SPECIAL MISSIONS

NAVSEA WARFARE CENTERS CRANE

A Method for Determining the Effects of Overpressure from Small/Medium Weapons Fire

– Abstract 11838

30 August 2011

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Small Arms Air Platform Integration

- Small/Medium Caliber Weapons on Air Platforms
- SH-60S Armed Helicopter
  - GAU-21 (.50-cal)
  - M240 7.62 mm
  - 20 mm Weapon Systems
  - RAMICS
- Aircraft Skin Limits

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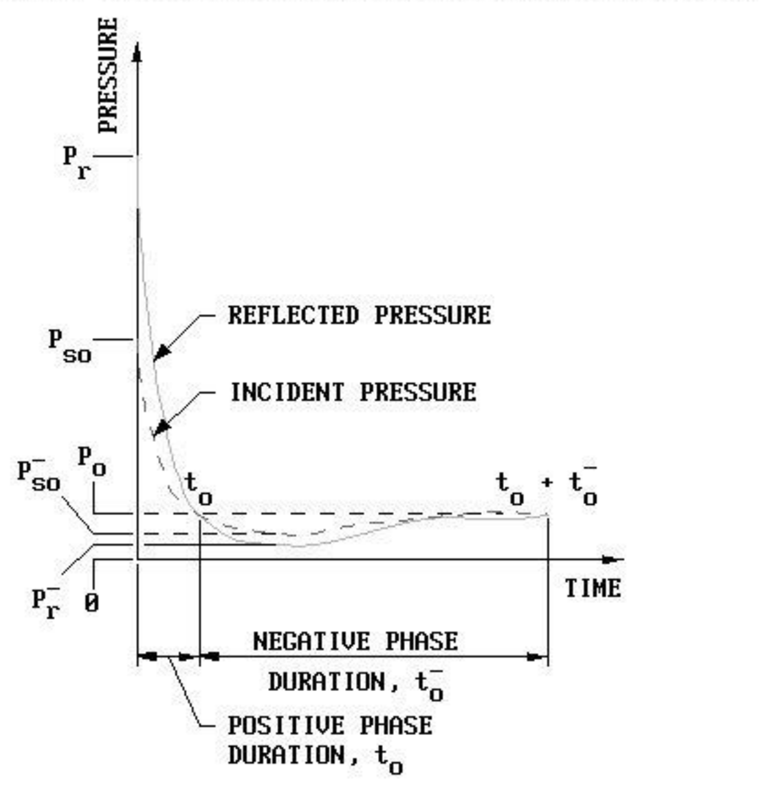
Shockwaves

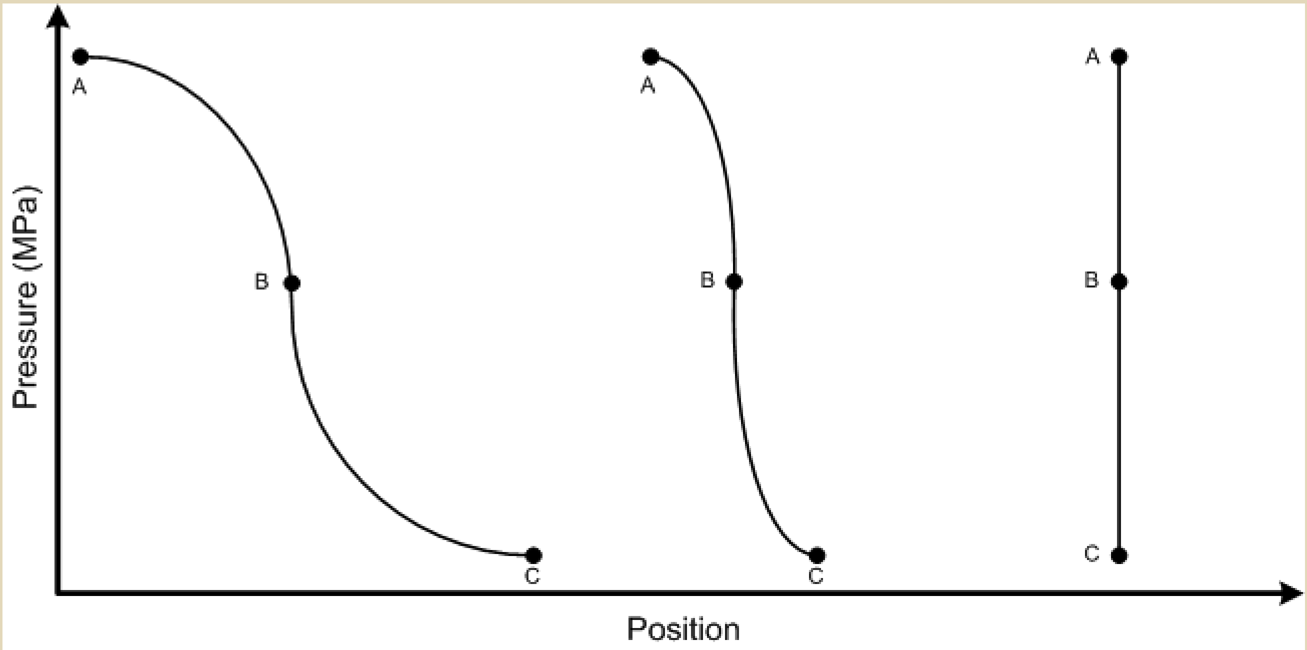
- Shockwave - a region across which there is a rapid pressure, temperature and density rise, usually caused by a body moving supersonically in a gas or by a detonation
- Characteristics:
  - Near-discontinuous pressure rise
  - Exponential decay. Positive Phase duration. Relatively short duration.
  - Negative phase.
  - Dependent on angle of incidence.

Figure 2-5. Pressure-time variation for a free-air burst



Shock Waves from Gunfire

- Non-ideal source. Source is not a detonation.
- Similar to "Shocking Up"



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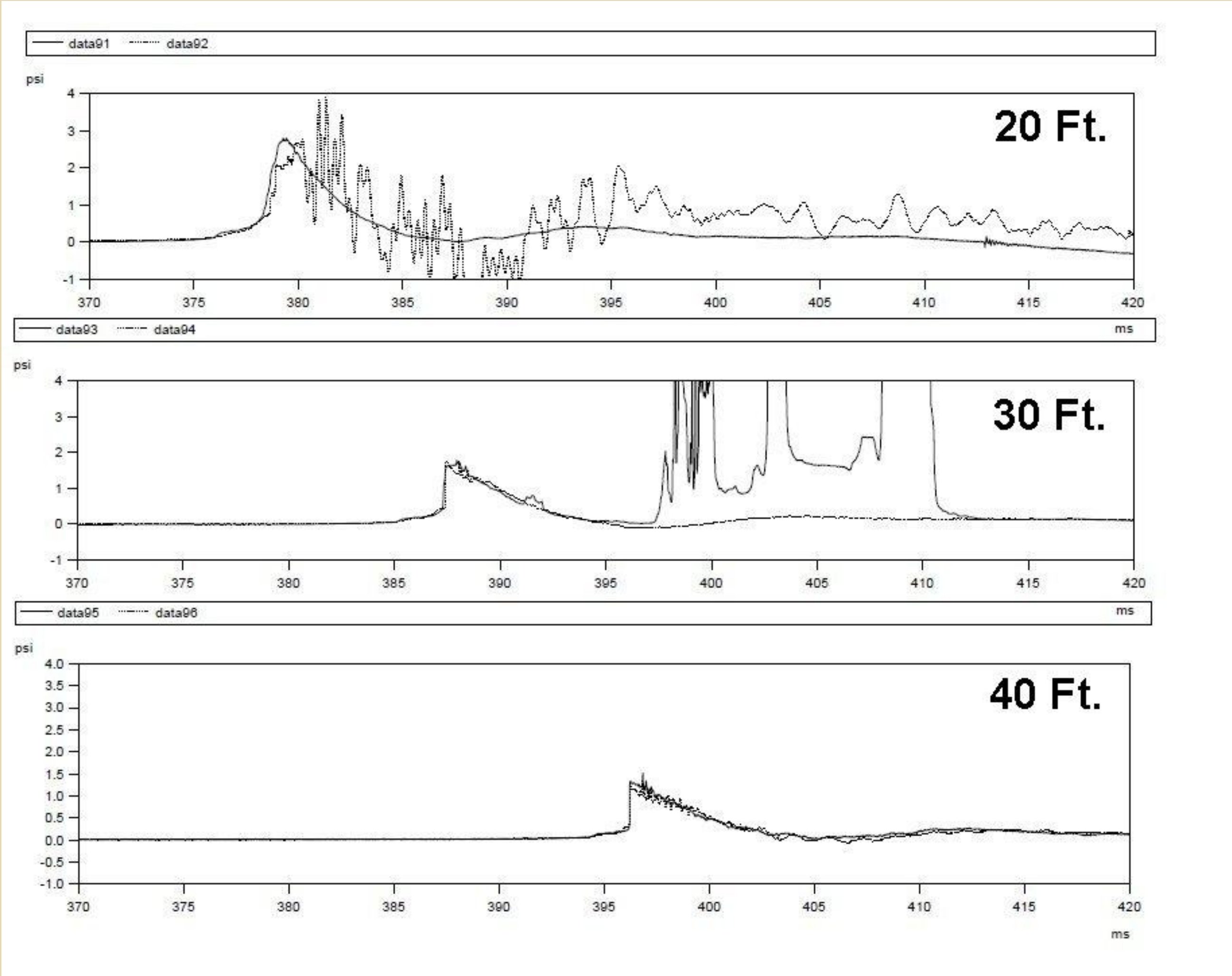
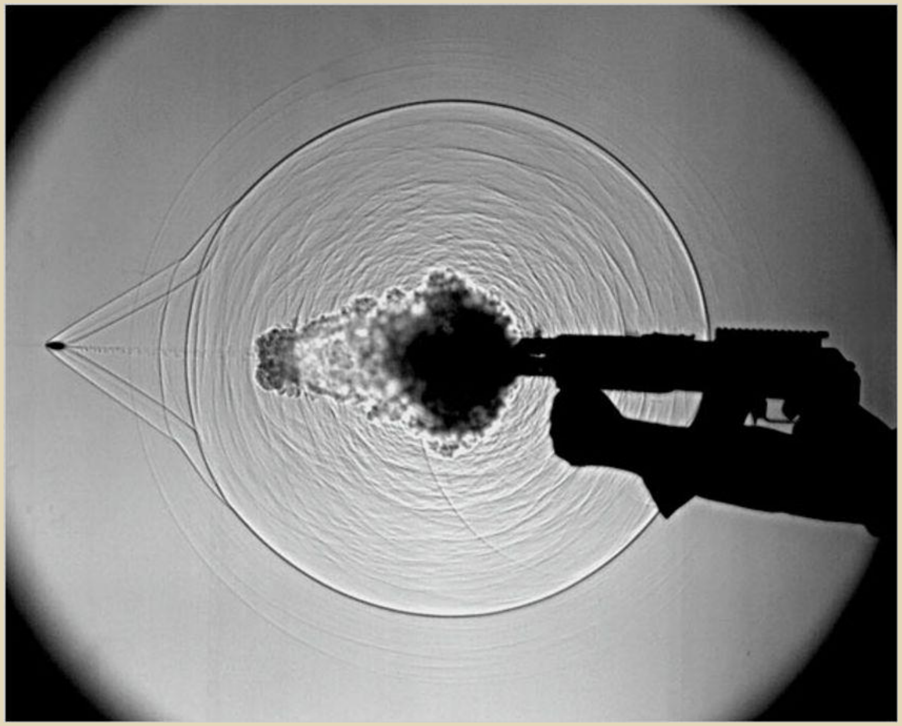
Shock Waves from Gunfire

- Shocking Up



Shock Waves from Gunfire

- **Measurement may see both projectile shockwave (N-wave) and the Muzzle Blast**



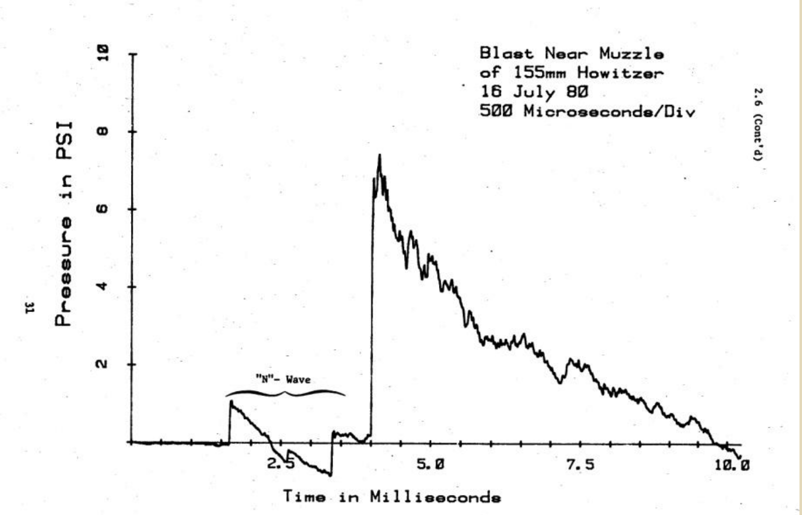
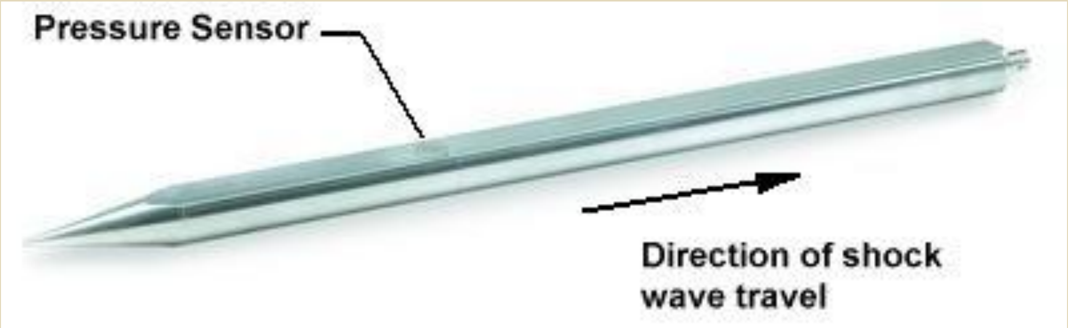
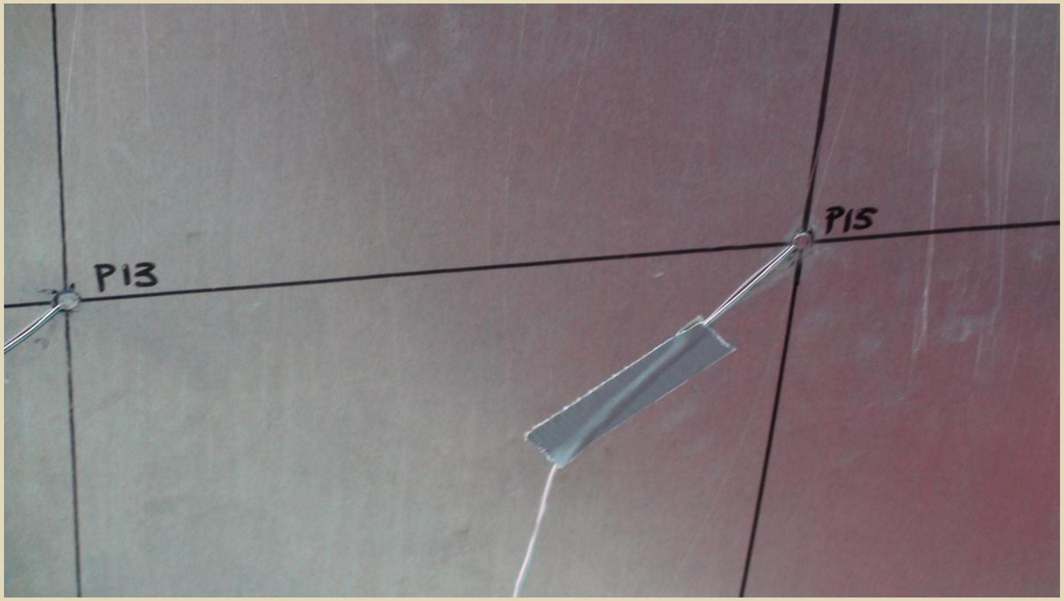


Figure 2.6-2. Pressure measurement showing both projectile "N" wave and muzzle blast wave.

Shock Measurements



PCB Model 137A23 Blast Probe – (Incident Pressure)



Endevco Model 8515C-15 Pressure Sensor (Reflected Pressure)

Incident Pressure vs. Reflected Pressure (Ideal)

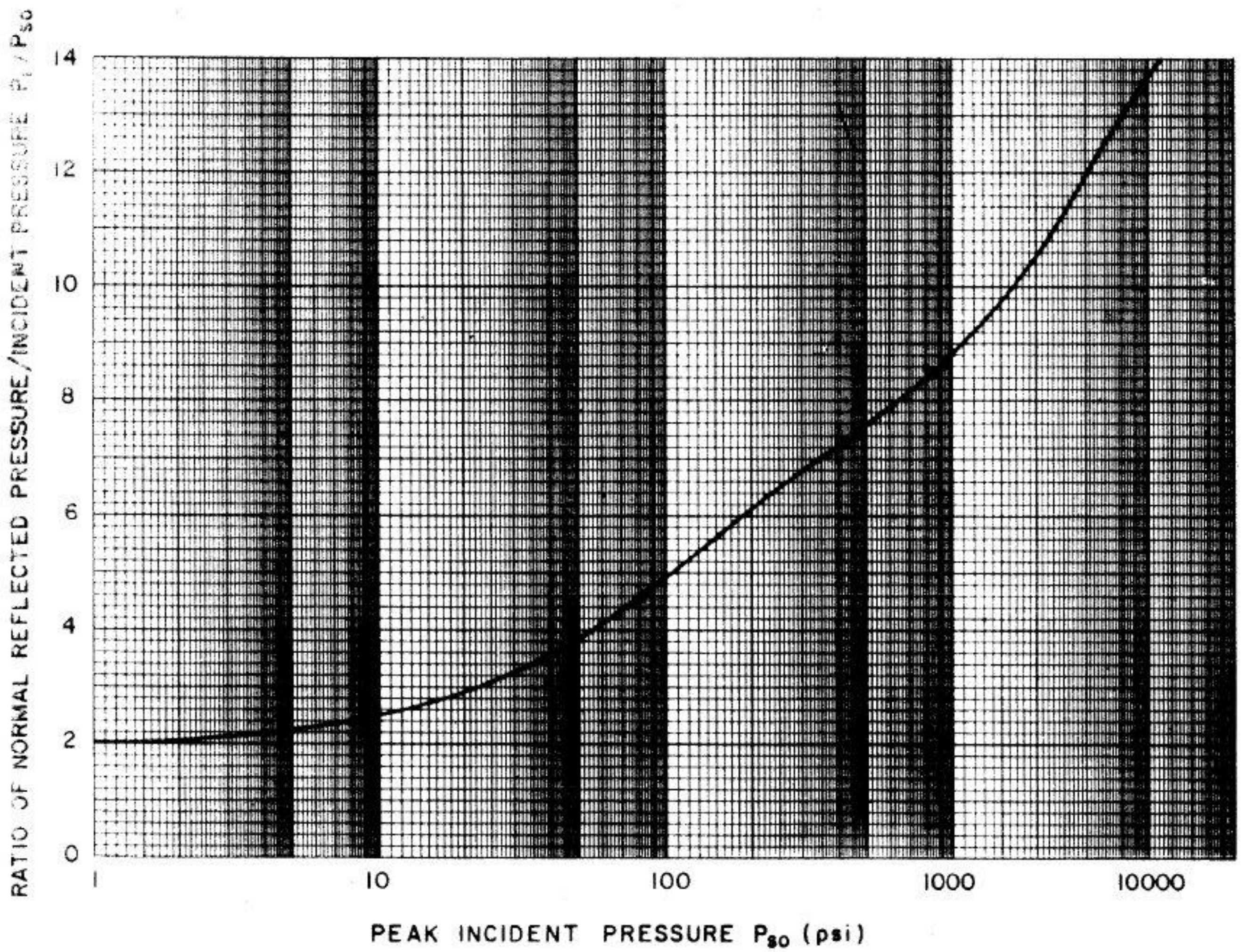


Figure 2-6 Peak incident pressure versus the ratio of normal reflected pressure/incident pressure for a free air burst

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Angle of Incidence

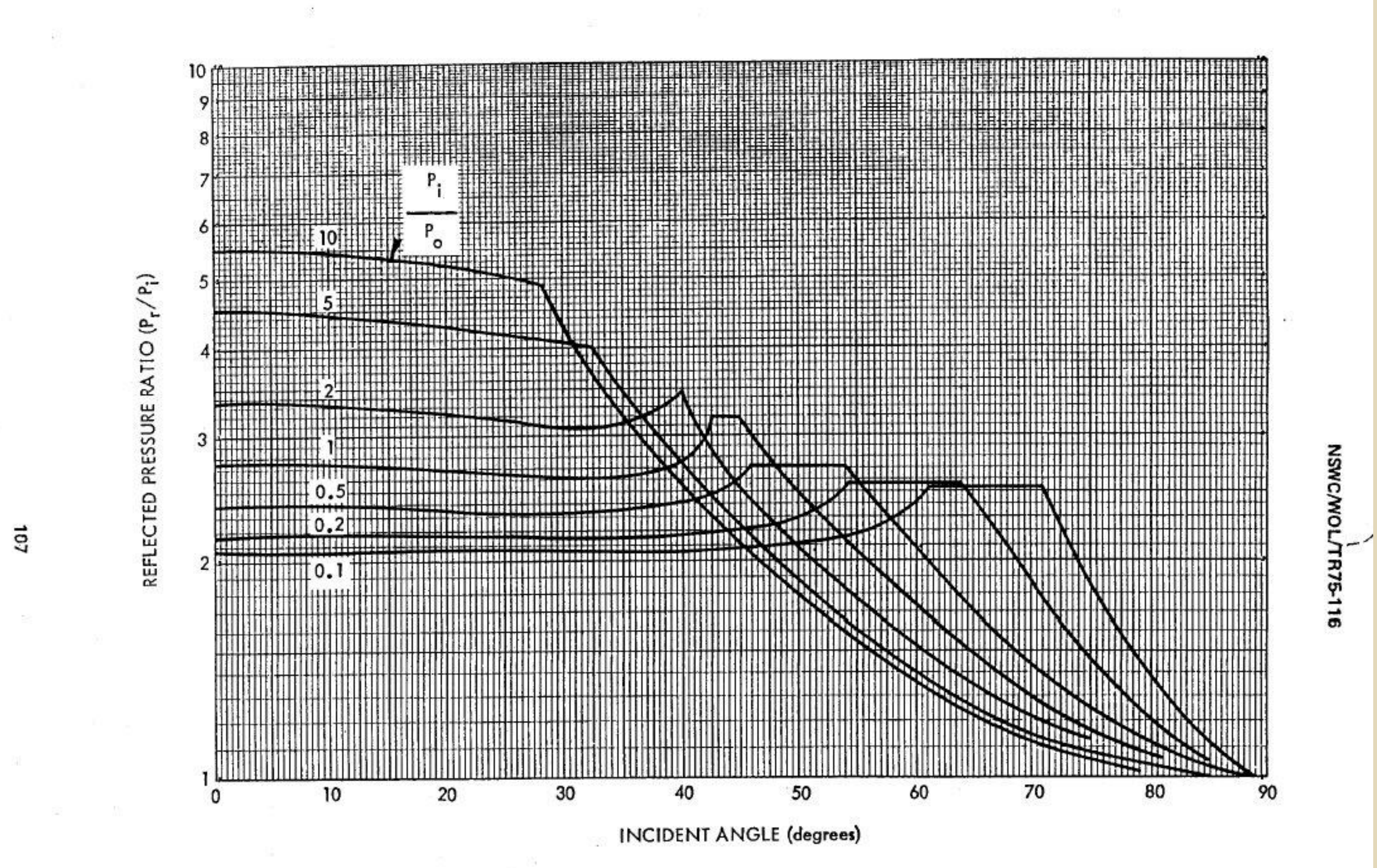

FIG. 13a REFLECTED OVERPRESSURE RATIO VS ANGLE OF INCIDENCE FOR VARIOUS INCIDENT OVERPRESSURE RATIOS

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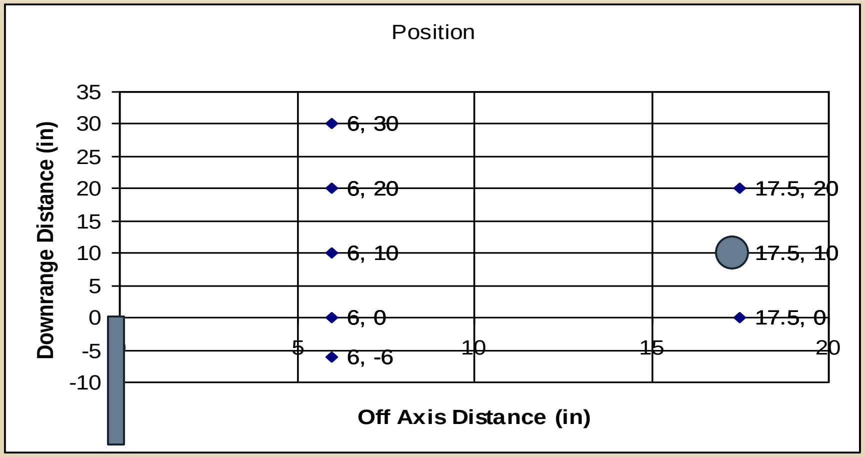
GAU-21 Data



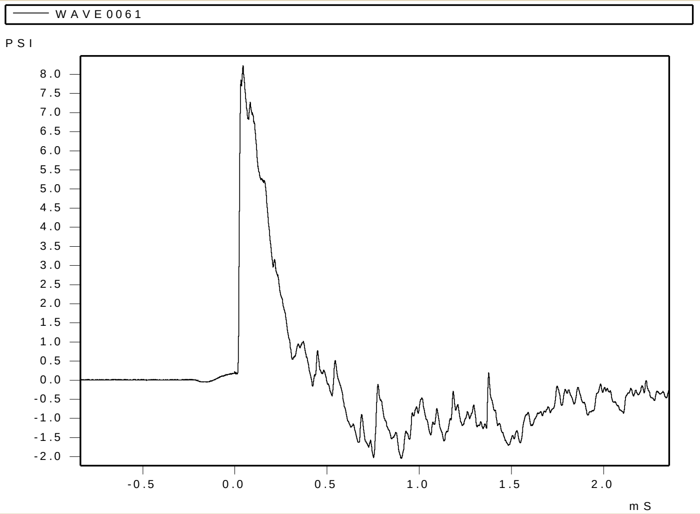


Table 1. Raw Data

Test	Peak Incident (Side-On) Overpressure (psig)	Positive Phase Duration (ms)	Incident Impulse (psi-ms)
61	8.225	0.394	1.375
62	7.585	0.353	1.340
63	7.876	0.416	1.357

Table 2. Some Calculated Data

Test	Reflected Overpressure	Incident Impulse (psi-ms)	Calculated Equivalent Weight of TNT (lbs)
61	20.14	1.375	0.004139
62	18.20	1.340	0.003619
63	18.93	1.357	0.003813

- Biggs, Introduction to Structural Dynamics, MIT, 1964
  - Assumed undamped linear spring-mass system

$$DLF = \frac{y}{y_{st}}$$

  - Generates a General Response Equation

$$y = y_0 \cos \omega t + \frac{\dot{y}_0}{\omega} \sin \omega t + y_{st} \omega \int_0^t f(\tau) \sin \omega (t - \tau) d\tau$$

  - For Triangular Force Input,

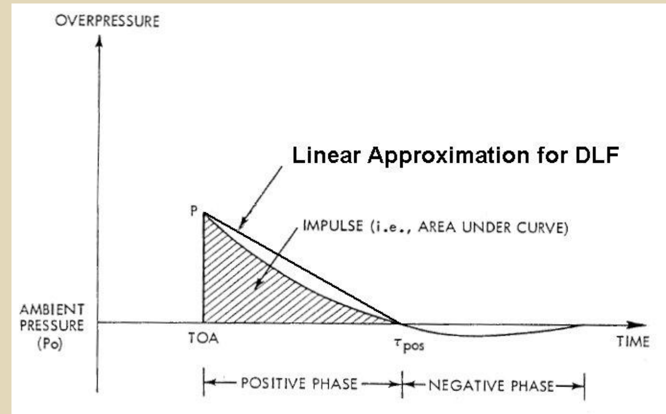
$$f(\tau) = 1 - \frac{\tau}{t_d}, t \le t_d$$

$$f(\tau) = 0, t \ge t_d$$

  - Substituting, Integrating and Simplifying,

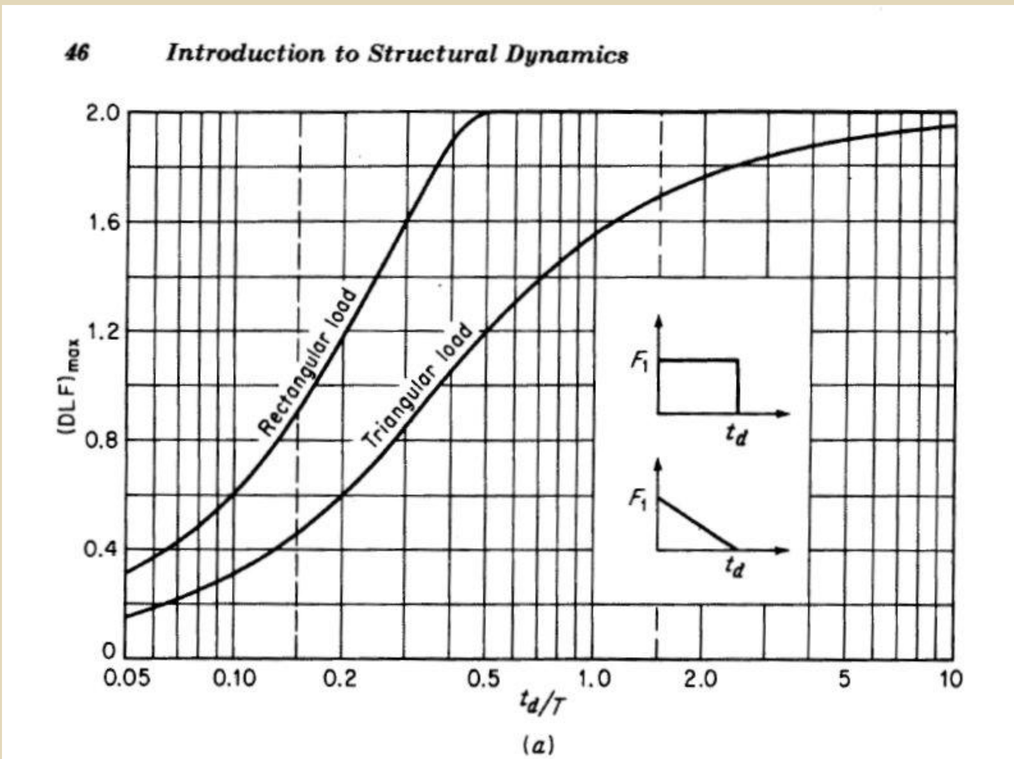
$$DLF = 1 - \cos \omega t + \frac{\sin \omega t}{\omega t_d} - \frac{t}{t_d}, t \le t_d$$

$$DLF = \frac{1}{\omega t_d} \left[\sin \omega t - \sin \omega (t - t_d) \right] - \cos \omega t, t \ge t_d$$



Dynamic Load Factor (DLF)

- **Differentiating, equating to 0 and plotting versus Td/T,**



Right Side
(td/T)>5

Left Side
td/T<0.1

Using DLF

- **Required Values**
  - **From Pressure Measurements**
    - T_d = Positive Phase Duration
    - P_r = Peak Dynamic Pressure applied to surface
  - **From Structure**
    - T_n = Natural Period
      - » Reference (d) gives a formula to determine the natural frequency of a flat plate with all of the edges fixed or simply supported (Table 36; cases 15&16):

$$f = \frac{K_1}{2\pi}\sqrt{\frac{Dg}{wa^4}}$$

where, K_1=23.6 for a rectangular plate with fixed edges and K1 = 11.5 for rectangular plate with simply supported edges

E = Modulus of Elasticity for material

ν = Poisson's Ratio for the material

g = gravitational constant

w = unit load per unit area including weight of plate

a = length of short edge of plate

GAU21/H-60S on full rear train

- Impinges on an 18” X 7.25” panel
  - T_n = 3.88 ms for fixed edges
  - T_n = 7.97 ms for dimply supported edge
- Worst pressure case from GAU-21 testing
  - P_r = 20.14 psi
  - T_d = 0.394 ms
- Td/Tn = 0.102 for Fixed DLF_{max} = 0.33
- Td/Tn = 0.049 for Simple DLF_{max} = 0.17

Equivalent Static Pressure

- $P_{eq} = P_r * DLF_{max}$
- Fixed Edges
  – P_{eq} = 20.14 psi * 0.33 = 6.65 psi
- Simply Supported Edged
  – P_{eq} = 20.14 psi *0.17 = 3.42 psi

Alternatives and Caveats

- Alternative - Dynamic FEA
- Only the simplest of structures can be hand cranked. FEA may be inevitable.
- Doesn't take into account flexing of the supporting structure.
- Pressure profiles for weapons are hard to come by and do not match pressure versus distance equations for explosives

Conclusions

- That’s why helicopters don’t fall out of the sky when they fire their weapons.

Thank you for your time and attention!

For more information on NSWC Crane, please visit www.crane.navy.mil

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