CONTROLLED ROCK BLASTING

PART 1 GENERAL

1.1 WORK INCLUDES

A. Rock blasting necessary for site grading, trenching excavations for utilities and associated excavations.

1.2 REFERENCES

A. The Contractor shall comply with the applicable rules, regulations and standards established by the Regulatory Agencies, codes and professional societies listed herein, including rules and regulations for storage, transportation, and use of explosives. These rules and standards include but are not limited to the following:

1. The Federal Occupational Safety and Health Act of 1970 and the Construction Safety Act of 1969, as amended.
2. OSHA of 1970, 29 U.S.C., Section 651 et seq., including safety and health regulations for construction.
3. CFR 27, U.S. Department of Justice, Alcohol, Tobacco, Firearms and Explosives Division (ATF). 27 CFR Part 555, Implementation of the Safe Explosives Act, Title XI, Subtitle C of Public Law 107-296; Interim Final Rule.
4. Organized Crime Control Act of 1970, Title XI, Public Law 91-452, approved October 15, 1970, as amended.
5. CFR 49, Parts 100-177 (DOT RSPA); 301-399 (DOT FHA).
6. California Contractor's State License Board (CSLB), Section 4100 et seq. of the Public Contract Code.
7. Riverside County Ordinance 787.5.
    a. Riverside County Sherriff’s Explosives Use Permit
8. California Code of Regulations (CCR)
    a. Title 8, Chapter 4, Subchapter 20, Tunnel Safety Orders
    b. Title 8, General Industry Safety Orders, Subchapter 7, Group 18. Explosives and Pyrotechnics
9. Non-regulating Industry Support Organizations

a. Vibration Subcommittee of the International Society of Explosive Engineers (ISEE), blast monitoring equipment operation standards (1999 or later version if available).

b. IME (Institute of Makers of Explosives) Safety Library Publications (SLPs).

1.3 DEFINITIONS

1. Air-overpressure – absolute value of increases or reductions to atmospheric pressure measured with a 2-Hz flat-response microphone and expressed in decibels or psi.

2. Blaster-in-Charge or Blasting Supervisor - The single designated and licensed person with complete responsibility and total authority over all decisions involving safe handling, use and on-site security of explosives.

3. Blast Mats – Heavy mats for suppressing movement of blasted rock and ground. For this work, mats shall be constructed with stacked sections of cut rubber tires woven together with steel cables. The minimum weight of rubber-tire mats, without exception, shall be 30 pounds per square foot.

4. Charge-per-Delay - For vibration control, any charges firing within any 8-millisecond time period are considered to have a cumulative effect on vibration and air-overpressure effects. Therefore, the maximum charge-per-delay (W) is the sum of the weight of all charges firing within any 8-millisecond time period. For example, if two 100-lb. Charges fire at 100 ms and one 115-lb charge fires at 105 ms, the maximum charge per delay would be 315 lbs.

5. Controlled Blasting – Excavation of rock using explosives, wherein the blast is carefully designed and controlled to provide a distribution of charge and confining stemming that will excavate the rock to the required limits but minimize overbreak, control rock movement, and assure that intensities of blast-induced vibration and air-overpressure do not exceed regulated or specified limits.

6. Delay-Decked-Charge – Multiple charges with differing firing times placed within a single blasthole that are separated by inert stemming material.

7. Line Drilling - A method of overbreak control in which a series of very closely spaced holes is drilled at the perimeter of the excavation. These holes are not loaded with explosives.

8. Occupied Building - Structure on or off construction limits that is occupied by humans or livestock.

6. Over-excavation – Excavation beyond the neat lines shown on the Drawings.

7. Peak Particle Velocity - Peak Particle Velocity (PPV): The maximum of the three ground vibration velocities measured in the vertical, longitudinal and transverse directions. PPV measurement units are expressed in inches per second (ips).

9. Pre-splitting - A drilling and blasting technique wherein small diameter holes are drilled on close-spacing along the neat excavation lines. The charges are small in diameter, specially prepared for pre-splitting, and are detonated ahead of the main production charges. This technique requires free relief of the perimeter and may require advance excavation of the production area to provide that relief.

10. Primary Initiation - The method used to initiate a blast(s) from a remote and safe location. Primary initiation systems use shock-tubes or electrical current to convey firing energy from the point of initiation to blast locations.

11. Production Holes - Blast holes in the main body of the rock mass being removed by drilling and blasting.

12. Prohibited Persons - Persons prohibited from handling or possessing explosive materials as defined by the seven categories described in Section 555.11 of 27 CFR (ATF Rules).

13. Scaled Distance: A calculated value describing relative vibration energy based on distance and charge-per-delay. For ground vibration control and prediction purposes, Scaled Distance (Ds) is obtained by dividing the distance of concern (D) by the square root of the charge-per-delay (W); so $Ds = D/W^{1/2}$ or when a minimum defined scaled distance is defined to limit charge weight, $W = (D/Ds)^2$. For example, if a blast is designed to meet a minimum scaled distance of 60, the maximum charge-per-delay for a blast located 600 feet from the structure of concern would be $(600/60)^2$, or 100 pounds.

13. Seismograph – An instrument used to record the intensity and frequency of ground vibrations measured with three mutually perpendicular geophones and a linear-scale microphone that measures air-overpressure.

1.4 SUBMITTALS

A. Administrative

1. Blasting Licenses and Permits:
   a. Copy of CalOSHA Blasting Licenses with Construction and Non-electric initiation system endorsements for all proposed blasters-in-charge.
   b. Copies of all blasting permits required by Riverside County.
   c. Copy of Blasting Contractor's federal ATF License.
   d. Copy of the Blasting Contractor's Class "A" or other compliant license issued by the California State Licensing Board (CSLB). The Prime Contractor must also have a Class "A" CSLB license and it will satisfy this requirement if they are self-performing the blasting work. In any case, the specific Contractor that is named and insured to perform drill-blast work, must submit this license.
   e. The sole insured Blasting Contractor of record and or their employees shall have and submit valid copies of all required licenses. No blasting shall occur if varying company names are shown on any required licenses.

2. Conceptual Blasting Plan. Submit at least 30 days prior to start of blasting:

   a. General blasting methods that are expected to be used for rock excavation.
   b. Description of blasting techniques as well as techniques to control noise, blasting vibrations, air-overpressures, and fly rock. Include detailed specifications of blasting mats and how they will be safely placed to cover all blasts as required Part 3.1.D.
   c. Name and qualifications of the person(s) responsible for monitoring and reporting blast vibrations.
   e. Detailed description of clearing, guarding and warning signals that will be applied to assure that no persons or visible wildlife will be in areas where any harm could be caused by blasting operations.

3. Blasting Safety Plan

   a. A description of the clearing and guarding procedures that will be employed to ensure personnel, staff, visitors, and all other persons are at safe locations during blasting. Also describe the primary initiation method and the system by which the blaster-in-charge will communicate with site security guards.

   b. Describe how explosives will be safely transported and used at the various work sites. Plans shall explain how day-storage boxes and explosive transport vehicles will satisfy all applicable regulations. This plan shall also indicate how explosives will be secured while on site.

c. Contingency plans for handling of misfires caused by cut-offs or other causes.

4. Qualifications:

a. Submit names of all proposed Blasters-in-Charge and include experience summaries documenting they have a minimum of 10 years of construction blasting experience at projects with similar blasting conditions.

c. Submit qualifications of proposed Property Condition Survey Professional in conformance with Part 1.5.C.

5. At least 10 days before surveys are done, submit name and qualifications of the independent Professional or firm proposed to conduct pre-blast condition survey(s), including a list of references.

6. Blast Monitoring Equipment – Details of instrumentation to be used to monitor vibrations and air-overpressure levels complete with performance specifications and user's manuals supplied by the manufacturer. Also submit copies of calibration certificates from the equipment maker certifying that microphones, geophones and all recording equipment has been calibrated within 12 months of the time it will be used.

7. Submit three copies of all pre-blasting reports including photographs and video in DVD format to UCI'S Representative at least 10 calendar days before any blasting occurs.

B. Individual Blasting Records:

1. Blast Monitoring Records: Submit the following within 24 hours after all blasts:

a. A copy of the instrument-software generated blast monitoring report at each instrument location that includes measured peak particle velocity in inches per second, peak air-overpressure in linear-scale decibels and vibration and air-overpressure event plots, date and time of event recording, and date the instrument was last calibrated.

c. Include a scaled site map showing monitor locations and distances to an outlined blast area.

2. Blast Reports: Submit the following within 24 hours after all blasts:

   a. Submit blast report showing actual charge delay timing details showing surface and in-hole firing times of all initiators, summaries of all explosives and initiators used, maximum charge-per-delay, hole diameters, spacing, depths, burden, and hole charging and stemming configuration of typical holes. Also include all information required by State of California CalOSHA regulations.

C. Approval by UCI'S Representative of the Conceptual Blasting Plan proposed by CONTRACTOR will only be with respect to the basic principles and methods that CONTRACTOR intends to employ. Authorization of work by UCI'S Representative does not relieve CONTRACTOR of sole responsibility and liability for the safety of persons and property.

1.5 QUALITY CONTROL

A. All Blasters-in-charge shall be properly licensed and have a minimum of ten years of construction blasting experience at projects with similar scope and complexity.

C. The independent professional performing the pre-blast condition surveys shall have at least 5 years of documented experience in performing surveys of structures at dams and other heavy civil structures. The survey professional must also be a completely independent third party who is not be an employee of the Contractor, associated companies, or any suppliers to the work.

D. Images of all blasts shall be recorded with a digital video camera. Copies of blast video files shall be submitted to UCI'S representative within 24 hours and before any subsequent blasting work occurs.

1.6 BLASTING SAFETY AND EXPLOSIVES SECURITY

A. Comply with all applicable federal, state and local regulations.

B. Protect the safety of all persons and wildlife; and protect all property during blasting operations.

C. Explosives Security: The responsible CONTRACTOR holding the ATF permit and State of California Contractor's license for this work shall ensure the security of explosive materials at all times when explosive materials are used or kept on the project site and the CONTRACTOR shall ensure that:

1. All persons that handle explosive materials, have control over them, or access to them, must not be prohibited persons, as defined in Section 555.11 of 27 CFR (ATF Rules).

2. All blasting work and explosive handling activities are done under the direct supervision of a properly licensed Blaster-in-Charge.

3. When explosives are delivered to the work sites, they must not be unloaded from delivery vehicles until a responsible blaster-in-charge has signed the delivery paperwork and assumes full authority and responsibility for the security of the explosive materials. Unused explosive materials must be similarly signed over to a properly licensed driver with a Commercial Drivers License with a Hazmat endorsement before explosive materials are loaded onto a fully-DOT-compliant vehicle for removal from the site.

4. The CONTRACTOR shall maintain copies of ATF Employee Possessor questionnaire forms (OMB No. 1140-0072) or documentation of ATF clearance on the CONTRACTOR's ATF license for all employees who will possess, handle or have access or control over explosives for this work as defined in 27 CFR Part 555. This documentation must be available upon request by the appropriate authorities or UCI'S Representative. CONTRACTOR and subcontractor employees, without submitted evidence of satisfactory ATF clearance, must not handle, control or have access to explosive materials.

1.7 EXPLOSIVE STORAGE

A. No explosives shall be stored overnight on site and all explosives shall be removed from the site within one hour after blasting.

1.8 PRE-BLAST CONDITION SURVEY

A. Prior to any blasting, perform a pre-blast survey of the conditions of all existing property and aboveground utilities located within 500 feet of any potential blasting areas. The pre-blast survey shall include a photographic record of all visible and accessible structures, facilities, utilities or other improvements.

B. Survey the interior and exterior conditions of all residential property and associated structures located within 500 feet of blasting areas. If property owner's refuse surveys, provide copies of certified-mail letters documenting attempts to provide the survey by a third-party professional survey company.

C. Type written reports shall include a description of the interior and exterior condition of the various structures examined. Descriptions shall include the locations of any cracks, damage, or other existing defects and shall include information needed to identify and describe the defect, if any, and to evaluate the construction operations on the defect.

D. Reports shall include hard copy color photographs sized at least 4 x 6 inches, printed in glossy format on paper designed for color photo images. If digital cameras are used, resolution of images shall be 5 megapixels or greater. Photos must be taken of all cracks and other damaged, weathered or otherwise deteriorated structural conditions. If necessary, macro lenses and flash illumination shall be used to ensure defects are shown clearly in the photographs. Photos shall contain an accurate date stamp.

E. Structure condition surveys shall be repeated at facilities or properties where damage concerns have been expressed. Details of any observed changes to surveyed structures and documenting photos shall be reported and submitted as required. All reports shall be type written.

1.10 SEQUENCING, SCHEDULING AND NOTIFICATION

A. Controlled rock blasts shall occur only between the hours of 9:00 a.m. and 5:00 p.m. on weekdays; no blasting shall occur on weekend days or holidays.

B. Provide notification to UCI's Representative at least 24 hours in advance of each blast.

C. No more than one blast with a total charge not exceeding 10,000 pounds shall occur each day.

PART 2 PRODUCTS

2.1 ALLOWABLE EXPLOSIVE MATERIALS AND INITIATORS

A. Only non-electric (Shocktube) or electronic initiation systems shall be used for blasting.

B. Use of cap and fuse is prohibited.

PART 3 EXECUTION

3.1 BLASTING

A. All explosive charges shall be stemmed with clean washed angular crushed stone sized from 3/8 to 3/4 inches. The amount of stemming in rock (overburden is excluded) shall be at least 25-charge-diameters. For instance, if charge diameter is 2 inches, minimum stemming is 50 inches or 4.2 feet.

B. The minimum confining burden on all explosive charges with exposure to open rock or ground surfaces shall be at least 25-charge-diameters.

C. All blasts located within 500 feet of any structures or above ground utilities shall be covered with woven steel cable or steel-cable and rubber-tire blasting mats with a minimum weight of 30 pounds per square foot. Woven polypropylene or similar weed-barrier fabric, covered with at least 6 inches of soil or sand shall be placed over blast areas to protect initiators before mats are placed. Mats shall be overlapped at least 3 feet and shall completely cover the blast area and extend at least three feet beyond the blast area in all directions. If any flyrock or blasted material is thrown more than 10 feet or half the distance to the nearest structure, whichever is less, blasting shall be suspended until UCI's Representative has approved the Contractor's revised blasting plan showing revisions to assure adequate ground movement control.

D. Before blasts are covered, all loose soils above the blast should be removed as possible. Remaining ground located within 20 feet of the blast shall be thoroughly wetted with water to suppress airborne dust. Sand or soils placed over weed-barrier fabric shall be similarly wetted before placing blast mats.

E. The depth of blasted rock benches, excluding 2-feet of sub-drilling, shall not exceed 20 feet.

F. Perform blasting Monday through Friday only between the hours of 8:00 a.m. and 5:00 p.m. only.

G. Blasting shall conform to the following PPV Limits and Minimum Scaled Distance Requirements:

Structure	Maximum PPV (in/s)	Minimum Scaled Distance (ft/lb^2)
Offsite Residential Structures	0.5	60
Ground over or near Utilities	3.0	20

H. Intensity of air-overpressure at any off-site structures shall not exceed 133 decibels (0.01295 psi).

I. The diameter of holes drilled in rock for blasting shall not exceed 4.0 inches.

J. If specified vibration limits are exceeded, blasting operations shall cease immediately and a revised blasting plan shall be submitted to UCI'S Representative. Blasting shall not resume until a revised blasting plan has been reviewed by the ENGINNER and the UCI'S Representative has expressed in writing the conditions that will be applied to further blasting work.

K. After a blast has been fired, the Blaster-in-Charge shall inspect the area to determine that all charges have fired as planned and that no hazards exist in the blast area before the all clear signal is sounded and workers are allowed to return to the area.

L. The maximum charge-weight-per-delay shall not exceed 50 pounds.

M. No blasting shall be done when wind speed exceeds 15 miles per hour.

N. No blasting shall occur closer than 300 feet from residential structures.

3.2 BLAST MONITORING

A. Blast Monitoring

1. The CONTRACTOR shall provide a minimum of three seismographs for monitoring peak ground vibration and air-overpressure. The equipment and its use shall conform fully to the standards developed by the Vibration Section of the International Society of Explosive Engineers (ISEE). See Attachment I.

2. For all blasts, monitor ground motion and air-overpressure at the nearest two residential properties. The third instrument shall be operated on ground adjacent to the nearest utilizes or other structure of concern.

3. Minimum trigger levels for monitoring shall be 0.05 in/s for ground motion and 120 dB for air-overpressure. Trigger level may be adjusted to higher levels if authorized by UCI'S Representative.

3.3 REPAIR OF DAMAGE

A. When blasting operations damage offsite properties, or a portion of the work, or material surrounding or supporting the work, the Contractor shall promptly repair or replace damaged items to the condition that existed prior to the damage, to the satisfaction of UCI'S Representative.

3.4 SUSPENSION OF BLASTING

A. Blasting operations may be suspended by UCI'S Representative for any of the following reasons:
   1. Contractor's safety precautions are inadequate.
   2. Ground motion vibration levels exceed specified limits of maximum particle velocity or maximum particle displacement.
   3. Air-overpressure levels exceed specified limits.
   4. Existing structural conditions are aggravated or adjacent improvements are damaged as a result of blasting.
   5. Blasting endangers the stability or causes damage to rock outside the prescribed limits of excavation.
   6. The results of the blasting, in the opinion of UCI'S Representative, are not satisfactory.

B. Blasting operations shall not resume until UCI'S Representative has approved the Contractor's revised blasting plan providing modifications to correct the conditions that resulted in the suspension.

END OF SECTION

ATTACHMENT I

International Society of Explosives Engineers

ISEE FIELD PRACTICE GUIDELINES FOR BLASTING SEISMOGRAPHS 2015

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This edition of *ISEE Field Practice Guidelines for Blasting Seismographs* was revised by the ISEE Standards Committee on July 2, 2015, and supersedes all previous editions. It was approved by the Society's Board of Directors in its role of Secretariat of the Standards at its July 31, 2015, meeting.

International Society of Explosives Engineers (ISEE) – Standards Committee Members[1]
Chairman, Kenneth K Eltschlager, U.S. Office of Surface Mining Reclamation and Enforcement
William Birch, Blastlog
Steven DelloRusso, Simpson Gumpertz & Heger Inc.
Alastair Grogan, Grogan Rock Consulting Ltd.
Michael Mann, Ohio Department of Natural Resources
Alan Richards, Terrock Consulting Engineers
Douglas Rudenko, Vibra-Tech Engineers, Inc.
Robert Turnbull, Instantel
Randall Wheeler, White Industrial Seismology
Board Liaison, Dr. Braden Lusk, University of Kentucky

[1]This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred.

Committee Scope: This Committee shall have primary responsibility for documents on the manufacture, transportation, storage, and use of explosives and related materials. This Committee does not have responsibility for documents on consumer and display fireworks, model and high power rockets and motors, and pyrotechnic special effects.

Origin and Development of ISEE Standards for Blasting Seismographs
One of the goals of the ISEE Standards Committee is to develop uniform and technically appropriate standards for blasting seismographs. The intent is to improve accuracy and consistency in vibration and air overpressure measurements. Blasting seismograph performance is affected by how the blasting seismograph is built and how it is placed in the field.

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 at its annual conference held in February 1995. The committee was comprised of seismograph manufacturers, researchers, regulatory personnel and seismograph users.
In 1997, the Committee became the Blast Vibrations and Seismograph Section. The initial standards were drafted and approved by the Section in December 1999. Subsequently, the ISEE Board of Directors approved two standards in the year 2000: 1) ISEE Field Practice Guidelines for Blasting Seismographs; and 2) Performance Specifications for Blasting Seismographs.

In 2002, the Society established the ISEE Standards Committee. A review of the ISEE Field Practice Guidelines and the Performance Specifications for Blasting Seismographs fell within the scope of the Committee. Work began on a review of the Field Practice Guidelines in January 2006 and was completed in February 2008 to produce the 2009 edition. A revision to the Performance Specifications was started in 2009 and completed in 2011.

The ISEE Standards Committee takes on the role of keeping the standards up to date every 5 years. This document is the result of the latest effort by the ISEE Standards Committee to keep the standards up to date with current field techniques and technology.

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

PREFACE

Blasting seismographs are used to establish compliance with Federal, state and local 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 dependent on the accuracy of ground vibration and air overpressure data. In terms of explosive performance the same holds true. One goal of the ISEE Standards Committee is to ensure consistent recording of ground vibrations and air overpressure between all blasting seismographs.

ISEE Field Practice Guidelines
for Blasting Seismographs
2015 Edition

PART I. GENERAL GUIDELINES

Blasting seismographs are deployed in the field to record the levels of blast-induced ground vibration and air overpressure. Accuracy of the recordings is essential. These guidelines define the user's responsibilities when deploying blasting seismographs in the field and assume that the blasting seismographs conform to the ISEE "Performance Specifications for Blasting Seismographs" [3].

1. Read the instruction manual and be familiar with the operation of the instrument. Every seismograph comes with an instruction manual. Users are responsible for reading the appropriate sections and understanding the proper operation of the instrument before monitoring a blast.

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

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

4. 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.

5. 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 meters or feet would be measured to the nearest tens of meters or feet respectively and a blast within 10,000 meters or feet would be measured to the nearest hundreds of feet or meters respectively. Where elevation changes exceed 2.5 horizontal:1 vertical, slant distances or true distance should be used.

6. 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.

7. Record the full time history waveform. Summary or single peak value recording options available on many seismographs should not be used for

monitoring blast generated vibrations. Operating modes that report peak velocities over a specified time interval are not recommended when recording blast induced vibrations.

8. Set the sampling rate. The blasting seismograph should be programmed to record the entire blast event in enough detail to accurately reproduce the vibration trace. In general the sample rate should be at least 1000 samples per second.

9. 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.

10. 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.

11. 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.

12. 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.

13. Know the temperature. Seismographs have varying manufacturer specified operating temperatures.

14. 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 ground-borne vibration levels received at the structure. The sensor should be placed within 3.05 meters (10 feet) of the structure or less than 10% of the distance from the blast, whichever is less.

2. Soil density evaluation. The soil should be undisturbed or compacted fill. Loose fill material, unconsolidated soils, flower-bed mulch or other

unusual mediums may have an adverse influence on the recording accuracy.

3. The sensor must be nearly level.

4. Typical practice is to point the longitudinal/radial channel towards the blast site. However, other sensor orientations are allowed.

a. For blast-by-blast sensor deployment, the longitudinal/radial channel should be pointed towards the closest blast hole. Records should indicate if this condition is met.

b. For multiple-blast sensor deployment, the azimuth (0-360 degrees, +/- 5 degrees) of the longitudinal/radial channel relative to true north should be recorded.

5. Where access to a 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 1.96 m/s^2 (0.2 g), decoupling of the sensor may occur. 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 1.96 m/s^2 (0.2 g), no burial or attachment is necessary.

b. Between 1.96 m/s^2 (0.2 g), and 9.81 m/s^2 (1.0 g), burial or attachment is preferred. Spiking may be acceptable.

c. Greater than 9.81 m/s^2 (1.0 g) , burial or firm attachment is required [7].

The following table exemplifies the particle velocities and frequencies where accelerations are 1.96 m/s^2 (0.2 g) and 9.81 m/s^2 (1.0 g).

Frequency, Hz	4	10	15	20	25	30	40	50	100	200
Particle Velocity mm/s (in/s) at 1.96 m/s^2 (0.2 g)	78.0 (3.07)	31.2 (1.23)	20.8 (0.82)	15.6 (0.61)	12.5 (0.49)	10.4 (0.41)	7.8 (0.31)	6.2 (0.25)	3.1 (0.12)	1.6 (0.06)
Particle Velocity mm/s (in/s) at 9.81 m/s^2 (1.0 g)	390 (15.4)	156 (6.14)	104 (4.10)	78.0 (3.07)	62.4 (2.46)	52.0 (2.05)	39.0 (1.54)	31.2 (1.23)	15.6 (0.61)	7.8 (0.31)

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 [1], 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 adhering the sensor to the rock surface.

c. The sensor may be attached to the foundation of the structure if it is located within +/- 0.305 meters (1-foot) of ground level [5]. 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 4.55 kilograms (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. Programming Considerations

Site conditions dictate certain actions when programming 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 1.3mm/s (0.05in/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 335 meters (1100 feet) from the blast.

PART III. AIR OVERPRESSURE 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 microphone may be placed at any height above the ground [2].

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 air overpressure 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. [6].

5. The orientation of the microphone is not critical for air overpressure frequencies below 1,000 Hz [6].

6. The microphone element must be kept dry to help maintain proper calibration and minimize the potential for corrosion. A common practice is to place a windscreen (typically provided by the manufacturer) on the microphone and cover it loosely with a thin plastic bag, or "rain shield." Other methods can be used to protect the microphone from moisture; however, the pressure around the microphone sensing element must be able to change in relation to the pressure change caused by the blast overpressure.

a. When using a plastic bag as a rain shield, the bag should be tied loosely around the microphone, allowing some exchange of air between the inside and outside of the shield. Completely sealing a rain shield could result in the following:

i. Condensation – water accumulates inside the shield. A small hole in the bottom of the shield can help mitigate this issue.
ii. Static Pressure – over time pressure could build in the shield.
iii. Rain Triggers – rain drops striking a tightly sealed shield will cause pressure pulses that could trigger the seismograph.

b. It is acceptable to keep microphones inside security boxes or other protective covers as long as the pressure change in the enclosure reflects the pressure change outside of the protective cover in the surrounding environment.

B. Programming Considerations
Site conditions dictate certain actions when programming the seismograph to record air overpressure.

1. Trigger Level – When only an air overpressure measurement is desired, the trigger level should be low enough to trigger the unit from the air overpressure 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 20 Pa (0.20 millibars or 120 dB).

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

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