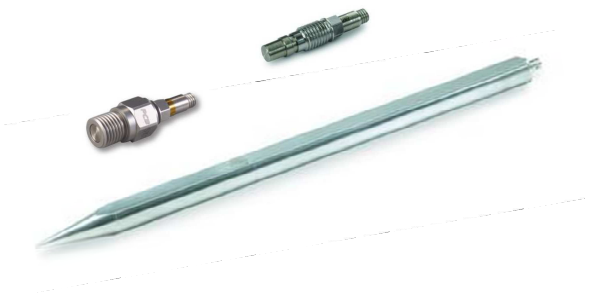
Air Blast and the Science of Dynamic High Amplitude Acoustic Pressure Measurements



Agenda

- Blast Pressure Summary
- Pencil Probe Design
- Pencil Probe Positioning
- Other Blast Pressure Sensors
- Microphones and Sound Level Meters

Explosions Defined

Explosion: A process by which a pressure wave of finite amplitude is generated in air by a rapid release in energy.

Energy sources:

- Weapons
- Ordnance
- Gun muzzle blast

Focus on Freely Expanding Air Shocks

A Nonlinear Process

The properties of air as a compressible gas cause the front of the disturbance to steepen as it passes through the air (i.e. it "shocks up")

- Discontinuities occur across the shock front in:
  - Pressure
  - Density
  - Temperature
- Shock front moves supersonically

Focus on Freely Expanding Air Shocks

A Nonlinear Process

Shock Front Formation

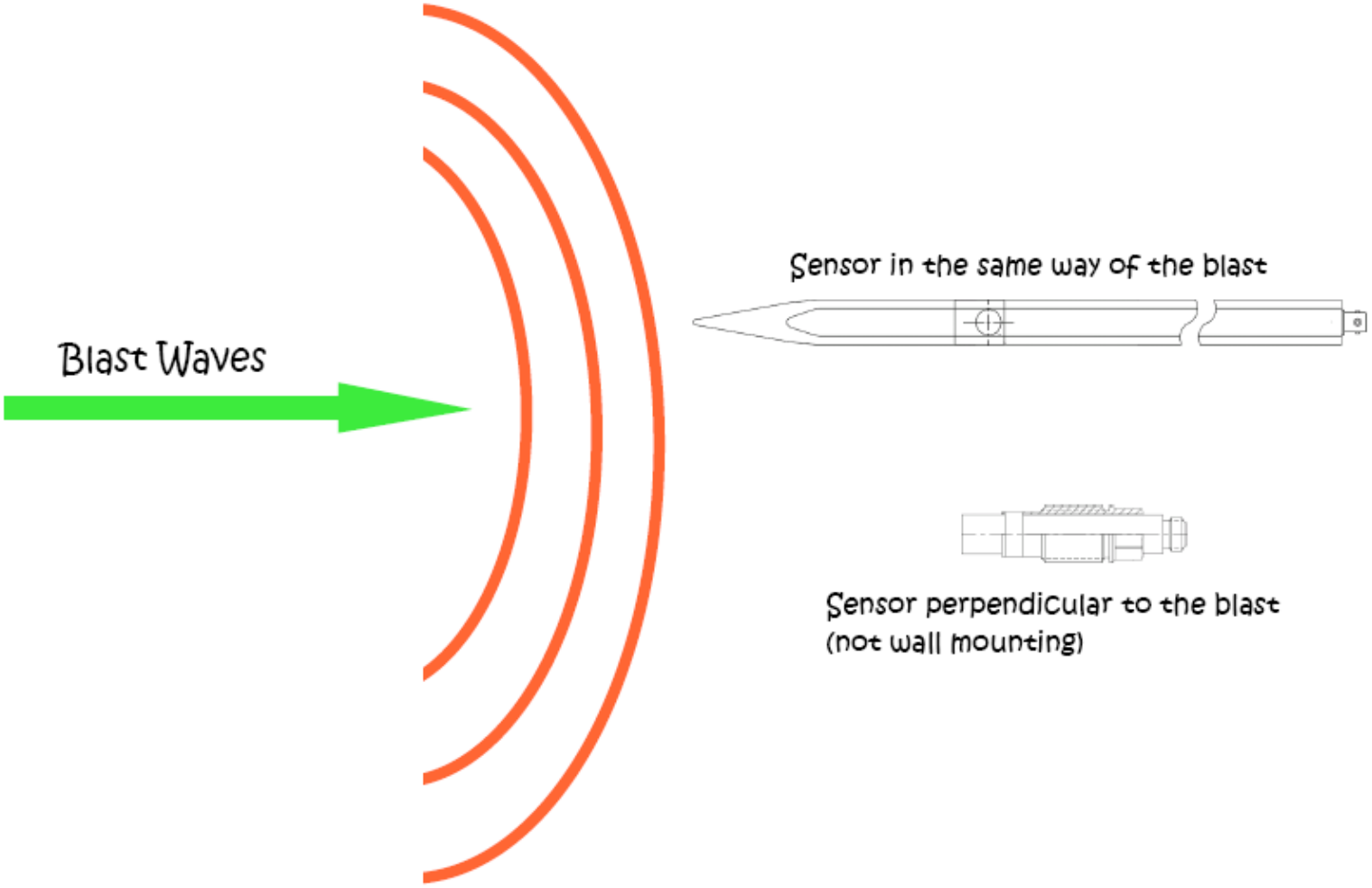
Static Over Pressure on the Battlefield

- Static overpressure: transient differential pressure in air blast relative to ambient pressure just before shock wave arrival
- Measured with pressure transducer whose diaphragm is oriented in a plane parallel to flow velocity vector
- Blast is an Acoustic Measurement
  - Measured primarily quartz piezoelectric pencil probes (PCB 137)
    - High stiffness for fast rise time
    - ICP® output for good signal quality and resolution to **0.7 mili-psi (5 Pa)**
  - Pressure Microphone could by used (PCB 378C10) but lack a robust diaphragm required for the battlefield

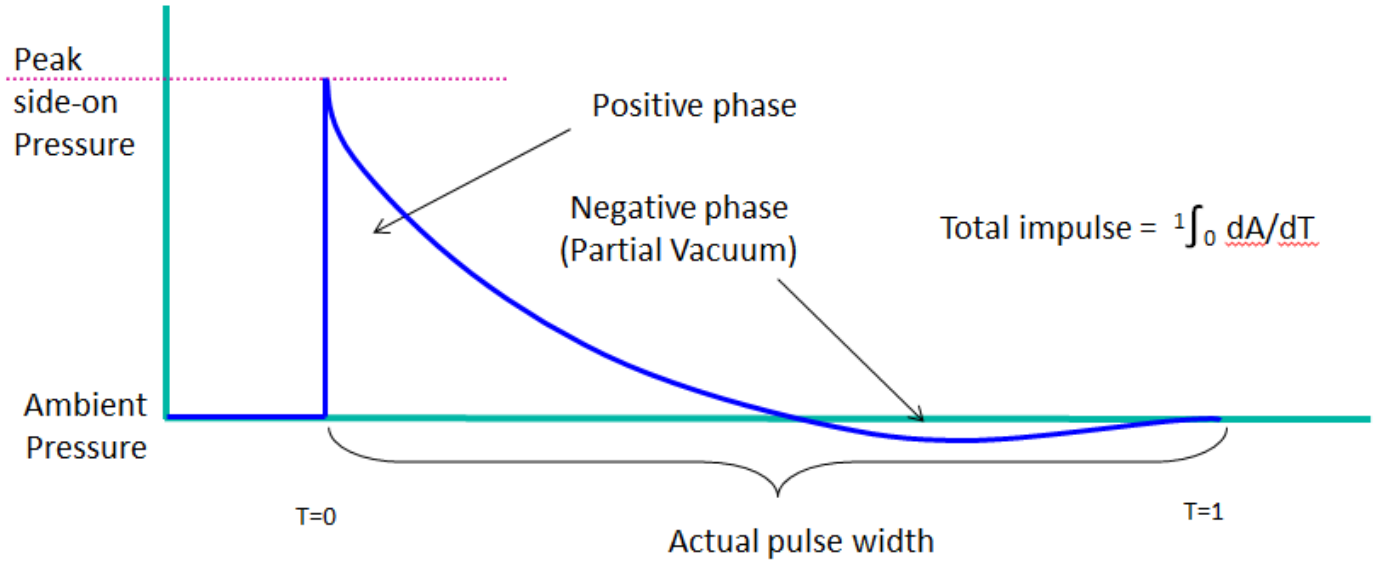
Series 137A Quartz ICP® free-field blast pressure pencil probe

Model 378C10 ICP® pressure Microphone

Picture of Probe/Shock Waver Interaction



Ideal Pressure-time Response to an Explosion in Still, Homogeneous Atmosphere



Net (positive + negative areas) = total impulse

$$I = \int (p(t))dt$$

Human hearing responds to impulse

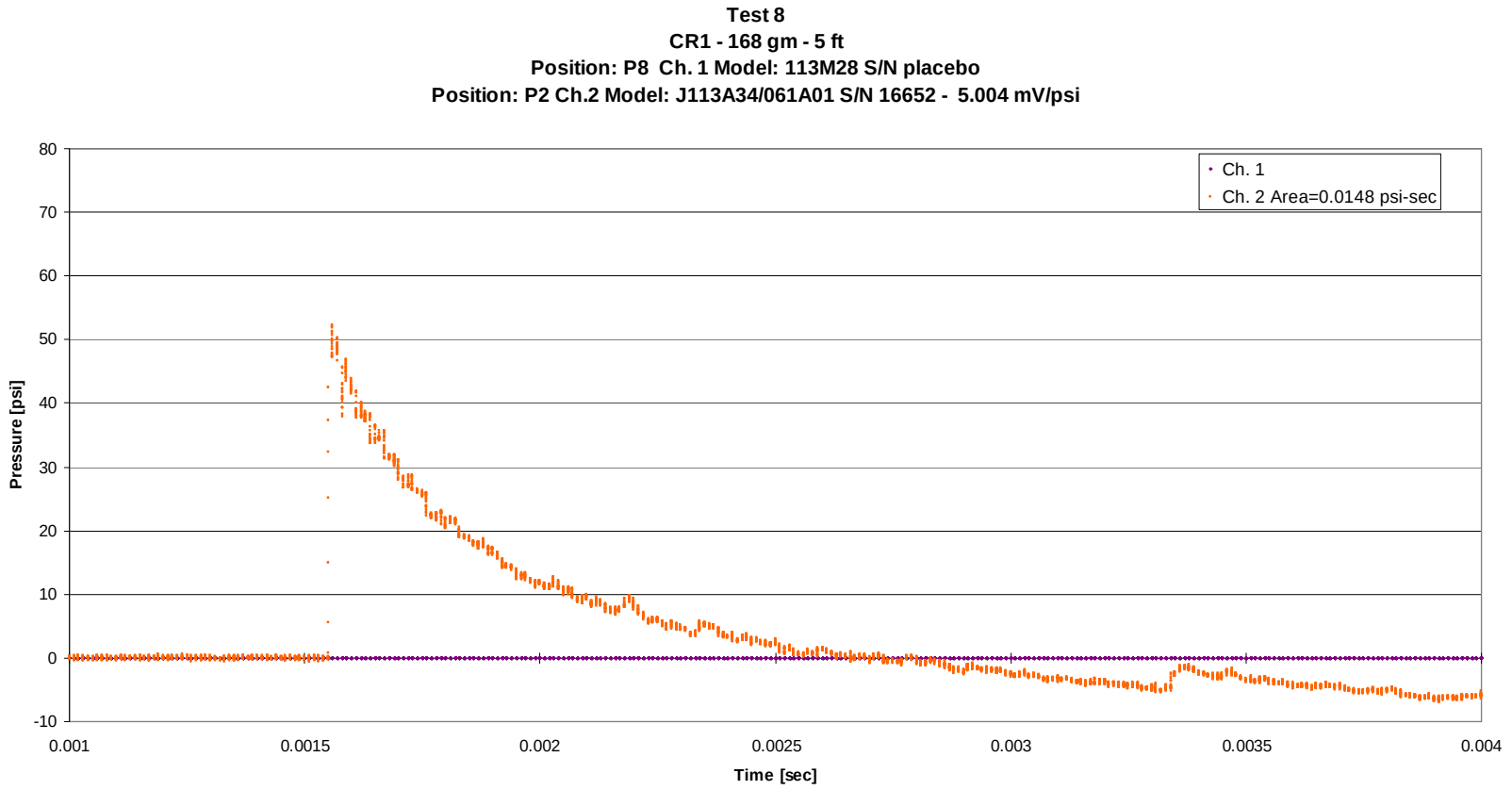
Deviations From Ideal Responses Occur

Causes:

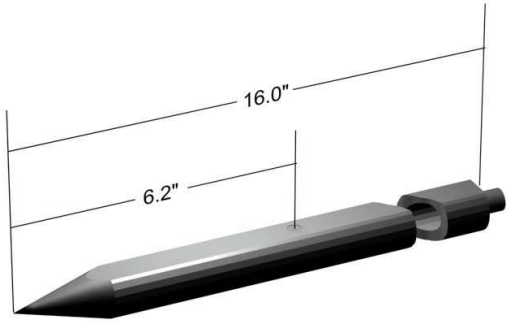
- Reflections at contact surface between explosion products and air
- Low specific energy source may result in long travel distances before “shock up” occurs
- *Cased* explosives may result in fragments that temporarily outrun the blast wave
- Ground effects (dust, heat reflecting surfaces)
- Reflections from solid object or diffraction around them

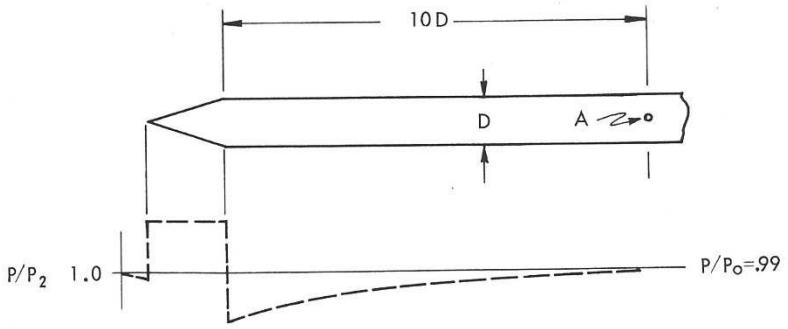
Actual Test Data Recorded Correctly

Good data can be obtained but it is challenging to acquire



Pencil Probe for Side on Air Blast Measurements





a) CONE-CYLINDER PROBE

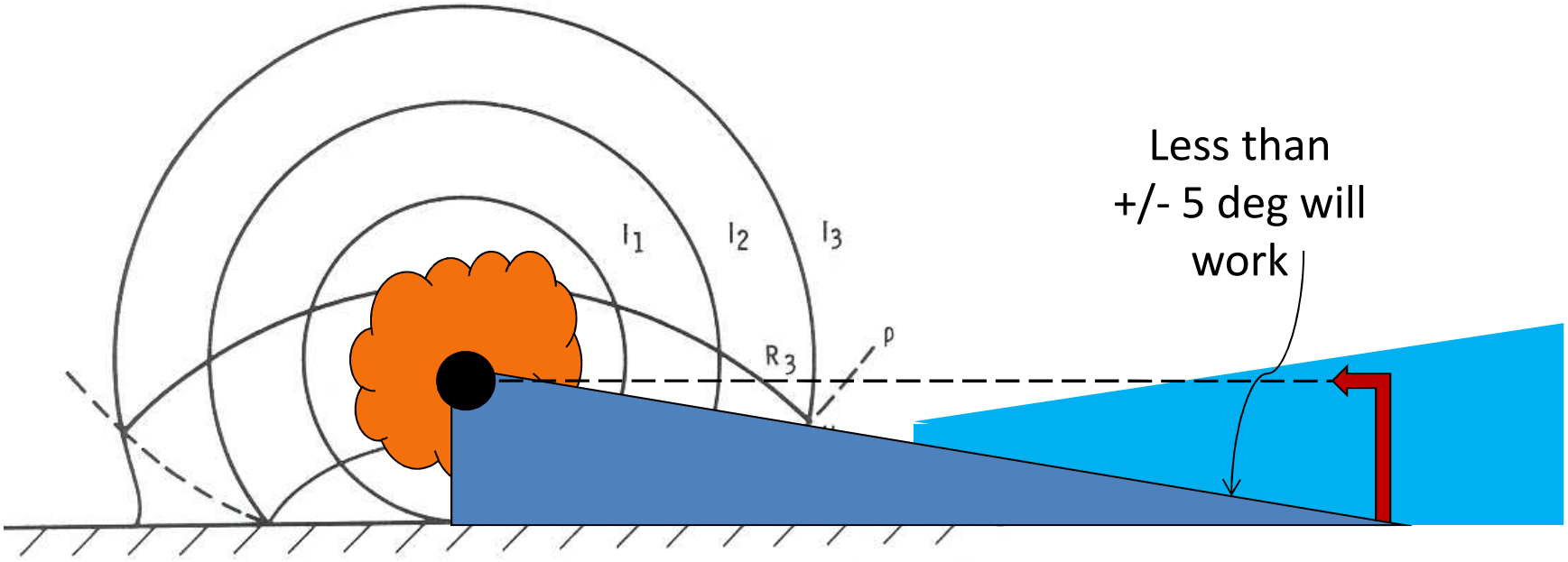
- Assume a shock front is moving at 3,300 feet per second. The wavelength λ corresponding to a spectral frequency *f* of 20,000 Hz in the front would be:

$$\lambda f = c = 3300\ (12) \text{ inches per second or}$$
$$\lambda = 1.98 \text{ inches.}$$

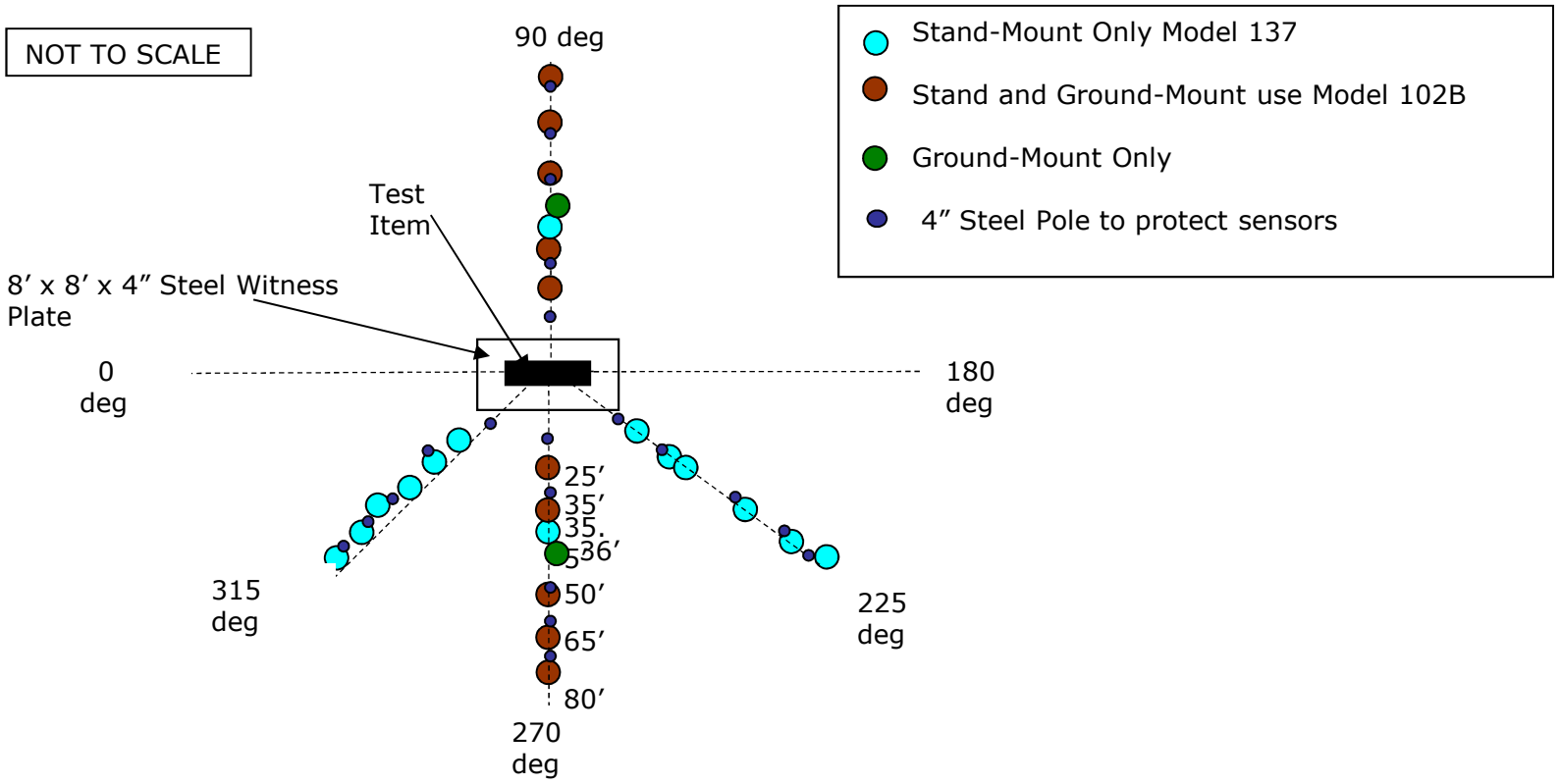
- Looking pencil probe dimension relative to the value of λ, it is clear that the probe has the potential to act as a reflecting body to high frequencies in the approaching shock front.
- In order to minimize reflections, the probe is tapered over approximately its first two-inches of length

Pencil Probe Position

- It's typically desirable to measure in the mach-stem where the shock front becomes near planar
  Be sure you have adequate sensor sensitivity for the expected pressure
  Analyze data as a hemispherical burst typically 1.8 to 2.0 time higher than an air burst

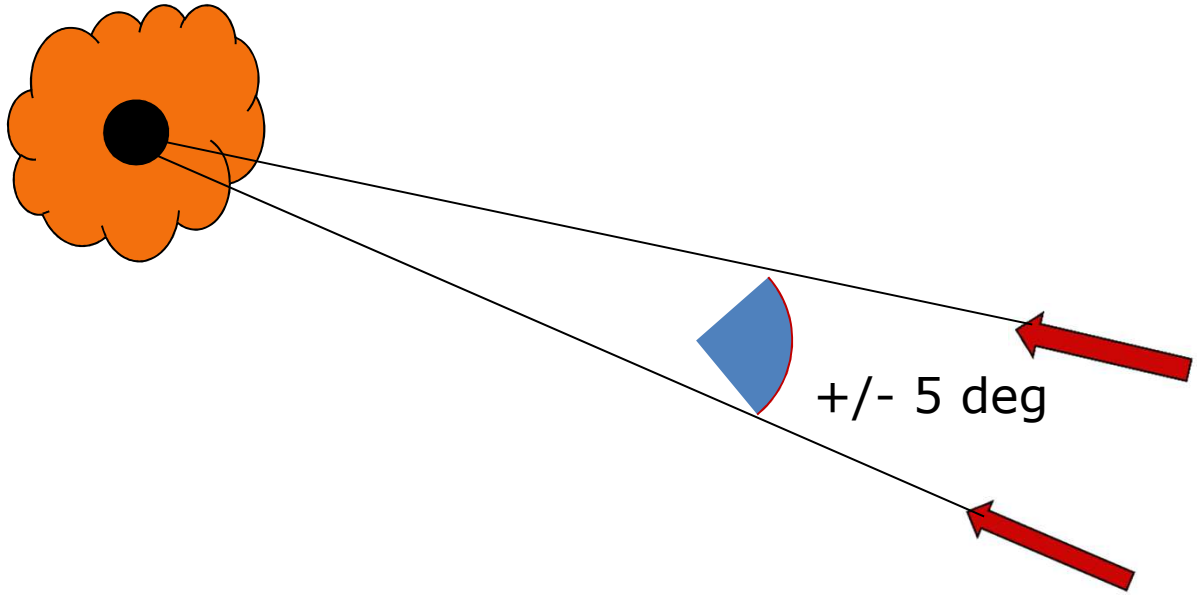


Pencil Probe Position



Pencil Probe Position

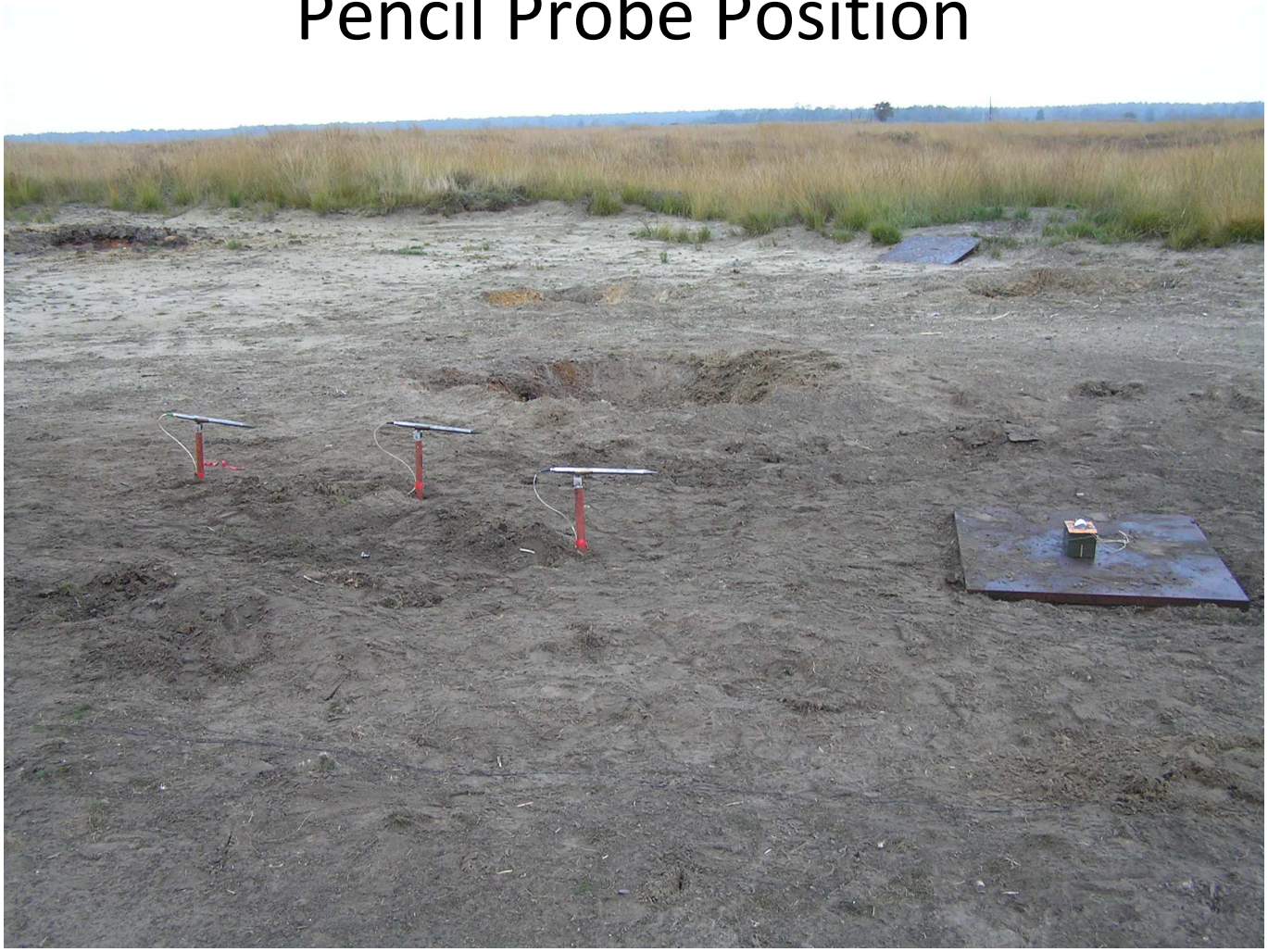
- Probe should be aligned at target within +/- 5 degrees (per Aberdeen study)
- It should be far enough away that the explosion appears as a point source, approximately 1 meter or more



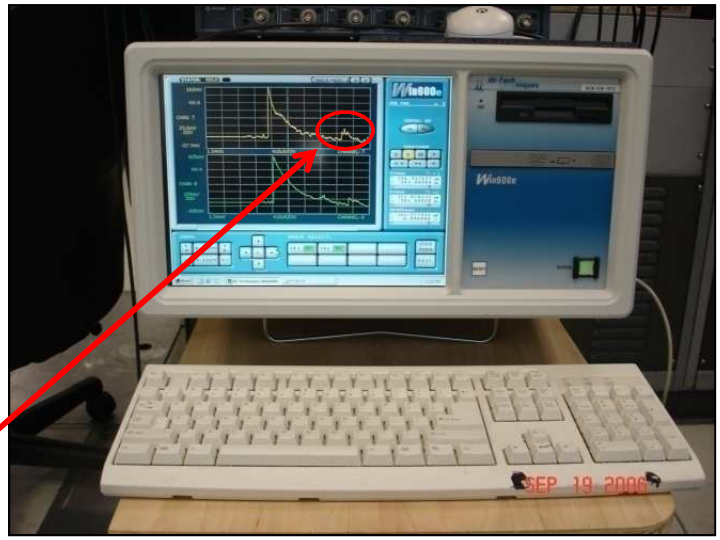
Pencil Probe Position

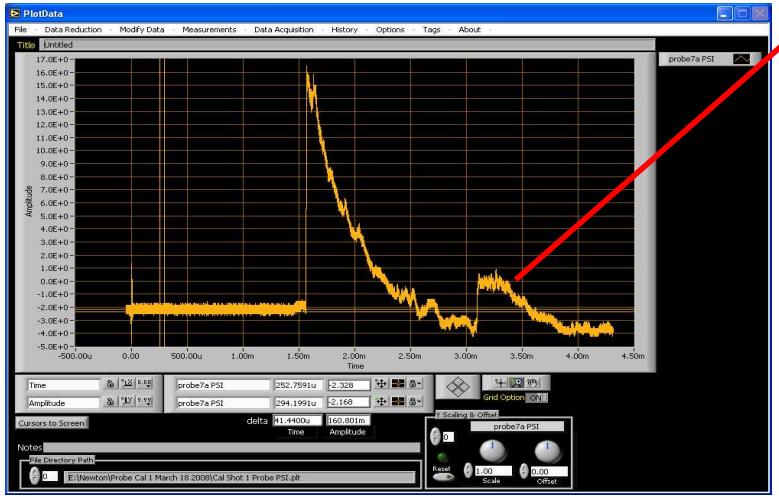
- Use a fragment pole for cased explosives
  - Note one pole did not do its job!
- While not as reliable due to interference at the surface, a ground transducer can accompany the pencil probe

Pencil Probe Position



Indoor Pencil Probe Applications





- Good data when stands are positioned back far enough so explosion acts as a point source
- Watch for reflections

Other Air Blast Pressure Sensors

- For high-frequency measurements
- ICP® output
- Sensitivities 0.5 to 100 mV/psi (0.073 to 14.5 mV/kPa)
- Measuring ranges 50-10,000 psi (345 to 69k kPa)

Series 113B Quartz ICP®, blast sensor

Series 102B Quartz ICP®, ground isolated blast sensor

Series 134A Tourmaline pressure bar

Series 132A ICP®, time of arrival sensor

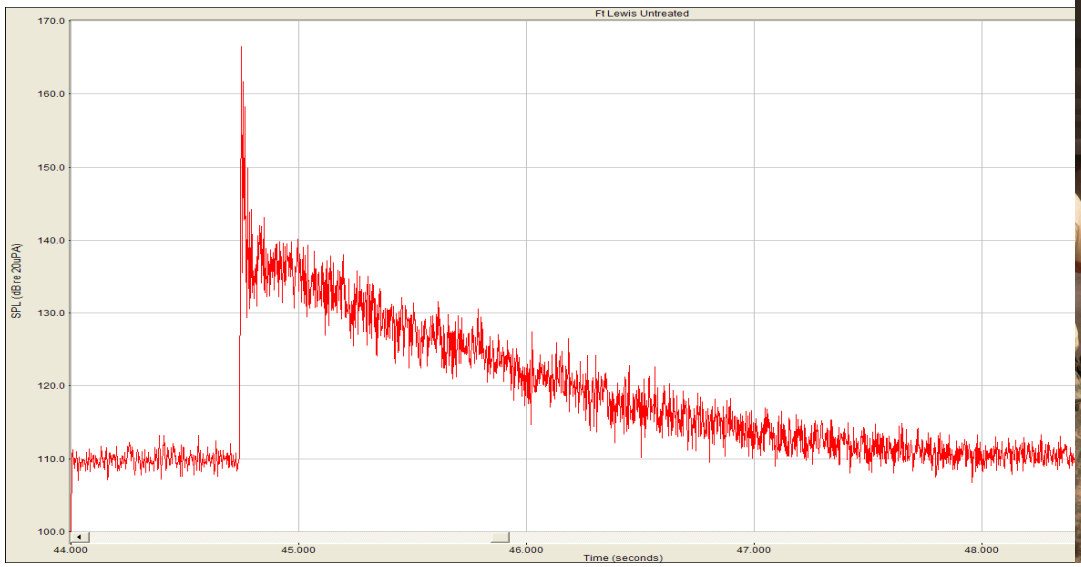
Microphones for Gunshot Impulsive Noise

- Model 378C01
- ICP® output
- Sensitivity 1 mV/Pa
- Measuring ranges 174 dB
  - most small arms gunshot below 170 dB

Model 378C10 ICP® pressure Microphone

Microphones for Gunshot Impulsive Noise

- MIL-STD-1474 calls for acoustic measurement
- Peak from sample data set show 166 dB for 3.3 seconds
- Primary concern on gun range for hearing conservation to daily/weekly exposure



Model LXT1-QPR
for Firearms Acoustic Analysis

- While it does not quite meet the current rise time requirements of MIL-STD-1474D (20 µSec), the LxT1-QPR has a rise time <30 µSec
- Could meet the requirements of the proposal for revised standards for suppressor testing
- Deployable in the field with battery power

Summary

- Series 137B Pencil Probes have been the DOD battlefield standard pressure sensors since 1967 for static over pressure in air blast
- They have the robust ability to survive blast overpressure and provide a resolution of 0.7 mili-psi (5 Pa)
- ¼ inch pressure microphones become ideal for the lower acoustic pressures of gunshot impulsive noise
- A sound level meter such as LXT1-QPR provides a field deployable unit for gunshot.