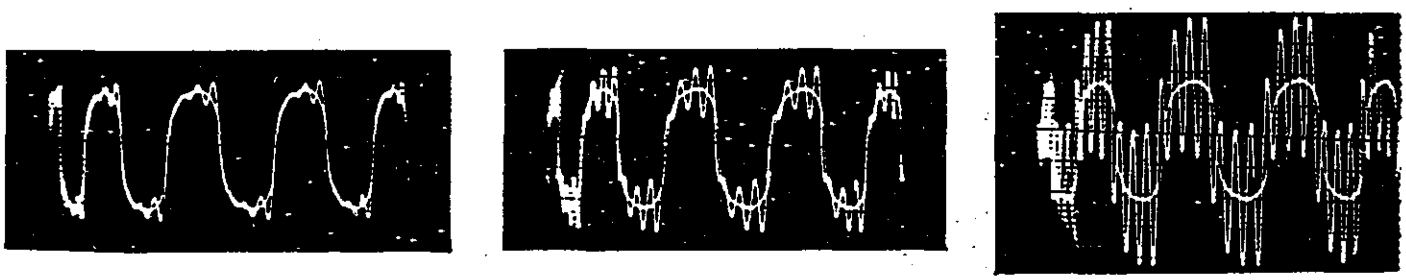


Figure 4-7 Output Recording of a Frequency-Spectrum Analyser using filter bandwidth = 1/3 octave

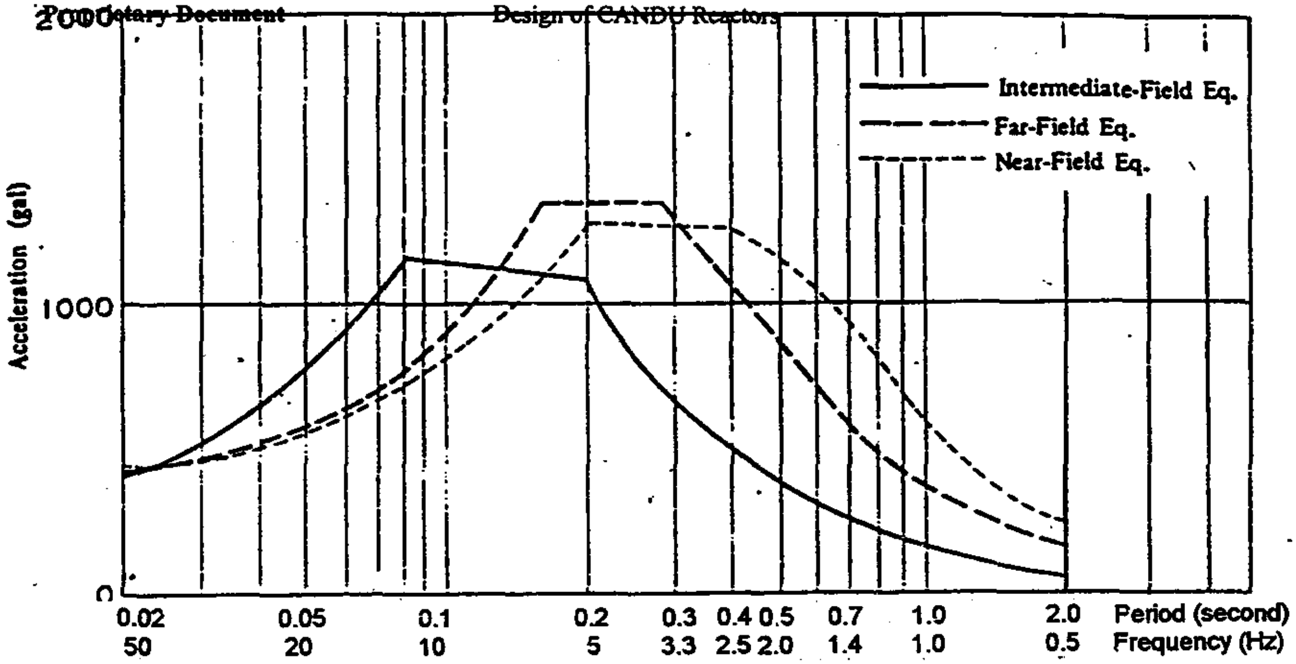


(i) Addition of two signals with the same amplitude but different frequencies

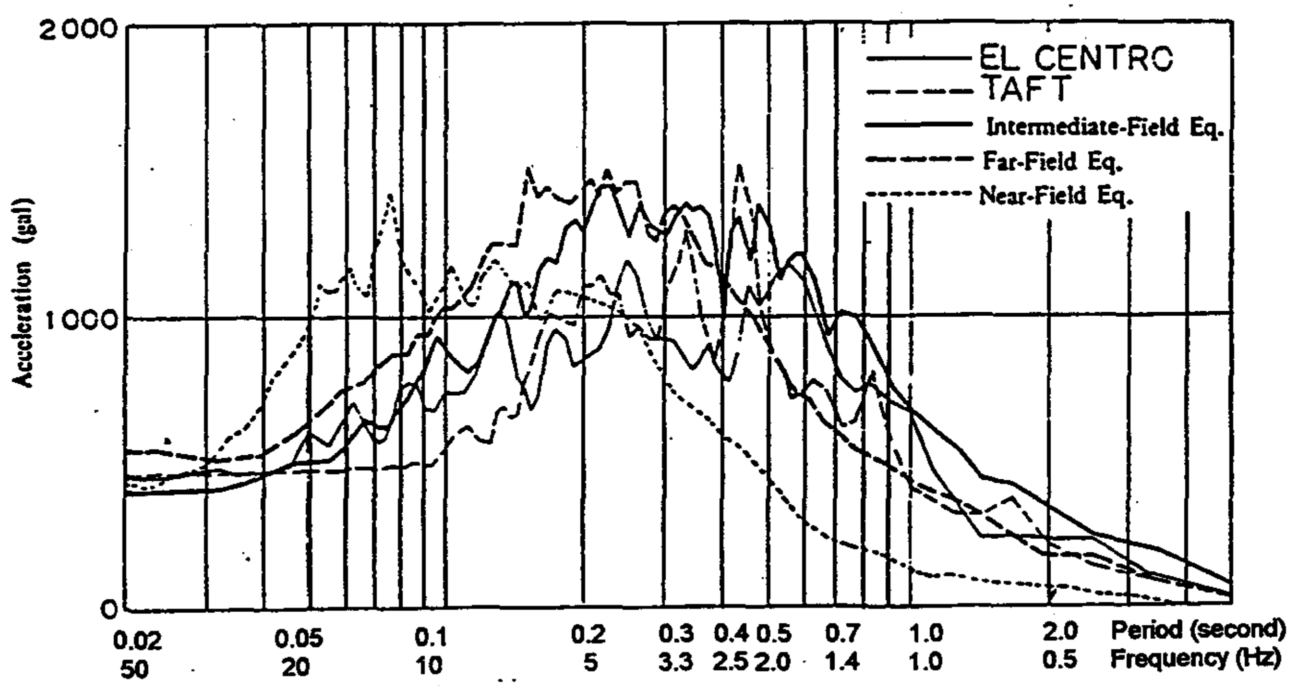


(ii) Three recordings showing the addition of high frequency waves to a low frequency wave, where the amplitude of the second wave is much smaller than, 1/4 as big as, and equal to that of the first wave. The first wave is also shown in each case, for reference.

Figure 4-8 Addition of Two Vibrations of Different Frequencies



(a) Smoothed envelope curve used for design



(b) Acceleration response spectra for recorded and synthesized earthquakes

Figure 4-9 Design Response Spectra for Recorded Earthquakes

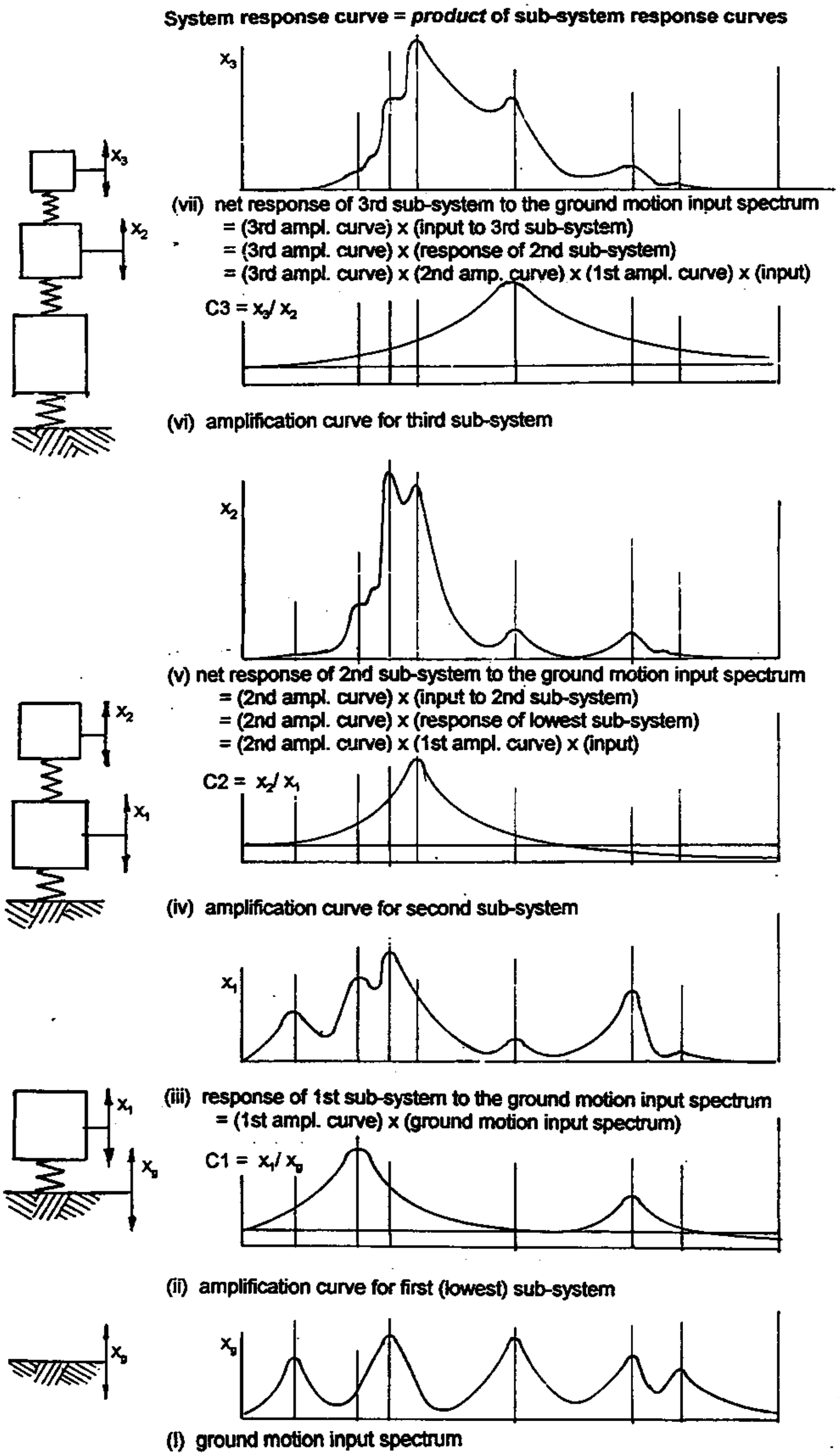


Figure 4-10 Added Responses for a Simplified Representation of a Complex Structure

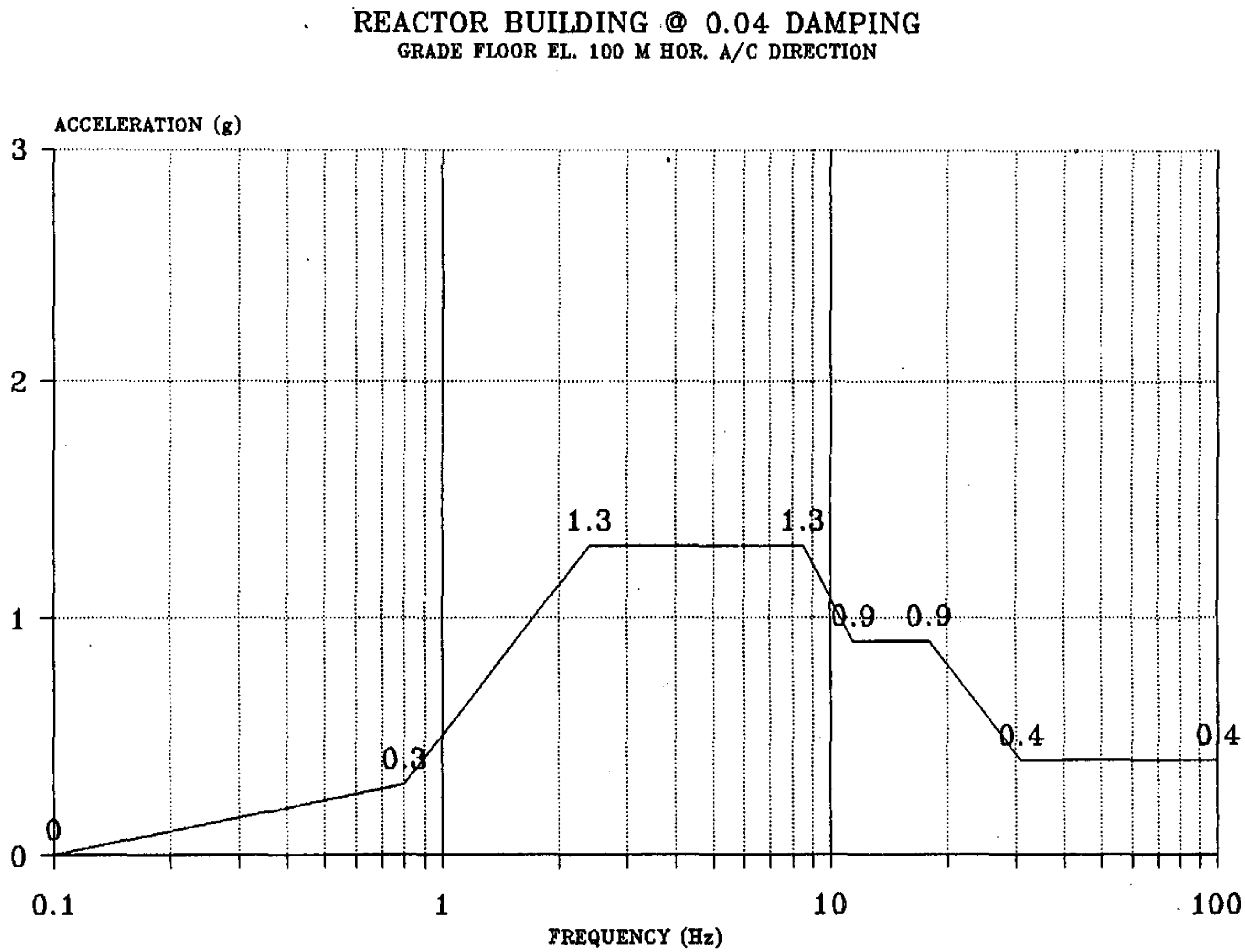


Figure 4-11 Floor Response Spectrum for CANDU 6 Reactor Structure

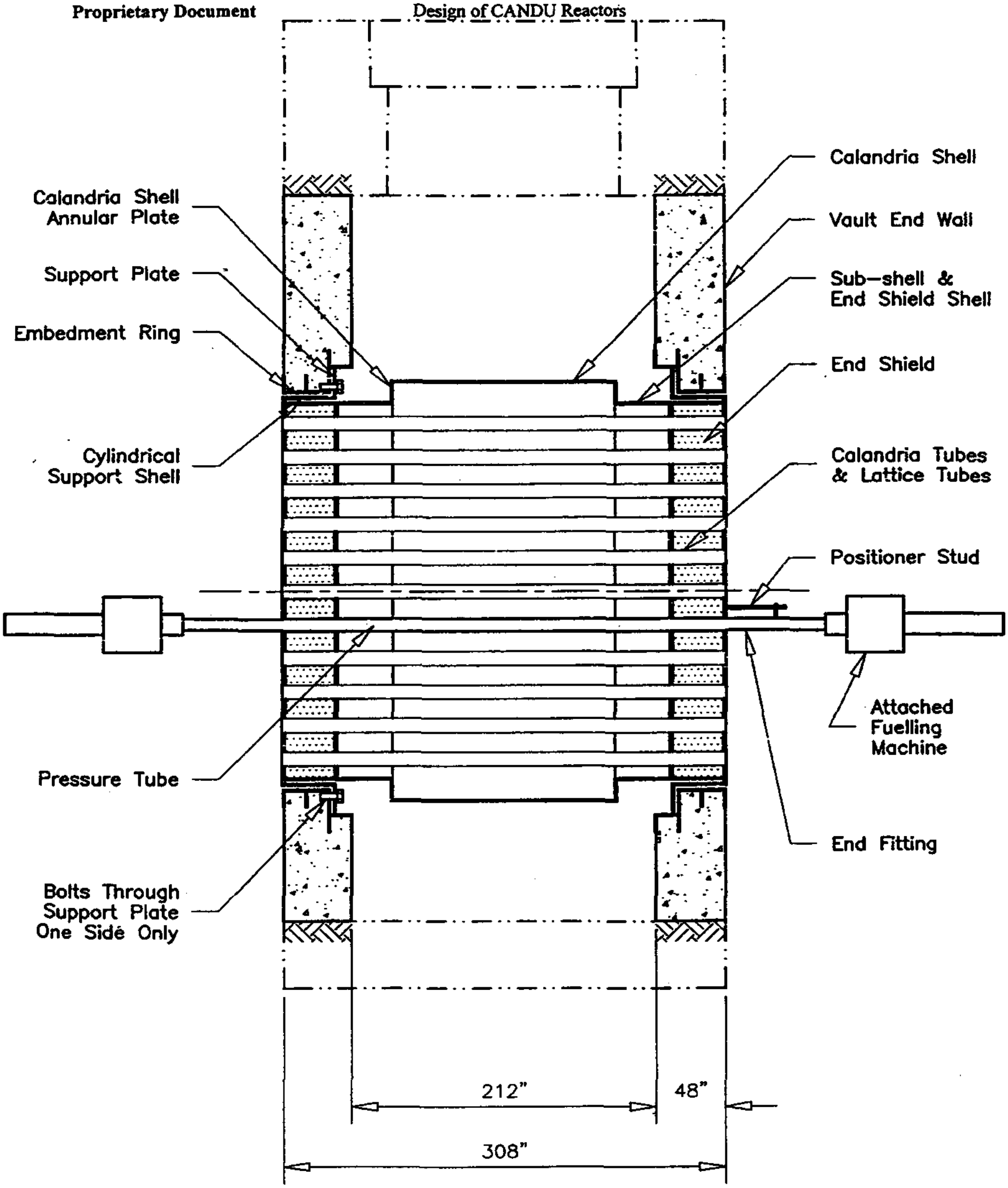


Figure 4-12 Structure Schematic of Present CANDU 6 Reactor Assembly

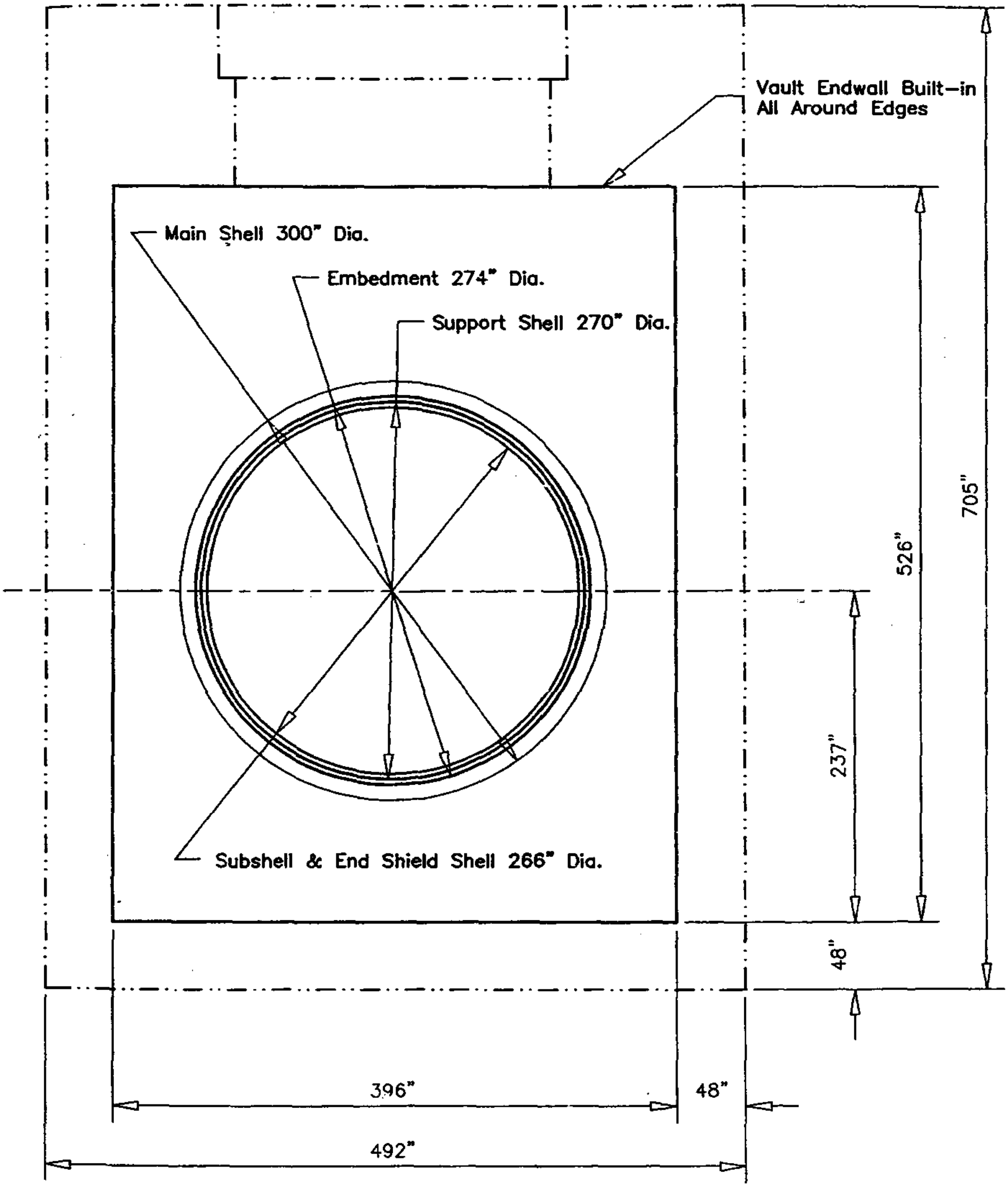


Figure 4-13 Dimensions of Present CANDU 6 Reactor Assembly

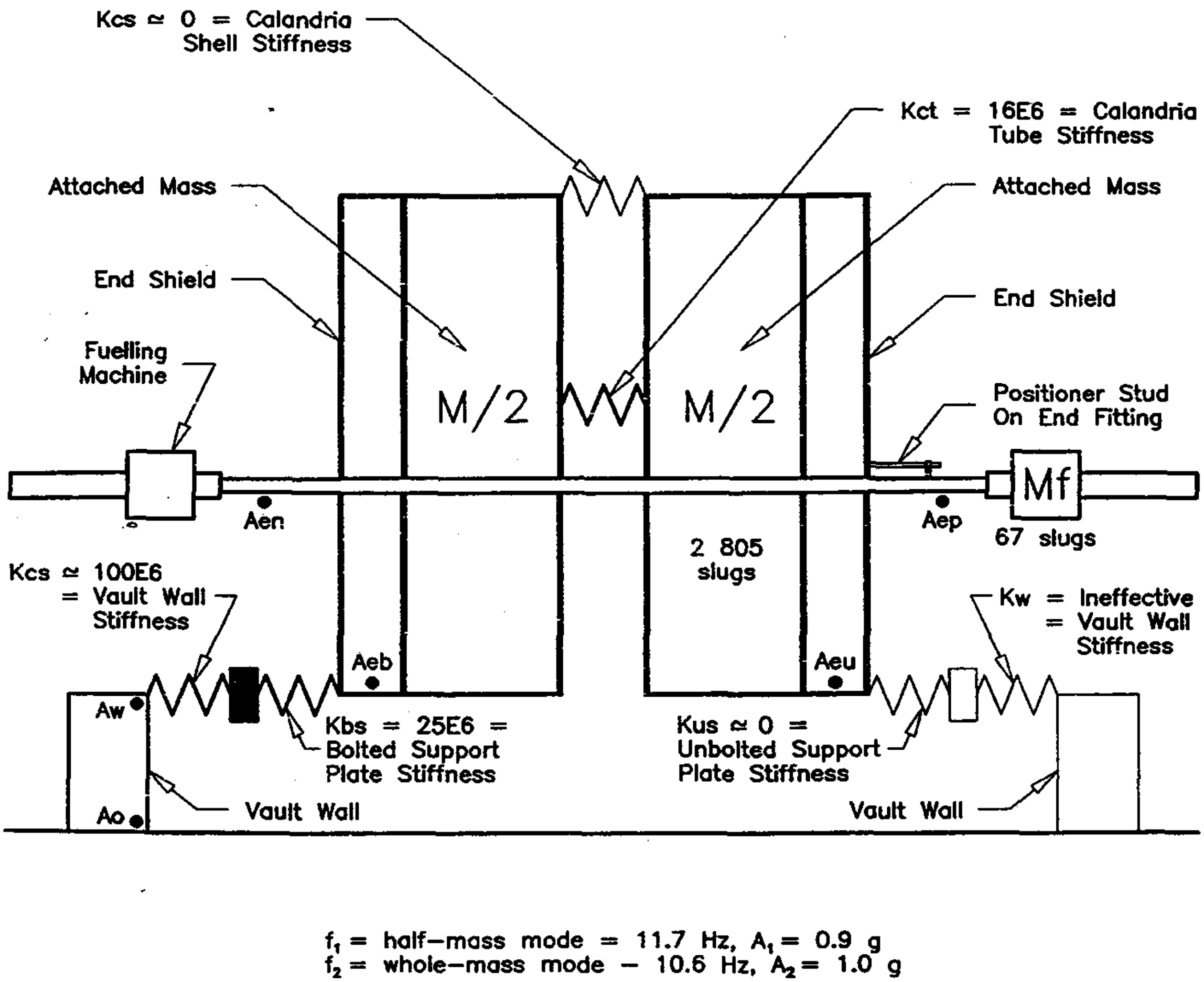
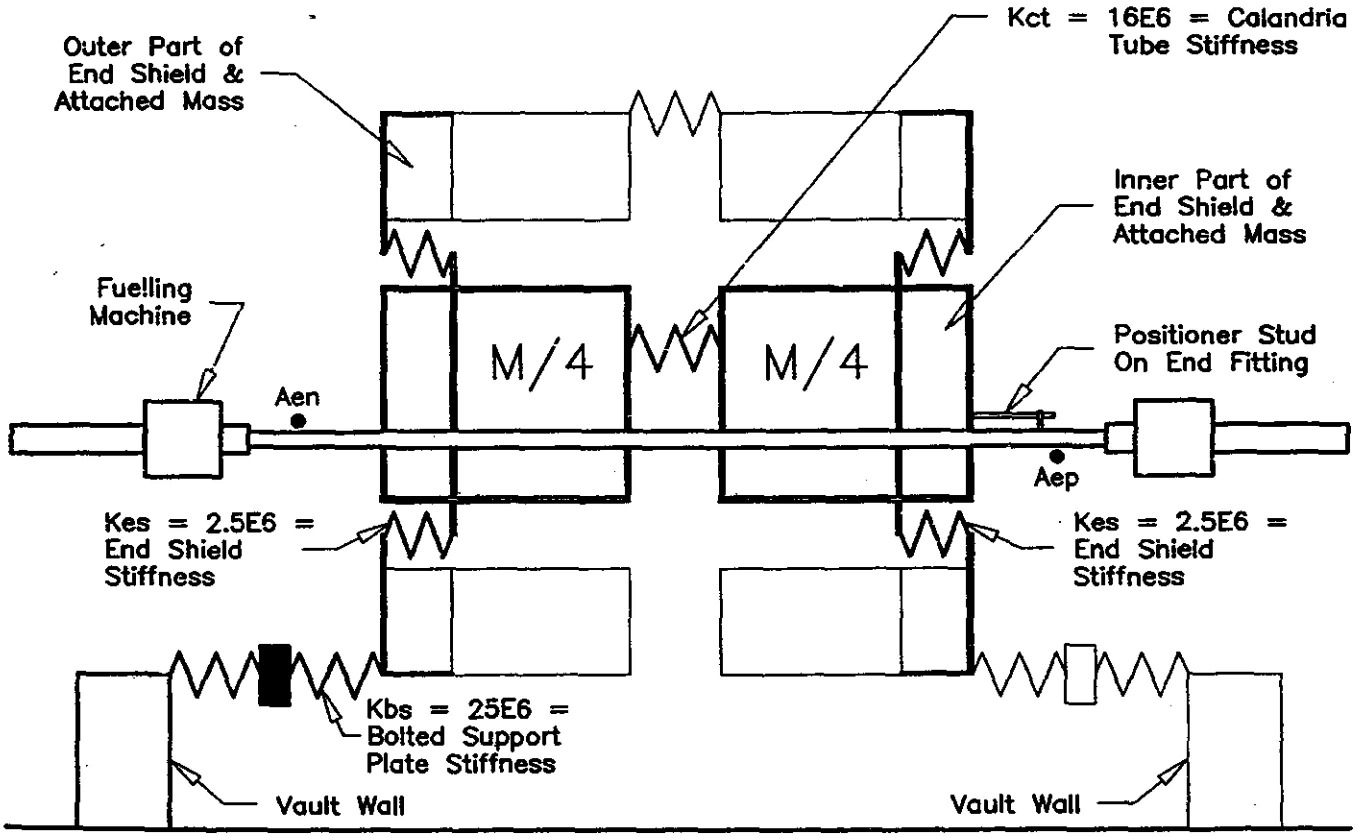
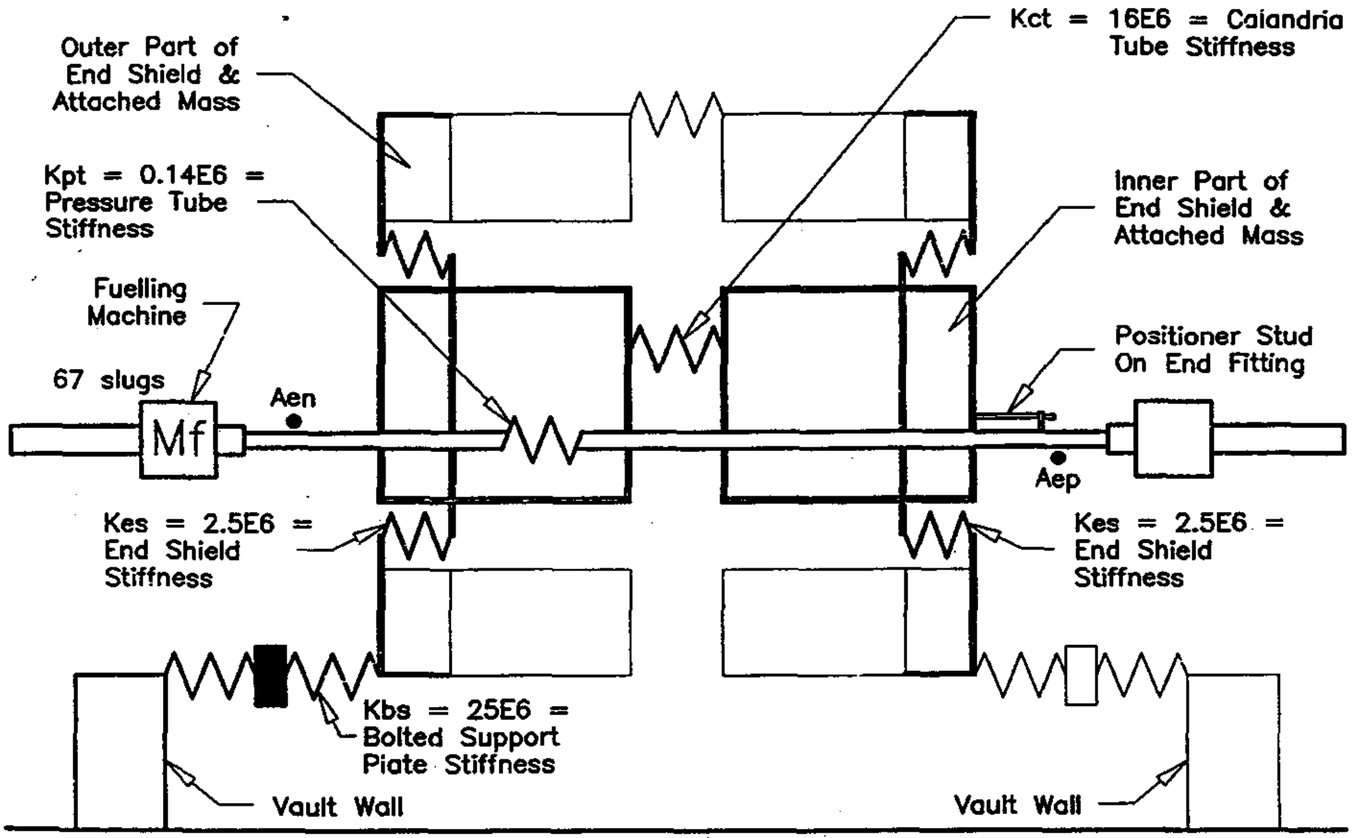


Figure 4-14 Seismic Schematic of Present Reactor Assembly - Basic Response Modes and Frequencies



f_3 = end shield mode = 6.6 Hz, A_3 = 1.3 g

Figure 4-15 Seismic Schematic of Present Reactor Assembly - End Shield Response Mode and Frequency



$f_4 = 7.4$ Hz, $A_4 = 1.3$ g

Figure 4-16 Seismic Schematic of Present Reactor Assembly - Fuel Channel Response Mode and Frequency

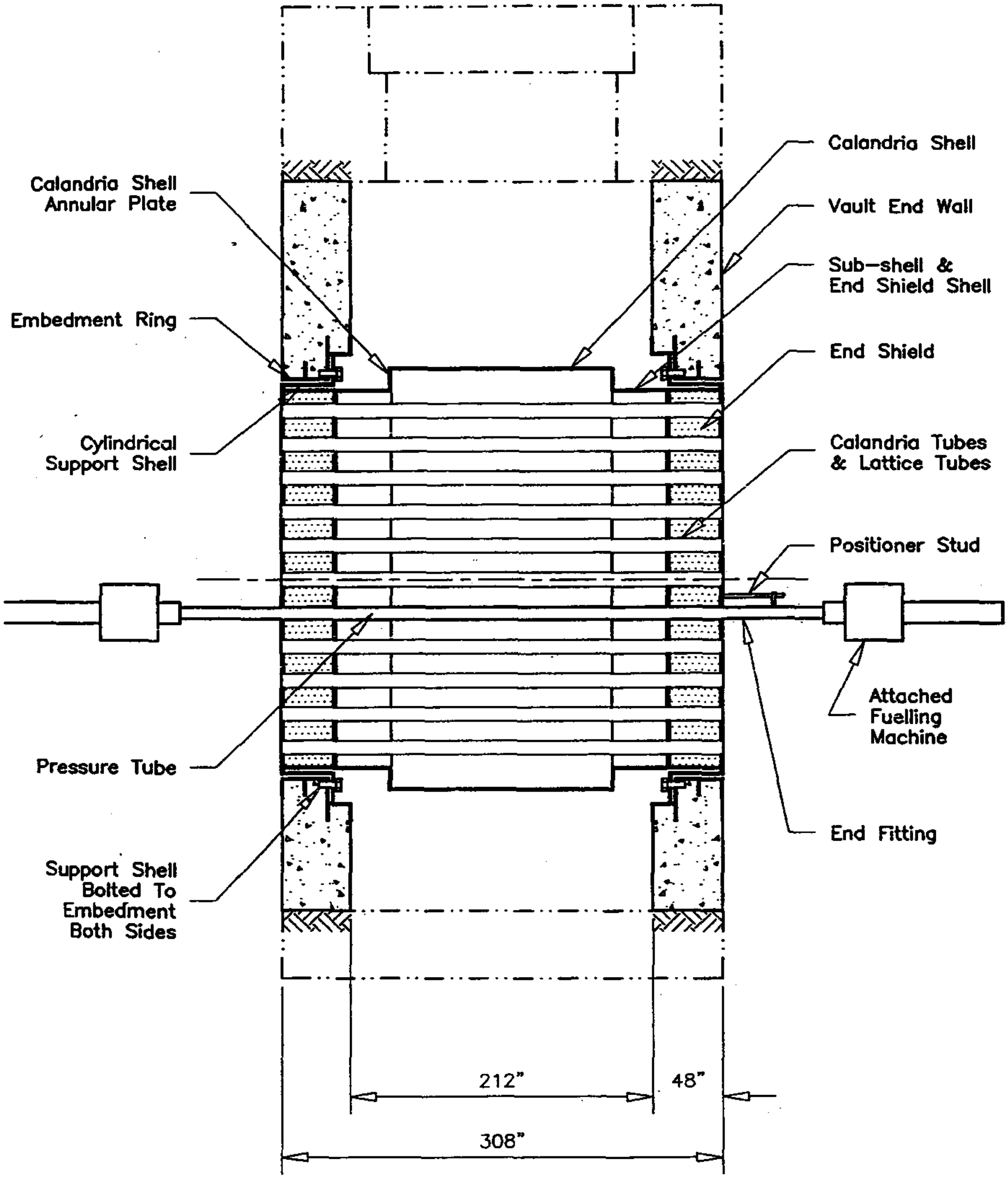
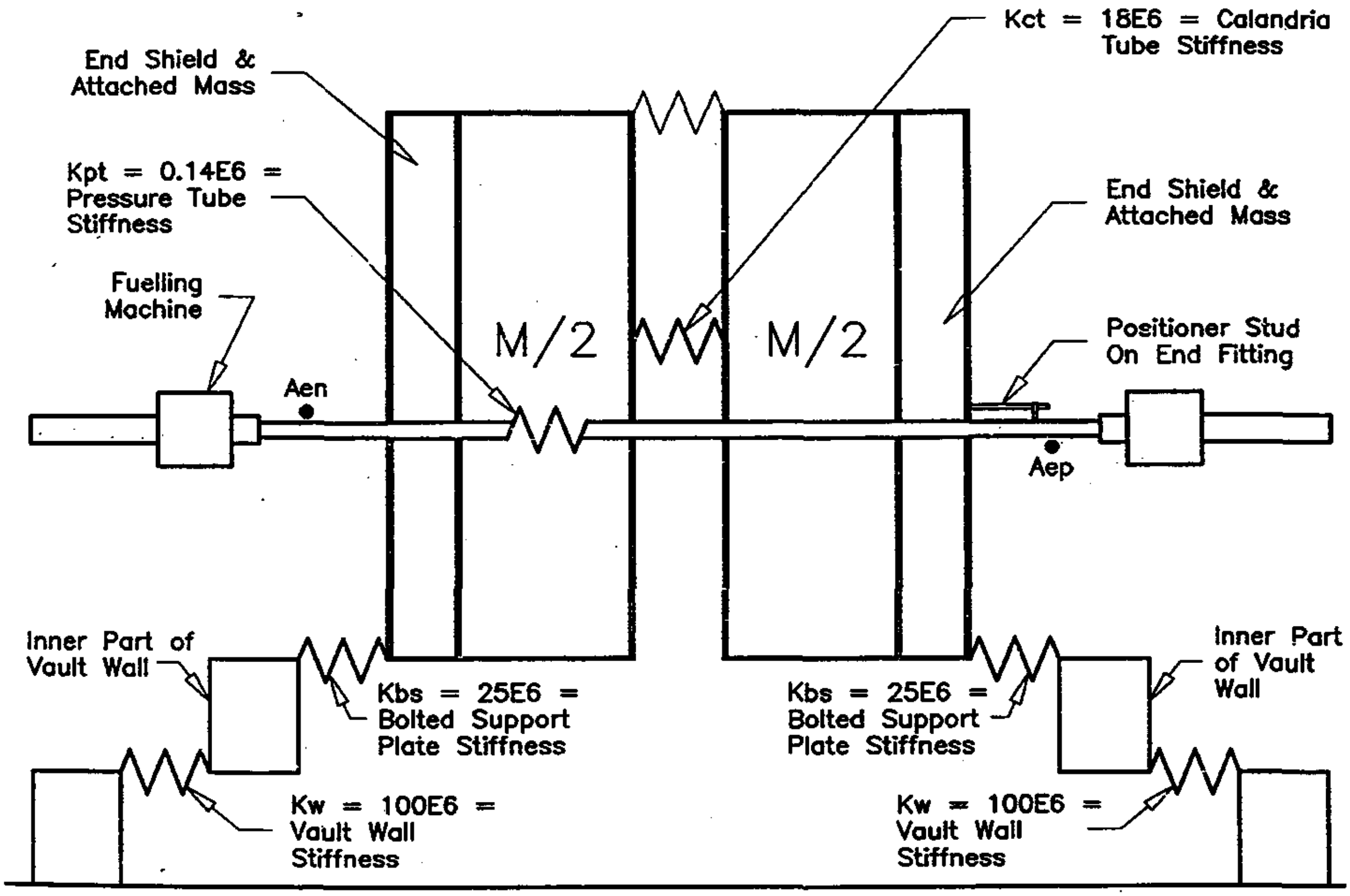


Figure 4-17 Structure Schematic of Modified Reactor Assembly - Axial Support by Bolts at *Both* Ends



$f_5 = 14.9$ Hz, $A_5 = 0.9$ g

Figure 4-18 Seismic Schematic of Modified Reactor Assembly - Basic Response Modes and Frequencies

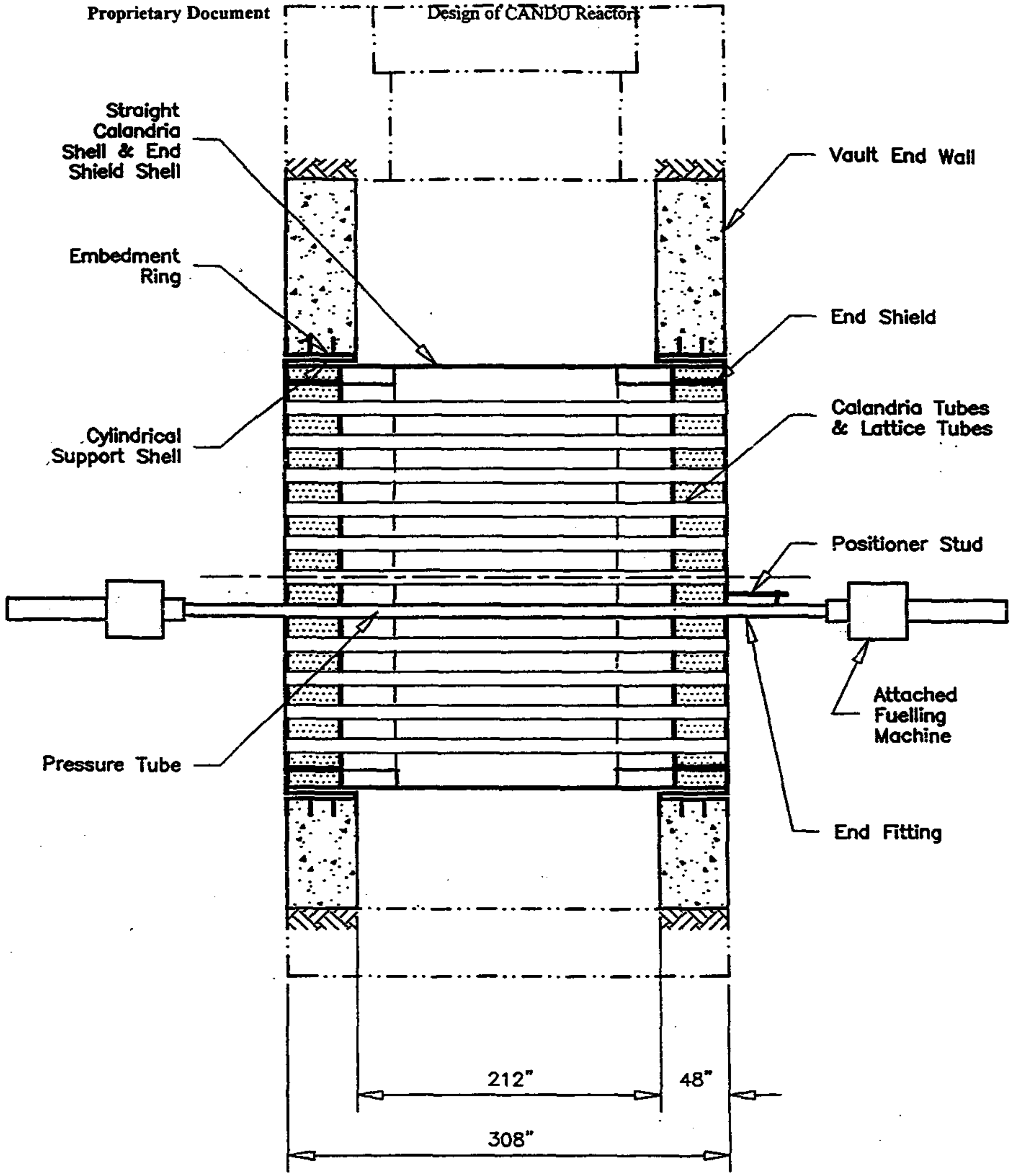
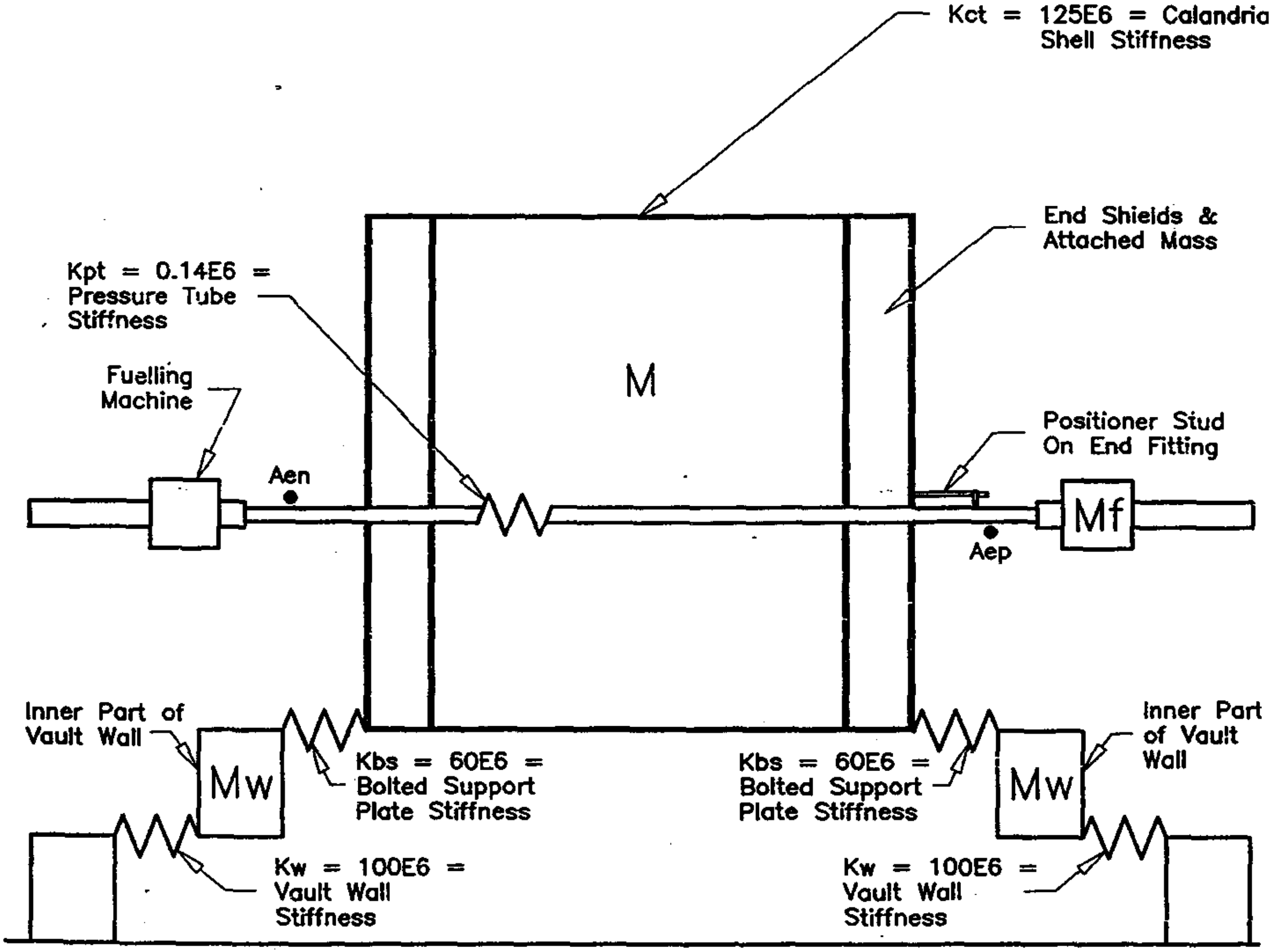


Figure 4-19 Structure Schematic of Straight-shell Reactor Assembly - Axially Rigid Joint Direct to Vault at Both Ends

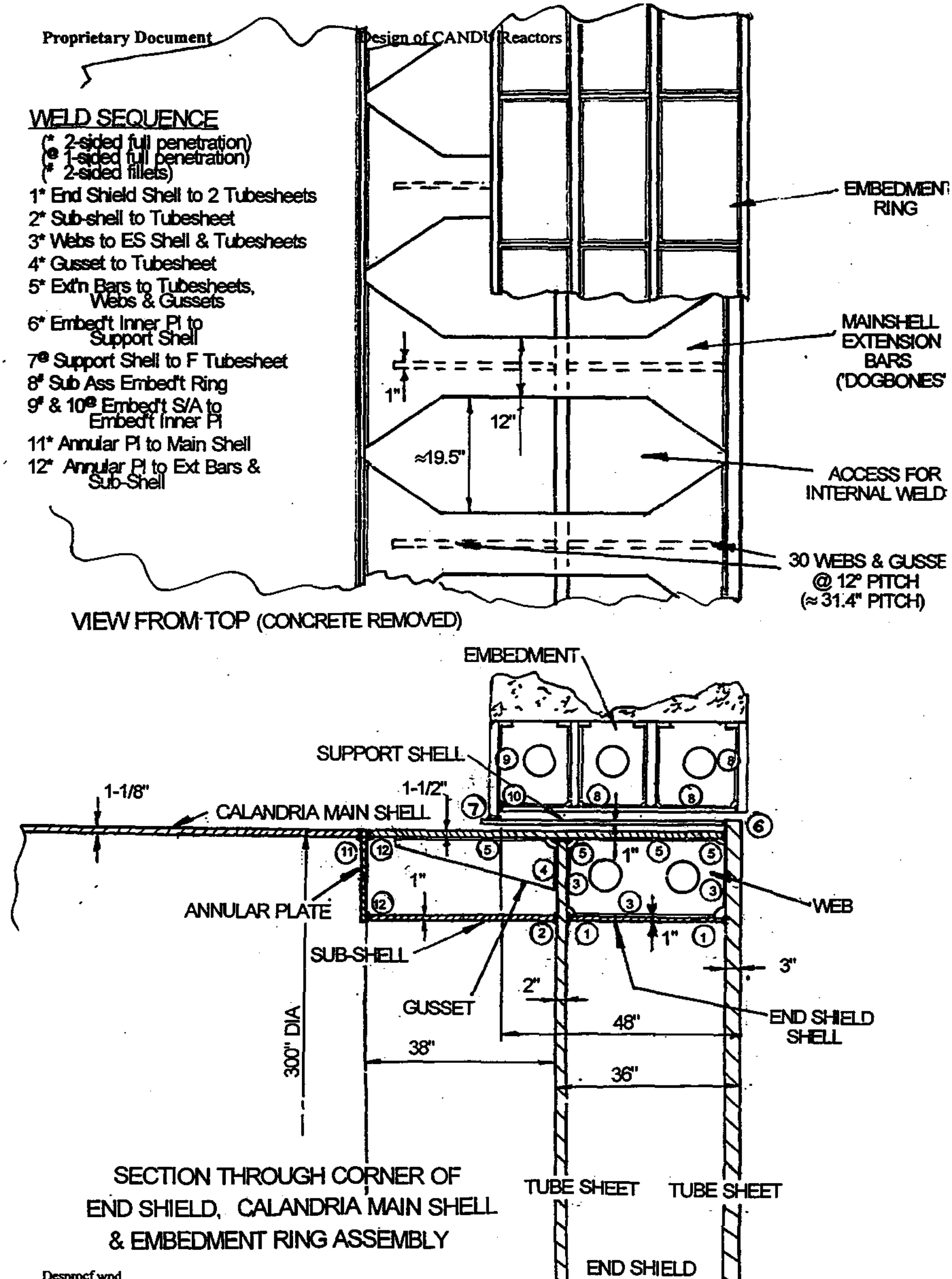


$f_5' = 23.1$ Hz, $A_5' = 0.89$ g

Figure 4-20 Seismic Schematic of Straight-shell Reactor Assembly - Basic Response Modes and Frequencies

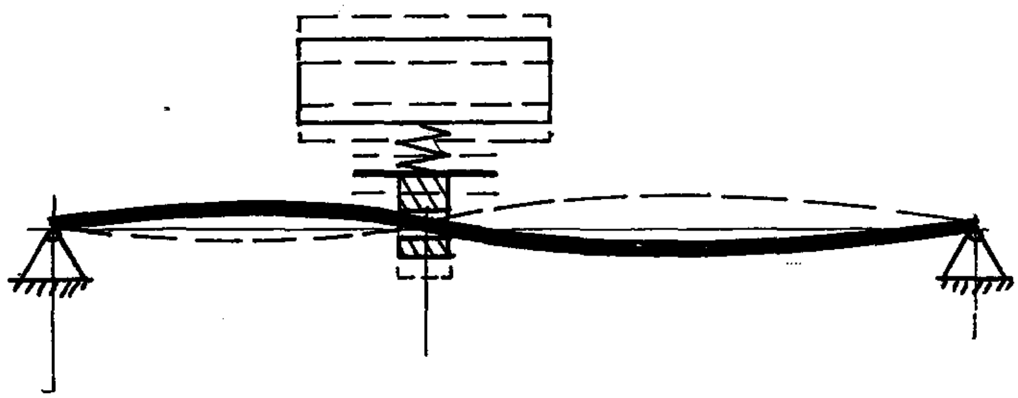
DESIGN OPTION	Half-Body Mode		Whole-Body Mode		End Shield Mode		FM/PT Mode		Positioner Assembly End		Non-Positioner Assembly End		CT Stress (Net)
	f_1	A_1			f_3	A_3	f_4	A_4	1.2 Aep	P_{PA}	1.2 Aen	P_{RJ}	
			f_2	A_2									
STANDARD CANDU 6	11.7 Hz	0.9 g	10.6 Hz	1.0 g	6.6 Hz	1.3 g	7.4 Hz	1.3 g	2.25 g	58100 lb	2.74 g	70800 lb	Outer 145 Comp Inner 1450 Tens
			f_5	A_5									
BOLTED BOTH ENDS	n/a		14.9 Hz	0.9 g	6.6 Hz	1.3 g	7.4 Hz	1.3 g	1.90 g	49100 lb	2.46 g	63500 lb	Outer 190 Comp Inner 1080 Tens
			f'_5	A'_5									
STRAIGHT CALANDRIA SHELL	n/a		23.1 Hz	0.8 g	6.6 Hz	1.3 g	7.4 Hz	1.3 g	1.83 g	47400 lg	2.40 g	62300 lb	Outer 1000 Tens Inner 2000 Tens σ cal shell= 6000 Comp

Figure 4-21 Comparison of Present and Proposed Designs

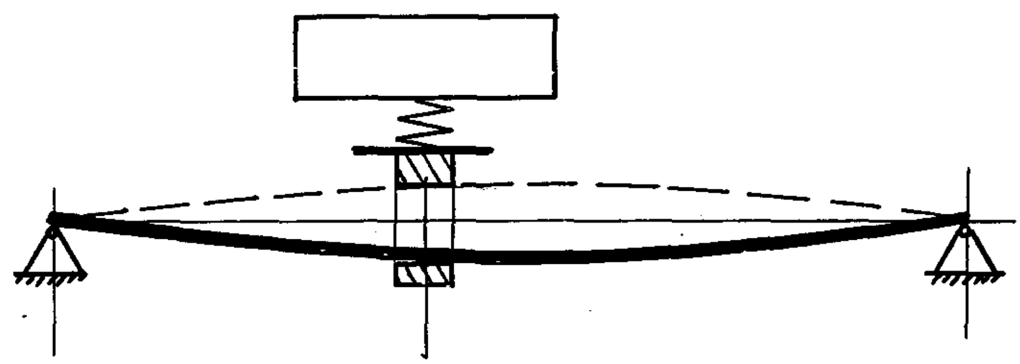


Desprocf.wpd

Figure 4-22 Details of Area of Structure at Reactor Support for Straight-shell Design



(b) Behaviour when response amplitude becomes bigger than gap
- beam has 3-point support, coupling it to downstream sub-system



(a) Behaviour when response amplitude is less than gap
- beam is simply supported and decoupled from downstream sub-system

Figure 4-23 Vibration Behaviour of a System with a Gap

Simply supported beam with a large gap at mid-span at connection to the downstream sub-system