FIRE AND BLAST INFORMATION GROUP

TECHNICAL MEETING REVIEW

"Blast Resistant Design of Topside Structures"

The FABIG Technical Meetings on "Blast Resistant Design of Topside Structures" included the following presentations:

- *FABIG Technical Note No 4: Explosion Resistant Design - Purpose and Content*
  Bob Brewerton
  Natabelle Technology Ltd
- *Review of Technical Note 4*
  David Ward-Gittos
  Brown & Root Energy Services
- *Blast Response - Dynamic Effects and Loads*
  Steve Walker
  SLP Engineering
- *Response to Real Explosions and Simplified Methods for Membrane Effects*
  Rob Harwood
  Shell UK Exploration and Production Ltd
- *Some Considerations in Design for Blast Resistance*
  Brian Corr
  BP Exploration
- *Recent Research at City University into Blast Response of Offshore Topsides*
  Luke Louca
  City University
- *Gas Explosion Engineering Joint Industry Project (GEEJIP)*
  Jurek Czujko
  Offshore Design
- *Summary of Questions and Discussion*

The enclosed review of the meetings includes, where available, copies of overheads and other additional information.

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"Blast Response - Dynamic Effects and Loads"

SLP Engineering

Mr Steve Walker
Technical Consultant

- A photocopy of the presentation material

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Blast Response - Dynamic Effects and Loads

1. **Conventional static analysis - module response**

2. **Non-linear one degree of freedom methods (Biggs' Method)**

3. **Extensions of Biggs' method**

   3.1 Generalised resistance functions
   - Beams - equipment loads
   - Columns - in-plane loads, end moments
   - Panels - membrane effects

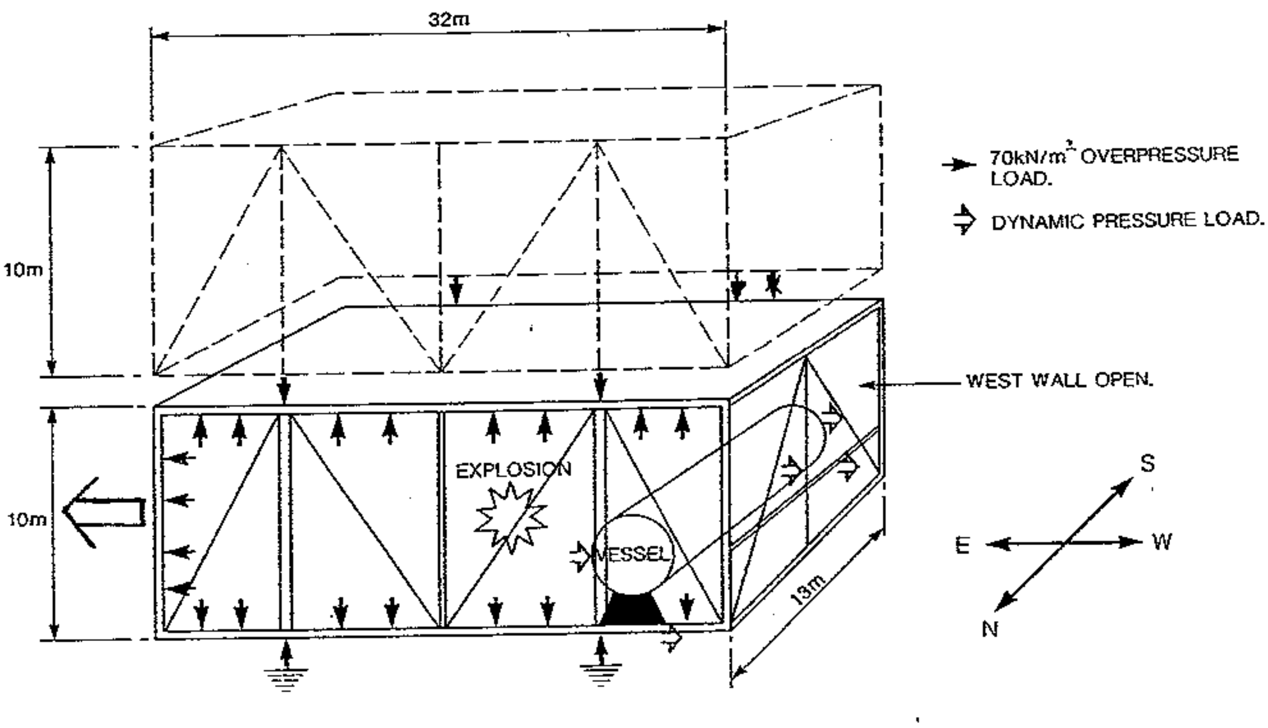
   3.2 Generalised loading
   - Load transfer - floors and ceilings
   - Suction phase
   - High frequency components

4. **Rebound**
   - Free Rebound
   - Forced Rebound
   - Design charts

5. **Out of balance loads - venting**

FABIG Technical Meeting 1/7/97 & 2/7/97

Steve Walker/Mike Howarth
Odebrecht SLP Engineering



Compartment Loading and General Layout

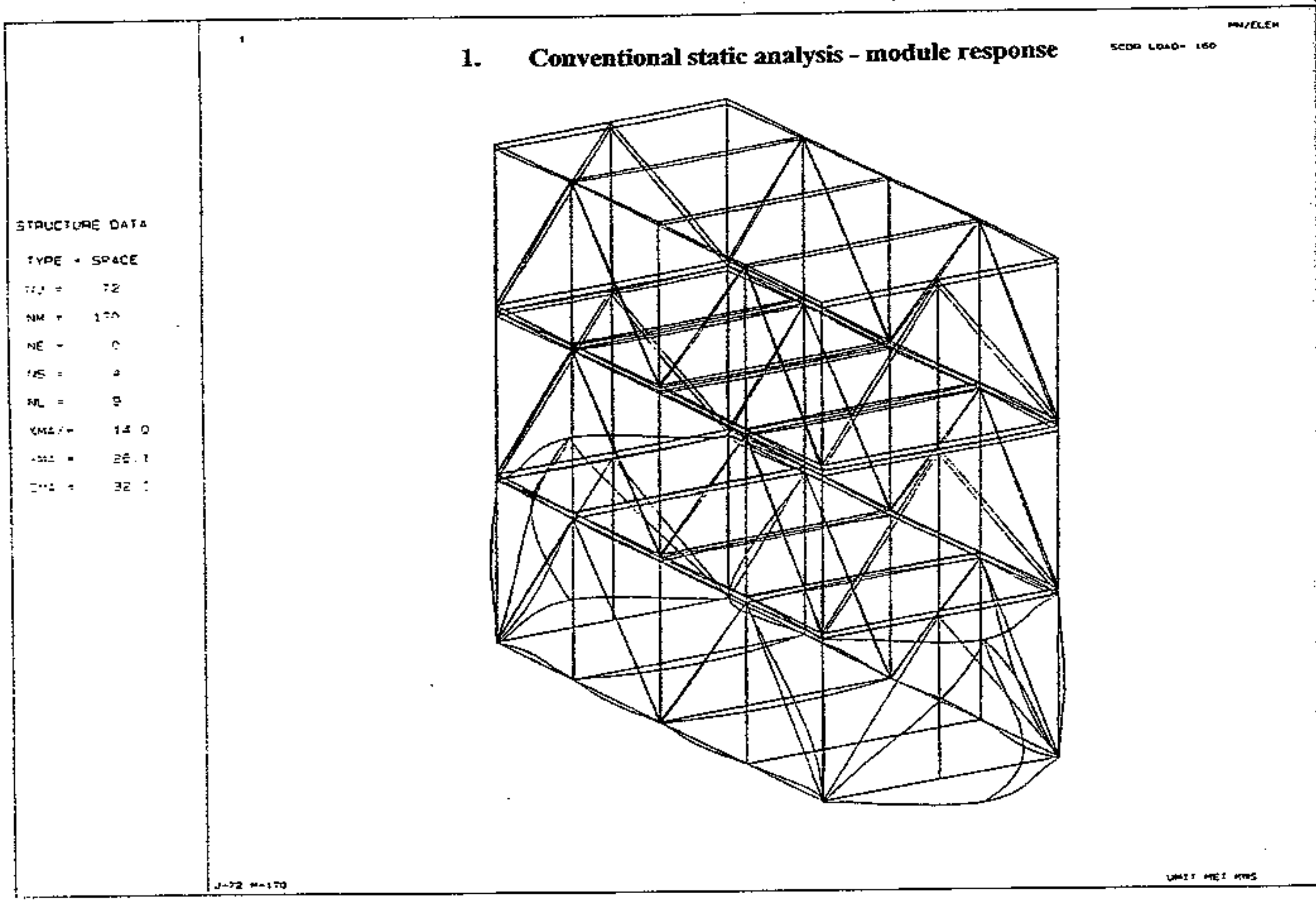
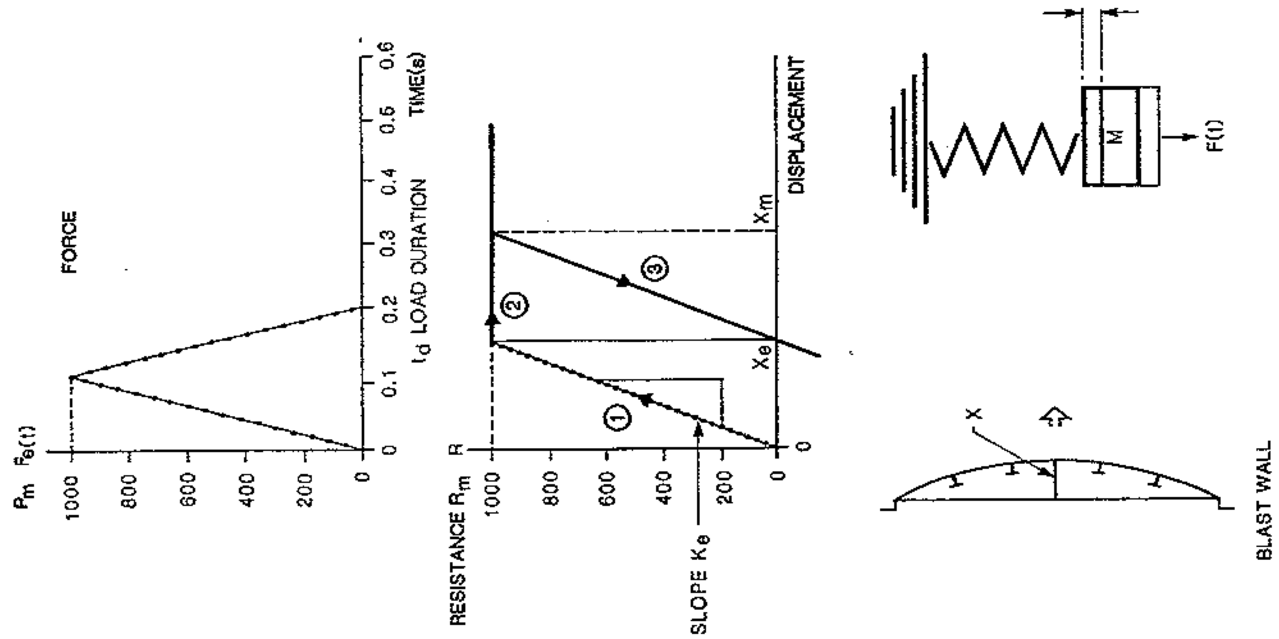


FIGURE 5.4

DEFLECTED SHAPE OF MODULE 1 UNDER BLAST LOADING



3.1 Generalised resistance functions

Fixity variation - between clamped and pinned

Beams - equipment loads

Columns - in-plane loads, end moments

Panels - membrane effects

End fixity variation - from clamped (1) to pinned (0)

End fixity modelled by rotational spring Ks

Ks determined by adjacent connections

Effect of moment release :-

1. Stiffness decrease (pinned = 5 x clamped deflection)
2. Hinges may form in middle first rather than at ends (transition at Ks = 6EI/L)
3. Natural period increase over clamped assumptions

Moment release gives increased response under blast loads

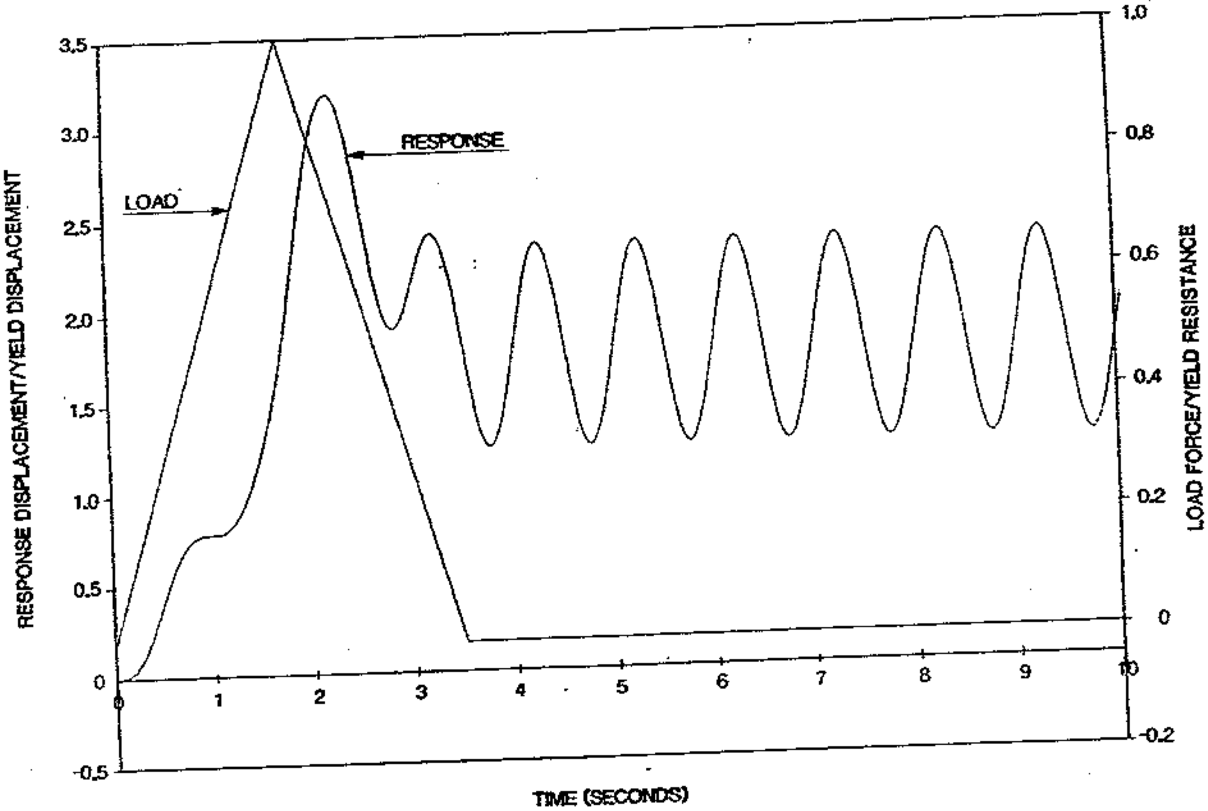
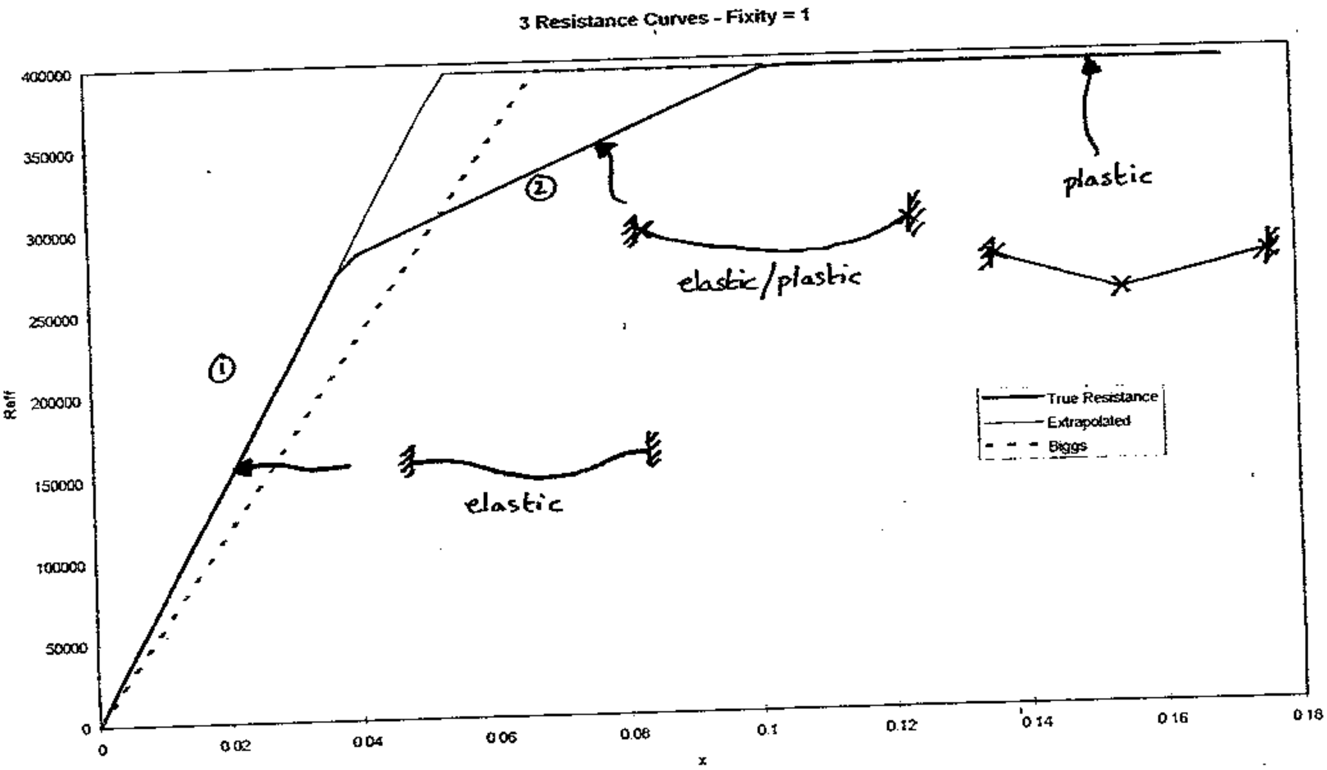
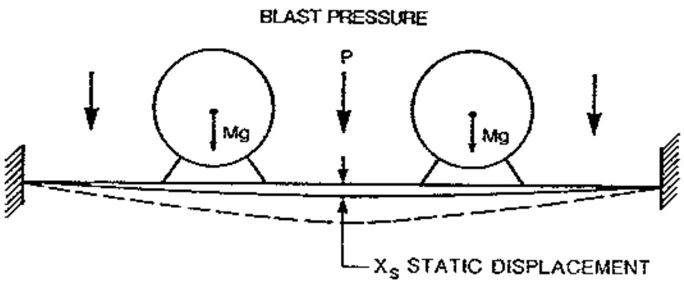


FIGURE 2.2

TYPICAL BLAST RESPONSE AND LOAD TIME HISTORY



Equipment loads - floors and ceilings



Effect on floor beam:-

Elastic

1. Initial deflection and pro-rata decrease in blast capacity

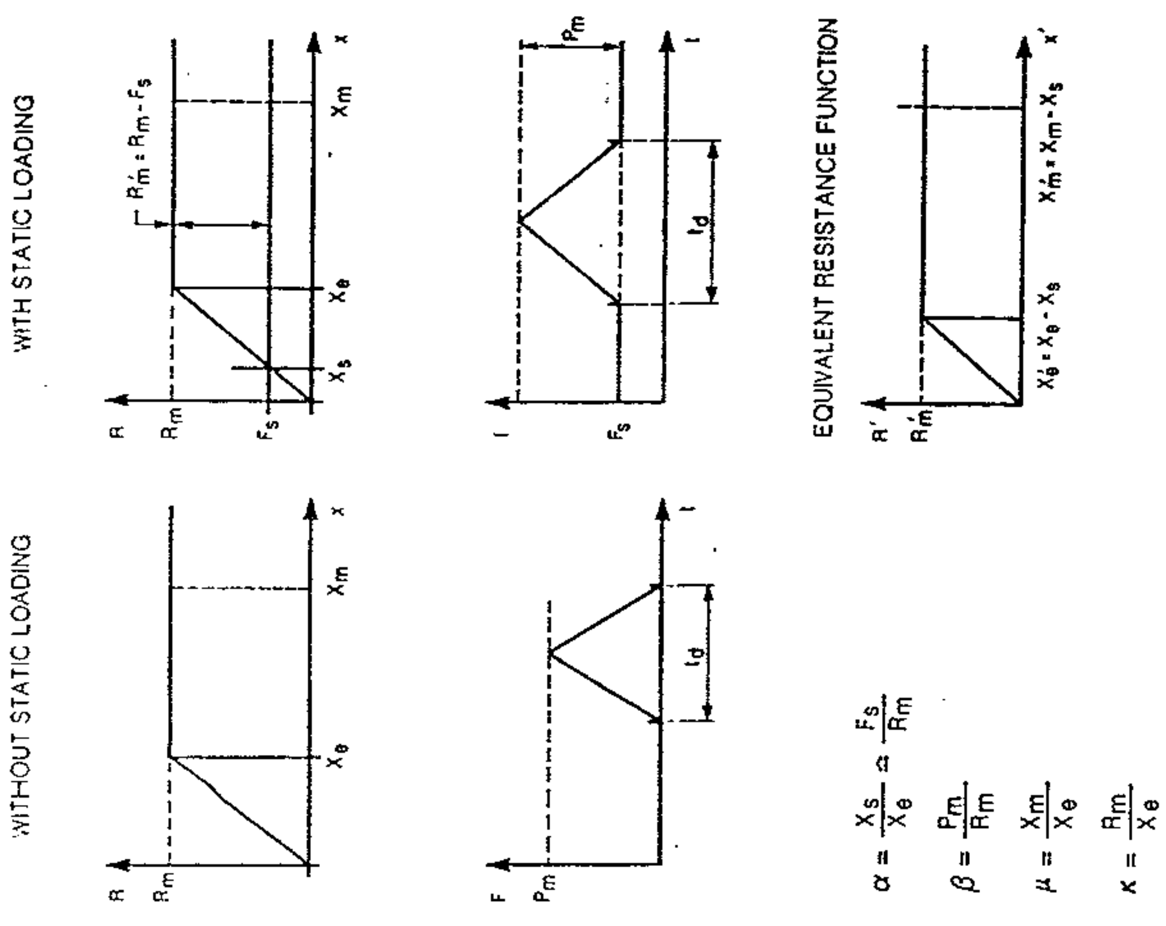
2. Added equipment masses give increased natural period

Plastic

3. Not usually allowed

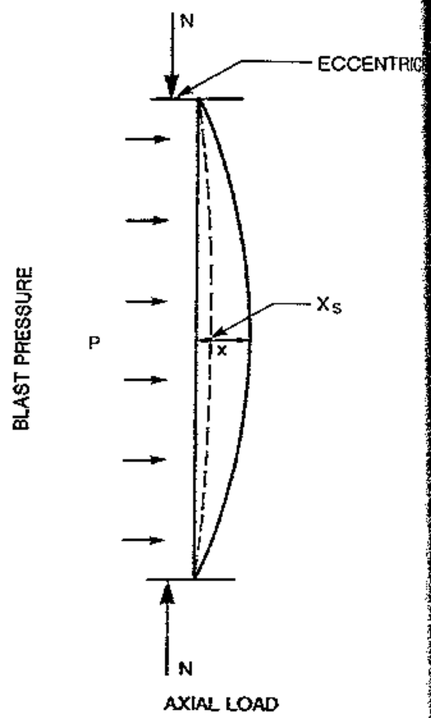
Gives increased floor response under blast loads

May decrease ceiling peak response (but beware of rebound)



OUT OF PLANE STATIC LOADING - NOTATION

In-plane or axial loads - columns and wall members



Effects of compression :-

Elastic

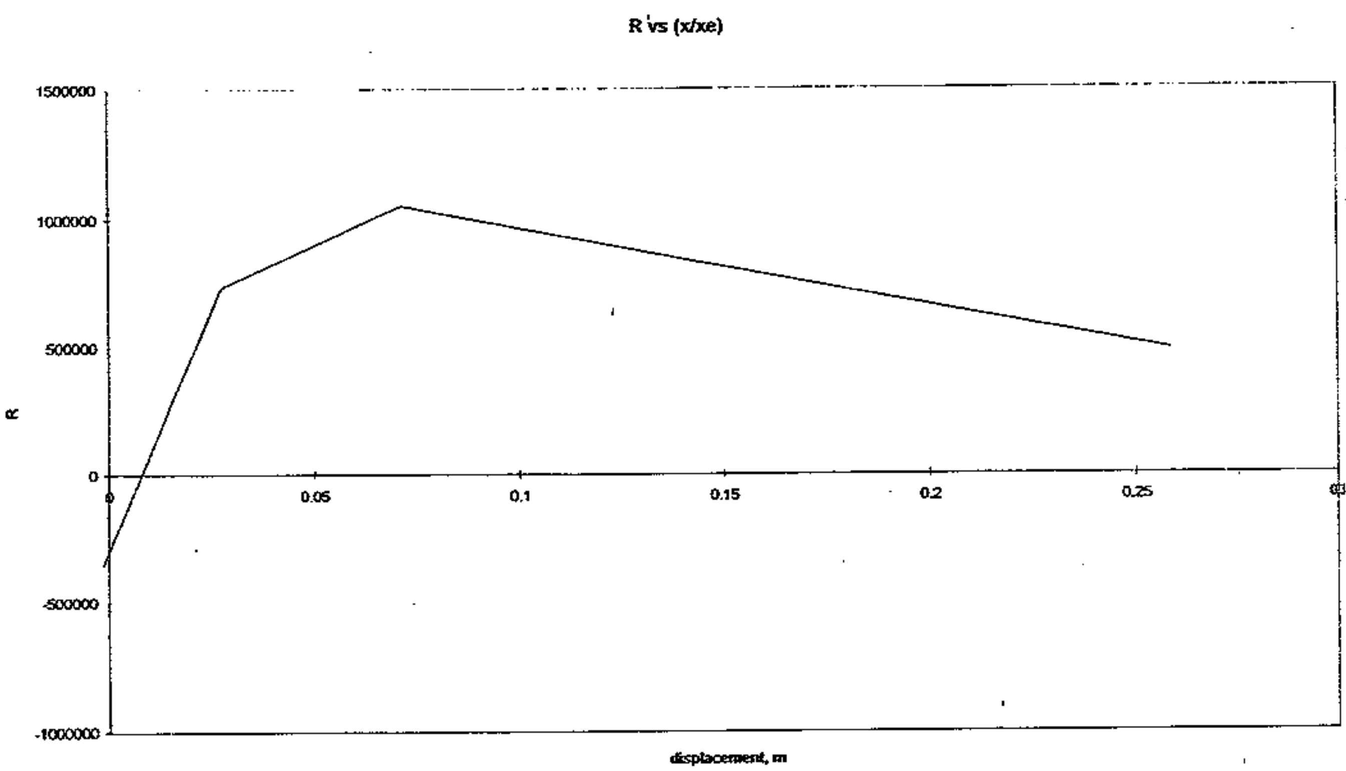
1. Reduced stiffness
2. Increased natural period

Plastic/elasto-plastic

3. Additional moment from applied load (P delta)
4. Reduced plastic moment capacity

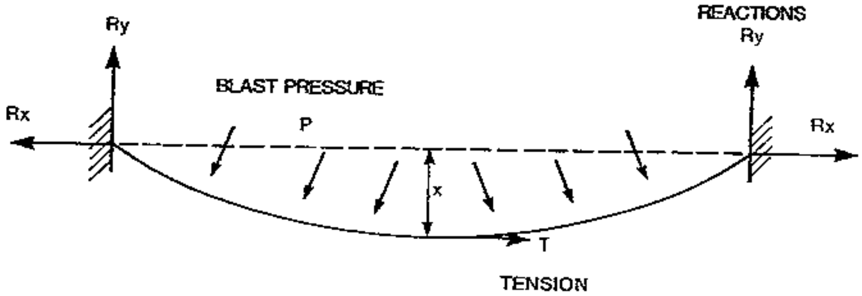
Compression gives increased response under blast loads

Column Resistance/displacement Function



Membrane and tension effects - panels

Yield line analysis gives lower bound
uniform stress through thickness (tension) gives upper bound.



At deflections > thickness, tension effects important.

Effect of tension is to increase stiffness in a non-linear way.

Supports need to resist this effect - reaction loads obtained for application to end columns.

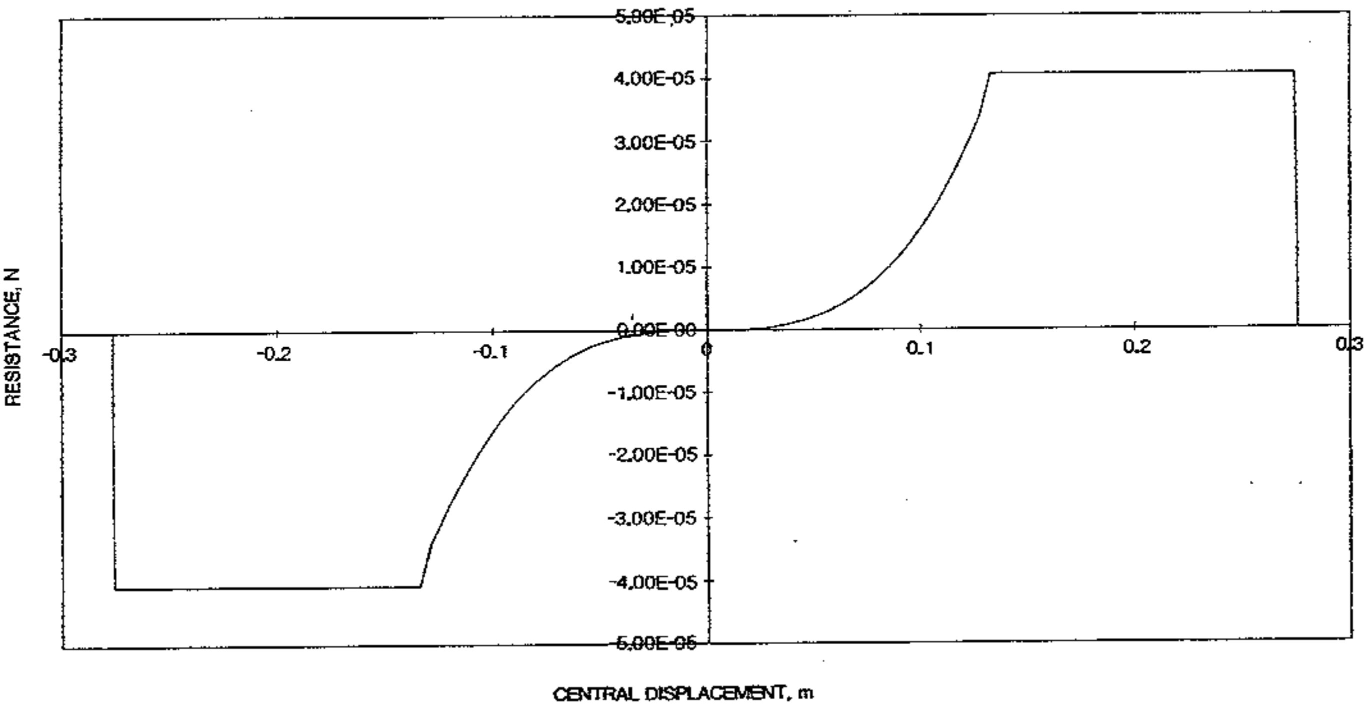


FIGURE 2.21

RESISTANCE DISPLACEMENT CURVE FOR 8mm THICK PANEL

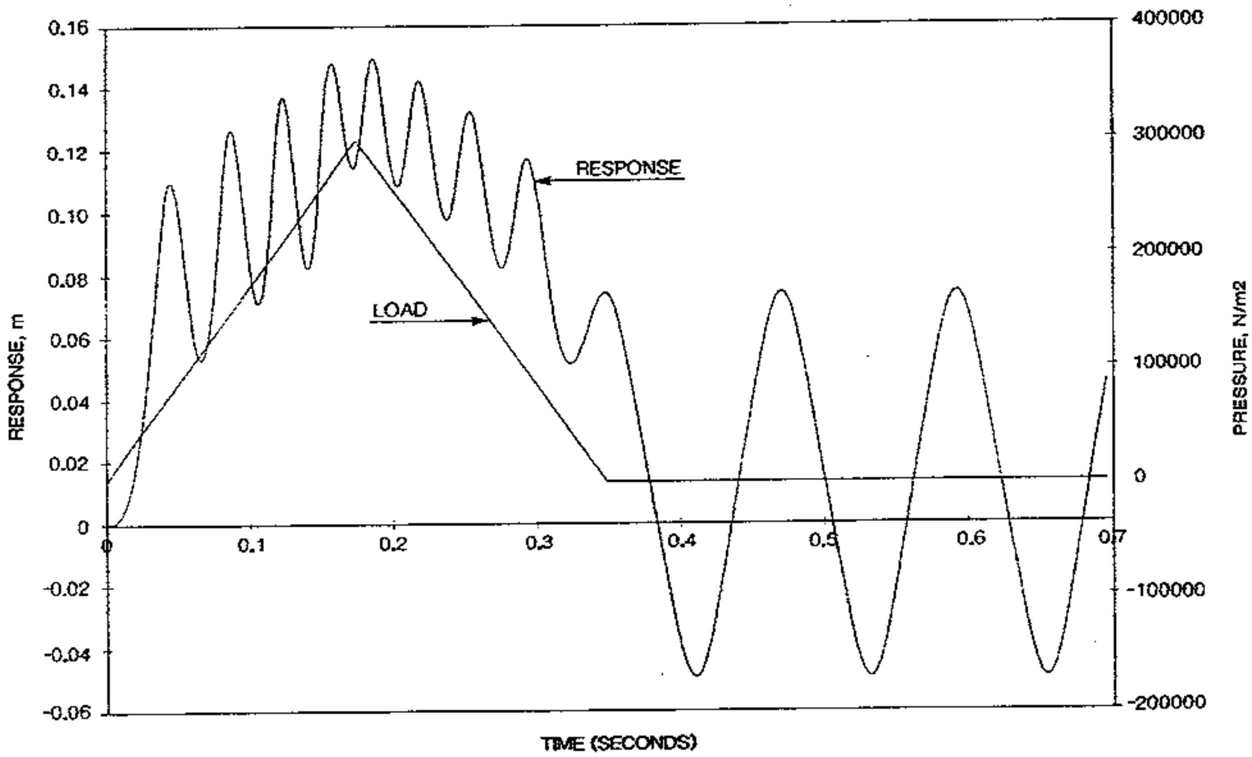


FIGURE 2.22

TYPICAL PANEL RESPONSE TO BLAST LOADING

3. Extensions of Biggs' method

Static Vs Biggs - (Primary structure response)

Static frame model	**Biggs (1DOF)**	**Extended Biggs**
Elastic	Elastic/plastic	Elastic/plastic
End Fixity	Pinned/Clamped	Rotational end stiffness
Applied in-plane loads	NO	Applied in-plane loads
End moments/eccentricity	NO	End moments/eccentricity
Equipment loads (o.o.p. loads)	NO	Equipment loads and masses
Load transfer (floors/ceilings)	NO	Load transfer (floors/ceilings)
Peak overpressure	Triangular load history	General time history
Rebound overpressure	Rebound deflection (free rebound)	Rebound deflection (forced rebound)
Static reactions	Dynamic reactions	Dynamic reactions
Strain rate effects (Yield stress adjustable)		Strain rate effects (Cowper-Simmonds)
Venting - out of balance pressures		

3.2 Generalised loading

Load transfer from floors and ceilings

Suction phase

High frequency components

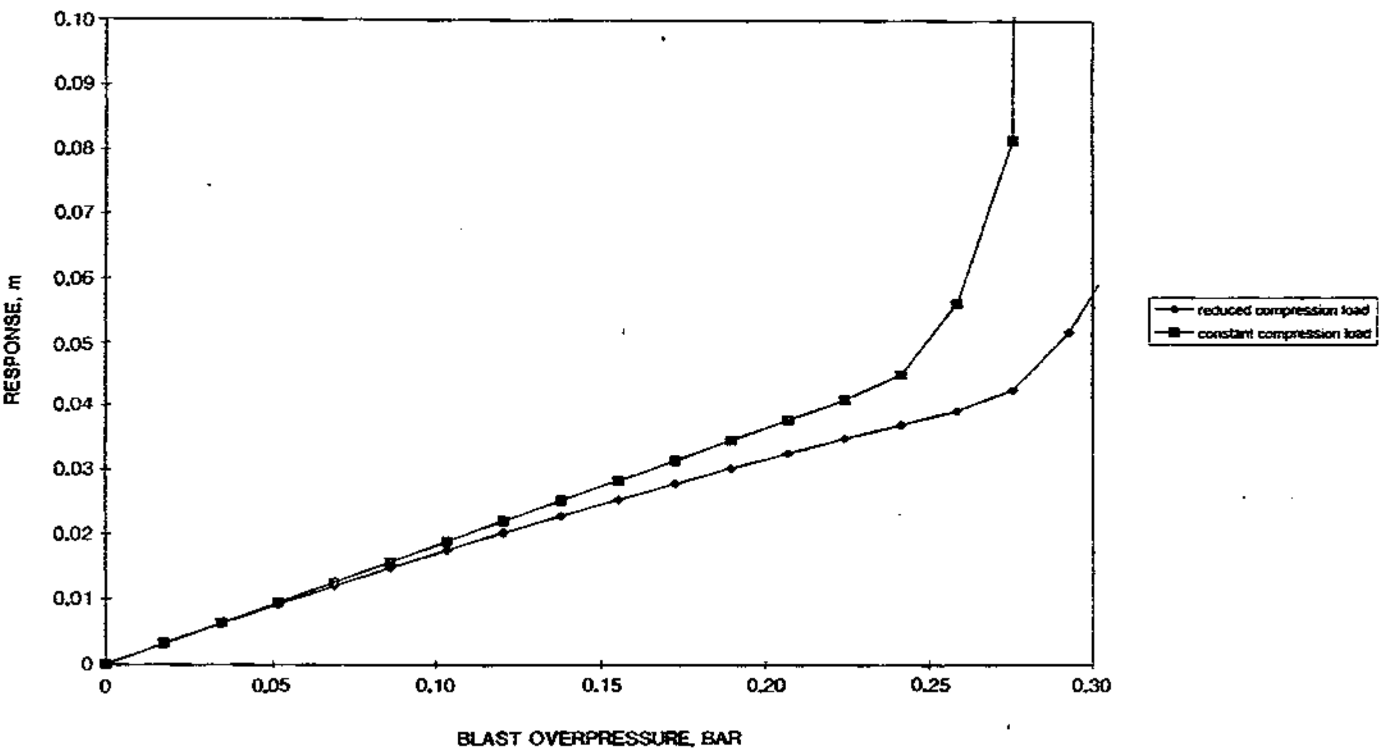


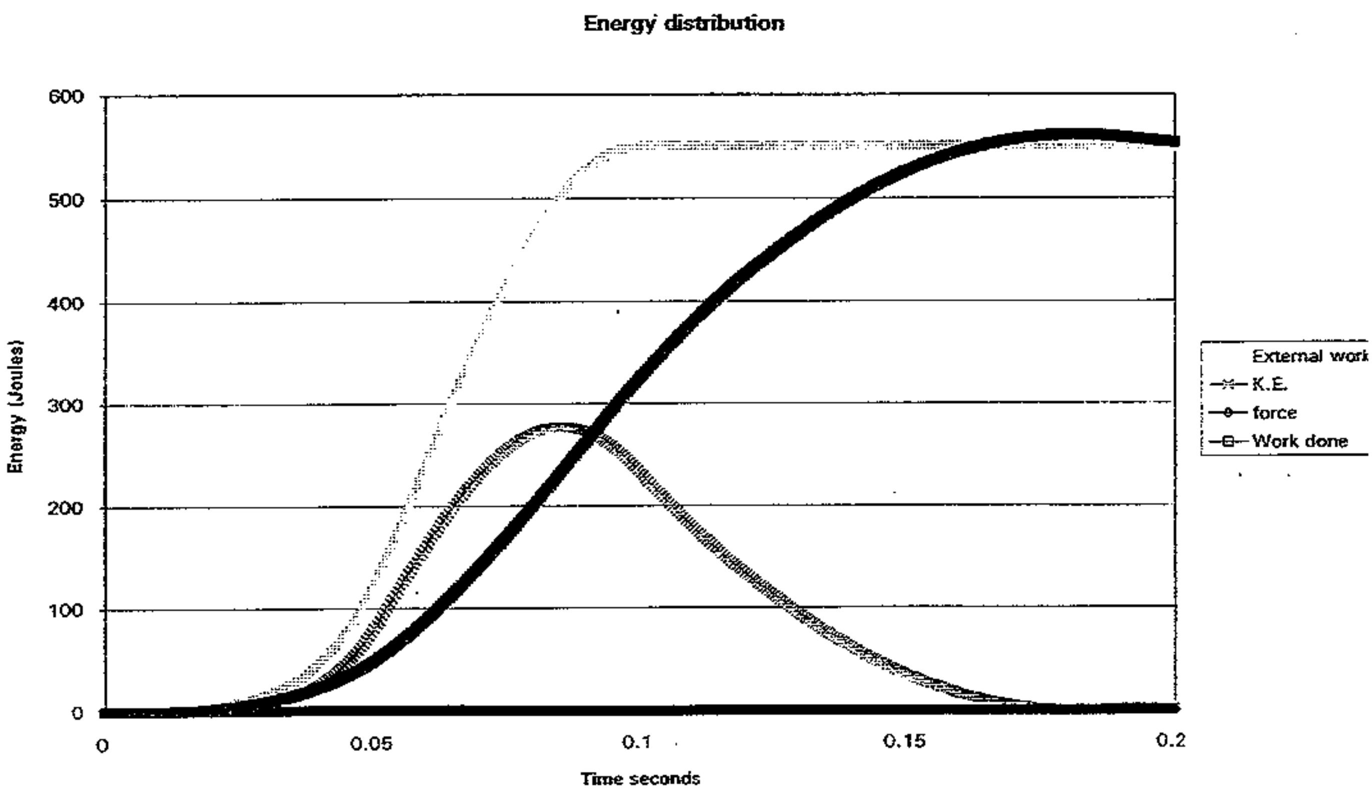
FIGURE 5.5

THE EFFECT OF REDUCED AXIAL LOAD ON BLAST RESPONSE

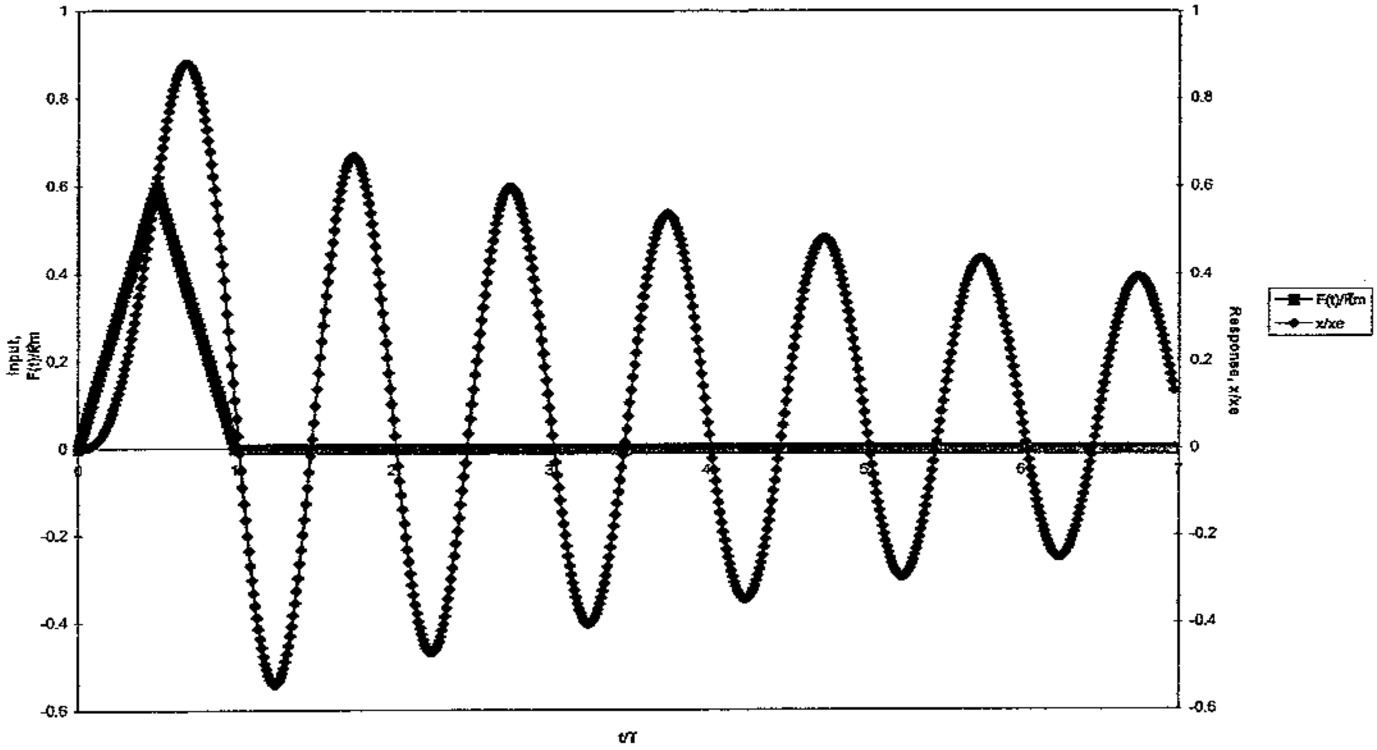
4. Rebound

- Free Rebound
- Forced Rebound
- Design charts

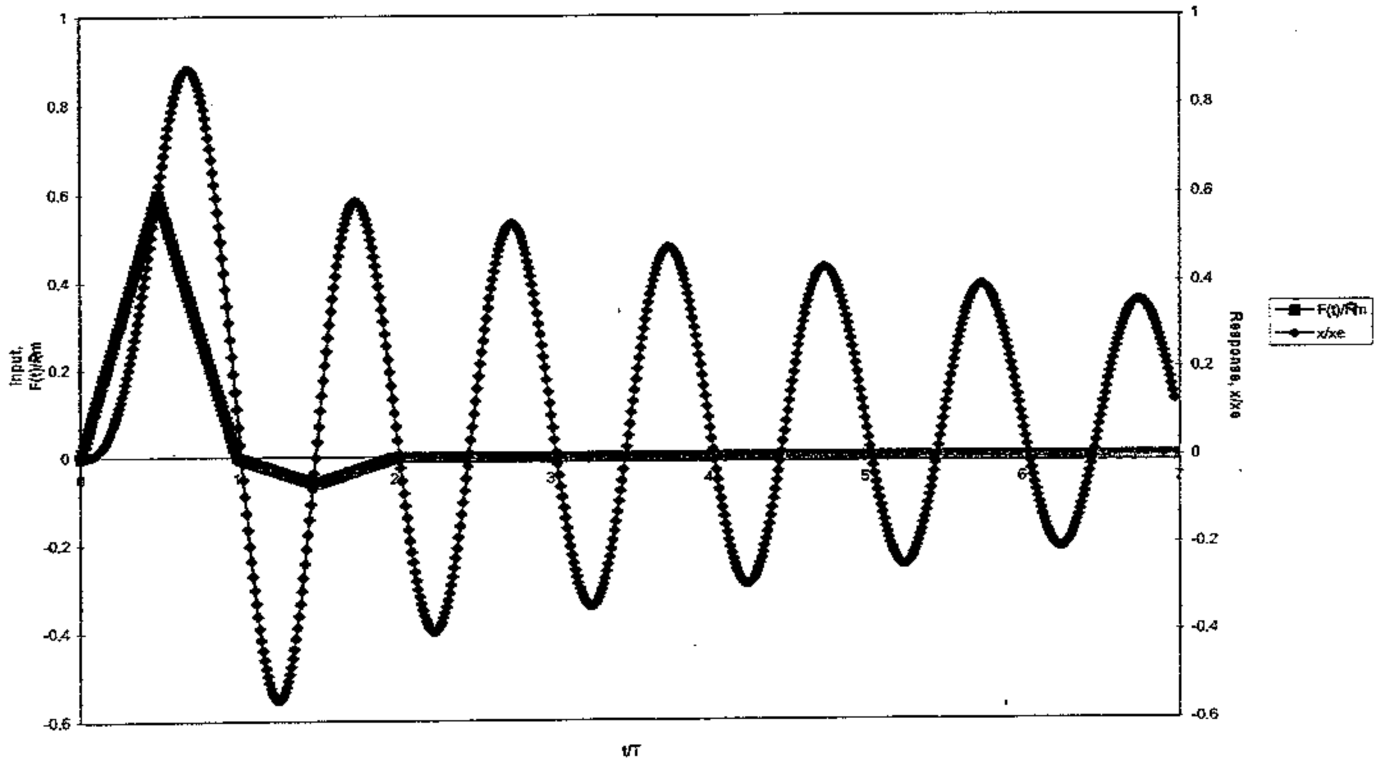
energy

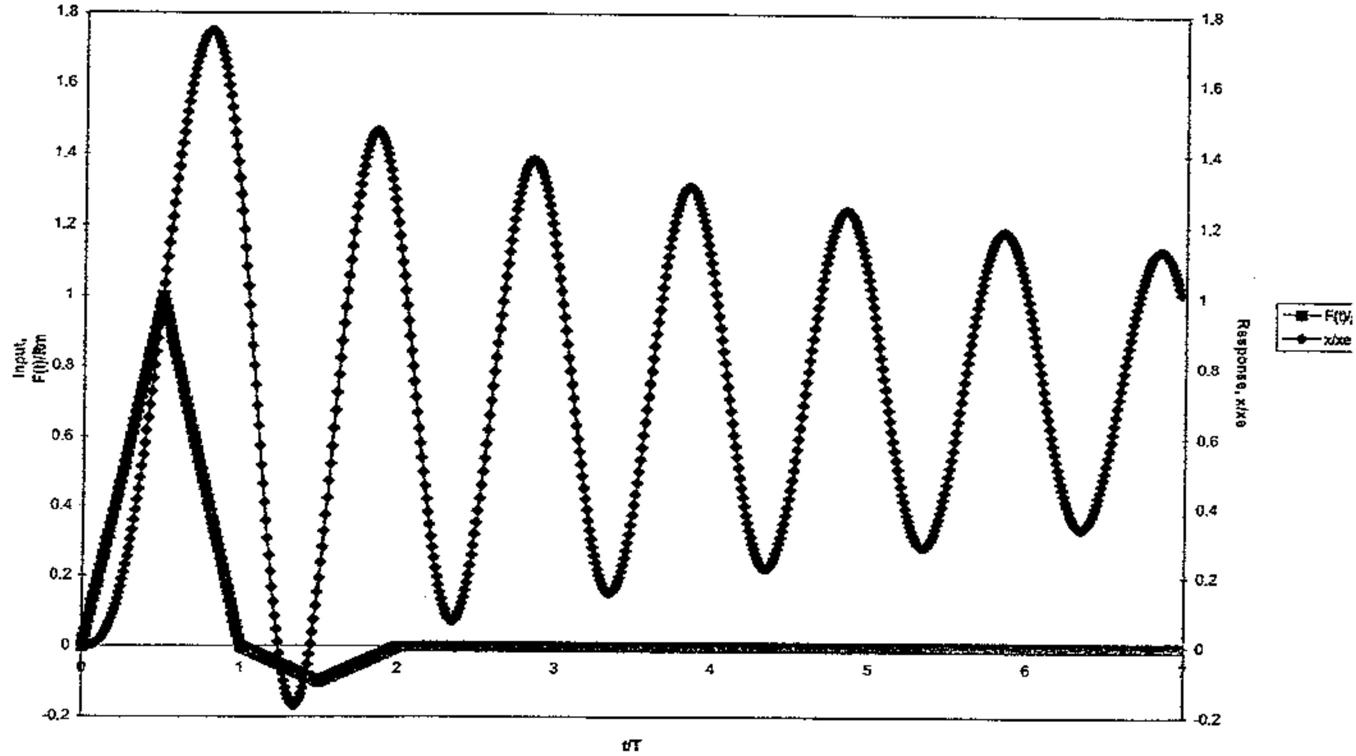


Free Rebound



Forced Rebound





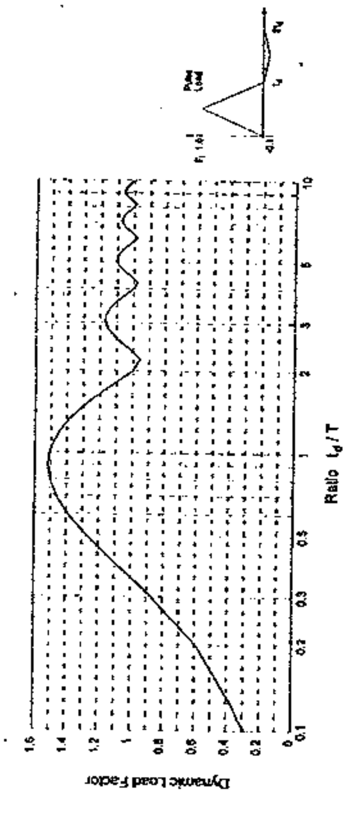


Figure A1
Dynamic Load Factor for First Response (DLF) - No Damping

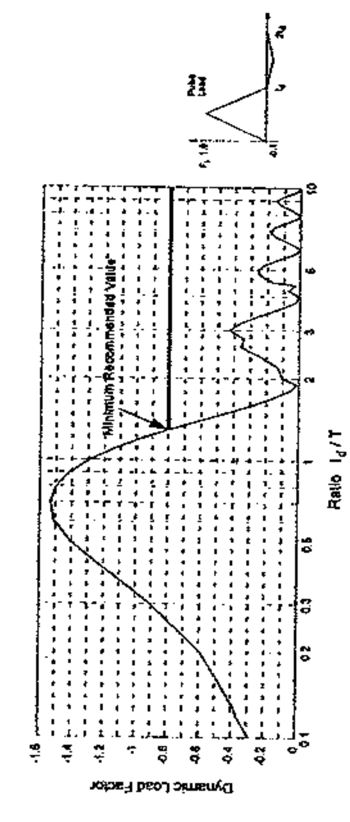
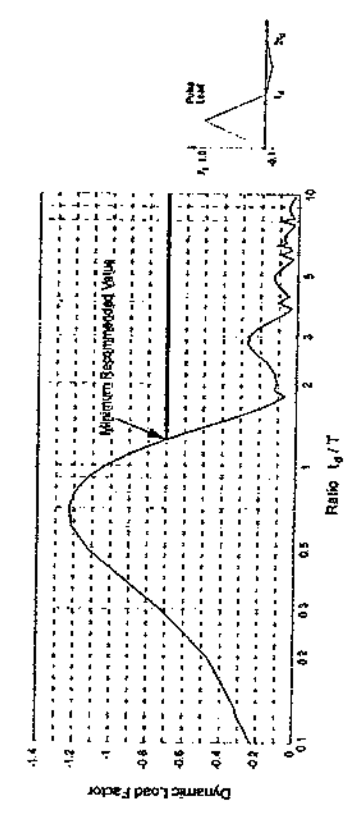
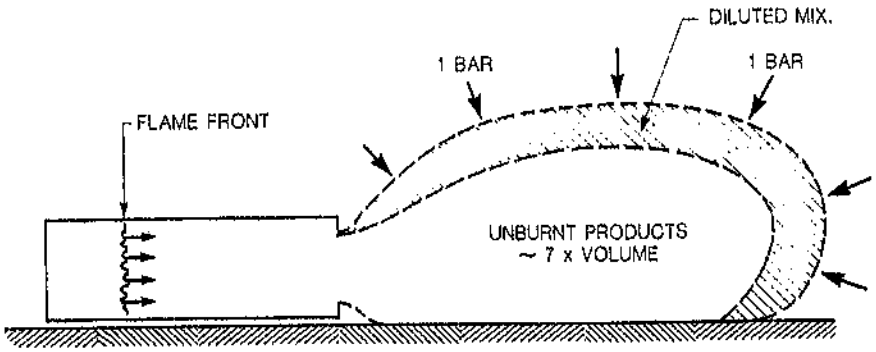


Figure A2a
Dynamic Load Factor for Rebound Response (RDLF) - No Damping



2. Explosions

Typical Parameters



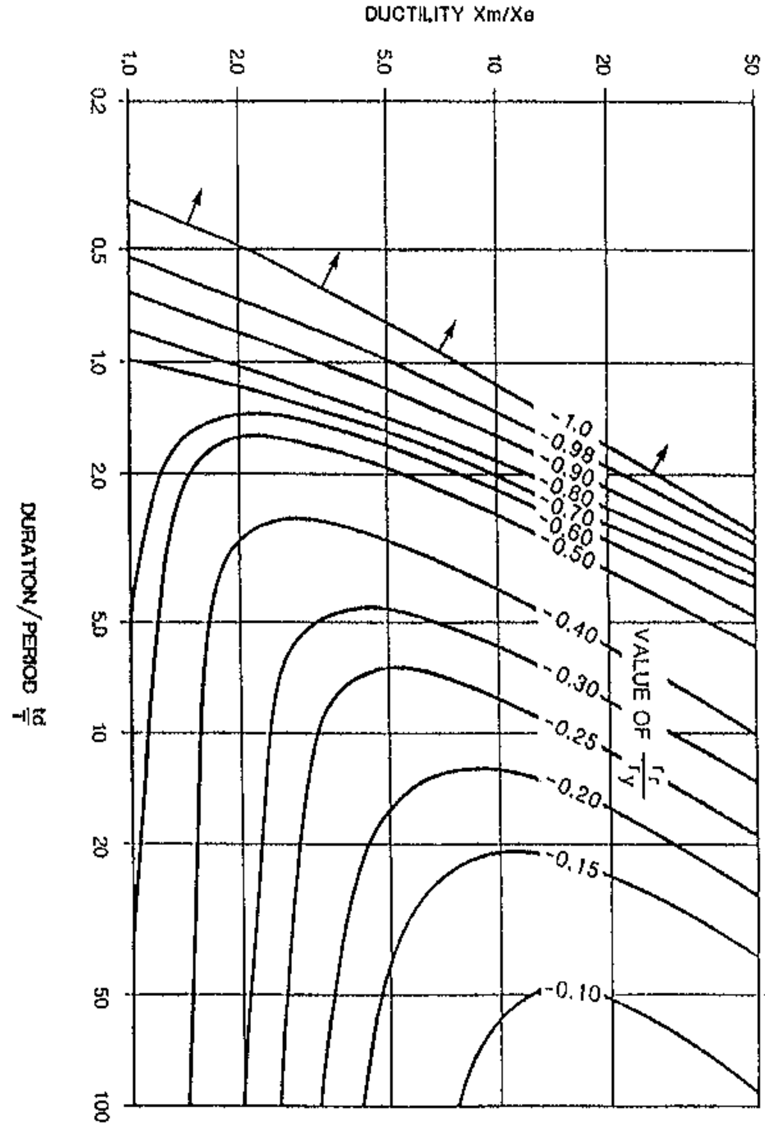
Example.	Module	30m x 17m x 10m	Volume = 5100m^3
	Loading	1bar overpressure,	(200ms rise time,400ms duration)
	Weight	1,000 Tonnes	

Total Heat Energy released — 17,290MJ
(10% concentration methane (stoichiometric) 343kg at 50MJ/kg)

Closed compartment (7bar) Pressure energy — 3,500MJ

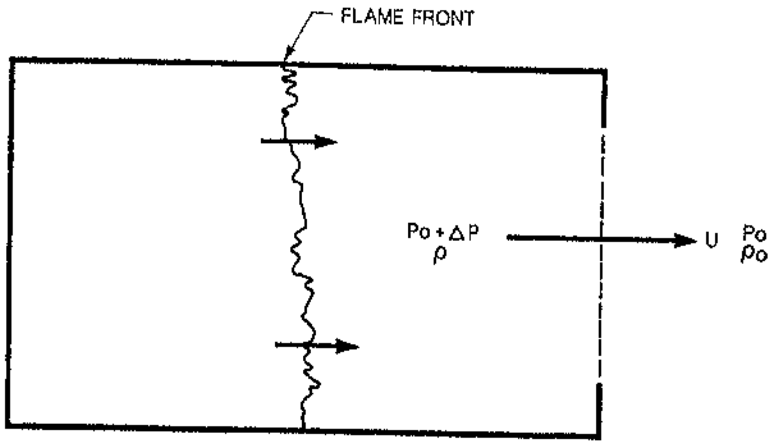
Vented compartment (1 bar)

Pressure energy (1 bar)	521MJ
Work done against external atmosphere	3,000MJ
Work done in structural deformation	20MJ
Work done in global structural response	1MJ



ASCE 42 – NUCLEAR PROTECTIVE STRUCTURES

Gas Velocities



Rankine - Hugoniot Relations for unburnt mixture ahead of flame*

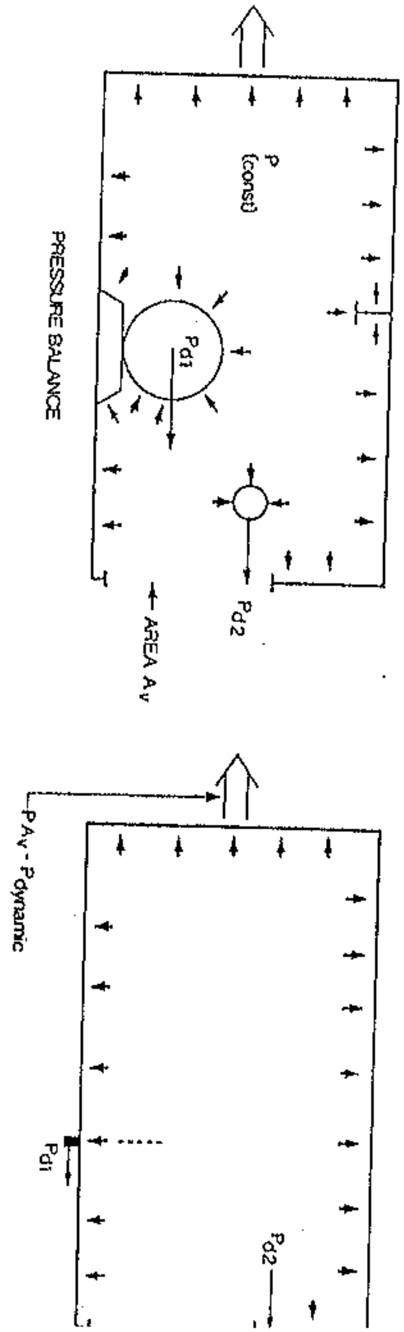
$$\frac{U}{C} = \frac{\Delta P}{P_0}\,\frac{1}{\gamma}\left\{1 + \frac{(\gamma + 1)}{2\gamma}\,\frac{\Delta P}{P_0}\right\}^{-1/2}$$

Where
- U is the unburnt gas mixture velocity in m/s
- γ is the ratio of specific heats (1.4)
- C is the velocity of sound in the mixture
- ΔP is the overpresssure (N/m2)
- P_0 is the ambient (outside) pressure

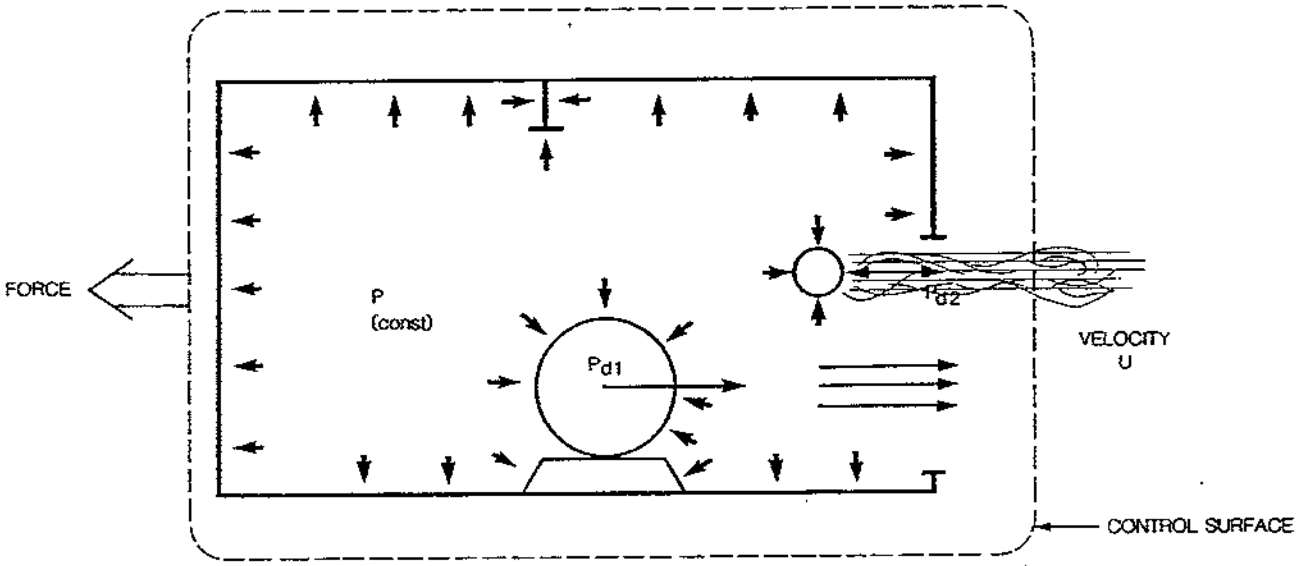
The density of the mixture may also be related to the overpressure.

Gas velocity = 100m/s at 100ms (180m/s at 200ms)
Mass Release at 100ms = 200Kg/s/m2 - total 27Tonnes/s

*e.g. Reference 6 - Catlin C.A., Mihsein M. and Younger B.
The Blast Loading Imparted to a Cylinder by Venting of a Confined Explosion, ERA November 1993.
Also ERA 94 SLP Supplementary paper 5.3



REACTION LOADS



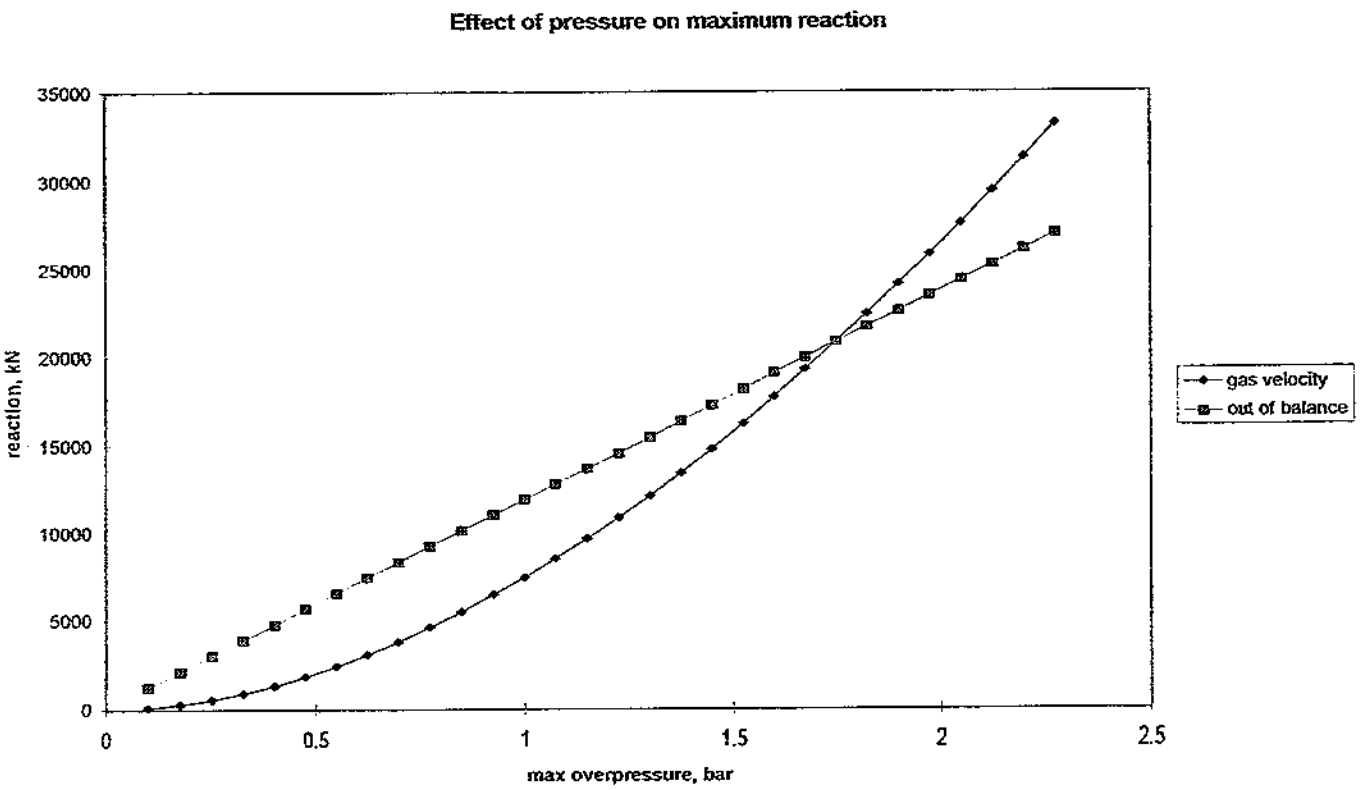
NEWTON'S LAW

THE RATE OF CHANGE OF MOMENTUM OF A BOUNDED MASS SYSTEM OF DISCRETE PARTICLES IS EQUAL TO THE SUM OF EXTERNAL FORCES ACTING ON THE SYSTEM

$$\text{FORCE} \simeq \int_{VENT} \rho U^2 dA \approx P\bar{U}^2 A_v$$

MOMENTUM THEOREM APPROACH

Chart1



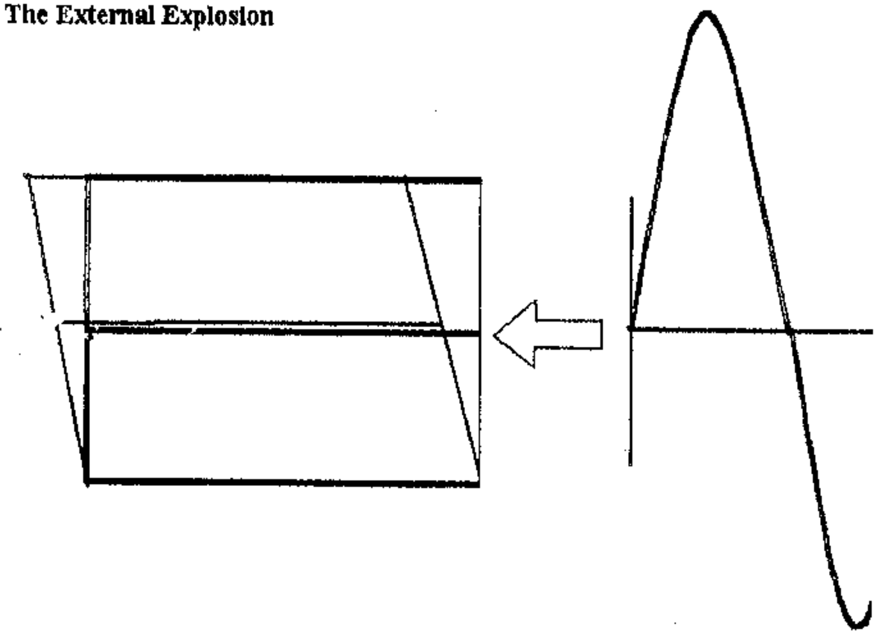
ummary

1. The consideration of dynamic effects is essential

2. The consideration of dynamic effects need not be expensive or cause delay

3. The consideration of dynamic effects may be beneficial (The Static approach may be over conservative)

The External Explosion



1. **Dynamic Aleviatio**

2. **Pressure doubling possible**

3. **Factors available for front side roof and back walls (The Effects of Nuclear Weapons)**