VIBRATION MONITORING

with

BLASTING SEISMOGRAPHS

Ken Eltschlager, Mining/Explosives Engineer
keltschlager@osmre.gov or (412) 937-2169
Disposal Goals

• Prevent Injury to people

• Prevent Damage to property

• Minimize Annoyance

• Keep from getting sued!
Disposal Site and People
Vibrations Leave the Site
Vibration Energy

Blast
Airblast 1,100 fps
Home

Body Waves 20,000 fps
Surface Waves 5,000 fps
** SAFEGUARD SEISMIC UNIT 2000DK **
SN: 2243

DATE: 09/12/95  TIME: 15:18:06
Event: 009  Recording Time: 10
Client: ROBERTSON
Operation: BUCKEYE IND. MINING CO.
SSU Location: ROBERTSON YARD
Distance to blast: 1385
Operator: M.MANN/ODNR
Comments:
Trigger Level: .05 IN/SEC

<table>
<thead>
<tr>
<th>Summary</th>
<th>L</th>
<th>T</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPV (in/sec)</td>
<td>0.10</td>
<td>0.14</td>
<td>0.07</td>
</tr>
<tr>
<td>PD (in x.001)</td>
<td>2.39</td>
<td>2.97</td>
<td>1.38</td>
</tr>
<tr>
<td>PPA (g)</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>FREQ (Hz)</td>
<td>8.0</td>
<td>7.6</td>
<td>16.6</td>
</tr>
<tr>
<td>RESULTANT PPV (in/sec):</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEAK AIR PRESSURE: (dB)</td>
<td>114</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(psi)</td>
<td>0.00145</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**VELOCITY WAVEFORM GRAPH SCALE**
TIME = 100 MSEC PER MARK
SEISMIC = +/- .64 IN/SEC
SOUND = +/- 0.00232 PSI

**SHAKETABLE CALIBRATED: 06/20/95**
By GeoSonics, Inc.
Box 779, Warrendale, PA 15095 U.S.A.
TEL: 412.934.2900  FAX: 412.934.2999

Time Histories, Waveforms, Component motions
Why Use Blasting Seismographs?

- **Show Compliance with Safe Limits**
- **Evaluate Blast Performance**
- **Provide Liability Protection**
Recordings are controlled by:

• How the seismograph is made

• How the seismograph is placed in the field
  – ISEE Field Practice Guidelines for Blasting Seismographs (1999)

• For specifications on each:
  http://www.isee.org/sections/blast.htm
Thomas
PARTS OF A BLASTING SEISMOGRAPH

- Longitudinal
- Vertical
- Transverse

SUMMARY: R0.063 005
003 082 V0.020, 100.0
10/24 L0.030, 71.4
16:12 T0.058, 50.0
ISEE FIELD PRACTICE GUIDELINES FOR BLASTING SEISMOGRAPHs

General Guidelines

Ground Vibration Monitoring

Airblast Monitoring
General Guidelines

Read the Instruction Manual
General Guidelines

Annual Calibration
**General Guidelines**

**Identify the User’s Name**

**Correct Date and Time**

---

**Seismograph Log**  
**KQQ serial number 2230**

<table>
<thead>
<tr>
<th>Entry</th>
<th>Set up Date</th>
<th>Time</th>
<th>Location</th>
<th>Operator</th>
<th>Break down Date</th>
<th>Time</th>
<th>Lat / Lon</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>12/12/2003</td>
<td>11:00</td>
<td>P.A.P. Garage 2213 Hwy 1002 Cox Creek, KY</td>
<td>Jim Cruiser</td>
<td>12/24/2003</td>
<td>16:30</td>
<td>37° 64.536' 85° 34.430'</td>
</tr>
<tr>
<td>2</td>
<td>1/12/2004</td>
<td>9:00</td>
<td>Samuel's Field Hwy 62 Bardstown, KY</td>
<td>B. Boyd</td>
<td>2/12/2004</td>
<td>14:45</td>
<td>37° 48.946' 85° 29.938'</td>
</tr>
<tr>
<td>3</td>
<td>2/2/2004</td>
<td>14:15</td>
<td>B12 job #21 Clark, IN</td>
<td>Jim Crusier</td>
<td>2/2/2004</td>
<td>15:00</td>
<td>38° 21.940' 85° 44.30'</td>
</tr>
</tbody>
</table>
General Guidelines

Record the Blast

AUG. 22, 1993
General Guidelines

Record the Full Waveform
General Guidelines

Document the Location of the Seismograph

- Full name & 911 address
- Setup time & date
- Removal time & date
- Azimuth to blast
General Guidelines

Know the distance to the Blast

690 Feet

Jones Residence
General Guidelines

*Know the Processing Time of the Seismograph*

None? 1 Minutes? 5 Minutes? 20 Seconds? 5 Minutes?
General Guidelines

Know the Memory or Record Capacity of the Seismograph
General Guidelines

Know the Nature of the Report that is Required

<table>
<thead>
<tr>
<th>PPV</th>
<th>Full Waveform</th>
<th>Digital Data</th>
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</thead>
<tbody>
<tr>
<td>Frequency Data</td>
<td></td>
<td>Zero Crossing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fast Fourier Transform</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Response Spectra Analysis</td>
</tr>
</tbody>
</table>
General Guidelines

Allow Ample Time for Setup
General Guidelines

Know the Temperature
General Guidelines

Attach Cables

Avoid Suspending Cables
Ground Vibration Monitoring

Sensor Placement

Sensor Coupling

Programming Considerations
SENSOR PLACEMENT

Place the sensor on the ground
SENSOR PLACEMENT

Location Relative to the Structure

Within 10 Feet of the Structure

or

Within 10% of the Distance from the Blast
SENSOR PLACEMENT

Soil Density Evaluation

Soil Density > Sensor Density
SENSOR PLACEMENT

Level the Sensor
SENSOR PLACEMENT

Longitudinal Channel Points to the Blast
SENSOR PLACEMENT

When access to a property is not attainable,

Place the sensor closer to the blast in undisturbed soil.
SENSOR COUPLING

Acceleration > 1.0 g

Bury the Sensor or Attach to Bedrock
SENSOR COUPLING

$0.2 \text{ g} < \text{Acceleration} < 1.0 \text{ g}$

- Burial preferred
- Spiking maybe
SENSOR COUPLING

Acceleration < 0.2 g

- Shallow Burial
- Sand Bagging
- Spiking
<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>PARTICLE VELOCITY 0.2g</th>
<th>PARTICLE VELOCITY 1.0g</th>
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<tr>
<td>4</td>
<td>3.07</td>
<td>15.40</td>
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<td>10</td>
<td>1.23</td>
<td>6.15</td>
</tr>
<tr>
<td>15</td>
<td>0.82</td>
<td>4.10</td>
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<tr>
<td>20</td>
<td>0.61</td>
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<td>25</td>
<td>0.49</td>
<td>2.45</td>
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<tr>
<td>50</td>
<td>0.25</td>
<td>1.25</td>
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<tr>
<td>100</td>
<td>0.12</td>
<td>0.60</td>
</tr>
<tr>
<td>200</td>
<td>0.06</td>
<td>0.30</td>
</tr>
</tbody>
</table>
SENSOR COUPLING

*Foundation Attachment within +/- Foot of the Ground Level*
SENSOR COUPLING

- PPV will be similar to outside in the soil
- Actually measuring the structure
PROGRAMMING CONSIDERATIONS

• Trigger Level > Background
  (Start – 0.05 in/s)

• Dynamic Range Resolution

• Record Duration = Blast duration + 2 seconds + 1 second for each 1100 ft
Airblast Monitoring

Microphone Placement

Programming Considerations
MICROPHONE PLACEMENT

Attach Wind Screen
MICROPHONE PLACEMENT

+ 3 feet above the ground or within 1.2 Inches of the ground
MICROPHONE PLACEMENT

Avoid Shielding

Jones Res.

Mine
MICROPHONE PLACEMENT

Minimize reflections
PROGRAMMING CONSIDERATIONS

- Trigger Level > Background
  (Start – 120dB)

- Record Duration = Blast duration + 2 seconds
Happy Monitoring! Outside in Teams
Each Team

• 1 Blasting Seismograph
• Un-box the unit
• Attach spikes and anchor to the ground
  – Each person must do this activity
• Attach microphone to the stand
• Connect Sensor and microphone wires
• Create a false trigger
• Break down the unit and box
What are the Adverse Effects of Blasting

- Ground vibrations
- Airblast / Concussion
- Flying Debris
- Fumes
Terms

Blast Site

Blast Area

Project Area / Permit / Range

House
What are the Most Important Parameters That Affect Vibrations?

- Distance
- Charge weight per delay
- Confinement
- Spatial relationships
Charge Weight per Delay
Confinement

(a) $B = 15'$
Completely contained, only failure is pulverisation near the charge and radial tensile failure running out from it.

(b) $B = 12'$

(c) $B = 9'$
Surface and subsurface failure almost meet. There will be a shelf of unbroken rock between the two. Doming or surface bulging.

(d) $B = 6'$
Full crater, burden completely broken out. Surface and subsurface failures run through to the surface.

(e) $B = 3'$
Full crater, lower volume than optimum fine fragmentation. Noise, flyrock, bowl shaped crater.

Assume Explosive = 40 lb. ANFO

Figure 7.17. Schematic of the Effect of Decreasing the Burden on Charges Fired in Rock.
Spatial Relationships

Complaint House, 550’

Complaint House 2, 1500’

Compliance House, 450’
Vibrations Leave the Site
BLASTING TIME HISTORY

Amplitude versus time.
For this record, it is particle velocity amplitude. Vibration records could also be acceleration or displacement time histories depending on the devices used to measure the motion.

Period (T) is the time in seconds for one complete vibration cycle or “seconds per cycle.”

Frequency (f) is 1/T or “cycles per second” also “Hz”

Amplitude – Particle Velocity or Pressure

Time (sec)

Period (and frequency) can usually be estimated by measuring the time between zero crossings, particularly for a record which has a uniform or one dominant frequency.

In this example, the timing marks represent 0.1 sec (100 ms) and the measured period is about 88 percent of the time between marks.
Frequency

• Number of cycles per second
  – Measured in Hertz (Hz)

• $f = \frac{1}{T}$
  – $T$ is the time of one cycle

• Zero-crossing used by seismographs
  – $F = \frac{1}{2t}$
  – $t$ is the time of $\frac{1}{2}$ a cycle or where the wave crosses zero
**SAFEGUARD SEISMIC UNIT 2000DK**

SN: 2243

DATE: 09/12/95   TIME: 15:18:06

Event: 009   Recording Time: 10

Client: ROBERTSON
Operation: BUCKEYE IND. MINING CO.
SSU Location: ROBERTSON YARD
Distance to blast: 1385
Operator: M. MANN/ODNR
Comments: Trigger Level: .05 IN/SEC

**SUMMARY**

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**VELOCITY WAVEFORM GRAPH SCALE**

- TIME = 100 MSEC PER MARK
- SEISMIC = +/- .64 IN/SEC
- SOUND = +/- 0.00232 PSI

SHAKETABLE CALIBRATED: 06/20/95

By GeoSonics, Inc.

Box 779, Warrendale, PA 15095 U.S.A.
TEL: 412.934.2900 FAX: 412.934.2999
Ground Vibration Characteristics

- Body waves – 10,000 to 25,000 ft/s
- Surface waves – 3,000 to 10,000 ft/s
- Arrive at the sensor instantly
- Measured as Particle Velocity
- All 3 channels begin activity at the same time
- Last longer than the blast duration
- Peaks occur at different times
Ground Vibration Prediction
Scaled Distance

Square root scaling of the charge weight \((CW^{1/2})\)

\[ SD_G = \frac{D}{CW^{1/2}} \]

\(D = \text{Distance} \quad CW = \text{Charge Weight per Delay} \)
OSM Scaled Distance Line: $PPV = 438(SD)^{-1.52}$

$CW = 100 \text{ lb}; \ D = 550 \text{ ft}$
Ground Vibration Limits

PPV = 0.5 in/s

When

Frequencies are less than 20 Hz

Or SD_G = 55 (monitor)

All seismographs manufactured today measure particle velocity and report frequency.
Airblast Characteristics

- Compression wave
- Speed – 1,100 ft/s
- Air is homogenous
- Measured in pressure
- Reported in decibels
- Pressure doubles for each 6 dB
- Inaudible – concussion below 20 Hz
Airblast Sources

• **Air Pressure Pulse** – rock displacement at the face, low frequency
• **Rock Pressure Pulse** – Seismically induced from the ground at the blasting seismograph
• **Gas Release Pulse** – Gases venting through the fractured rock, low frequency
• **Stemming Release Pulse** - Blow-out of the stemming, high frequency on top of the air pressure pulse
• **Noise** – High frequency from Det cord or surface delays
Gas Release Pulse
Air Pressure Pulse

29S2-HW
8th May 2002
Stemming Release Pulse
Stemming Release Pulse
Airblast Propagation

- Ground vibrations typically attenuate over distance quicker than Airblast

- Perceptible airblast levels may occur at much greater from blasting distances than perceptible ground vibration

- Cube root scaled distance is used to estimate amplitudes
TEMPERATURE OR SOUND SPEED

TEMPERATURE DROPS WITH INCREASING ALTITUDE. NORMAL CONDITION. SOUND REFRACTS UPWARD, DIES OUT IN NORMAL FASHION.

TEMPERATURE INVERSION, I.E. TEMPERATURE RISES WITH INCREASING ALTITUDE. SOUND REFRACTS DOWNWARD, CARRIES TO GREATER DISTANCE.

CLOUDS MAY FORM AT TOP OF INVERSION IF ENOUGH MOISTURE IS PRESENT

TEMPERATURE GRADIENTS FORM LAYERED CONDITION. SOUND IS REFLECTED FROM LAYERS, RETURNS TO GROUND SURFACE TO REINFORCE DIRECT WAVES, INCREASING SOUND LEVEL ABOVE ITS NORMAL LEVEL AT GREATER DISTANCES.

EFFECTS OF TEMPERATURE GRADIENTS ON SOUND TRANSMISSION (ADAPTED FROM COOK, 1958)
Inversions

120 dB 140 dB
Airblast Considerations

• Focusing
  – Airblast may be enhanced from ridge to ridge, up to 300 % over flat terrain
  – Topographic features may enhance airblast down valleys
  – Wind direction

• Design
  – Airblast travels @ 1,100 ft/s or about 1 ft/ms
  – What if two holes detonate 17 ms apart and have a spacing of 17 feet?
Airblast Prediction
Scaled Distance

• Cube root scaling of the charge weight \((CW^{1/3})\)

\[
SD_A = D / CW^{1/3}
\]

\(D = \text{Distance} \quad CW = \text{Charge Weight per Delay}\)

Example: \(1000/1^{1/3} = 1000/1 = 1000\)
CW = 1 lb; D = 1000 ft

Unconfined Airblast

Unconfined

PSI = 187 (SD)^{-1.38}

(Perkins and Jackson, 1964)
Airblast Limits

2 Hz microphone 133 dB

Or $S_{DA}$ of 1000 (unconfined)

All seismographs manufactured today have 2 Hz lower frequency response range.
When Range Limits are unknown or at an Expedient Location

- Estimate the target N.E.W. for airblast control using a scaled distance of 1000 (about 133dB)
- What is the maximum allowable charge weight per delay with a house 2000 feet away from the blast site?

\[
CW = \left(\frac{D}{1000}\right)^3
\]

\[
CW = \left(\frac{2000}{1000}\right)^3
\]

\[
CW = 2^3
\]

\[
CW = 8 \text{ lbs}
\]

Charges over 8 lbs should be monitored!
Waveforms - Is the Event Blast-Induced?
CALIBRATION DUE IN LESS THAN ONE MONTH
LAST CALIBRATION: 05/08/98

BAT: 13.0 SN: 2243 V3.75 4/15/99 14:57
RECORD <5> GRAPH <2 in> COPIES <1>
OSM CHARTS <DISABLED> DISK COPIES <1>
EVENT HOLD <DISABLED> ALARM <DISABLED>
TRIGGERS: SEIS <0.04> SOUND <123 db>
COMMAND:

TRIGGER ACTIVE, 4/15/99 14:57:21

NO EVENTS ABOVE 0.04 in/sec, 123 db
EXIT TRIGGERED, 4/15/99 14:57:36
**SAFEGUARD SEISMIC UNIT MICRO-SEIS**

SN: 4106

Monday, 10/20/03 10:59:19

Event: 000
Client: BVS SECTION
Operation: PATRIOT, WV
SSU Location: MONTMAYERA
Distance to Blast: NA
Operator: KELTSCHLAGER
Comments: AIRBLAST STUDT
Digital Filter: OFF
Trigger Levels: 0.10 in/sec. No db
Record Time: 5 secs
Range: Auto 5 ips

VIBRATION & SOUND TIME HISTORY

Time Scale: 0.1 (sec/div)
Data Scale (seismic): 0.64 (in/sec)
Data Scale (air): 0.009 (psi)

SUMMARY

<table>
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<tr>
<th>PPV (in/sec)</th>
<th>L</th>
<th>T</th>
<th>V</th>
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</thead>
<tbody>
<tr>
<td>0.35</td>
<td>0.25</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>PD (0.001 ln)</td>
<td>6.33</td>
<td>6.32</td>
<td>2.42</td>
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<tr>
<td>PPA (g)</td>
<td>0.15</td>
<td>0.10</td>
<td>0.15</td>
</tr>
<tr>
<td>FREQ (Hz)</td>
<td>10.0</td>
<td>6.7</td>
<td>16.6</td>
</tr>
</tbody>
</table>

RESULTANT PPV: (in/sec) 0.42
PEAK AIR PRESSURE: (db) 120 (psi) 0.00290

Monday, 10/20/03 10:59:19
ODNR SEISMO. DATA/M. MANN/RECORDED AT: Dave Sugar, Inc., Permit IM-1091 (S & G Pit) (Approx. One-half Mile E of Petersburg, OH) 300 ft. NW of Flooded Gravel Pit Where DTS Corp. Detonates Plastic Explosives (3 lbs. +/-) Glued To Railroad Crossings, Under 10 ft. of Water
Event Number: 003 Date: 12/17/97 Time: 8:56
Acoustic Trigger: 112 dB Seismic Trigger: 0.02 in/s Serial Number: 1172

### Amplitudes and Frequencies

**Acoustic:** 128 dB @ 42.6 Hz.

**Radial:** 0.0875 in/s @ 20.4 Hz.

**Vertical:** 0.06 in/s @ 18.2 Hz.

**Transverse:** 0.03 in/s @ 17.0 Hz.

**Vector Sum:** 0.0875 in/s

### Graph Information

**Duration:** 0.000 sec To: 3.010 sec

**Acoustic:** 0.52 Mb (0.13 Mb/div)

**Seismic:** 0.09 in/s (0.0225 in/s/div)

**Time Lines at:** 0.50 sec intervals

---

![Graph](image_url)
<table>
<thead>
<tr>
<th>Channel</th>
<th>Acoustic</th>
<th>Radial</th>
<th>Vertical</th>
<th>Transverse</th>
<th>Vector Sum</th>
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</thead>
<tbody>
<tr>
<td>Peak Amplitude</td>
<td>0.22 Mb</td>
<td>121 dB</td>
<td>0.37 In/Sec</td>
<td>0.22 In/Sec</td>
<td>0.25 In/Sec</td>
</tr>
<tr>
<td>Frequency:</td>
<td>3.2 Hz</td>
<td>8.1 Hz</td>
<td>8.8 Hz</td>
<td>8.3 Hz</td>
<td>N/A</td>
</tr>
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</table>

**Seismogram**

Data Scale: Acoustic = 0.10 Mb/Div  Seismic = 0.04 IPS/Div  Time Scale = 0.50 Sec/Div

- **Acoustic**
- **Radial**
- **Vertical**
- **Transverse**
Amplitudes and Frequencies

Acoustic: 138 dB @ 1.9 Hz.
Radial: 0.01 in/s @ 0.0 Hz.
Vertical: 0.01 in/s @ 0.0 Hz.
Transverse: 0.01 in/s @ 0.0 Hz.
Vector Sum: 0.0125 in/s

Graph Information

Duration: 0.000 sec To: 6.500 sec
Acoustic: 1.50 Mb (0.38 Mb/div)
Seismic: 0.01 in/s (0.0025 in/s/div)
Time Lines at: 1.00 sec intervals
Amplitudes and Frequencies

Acoustic (A): 122 dB @ 9.3 Hz
(0.26Mb 0.0038psi 0.0260kPa)

Radial (R): 0.025in/s 0.635mm/s @ 8.8Hz

Vertical (V): 0.02in/s 0.508mm/s @ 10.8Hz

Transverse (T): 0.025in/s 0.635mm/s @ 9.8Hz

Graph Information

Duration: 0.000 sec To: 4.500 sec

Acoustic Scale:
122dB 0.25Mb (0.063Mb/div)

Seismic Scale:
0.20in/s (0.050in/s/div) 5.08mm/s (1.270mm/s/div)

Time Lines at: 0.50 sec intervals
Event Number: 012   Date: 5/7/97   Time: 14:11
Acoustic Trigger: 114 dB   Seismic Trigger: 0.04 in/s   Serial Number: 404

Amplitudes and Frequencies

Acoustic: 127 dB @ 14.6 Hz.
Radial: 2.52 in/s @ 24.3 Hz.
Vertical: 1.92 in/s @ 46.5 Hz.
Transverse: 1.98 in/s @ 39.3 Hz.

Graph Information

Duration: 0.000 sec To: 4.500 sec
Acoustic: 0.46 Mb (0.12 Mb/div)
Seismic: 2.52 in/s (0.63 in/s/div)
Time Lines at: 0.50 sec intervals   Cal 1.00

Cal 1.00
Cal 0.50
Cal 0.50
Cal 0.50

0.00s 0.50s 1.00s 1.50s 2.00s 2.50s 3.00s 3.50s 4.00s 4.50s
DATE: 07/06/98          TIME: 10:14:30          Summary
Event: 002             Recording Time: 1
Client: THUNDER
Operation:
SSU Location:
Distance to blast:
Operator:               RESULTANT PPV (in/sec):  0.0
Comments: Carpe Diem.  PEAK AIR PRESSURE: (db) 116
Trigger Level: .05 IN/SEC  114 (db)  (psi) 0.00174

VELOCITY WAVEFORM GRAPH SCALE
TIME = 100 MSEC PER MARK  SHAKEABLE CALIBRATED: 08/19/97
SEISMIC = +/- .32 IN/SEC
SOUND = +/- 0.00232 PSI

By GeoSonics Inc.
Box 779, Warrendale, PA 15095 U.S.A.
TEL: 412.934.2900  FAX: 412.934.2999
DATE: 07/06/98     TIME: 10:15:26
Event: 003     Recording Time: 1
Client: THUNDER
Operation:
SSU Location:
Distance to blast:
Operator:
Comments: Carpe Diem. Low Rumble
Trigger Level: .05 IN/SEC  114 (db)

PPV (in/sec) | L  | T  | V  |
-------------|----|----|----|
0.0          | 0.0| 0.0| 0.02|
PD (in x.001) | 0.00| 0.00| 0.65|
PPA (g) | 0.00| 0.00| 0.05|
FREQ (Hz) | 0.0| 0.0| 0.0|
RESULTANT PPV (in/sec): | 0.02|
PEAK AIR PRESSURE: (dB) | 119|
             (psi) | 0.00261|

VELOCITY WAVEFORM GRAPH SCALE
TIME = 100 MSEC PER MARK
SEISMIC = +/- .32 IN/SEC
SOUND = +/- 0.00464 PSI

SHAKEABLE CALIBRATED: 08/19/97
By GeoSonics Inc.
Box 779, Warrendale, PA 15095 U.S.A.
TEL: 412.934.2900  FAX: 412.934.2999
DATE: 11/09/95    TIME: 05:58:21
Event: 003    Recording Time: 10
Client: ODNR, ROBERTSON
Operation: BUCKEYE IND.
SSU Location: ROBERTSON SILO TOP
Distance to blast: NA
Operator: KELTSCHLAGER/MMANN
Comments: Trigger Level: 1.2 IN/SEC 112 (db)

PPV (in/sec)    L  T  V
PD (in x.001)   14.42 1.59 4.21
PPA (g)        .2 .42 .45
FREQ (Hz)      4.8 2.3 9.6
RESULTANT PPV (in/sec): 0.48
PEAK AIR PRESSURE: (db) 124
(psi) 0.00464

VELOCITY WAVEFORM GRAPH SCALE
TIME = 100 MSEC PER MARK
SEISMIC = +/- .64 IN/SEC
SOUND = +/- 0.00928 PSI

SHAKETOIBLE CALIBRATED: 10/13/95
By GeoSonics, Inc.
Box 779, Warrendale, PA 15095 U.S.A.
TEL: 412.934.2900    FAX: 412.934.2999
Event Number: 023    Date: 6/26/1999    Time: 15:11
Acoustic Trigger: 127 dB    Seismic Trigger: 0.03 in/s    Serial Number: 914

<table>
<thead>
<tr>
<th>Amplitudes and Frequencies</th>
<th>Graph Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acoustic:</strong> 112 dB @ 170.6 Hz.</td>
<td><strong>Duration:</strong> 0.000 sec To: 6.500 sec</td>
</tr>
<tr>
<td><strong>Radial:</strong> 0.0575 in/s @ 56.8 Hz.</td>
<td><strong>Acoustic:</strong> 0.20 Mb (0.05 Mb/div)</td>
</tr>
<tr>
<td><strong>Vertical:</strong> 0.05 in/s @ 128.0 Hz.</td>
<td><strong>Seismic:</strong> 0.06 in/s (0.015 in/s/div)</td>
</tr>
<tr>
<td><strong>Transverse:</strong> 0.035 in/s @ 85.3 Hz.</td>
<td><strong>Time Lines at:</strong> 1.00 sec intervals</td>
</tr>
</tbody>
</table>

Cal 1.04
Cal 0.50
Cal 0.51
Cal 0.51

- A
- R
- V
- T
Amplitudes and Frequencies

| Acoustic:    | <100 dB |
| Radial:      | 0.03 in/s @ 36.5 Hz. |
| Vertical:    | 0.005 in/s @ 128.0 Hz. |
| Transverse:  | 0.0125 in/s @ 51.2 Hz. |

Graph Information

| Duration:    | 0.000 sec To: 6.500 sec |
| Acoustic:    | 0.20 Mb (0.05 Mb/div) |
| Seismic:     | 0.03 in/s (0.0075 in/s/div) |
| Time Lines at: | 1.00 sec intervals |

---

Cal 0.98

Cal 0.59

Cal 0.55

Cal 0.55
Airblast = 93 dB

Transverse = 0.09 in/sec

Vertical = 0.04 in/sec

Longitudinal = 0.15 in/sec
115' behind Corner 5 @
59 degree bearing

Flyrock landing exactly on top of
buried geophone.

Amplitudes and Frequencies

Acoustic: 148 dB @ 3.2 Hz
(5.08 Mb/0.0737 psi/0.5079 kPa)

Radial: 2.56 in/s 65.024 mm/s @ 2.6 Hz
Vertical: 2.44 in/s 61.976 mm/s @ 22.2 Hz
Transverse: 2.48 in/s 62.992 mm/s @ 3.8 Hz

Graph Information

Duration: 0.000 s to 12.500 s
Acoustic Scale:
148dB 5.02 Mb (1.256 Mb/div)
Seismic Scale:
2.56 in/s (0.640 in/s/div) 65.02 mm/s (16.256 mm/s/div)
Time Line Intervals at: 1.00 s
Approx. 845' S. of Silver Spade Demolition Blast
Approx. 14.3 lbs. RDX in shaped charges
Detonated Instantly to Sever 10 Cable Anchors

Amplitudes and Frequencies

Acoustic: 148 dB, 5.08 Mb, 0.0737 psi, 0.5080 kPa @ 50 Hz
Radial: 0.1200 in/sec @ 6.0 Hz
Vertical: 0.0550 in/sec @ 30.1 Hz
Transverse: 0.0850 in/sec @ 6.0 Hz

Graph Information

Duration: 0.000 s To: 5.500 s
Acoustic Scale: 148 dB
Seismic Scale: 0.20 in/sec (0.050 in/sec/div)
Time Line Intervals at: 1.00 s
Results – Single Charge

Amplitudes and Frequencies
- Acoustic: 136 dB, 1.20 Mb, 0.0174 psi, 0.1200 kPa @ 34 Hz
- Radial: 0.0300 in/sec @ 73.1 Hz
- Vertical: 0.0200 in/sec @ 0.0 Hz
- Transverse: 0.0100 in/sec @ 0.0 Hz

Graph Information
- Sample Rate: 1024
- Record Duration: 4.0 Seconds
- Pre-Trigger: 0.30 Seconds
- Time Line Intervals at: 0.50 s

Acoustic Scale: 136 dB
Seismic Scale: 0.20 in/sec (0.050 in/sec/div)
### Results – Multiple Charges

#### Amplitudes and Frequencies

- **Acoustic:** 128 dB, 0.48 Mb, 0.0070 psi, 0.0480 kPa @ 39 Hz
- **Radial:** 0.0100 in/sec @ 0.0 Hz
- **Vertical:** 0.0100 in/sec @ 0.0 Hz
- **Transverse:** 0.0100 in/sec @ 0.0 Hz

#### Graph Information

- **Duration:** 0.000 s to 3.000 s
- **Acoustic Scale:** 128 dB
- **Seismic Scale:** 0.20 in/sec (0.050 in/sec/div)
- **Time Line Intervals at:** 0.50 s

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![Graph](image-url)
OSM Resources

• Appalachian Region Blasting Web Page
  – Reports and Publications

• Technical Innovation and Professional Services (TIPS)
  – www.tips.osmre.gov
  – Blast Log Evaluation Program (BLEP)

• keltschlager@osmre.gov or (412) 937-2169
Explosive Disposal Monitoring

- Document coordinates
  - Blast
  - Blasting seismograph
- Record blast details
  - Date and time
  - Charge weight per delay
  - Sketch
- Deploy blasting seismograph
  - Proper placement and setup
  - Evaluate results
GPS to Document Locations

- Spatial relationships
- Blast site
  - Latitude/Longitude
  - UTM
- Nearby structures
- Monitoring locations
- WAAS enabled <10’ accuracy
Blast Locations and Range 13
Based on GPS Data
Seismograph Locations
Based on GPS data
ATF CES - Blasting Seismograph PE 2007/2008 - Field Data Sheet

Team # __________ Date: __________ Time: __________

Location (coordinates): ____________________________

N.E.W. per Delay: __________ Target N.E.W. = (D/1000)^3 = __________

Weather Data
Temperature: ________
Wind Speed: ________
Wind Dir: ________
Cloud Cover: ________
Humidity: ________

CES: ________________

Field Sketch (Document Explosives Type and Wiring)

<table>
<thead>
<tr>
<th>Seismograph Location</th>
<th>Distance (ft)</th>
<th>D/CW^{1/3}</th>
<th>Est Airblast</th>
<th>Airblast (dB)</th>
<th>PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>385</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>805</td>
<td></td>
<td></td>
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<td></td>
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<tr>
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<td>4</td>
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<td>10</td>
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</tr>
</tbody>
</table>
Airblast Planning - Each Person

• Complete team #, date, and weather
• Determine approximate N.E.W. for your team (10, 2.5, 25, 5, 20 or 5)
• Calculate the Target N.E.W. for the Pavilion (= 961/1000)^3 (to stay under 133dB)
• Sketch blast lay out
• Calculate scaled distance for each blasting seismograph location
• Estimate the airblast for each site based on the Unconfined line on the graph
Unconfined Airblast

PSI = 187 \cdot (SD)^{-1.38}
In the Field - At the Range

• Observe blasting seismograph setup
• Designate note keeper
• Get GPS Coordinates from an instructor
• Observe blasting seismograph in action at the pavilion
• Obtain waveform after the blast
• Record time and decibel and pressure level
Conclusion

• Keep records!! Document locations!!
• Delayed Charges generate less airblast
• Calculate cubed root scaled distance for each blast
• Higher SD generate lower airblast
• If SD is less than 1000, monitor with a blasting seismograph
• Blasting seismographs with field printers are probably the best option for ATF