Blast Vibration and Seismograph Section 2002

Kenneth K. Eltschlager
Office of Surface Mining
Appalachian Regional Coordinating Center
Pittsburgh, Pennsylvania

ABSTRACT

The ISEE Blast Vibration and Seismograph Section provides a forum for the discussion of issues related to vibration and noise from mine, quarry and construction blasting. The section began as a Technical committee in 1995 to promote the accuracy of blasting seismographs. Currently five subcommittees exist within the section: Seismograph Standards; Seismograph Testing and Calibration; Vibration Limits, Technical; Vibration Regulations; and Program and Communications. Foremost, the Seismograph Standards section wrote the first two technical standards adopted by the ISEE. The historical accomplishments, current activities and objectives of the section are discussed.

INTRODUCTION

In 1994 questions were raised about the accuracy, reproducibility and defensibility of data from blasting seismographs. To address this issue, the International Society of Explosives Engineers (ISEE) established a Seismograph Standards Subcommittee in 1995. The committee was comprised of seismograph manufacturers, researchers, regulatory personnel and seismograph users. In 1997, it became the Blast Vibrations and Seismograph section. Since then the section has grown to five subcommittees with over 230 members. The ISEE assesses an annual fee for membership.

The current officers are:

Chairman Kenneth K. Eltschlager
Co-Chairman Randall M. Wheeler
Secretary Daniel Greico, Jr.

The Section meets at least once a year at the annual conference. Subcommittees meet on an as needed basis.

SECTION PURPOSE

Provide a forum for the discussion of issues related to vibration and noise from mine, quarry and construction blasting.

SECTION SCOPE

1. Develop a section of ISEE members with knowledge and interests in blast vibrations measurement, analysis, safe level criteria and regulation,
2. Conduct meetings at a frequency of at least one per year,
3. Form committees within the section to examine specific issues,
4. Develop objective standards for vibration measurement instrumentation and field use practices, and
5. Provide an advisory team for seismograph testing and calibration.

SEISMOGRAPH STANDARDS SUBCOMMITTEE
Chairman Kenneth K. Eltschlager

Purpose: Develop uniform and technically appropriate standards for seismograph performance.

The intent is to improve accuracy and consistency in ground vibration and airblast measurements. Seismograph performance is affected by how the seismograph is built and how it is placed in the field. This subcommittee completed two standards in the year 2000:

- Field Practice Guidelines for Blasting Seismographs (Appendix 1)
  - First official ISEE standard

- Adopted by numerous regulatory bodies
- Available in Spanish

- Performance Specifications for Blasting Seismographs (Appendix 2)
  - Current yardstick for designing blasting seismographs
  - A more stringent specification may be developed once a testing laboratory is found.

This group has no current activity other than gathering studies pertaining to the standards developed to date. The ISEE needs to decide on the frequency on which we revisit the standards. Obviously it is not an equitable use of member's time to review them annually, possibly once every 5 years. In the mean time, comments on the existing standards or any studies that would effect the standards may be sent to ISEE for future reference when revisiting the standards.

SEISMOGRAPH TESTING AND CALIBRATION SUBCOMMITTEE
Chairman David E. Siskind

Purpose: Develop a program to test blasting seismograph performance, enlist the services of a testing facility and maintain a seismograph calibration program.

The intent is to improve blasting seismograph accuracy and consistency in ground vibration and airblast measurements. The initial goal of this section was to ensure consistent, defensible measurements of blast-induced vibrations. The two standards we have developed to date have helped achieve consistency between manufactured blasting seismographs and use in the field. But to bring the effort to conclusion a testing facility is needed to review calibration of the current blasting seismographs.

Initially the ISEE thought the US Bureau of Mines equipment, obtained by the University of Missouri-Rolla, could be retooled. Unfortunately the equipment was too old. Afterwards, numerous testing laboratories were contacted and none were prepared to test both seismic and acoustic components of the blasting seismographs. Currently, a lab in Socorro, NM may be interested.

A draft testing protocol entitled "Certification of Seismographs Used to Monitor Vibrations from Blasting at Mines, Quarries and Construction Sites has recently been developed. The protocol addresses the basic frequency sweeps to evaluate seismograph performance.

VIBRATION LIMITS, TECHNICAL SUBCOMMITTEE
Chairman Richard Lamkie

Purpose: Establish a set of model standards for safe ground and air vibration levels during the surface use of explosives in mine, quarry and construction blasting.

While not encouraging new regulations, these will serve as a framework of scientifically-based levels and practices to guide rule making in this technical area. The intention is to improve the uniformity of regulatory practices between jurisdictions and hopefully serve against improper regulations.

This year the committee is working towards developing a standard on appropriate ground vibration and airblast limits at residential structures. The standard will provide guidance to regulatory personnel and contractors on safe vibration levels. Future standards may be recommended for other types of structures.

VIBRATION REGULATIONS SUBCOMMITTEE
Chairman Larry Schneider

Purpose: Catalogue the vibration and airblast regulatory levels being enforced at Federal, State and municipal government levels. A secondary purpose was to evaluate the consistency of the existing regulations with the current scientific findings on structural response and damage potential.

The subcommittee has compiled a database on the existing rules of Federal, State and local governments. In order to locate the jurisdictions that had regulations, a survey of all I.S.E.E. members was undertaken. In addition, members of the Blast Vibration and Seismograph Section and known regulatory agencies were contacted directly for copies of existing regulations pertaining to blast vibrations. The survey ask that respondents supply the following minimum information:

- Location or jurisdiction where the limit applies,
- Agency which is responsible for enforcing such limits,
- Maximum peak particle velocity limits,
- Type of structures to which the limits apply,
- Airblast limits that apply to blasting
- Legal citation of the regulation or statute.
- Any other comments or information deemed relevant

Information was obtained from 67 separate jurisdictions (Appendix 3) including:

- 44 States (U.S.)
- 11 cities
- 2 counties (U.S)
- 5 provinces or states (international)
- 5 countries

With regard to the 44 states (U. S.) for which information was obtained, 15 of them reported having no vibration regulations in effect. Of the remaining 6 states for which we have no information reported, it seems to be a valid assumption that most if not all have no regulations on blast vibrations.

A review of the rule found that a majority of the U.S. jurisdictions have based their vibration limits on research done by the United States Bureau of Mines. The research used is generally documented in two publications released by the Bureau.

These are:

- Bulletin 656 published in 1971, entitled *Blasting Vibrations and Their Effects of Structures*,

- Report of Investigation 8507 published in 1980 entitled *Structure Response & Damage Produced by Ground Vibration from Surface Mine Blasting.*

The database will hopefully be on the ISEE web site. Members are encouraged to send rules that are not in the database to the chairman or notify him of any rule changes.

PROGRAM AND COMMUNICATIONS SUBCOMMITTEE
Chairman Daniel Grieco, Jr.

Purpose: Improve education and disseminate technical information on blast vibrations and work towards other training and educational programs.

The group will concentrate on communications to the industry and public. They will accomplish this through; articles in the ISEE Journal; development of a simple brochure or other handout that will explain to the public as both an information service and a public relations tool for blasters; and solicitation of papers and presentations at dedicated sessions of the ISEE annual meeting.

Some of the section members are currently involved in the ISEE Public Education Committee. A video on the effects of blast vibrations on homes is being scripted. The video should be complete within a year. Otherwise all members are encouraged to present papers at the ISEE annual conference on vibration topics. If you become aware of a project worthy of publication by someone other than a section member, please contact the chairman.

SUMMARY

The section's next goals will be uniform guidelines on vibration limits and a more active role in outreach efforts. Vibration limit guidelines will be particularly useful in areas where no current limits exist and local governments wrestle both their constituents and the industry on safe levels. Outreach efforts will focus on helping the blasters articulate the impacts of vibrations on homes.

Subcommittee heads will be seeking new or continuing volunteers to serve as subcommittee members. Please think about serving on one of the subcommittees. Please contact me or anyone of the subcommittee chairmen to provide any ideas on how we can better serve the ISEE. My phone number is (412) 937-2169 and e-mail is keltschl@osmre.gov.

Appendix 1

ISEE Field Practice Guidelines for Blasting Seismographs

Disclaimer: These field practice recommendations are intended to serve as general guidelines, and cannot describe all types of field conditions. It is incumbent on the operator to evaluate these conditions and to obtain good coupling between monitoring instrument and the surface to be monitored. In all cases, the operator should describe the field conditions and setup procedures in the permanent record of each blast.

Preface: Seismographs are used to establish compliance with regulations and evaluate explosive performance. Laws and regulations have been established to prevent damage to property and injury to people. The disposition of the rules is strongly dependant on the reliability and accuracy of ground vibration and airblast data. In terms of explosive performance the same holds true. One goal of the ISEE Blast Vibrations and Seismograph Section is to ensure reliable and consistent recording of ground vibrations and air blasts between all blasting seismographs.

Part I. General Guidelines

Seismographs are deployed in the field to record the levels of blast-induced ground vibration and airblast. Accuracy of the recordings is essential. These guidelines define the user's responsibilities when deploying seismographs in the field.

1. Read the instruction manual. Every seismograph comes with an instruction manual. Users are responsible for reading the appropriate sections before monitoring a blast.

2. Seismograph calibration. Annual calibration of the seismograph is recommended.

3. Keep proper records. A seismograph user's log should note: the user's name, date, time, place and other pertinent data.

4. Record the blast. When seismographs are deployed in the field, the time spent deploying the unit justifies recording an event. As practical, set the trigger levels low enough to record each blast.

5. Record the full waveform. It is not recommended that the continuous recording option available on many seismographs be used for monitoring blast generated vibrations.

6. Document the location of the seismograph. This includes the name of the structure and where the seismograph was placed on the property relative to the structure. Any person should be able to locate and identify the exact monitoring location at a future date.

7. Know and record the distance to the blast. The horizontal distance from the seismograph to the blast should be known to at least two significant digits. For example, a blast within 1000 feet would be measured to the nearest tens of feet and a blast within 10,000 feet would be measured to the nearest hundreds of feet. Where elevation changes exceed 2.5h:1v, slant distances or true distance should be used.

8. Know the data processing time of the seismograph. Some units take up to 5 minutes to process and print data. If another blast occurs within this time the second blast may be missed.

9. Know the memory or record capacity of the seismograph. Enough memory must be available to store the event. The full waveform should be saved for future reference in either digital or analog form.

10. Know the nature of the report that is required. For example, provide a hard copy in the field, keep digital data as a permanent record or both. If an event is to be printed in the field, a printer with paper is needed.

11. Allow ample time for proper setup of the seismograph. Many errors occur when seismographs are hurriedly set-up. Generally, more than 15 minutes for set-up should be allowed from the time the user arrives at the monitoring location until the blast.

12. Know the temperature. Seismograph have varying manufacturer specified operating temperatures.

13. Secure cables. Suspended or freely moving cables from the wind or other extraneous sources, can produce false triggers due to microphonics.

Part II. Ground Vibration Monitoring

Placement and coupling of the vibration sensor are the two most important factors to ensure accurate ground vibration recordings.

A. Sensor Placement

The sensor should be placed on or in the ground on the side of the structure towards the blast. A structure can be a house, pipeline, telephone pole, etc. Measurements on driveways, walkways, and slabs are to be avoided where possible.

1. Location relative to the structure. Sensor placement should ensure that the data obtained adequately represents the vibration levels received at the structure being protected. The sensor should be placed within 10 feet of the structure or less than 10% of the distance from the blast, whichever is less .

2. Soil density evaluation. The soil density should be greater than or equal to the sensor density. Fill material, sand, unconsolidated soils, flower-bed mulch or other unusual mediums may have an influence on the recording accuracy if not properly dealt with during geophone installation.

3. The sensor must be nearly level.

4. The longitudinal channel should be pointing directly at the blast and the bearing should be recorded.

5. Where access to the structure and/or property is not available, the sensor should be placed closer to the blast in undisturbed soil.

B. Sensor coupling

If the acceleration exceeds 0.2 g, slippage of the sensor may be a problem. Depending on the anticipated acceleration levels spiking, burial, or sandbagging of the geophone to the ground may be appropriate.

1. If the acceleration is expected to be:
   a. less than 0.2 g, no burial or attachment is necessary
   b. between 0.2 and 1.0 g, burial or attachment is preferred. Spiking may be acceptable.
   c. greater than 1.0 g, burial or firm attachment is required (USBM RI 8506).

The following table exemplifies the particle velocities and frequencies where accelerations are 0.2 g and 1.0 g.

Frequency, Hz	4	10	15	20	25	30	40	50	100	200
Particle Velocity - in/s at 0.2 g	3.07	1.23	0.82	0.61	0.49	0.41	0.31	0.25	0.12	0.06
Particle Velocity - in/s at 1.0 g	15.4	6.15	4.10	3.05	2.45	2.05	1.55	1.25	0.60	0.30

2. Burial or attachment methods.

a. The preferred burial method is excavating a hole that is no less than three times the height of the sensor (ANSI S2.47-1990, R1997), spiking the sensor to the bottom of the hole, and firmly compacting soil around and over the sensor.

b. Attachment to bedrock is achieved by bolting, clamping or glueing the sensor to the rock surface.

c. The sensor may be attached to the foundation of the structure if it is located within +/- 1-foot of ground level (USBM RI 8969). This should only be used if burial, spiking or sandbagging is not practical.

3. Other sensor placement methods.

a. Shallow burial is anything less than described at 2a above.

b. Spiking entails removing the sod, with minimal disturbance of the soil and firmly pressing the sensor with the attached spike(s) into the ground.

c. Sand bagging requires removing the sod with minimal disturbance to the soil and placing the sensor on the bare spot with a sand bag over top. Sand bags should be large and loosely filled with about 10 pounds of sand. When placed over the sensor the sandbag profile should be as low and wide as possible with a maximum amount of firm contact with the ground.

d. A combination of both spiking and sandbagging gives even greater assurance that good coupling is obtained.

C. Programing considerations

Site conditions dictate certain actions when programing the seismograph.

1. Ground vibration trigger level. The trigger level should be programmed low enough to trigger the unit from blast vibrations and high enough to minimize the occurrence of false events. The level should be slightly above the expected background vibrations for the area. A good starting level is 0.05 in/s.

2. Dynamic range and resolution. If the seismograph is not equipped with an auto-range function, the user should estimate the expected vibration level and set the appropriate range. The resolution of the printed waveform should allow verification of whether or not the event was a blast.

3. Recording duration - Set the record time for 2 seconds longer than the blast duration plus 1 second for each 1100 feet from the blast.

Part III Airblast Monitoring
Placement of the microphone relative to the structure is the most important factor.

A. Microphone placement
The microphone should be placed along the side of the structure nearest the blast.

1. The microphone should be mounted near the geophone with the manufacturer's wind screen attached.

2. The preferred microphone height is 3 feet above the ground or within 1.2 inches of the ground. Other heights may be acceptable for practical reasons. (ANSI S12.18-1994, ANSI S12.9-1992/Part2) (USBM RI 8508)

3. If practical, the microphone should not be shielded from the blast by nearby buildings, vehicles or other large barriers. If such shielding cannot be avoided, the horizontal distance between the microphone and shielding object should be greater than the height of the shielding object above the microphone.

4. If placed too close to a structure, the airblast may reflect from the house surface and record higher amplitudes. Structure response noise may also be recorded. Reflection can be minimized by placing the microphone near a corner of the structure. (RI 8508)

B. Programing considerations
Site conditions dictate certain actions when programing the seismograph to record airblast.

1. Trigger level. When only an airblast measurement is desired, the trigger level should be low enough to trigger the unit from the airblast and high enough to minimize the occurrence of false events. The level should be slightly above the expected background noise for the area. A good starting level is 120 dB.

2. Recording duration. When only recording airblast, set the recording time for at least 2 seconds more than the blast duration. When ground vibrations and airblast measurements are desired on the same record, follow the guidelines for ground vibration programing (Part II C.3).

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International Society of Explosives Engineers
30325 Bainbridge Road
Cleveland, Ohio 44139-2295
Tel: 440-349-4400
Fax: 440-349-3788
www.isee.org

Appendix 2

ISEE PERFORMANCE SPECIFICATIONS FOR BLASTING SEISMOGRAPHS

GENERAL SPECIFICATIONS

Ground Vibrations Measurement:

Frequency range…….	2 to 250 Hz, within zero to -3 dB of an ideal flat response
Accuracy……..	±5 pct or ±0.02 in/sec (0.5 mm/sec), whichever is larger, between 4 and 125 Hz
Phase response…….	See Level #2
Cross-talk response…….	See Level #2
Density of transducer jug…….	<150 lbs/ft^3 (should be reported for user consideration)

Airblast Measurement:

Frequency range……	2 to 250 Hz flat, -3 dB at 2 Hz ±1dB
Accuracy……	±10 pct or ±1 dB, whichever is larger, between 4 and 125 Hz.

General Requirements:

Digital sampling……..	1000 samples/sec or greater, per channel
Operating temperature……..	10 to 120^{0}F (-12 to 49^{0}C)

Measurement Practices:
Specified in a separate specification: Seismograph Field Practice Guidelines

SPECIFIC USER NEEDS

Some requirements are specific to a user, an application, or a regional need. General Specifications listed above are to be considered minimums. Additional requirements can be requested by a customer, such as, use under arctic-type conditions requiring good performance at low temperatures or extended frequency ranges such as might be of concern for close-in construction blasting.

Other performance capabilities related to specific needs are:
1. Dynamic range (smallest to highest usable measurement)
2. Resolution
3. Trigger levels and options (vibration, airblast or both)
4. Recording duration (per event)
5. Memory or record capacity (number of events)
6. Nature of display and recording (hard copy, LCD, downloading, etc.)
7. Mounting options (transducer attitude, orientation, etc.)

Adopted 2/17/2000

Appendix 3

Current Vibration Regulations

States (U.S.) with Vibration Regulations

Alabama
Arkansas
Georgia
Illinois
Indiana
Iowa
Kentucky
Louisiana
Maine
Massachusetts
Maryland
Minnesota
Montana
New Hampshire
New Jersey
New Mexico
North Carolina
North Dakota
Ohio
Oklahoma
Pennsylvania
Rhode Island
South Carolina
Tennessee
Utah
Vermont
Virginia
West Virginia
Wyoming

States (U.S.) with No Vibration Regulations

Alaska
Arizona
California
Colorado
Florida
Hawaii
Idaho
Missouri
Nebraska
Nevada
New York
Oregon
South Dakota
Washington
Wisconsin

Provinces/States (International) with Vibration Regulations

Hamilton-Wentworth, Ontario
New South Wales, Australia
Ontario, Canada
Puerto Rico
Western Australia

Counties (U.S.) with Vibration Regulations

Broward County, FL
Clark County, NV

Cities with Vibration Regulations

Amherst, NY
Austin, TX
Charleston, WV
Clarence, NY
Gladstone, OR
Kansas City, KS
Lewiston, ID
Muskoka, Ontario
Peabody, MA
Phoenix, AZ
Sao Paulo, Brazil

Countries with Vibration Regulations

Brazil
Hong Kong
France
United Kingdom
Greece