ISEE Blasting Seismograph Standards 2017

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Abstract:

The International Society of Explosives Engineers (ISEE) Standards Committee has recently updated both the Field Practice Guidelines for Blasting Seismographs and the Performance Specifications for Blasting Seismographs. The revisions are the result of public and industry input along with recommendations of the ISEE Blast Vibration and Seismograph Section. The committee is comprised of blasting seismograph manufacturers, users and general interest personnel. On an as needed basis, subject matter experts are enlisted to advise the committee. Three phases of activities are necessary for each revision cycle: request for comment on the existing standard, first draft revision of the standard based on public input, and final draft approval by the ISEE Board of Directors. The ISEE standards revision process will be explained and each standard will be discussed along with the significant revisions from the latest revision cycle.

Origin and Development of ISEE Standards for Blasting Seismographs

The goal 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 maintained, 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 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 Seismograph Standards Subcommittee became part of 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) Field Practice Guidelines for Blasting Seismographs; and 2) Performance Specifications for Blasting Seismographs. In 2002, the Society established the ISEE Standards Committee, which began a review of the Field Practice Guidelines in January 2006 that 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 reviews and updates the standards every 5 years. The following two documents are the result of the latest efforts by the ISEE Standards Committee to keep the standards up to date with current field techniques and technology.

ISEE Standards Committee Scope

As stated in the ISEE charter: "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." For a detailed outline of the committee composition and procedures see Appendix A, ISEE Board of Directors, Organization, Information, and Policy Manual, 2012, Section 19 - Standard Setting.

Field Practice Guidelines for Blasting Seismographs (FPGBS), 2015 Edition

A request for comment on the Field Practice Guidelines for Blasting Seismographs – 2009 Edition, was published in the ISEE *Journal of Explosives Engineering (Journal)* September/October 2013 edition. In response, three proposed changes were received and debated by the committee. Subsequently the three proposals were published for comment in the *Journal* September/October 2014 edition. The final version of the standard included one unchanged proposal, one modified proposal and one proposal that was rejected. The final version was approved by the ISEE Board of Directors on July 31, 2015. Below is a summary of the rationale on keeping, modifying or rejecting the proposed changes.

FPGBS Proposal 1: Part I.A. Sensor Placement

Background: 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. The current standard reflects the deployment of sensors in the field on a blast-by-blast basis for ideal geophysical interpretation of the waveforms. Recent legal proceedings have questioned legitimacy of the recordings when the longitudinal channel is not "pointed directly at the blast" because the blasting seismograph was permanently deployed at a structure. With the increased use of telemetry equipment for data access, the standard should be revised to address geophone orientation for sensors that are permanently deployed in the field while the blast locations change day-to-day. By documenting the orientation of a permanent sensor relative to true north, component motions oriented towards the blast (based on the documented blast location) could be resolved. The following references indicate that longitudinal orientation of the sensor towards the blast is not essential.

- The horizontal components are traditionally labeled as "longitudinal" or "radial" (if aligned in the direction of the blast) and "transverse" (perpendicular to the direction of the blast). When not so aligned, they should be alternately identified as "H1" and "H2," respectively. (Siskind 2000, Vibrations from Blasting, Page 13)
- Structure response observations (i.e., damage observations and subsequently rules): The horizontal vibration components did not necessarily correspond to the true radial (or longitudinal) and traverse, since the velocity gages were oriented parallel to the structure walls. (USBM 8507 Pp 9 and 32)

Existing Part I.A.4. The longitudinal channel should be pointing directly at the blast and the bearing should be recorded.

First Draft Part I.A.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 blast site. Records should indicate if this condition is met and the azimuth (0-360 degrees) of the longitudinal/radial channel relative to true north should be recorded.

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

Final Part I.A.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.

Comment Disposition: Below are the comments received on the proposed standards and the responses by the Standards Committee.

Comment 1. I recommend including the conditions under which other sensor orientations are allowed. I recommend providing a tolerance on how closely the orientation of the longitudinal/radial channel needs to be pointed towards the blast and recommend +/-5 degrees based on the accuracy of most hand held devices (compass apps, compasses, etc.). Also should we specify that it should be pointed at the center of the blast?
Response 1. Agree with the comment, the verbiage is changed to allow a variance in the azimuth accuracy and more specifically define the target direction of the Longitudinal channel i.e. towards the closest blast hole. This is in line with many regulatory requirements for record keeping.
Comment 2: It seems in both cases below that it is recommended to record the azimuth from true north. Why not just make it a recommendation to record the azimuth from true north whenever a seismograph is set up.
Response 2. The azimuth is only necessary for long term deployments because blast log rules generally require the distance and azimuth from the nearest blast hole to the closest structure. In most instances the blasting seismograph would be set at this structure and the information would be redundant.
Comment 3. Blasting in the construction industry usually requires that the seismograph be moved between each blast; often the unit is in direct line of site of the blast pattern. When the blaster is looking at the blast and points the arrow at the closest hole what is the importance of the azimuth of the arrow to the record? Clearly the existing standards are satisfactory in these cases. Why are "close in" one time set ups, not excluded in the proposed standard? In my opinion the recording of azimuth is an unnecessary requirement for blasts where the seismograph is moved on a per shot basis. If and I am not convinced by this document that the arrow direction is that significant, recording the azimuth should necessary only for the so called "permanent installations". Also if the concern is valid, an azimuth variation or limit should be listed in the guidelines to indicate reorientation of the geophone is needed for "permanent installations".
Response 3. Agree, the standard has been changed to reflect this concern by deleting the requirement for azimuth recordings on a blast-by-blast basis.

Comment 4. With regard to the proposed changes in the above section, I would question the need for both subparagraph a. and b. The first sentence states what is the "typical practice" and allows for other orientations. Why then require (i.e. records should) the operator to record this information and in specific terms of azimuth in degrees. On many jobs, the person setting up a seismograph may only have an educated guess of the general geographical direction to the blast, and no idea of the azimuth to any certainty. Furthermore in civil cases, this could be another piece of data which if done incorrectly or omitted will provide fodder for plaintiff attorneys to question the legitimacy of the seismic data. Since in most permanent seismic installations. The orientation of the longitudinal/radial channel will necessarily vary as the blasting moves around the mine or construction site, what is the purpose in recording this data. In cases where this data may serve a purpose, it could certainly be recorded as needed. To state that all seismic records should have what seems to me to be an essentially useless information leaves room for doubt in the mind of anyone questioning the validity of the seismic data.
Response 4. Agree with the comment and the verbiage has been changed. The azimuth is only necessary for long term deployments because blast record rules generally require the distance and azimuth from the nearest blast hole to the closest structure. In most instances the blasting seismograph would be set at this structure and the information would be redundant.
Comment 5. We fully agree with and support the proposed revisions in Part II. A. 4. as well as those is Part III. A. 6.
Response 5. none

FPGBS Proposal 2: Part II.B.4. Special Soil Conditions.

Background: Current language in Part ll.B does not address special soil conditions that may be encountered at monitoring locations, such as sandy, non-cohesive soils, hard-packed surfaces and frozen ground. Such special conditions require special coupling methods and choices to ensure accurate readings. This problem can be addressed by adding a subsection focusing on special soil conditions and recommended coupling solutions. Justification for the change will be drawn from the vast years of field experience among the ISEE Standards Committee and Seismograph Section members, as well as from existing literature that might address special coupling solutions for difficult soil conditions.

Existing Part II.B.4 - none

First Draft Part II.B.4. Special soil conditions

a. Soil with a high sand content provides little or no cohesion and sensor burial is recommended. Loose, free-flowing sand should be avoided unless small accelerations (0.2 g) are expected or burial in a deeper, firmer soil layer can be achieved at that location. For sandy soil with some molding capacity (i.e., where the excavated hole remains open), soil with some clay content may be delivered and compacted/backfilled around and above the sensor.

b. For hard soil surfaces and frozen ground, sensor burial is recommended. In the excavated hole, unfrozen soil may be delivered and compacted/backfilled around and above the sensor. (Note that for long-term installations in frozen ground, the sensor should be checked for firm coupling after a spring thaw and reburied as needed.) Where surface coupling is necessary, pilot holes may be formed in the ground surface to accept the sensor’s spikes, or a spiked metal mounting plate may be driven into the ground and the sensor rigidly attached to it. For both

surface coupling methods, no air gap should remain between the ground surface and sensor or the bottom of the mounting plate.

c. Muddy or saturated soils and spongy, organic soils (e.g., woodland humus) are not suitable and should be avoided. However, sensor burial at these locations is acceptable providing a deeper, firmer soil layer can be found.

d. Careful documentation of all special soil conditions and the coupling method used to accommodate them is critical.

Final Part II.B.4. – Proposal rejected

Comment Disposition: Below are the comments received on the proposed standards and the responses by the Standards Committee.

Comment 1. Part IIB(4)(a). I recommend changing the first sentence to "Sensor burial is recommended in soils that provide little or no cohesion."
Response 1. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.
Comment 2. Part IIB(4)(b). Hard soil surfaces are not defined and might mean different things to different operators. How about replacing the first sentence with: "Sensor burial is recommended in soils where soil conditions (such as hard soil surfaces or frozen ground) prevent the sensor spikes from being readily driven into the ground."
Response 2. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.
Comment 3. Good addition to the standards.
Response 3. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.
Comment 4. 4a Is “where the excavated hole remains open” the acid test here? Soil type will affect the reading, yet how can this be introduced into a standard as it is written? It confuses me and I studied soils as an agriculture student as well as being on many blast sites over the years. Will a soil triangle chart be needed? As users, are we to run our own tests in order to determine if the soil is giving a good reading or if it needs to be modified with clay? Can blasters without a P.E after their name hope to make meaningful use of this statement or prevail when questioned in civil court!
Response 4. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.
Comment 5. 4b This statement is much clearer and provides simple guidance, except for “delivering unfrozen soil and compacted”; again I am not certain that this will provide usable guidance. If the soil must be modified or added to the hole, how much should be around the geophone, should it be similar to the surrounding soil? The wording should provide clear guidance, not here is the general idea, you figure it out from here.
Response 5. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.
Comment 6. 4c “Muddy or saturated soils”, we could live with this statement except the definition of muddy is fairly broad depending upon who you ask. Perhaps a field test could be devised to determine just how wet is too wet. A simple test used by famers all over world in

order to determine if the soil is to wet to till is to pinch a ball together or push a ribbon through your fingers, if it falls apart your good to go, if it passes between your fingers, it is too wet, something simple.
As it is written, both 4b and 4 c confuse me. What are we asking for with "special soil conditions", I cannot think of any condition where the person setting up the graph will describe that he set it up in a location that is not suitable; who would tell on them self?

Response 6. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.

Comment 7. 4d "Careful documentation" is very subjective wording and depending on who in the industry you ask would elicit totally different answers; in many places carful documentation would mean "do not prick yourself with the ink pen". It is not up to me to suggest wording , yet "Include in the record any special soil conditions and treatments made during setup" is more concise.
I strongly urge that statement d. be rewritten or eliminated.

Response 7. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.

Comment 8. This entire section on "Special Soil Conditions" concerns me. I was under the assumption that these guidelines are intended to clarify the procedures for installing and operating seismographs for the general blasting industry. This section presumes that the seismograph operator will recognize that a "special soil condition" exists and then have the means and knowledge to modify the soil around the sensor. While no doubt some seismograph consultants can do such soil modifications, that is a rare occurrence. I have been around many blasting operations with many seismographs installed by seismograph professionals for forty years and have never seen any situation where the person installing the seismograph had to have soil delivered in order to modify the area around the sensor. Putting it in a guideline for such specific and highly technical cases opens the door for great confusion and requires the seismograph operator to judge when if a soil is too " highly sandy" or too "saturated". All this information seems much too specific for the rare instances when the ground is not satisfactory for typical installations. It would be better to emphasize the importance of setting the sensor in good contact in undisturbed soil, and refer any of these special cases to a soil engineer.

Response 8. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.

Comment 9. This reality is well supported by research and addressed in the Part II section B.1, which delineates a three tiered strategy to address the primary cause of coupling loss. Proposed Part II. B.4, **Special soil conditions** is a discussion of soil conditions which should find its home in Part II A.2., under **Soil density evaluation**. The current proposed language addresses legitimate soil condition / circumstance which regularly presents in the field. While the guidance "may be" effective under limited acceleration it may not be when even moderate levels are present.

Response 9. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.

Comment 10. Our experience suggests In this environment, a sensor planted on or buried in sandy or gravely soil using commonly accepted practice will experience coupling loss if acceleration levels are high enough. This reality is well supported by research and addressed in the Part II section B.1, which delineates a three tiered strategy to address the primary cause of coupling loss. Proposed Part II. B.4, **Special soil conditions** is a discussion of soil

conditions which should find its home in Part II A.2., under **Soil density evaluation**. The current proposed language addresses legitimate soil condition / circumstance which regularly presents in the field. While the guidance "may be" effective under limited acceleration it may not be when even moderate levels are present. The offered solutions, where they currently reside, serve to potentially dilute the founded, proven guidance currently provided above. This especially concerning given the proposed language expressly says "and sensor burial is recommended" yet the current language directs in B.1, "burial or attachment". Whether intentional or not the proposed direction will serve to neuter the RI8969 option. Let us consider the reliability some of the proposed options.

Response 10. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.

Comment 11. Frozen Ground
Based on practical experience garnered from years of shadow monitoring we support the fact that a "frozen in place" sensor buried or spiked provides the same coupling as a sensor buried (as Duvall 9-12") or attached to the outside foundation (as RI 8969). Admittedly the freeze thaw disclaimer in the proposed guidance hints the truth that frozen embedment is only as good as the freeze union (spiked or buried) at the time of the shot. Experience dictates a warm spell or heavy rain as well late winter sun can dramatically affect **daily** freeze thaw cycling. The disclaimer in the proposed 4.B. "the sensor should be checked for firm coupling"… "and reburied as needed"**.** In real practice, excavation to examine coupling will likely be triggered by an anomalous exceedance. Exceedances are not readily, technically excused away to regulatory authority. Although this proposed guidance "may be" effective in some circumstances, it will not be consistently reliable or practical.

Response 11. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.

Comment 12. Clay Ball in Sand Although this is and an attractive concept, and "may be" effective for limited acceleration we have found coupling is not assured using this methodology. Its success may be dependent on the density match of the materials and the ability to effectively re-compact the excavation. Experience suggests in near field construction or quarry monitoring, attempts to install a sensor imbedded clay cannonball in sand filled transmission trenches; graveled easements; a sand landfill liner or other sandy based material whether compacted or not, may render exaggerated velocities, inconsistent and unreliable data when the sensor in subjected to acceleration above 0.2g. Our experience suggests that, when accelerations will exceed .2g and a soil evaluation suggests compacted burial may not be ideal, attachment to bedrock or a well-founded structure (transmission line, pole, foundation etc.) will provide the most practical, repeatable, reliable data.

Response 12. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.

Comment 13. Is the Committee confident that these proposed measures have "citable foundation" as does the current guidance? Is the Committee convinced the proposed direction is reliable enough to risk permit or license to operate? We are convinced by years of shadow monitoring, when confronted with the special soil conditions outlined in the proposed guidance, attachment to the foundation (RI 8969) or attachment to bedrock offer the only practical founded solution that "will be" effective. In near field acceleration environments when burial is made impractical by soil or condition, RI 8969 foundation attachment is the only practical solution. Please continue to embrace it and support the many Blasters in the

field who rely on this practice to collect accurate consistent data.
Response 13. Based on the comments received in response to the proposed verbiage, Part II.B.4 is rejected because inadequate foundation exists to justify the proposed changes.
Comment 14. This venue provides the perfect opportunity to address an inconsistency in the current language in Part II 2.B.2.c. As currently written the last sentence is inconsistent with the section, 2. Burial or attachment methods. This section is not describing spiking and sandbagging, these are described in section 3. Other sensor placement methods. To enhance technical clarity we recommend the proposed language below.[from II.B.2.c eliminate "burial, spiking or sandbagging is not practical"
Response 14. Comment rejected. This section is not open for modification at this time but will be considered in the next review cycle.
Comment 15. We are not confident that there exists agreed strong technical foundation for proposed 4.a. and 4.b. If foundation sources exist they should be cited. At a minimum these sections should carry a disclaimer concerning the assured reliability of described deployment. The disclaimer should point the user back to B.2., in the event the measures are inconsistent or ineffective.
Response 15. Agree, the proposed changes are withdrawn.

FPGBS Proposal 3: Part III.A.6. Microphone Protection

Background: The current guidelines do not address microphone protection. By necessity, the microphone must be open to the environment. Blasting seismograph microphones are somewhat water resistant, but not waterproof. Blasting overpressure is generally low frequency, i.e., less than 100 Hz. Therefore, it is important that the pressure change around the microphone be the same as that of the immediate environment. Use of a rain shield or other protective cover does not affect this pressure change as long as the microphone element is not restricted. No references were provided to support this change.

Existing Part III.A.6 - None

First Draft Part III.A.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:
    - Condensation – water accumulates inside the shield. A small hole in the bottom of the shield can help mitigate this issue.
    - Static Pressure – over time pressure could build in the shield.
    - 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.

Final Part III.A.6 – No Change from proposed draft.

Comment Disposition:

Below are the comments received on the proposed standards and the responses by the Standards Committee.

Comment 1. Good addition to the standards.
Response 1. None needed
Comment 2. I have no problem with item 6.
Response 2. None needed
Comment 3. We fully agree with and support the proposed revisions in Part II. A. 4. as well as those is Part III. A. 6.
Response 3. None needed

Performance Specifications for Blasting Seismographs (PSBS), 2017 Edition

A request for comment on the Performance Specifications for Blasting Seismographs – 2011 Edition, was published in the *Journal* November/December 2015 edition. In response, three proposed changes were received and debated by the committee. Subsequently one of the three proposed changes was published for comment in the *Journal* November/December 2016 edition. Three comments were received on the first draft and addressed as discussed below. The final version of the standard adopted one, rejected one and modified one of the proposals. The final version was approved by the ISEE Board of Directors on July 20, 2017. Below is a summary of the rationale on keeping, modifying or rejecting the proposed changes.

PSBS Proposal 1: Part IV Calibration

Background: The Standards Committee and manufacturers should encourage regulators/users to accept a seismograph's calibration certificate throughout the entire anniversary month in which it was calibrated. For example, if a seismograph was calibrated March 12, 2015; it would be accepted that the graph did not fall out of calibration on March 11, 2016, but rather unless disturbed, is considered calibrated throughout the entire month, through March 31, 2016. Including shipping, shelf time and access constraints, seismograph users can typically recuperate just 11 months of use for the cost of an annual calibration.

Existing Part IV – Calibration

To ensure proper operation, blasting seismographs should be calibrated annually by a facility authorized by the manufacturer.

Frequency…….. Annually
Traceability…… Calibration equipment accuracy must be traceable to National Institute Standards and Testing, National Research Council or equivalent.

Certificate …… Issued with each calibration and signed by the authorized service representative.
Documentation…. List the frequencies tested along with input and output values at each frequency. Provide documentation of measured frequency response characteristics.
Ground Vibration Sensor ….. Calibration must be of the assembled sensor. Component of individual sensors are not appropriate.

First Draft Part IV - None

Proposal Disposition: Committee rejected the recommendation based on the need to have a hard date for expiration as with other calibration equipment.

PSBS Proposal 2: Part IV Calibration

Background: A verbal comment was given to the Chairman to change language from **"**To ensure proper operation, blasting seismographs should be calibrated by a facility authorized by the manufacturer." to "To ensure proper operation, blasting seismographs should be calibrated." The justification is that anyone should be able to calibrate a unit on a shake table. If it is out of specification it may need to be sent to the manufacturer for repair.

Existing Part IV – See above

First Draft Part IV - None

Proposal Disposition: Committee rejected the proposal based on the fact that the current statement is a recommendation and not a requirement. Additionally, most blasting seismographs are programmed with the most recent calibration date that cannot be modified by an unauthorized lab. The date is displayed on each printed record of a blast event. Improper dates may lead to regulatory and legal problems. The owner may use other facilities at their own risk.

PSBS Proposal 3: Part IV Calibration

Background: The ISEE Blast Vibration and Seismograph (BVS) Section recommended verbiage for the Calibration section of the standard (See Appendix B, BVS Section Proposal). The objective is to provide a standardized list of documentation requirements that are to be provided as part of the calibration process for a blasting seismograph. The requirements are intended to be a minimum requirement only, as some calibration facilities and manufacturers may choose to provide additional information.

Committee adopted the proposal with modifications. The BVS document was folded into the existing standard as appropriate and modified as debated in a 7/5/2016 e-mail string for the frequency response characteristics of the microphones. The committee also considered splitting the performance specifications and calibration components from the recommendation and making a separate calibration standard. Based on the need to verify the performance of each unit and the additional administrative efforts needed by the ISEE, the committee decided to keep the calibration components as part of the performance specification.

Existing Part IV – Calibration (see above)

First Draft Part IV - Significant verbiage changes and appendices added per the BVS Section recommendation and debated within the Standards Committee, see Appendix B for the BVS proposal.

Final Part **IV -** Standard adopted as proposed with minor editorial changes, see PSBS 2017 edition for final verbiage, tables and graphics.

Comment Disposition: Below are the comments received on the proposed standard and the response by the Standards Committee.

Comment 1. With all due respect, I understand these recommendations were considered however, I would still like to make the following comments concerning the proposed 2016 Performance Specifications for Blasting Seismographs.

The Performance Specifications for Blasting Seismographs and documentation on calibration requirements have two different and distinct audiences and as such, should be considered separately and treated appropriately. The 2011 Specification for Blasting Seismographs is only 4 pages long (including cover and reference pages) and is relatively easy to understand and conveys what is important when making decisions as to appropriateness of a piece of measuring equipment used for blasting vibration measurement.

As an alternative, I would propose simply amending the 2011 specifications with respect to the actual specification changes and clarifications such as, air channel (7/5/2016), and further defined frequency response characteristics. Also by adding a reference in the calibration section of the specification such as- "Refer to additional ISEE documentation on calibration procedures for Blasting Seismographs". An example for alternate performance specification is offered as pdf attachment.

While the technical procedures included in the proposed 2016 specification do validate compliance, they involve considerable more testing than is necessary to insure proper operation, (assuming the instrument design was validated to meet these specifications in the first place). Secondly, it is not the only methodology available to insure that instrument calibration results in accurate, defensible data collection. Specific calibration procedures should be left to the manufacturer and or personnel with appropriate technical experience to perform such activities.

I would suggest we revisit suggested calibration requirements separately with an emphasis on validating instrument design and or possibly re-considering the draft put forth on 6/12/15, for minimum calibration requirements (with appropriate changes to accommodate specification changes). A pdf of draft revision e attached for reference.

Finally, I would suggest that imposing the level of testing for every calibration as included in the proposed 2016 Specification, that it will result in a burden to manufacturers and calibration facilities and not result in any improvement in overall accuracy. It will however, ultimately result in higher costs to the users and the manufacturers.

Response 1: The Standards Committee voted unanimously that the proposed changes be rejected. The committee has extensively debated these issues leading up to the development of the First Draft, as has the ISEE Blast Vibration and Seismograph Section during development of a Calibration recommendation. These discussions have focused on the needs of the manufacturer from a cost perspective, the users from a performance and cost perspective and the

regulators from a compliance perspective.

The proposal to make two standards from one for simplicity purposes unnecessarily divides the issue and complicates the management of the standards by ISEE. Performance and calibration sustain one another. Currently there is no standard for calibration nor is there an independent third party verifying performance of the blasting seismograph sensors. The only option to ensure adequate response across the entire frequency spectrum is through the unit-by-unit calibration process. Hence the two activities need to remain together for performance purposes and not split for simplicity. Furthermore the ISEE has limited resources to administer standards. Keeping the performance specification and calibration procedure together will minimize the efforts needed to maintain a separate standard which includes administrative costs and five-year review cycle costs.

The proposed technical calibration procedures are essential to establishing operation over the specified operating range of the sensors, especially when an independent third party is not verifying the operating range. One of the goals of the committee has been to work towards getting blasting seismographs to record the same in the field when placed side by side. To achieve this, all blasting seismographs would need to have the same response characteristics. Since the standard sets a minimum performance standard, some manufactures could choose to construct units with wider response characteristics. These would, under certain circumstances, record different amplitudes. By documenting the response characteristics of each unit, users and regulators will have additional information necessary to help resolve differences in field measurements.

Lastly, the first draft recommends two calibration formats, both as appendices. As such they are not part of the standard. However, both give the user an idea of what should be expected during the calibration to ensure that the unit meets the specification. Since these are "non-binding" there is not adequate justification for a separate standard.

The following comment in response to the draft proposal requested revision of new material. This comment was rejected and deferred to the next revision cycle.

Comment 1. I am pleased to comment on the current *Performance Standards for Blasting Seismographs 2011 Edition*. My thoughts are below.

Part V. Measurement Practices

C. Operator Responsibility: The operator is responsible for confirming that the blasting seismograph selected for measurement of ground vibrations and air overpressure in conditions not specifically covered by this standard, has performance characteristics to record data consistent with the tolerances described herein.

With particular respect to the highlighted segments above I am proposing the additional requirement be added to the General Guidelines:

"Blasting seismographs and geophones shall meet or exceed the IP68 standard."

Over the past 32 years of monitoring blasting activities I have stopped counting the number of times I personally have witnessed the loss or non-collection of data due to the malfunction/loss of operability to a seismograph prior to or shortly after a blast as a result of precipitation infiltrating the geophone or seismograph. All the tolerances prescribed for blasting seismographs is moot if the machine cannot function under normal field conditions. As you are aware, blasting locations do not mimic those found in a laboratory where tolerances are confirmed. This day in age there are numerous electronic instruments that are designed to be deployed in all weather conditions and I believe blasting seismographs should be included among them.
Response 1. The Standards Committee voted unanimously that the proposed change will be considered and discussed in the next revision cycle. At this time only comments on the proposed changes as published in the Journal are being addressed. The issue of specifying an IP68 rating, Ingress Protection for electrical systems against dust and water submersion, in the performance specification has been raised in the past. At that time there was no consensus of what the IP rating should be, if the entire system needed to meet this rating or if just the sensors needed to meet the rating. Vibration monitors are used in a wide variety of applications. In many applications the IP rating would only provide limited value for the users. If the monitoring system was installed inside a building or in a subway tunnel, it would not be exposed to the elements and therefore not require an IP rating. This is also partially true for remote installations where the monitoring unit and often the microphone are located inside a protective enclosure. However, unlike buildings or subway tunnels, in a remote installation the geophones can be exposed to the elements. In these installations having an IP rating on the geophone might make sense. The current Field Practice Guidelines for Blasting Seismographs does address the issue indirectly by encouraging the operator to evaluate individual site conditions and select the appropriate monitoring equipment for the application. The end user also can request the manufacturer to pot the sensors to limit exposure in wet conditions. This issue does require additional consideration and will be addressed during the next revision cycle of the performance specification.

Conclusion

The standard-setting process of the ISEE has evolved over the last 20 years. The process includes seeking public input for change on a 5-year review cycle, seeking public input for proposed modifications (first drafts), and approval of final draft standards by the ISEE Board of Directors. Beginning with the original Blast Vibration and Seismograph Section in 1997, numerous individuals from industry, seismograph manufacturing and government have worked together to develop these standards. The ISEE is committed to maintaining standards that are consistent with current technology and field practices. The current ISEE standards accomplish these goals and can be found at the ISEE website: https://www.isee.org/digital-downloads.

Acknowledgements:

The author, as the Chair of the Standards Committee, thanks the committee members for their dedicated efforts to both blasting seismograph standards.

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References:

ISEE Standards Committee. (2015). *ISEE Field Practice Guidelines For Blasting Seismographs 2015 Edition.* Cleveland: International Society of Explosives Engineers.

ISEE Standards Committee. (2017). *ISEE Performance Specifications For Blasting Seismographs 2017 Edition.* Cleveland: International Society of Explosives Engineers.

Appendix A – ISEE Board of Directors, Organization, Information, and Policy Manual, 2012

SECTION 19. STANDARD SETTING

Operating Principles and Procedures for ISEE Standard Documentation Process Adopted 7/04

A. Introduction and Overview- As the Society initiates, adopts, administers, and/or interprets consensus documents, it is our objective to provide an open and inclusive structure within which select documents can be developed. In so doing, we will work to achieve a consensus of those who are directly and materially affected while ensuring that the principles of openness, fairness, balanced representation, and due process are followed in all phases of the consensus document development, administration, and the appeal process.

The Society will make every effort to avoid duplicating any widely accepted and applied, pre-existing standard. Any Standards developed by the Society should be voluntary consensus performance standards. The Society will not use standardization as a device to fix prices, set fees, boycott, restrict the purchase or sale of a product or service, exclude competitors, control production, or otherwise lessen competition. With this in mind, ISEE adopts ***Operating Principles and Procedures*** for the ISEE consensus standard documentation process.

B. General - These procedures shall govern the activities of the International Society of Explosives Engineers (ISEE) related to the development, approval, revision, reaffirmation, and withdrawal of standards.

These Operating Principles and Procedures are based on American National Standards Institute (ANSI) Procedures for the Development and Coordination of American National Standards. When operating outside these ***Operating Principles and Procedures*** the ISEE Standards Committees shall follow operating guidelines as set out in the ISEE Constitution and the ISEE Board Policy Manual.

C. Organization

1) **ISEE Standards Committees –** The ISEE Standards Committee shall be responsible for developing and maintaining Standards as directed by the ISEE Board of Directors in accordance with these Operating Principles and Procedures for ISEE Standard Documentation.

Membership of these ISEE Standards Committees shall be sufficiently diverse to ensure reasonable balance without dominance by any single interest group. Such Committees shall operate in a manner consistent with operating principles and procedures found herein and shall report directly to the ISEE Board of Directors on the development or change of any standard.

2) **Secretariat –** The International Society of Explosives Engineers and its Board of Directors shall be the Secretariat for all ISEE Standards Committees operating in accordance with these procedures. The Secretariat shall:

a. Organize the ISEE Standards Committees.
b. Oversee compliance with these procedures, including legal review as necessary.
c. Ensure adherence to periodic maintenance of Standards.
d. Ensure maintenance of rosters of all ISEE Standards Committees.
e. Ensure maintenance of all records pertaining to the ISEE Standards Committees.
f. Provide administrative support, including secretarial services for the ISEE Standards Committees.
g. Ensure publication of approved standards and revisions thereto.
h. Perform other functions as required.

3) **Records –** Material associated with the development and revision of a standard,

Including: drafts, ballots, and appeals, shall be retained for one complete Standards cycle, or until the Standard is revised or reaffirmed. Records regarding the withdrawal of all Standards shall be retained for at least five years from the date of withdrawal.

4) **Membership** - Membership on ISEE Standards Committees shall be open to any person, materially or directly affected by the standardization activity in question. Participation shall not be conditional upon membership in any organization nor unreasonably restricted on the basis of technical qualifications or other such requirements. ISEE membership is not a prerequisite to participation.

Unless it is claimed by a directly and materially affected person that a single interest category dominated the standards development process, no test for dominance is required. ISEE, however, strives to assure that any single interest category does not constitute a majority of the membership of the formulating group dealing with Standards.

Reasonable dues and fees directly relating to the support provided and activities of a given ISEE Standards Committees shall be assessed with the approval of the ISEE Standards Committees. The Secretariat shall consider and may recommend reasonable limits on the size of the ISEE Standards Committees.

5) **Interest Categories –** All members of ISEE Standards Committees shall be classified as Producers, Users or General Interest representatives in accordance with the following definitions:

a. **Producers** - An individual or entity that provides blast vibration monitoring equipment and services. This category typically includes representatives from blast vibration seismograph manufacturers and manufacturers' representatives.

b. **Users** - An individual or entity that uses blast vibration monitoring equipment and services. This category typically includes those involved in with field blasting, blast monitoring, pre-blast surveys, safety; explosives manufacturers technical representatives, blast consultants and geotechnical and consulting engineers; contractors, government agencies, and utility companies.

c. **General Interest**: General Interest members are neither Producers nor Users. This category includes, but is not limited to, regulatory agencies (state and federal), researchers, other associations, and educators.

An individual in professional practice or a consultant, retained under an indefinitely continuing agreement with an organization, shall be classified in accordance with the classification of the organization retaining the individual and shall be so identified. There shall be a limit of one voting member from each entity, company, or organization.

6) **Membership Roster –** The Secretariat shall prepare and maintain a membership roster documenting the classification of each ISEE Standards Committee member.

7) **Membership Application –** Individuals seeking membership on an ISEE Standards Committee shall submit a written request to the Secretariat indicating their interest in the work of the ISEE Standards Committee, their qualifications, willingness to participate, interest category, and affiliations which might affect their classification.

8) **Process –** The Secretariat shall promptly process all membership applications. Applications shall be considered by the relevant ISEE Standards Committee Chairman who shall accept or reject all applications. Rejected applications shall have the right to appeal to the Secretariat in accordance with the process shown herein. Consideration shall be given to the following:

a. Need for active participation be members of each interest group.

b. Balance and potential for dominance by members of a single interest group.

c. Extent of interest by the applicant and willingness to participate.

d. Qualifications and ability to materially contribute to the work of the ISEE Standards Committee.

9) **Termination of Membership –** The Secretariat shall be authorized to terminate the membership of an individual of an ISEE Standards Committee for cause, including inactivity or failure to pay appropriate dues/fees as levied by the committee (unless a waiver by the committee is approved). An ISEE Standards Committee member shall be considered inactive for failure to return at least 75 percent of ballots issued during a calendar year. ISEE Standards Committee members shall notify the Secretariat of any changes in employment affecting representation and shall submit a new application if continued membership on the ISEE Standards Committee is desired.

10) **Committee Officers –** A chair and vice chair shall be appointed by the Secretariat from the individual members of the ISEE Standards Committee. Each will serve until a successor is appointed and ready to serve. The Secretary shall be appointed by the Secretariat; the secretary need not be a member of the ISEE Standards Committee.

11) **Standards Review –** The ISEE Board of Directors performs the final review and approval of all ISEE standards, materials, and/or reports. Any substantive changes made are subject to review using the process set forth in this document.

12) **Staff Liaison –** The ISEE Staff Liaison serves in an advisory capacity to assist in achieving compliance with these Procedures and is responsible for the editorial treatment of documents to ensure compliance with appropriate style. He or she shall perform such other functions as may be stated in these Procedures or assigned by the Secretariat.

D. Meetings

1) **Frequency –** ISEE Standards Committees will meet to develop Standards on an as needed basis.

2) **Notification –** At least 30 days notice via e-mail shall be given for meetings of all ISEE Standards Committee. An agenda shall be prepared and distributed with the meeting notice no later than two weeks prior to the meeting date.

3) **Open Meetings –** All meetings of ISEE Standards Committees shall be open, and **a**ttendance by any interested party shall be welcome, subject to the individual policy of each ISEE Standards Committee (e.g., regarding registration, meeting fee if required, etc.). Only members of the ISEE Standards Committee shall have the right to vote.

4) **Quorum –** A majority of the members of a ISEE Standards Committee shall constitute a quorum for conducting business at a meeting. Matters shall be deemed approved by the affirmative vote of a majority of the members present, except with respect to matters covered in Section E. If a quorum is not present, actions on agenda items may be taken but shall be subject to ratification by a letter ballot of the ISEE Standards Committee.

5) **Parliamentary Procedures –** For any procedural issues not covered under these procedures, *Robert's Rules of Order (Revised)* shall apply on questions of parliamentary procedure.

E. Notification of Standards Development - Notification of standards activity shall be announced in suitable media as appropriate to demonstrate provision of opportunity for participation by all directly and materially affected persons.

F. Substantive Change - A substantive change in a Standard is one that directly and materially affects the use of the Standard. Examples of substantive changes are below:

1) "shall" to "should" or "should" to "shall";
2) the addition, deletion or revision of requirements, regardless of the number of changes; and/or
3) the addition of mandatory compliance with referenced standards.

G. Voting Procedures

1) **Letter Ballots –** Votes for New Standards, reaffirmation and revision of Standards, and the withdrawal of Standards may be obtained by letter, fax, recorded votes at a meeting or electronic means. Additionally, substantive changes to and interpretations of all Standards may be obtained by letter, fax, recorded votes at a meeting or electronic means. All members of the ISEE Standards

Committee shall have the opportunity to vote. When recorded votes are taken at meetings, members who are absent shall be given the opportunity to vote before or after the meeting.
Administrative changes and editorial changes to Standards may be decided by a majority of the members present at a regularly scheduled meeting of the ISEE Standards Committee or by letter ballot.

2) **Voting –** Each member shall vote one of the following positions on letter ballots:

a. Affirmative.

b. Affirmative with comment.

c. Negative, with reasons.

d. Abstain.

3) **Voting Rights –** A member shall ordinarily cast the vote. The member's alternate shall cast the vote only if the member fails to vote.

4) **Proxies –** Proxies are not permitted.

5) **Voting Period –** The closure date for electronic ballots shall be at least 30 days from the date of the mailing of the ballots. The Secretariat shall be authorized to grant an extension of the voting period if deemed necessary.

6) **Approved Actions –** All electronic ballots shall be considered approved when all of the following conditions have been met:

a. Approval by at least a majority of the voting membership.

b. At least two-thirds of the votes cast, excluding abstentions and negatives without reasons, are affirmative.

c. All negative votes with reasons have been addressed in accordance w/Sect7

7) **Reporting Votes –** The results of each vote on all Standards shall be reported as follows:

a. Number of members.

b. Number of members voting affirmatively.

c. Number of members voting negatively with reasons.

d. Number of members voting negatively without reasons.

e. Number of members abstaining.

f. Number of members not returning ballots.

8) **Negative Votes –** A negative ballot shall be required to be accompanied by a reason and, if possible, shall include specific actions that will resolve the objection.

A negative ballot not supported by a reason is not required to be re-circulated. The ballot shall be counted as returned for the purpose of establishing a quorum.

A negative ballot with a reason that the ISEE Standards Committee determines is not directly related to the document will be placed on the agenda for consideration at the next regular meeting of the ISEE Standards Committee and the commenter shall be so notified.

9) Consideration of Views and Objections – The ISEE Standards Committee or Secretariat will endeavor to resolve all negative comments and shall use the following procedures in attempting to resolve negative votes:

a. All negative ballots and comments will be forwarded to the ISEE Standards Committee responsible for the proposed Standard for response and resolution. The Committee chair (with other Committee members, as necessary) will draft the response on behalf of the ISEE Standards Committee. Negative ballots may be judged as valid, invalid, or non-germane. All comments are given a comprehensive response.

b. The responses to negative ballots will be circulated by a new ballot to give the ISEE Standards Committee the opportunity to change their votes. In the case of public review comments, which are not votes, these comments with the accompanying responses will be circulated for new ballot as well.

c. Voting members or public review participants who have unresolved negative votes (comments) shall be notified of their right to appeal and of the appeals process.

d. Negative votes which are not accompanied by reasons shall be recorded as "negative without reasons" and no further action shall be required.

Previously-considered negative votes -- If the reasons for a negative vote have been previously considered by the ISEE Standards Committee, it shall not be necessary to reconsider the vote unless new information has been submitted. If no new information is submitted, the previous decision of the ISEE Standards Committee shall stand, and the negative voters shall be so advised.

H. Interpretations

1) **Processing Interpretations –** Requests for interpretations of Standards shall be submitted in writing to the Secretariat and shall be forwarded by the Secretariat to the ISEE Standards Committee Chairman or to the President of the ISEE Board of Directors. Proposed interpretations may be prepared by any ISEE Standards Committee member with particular expertise on the subject in question. All proposed interpretations shall be prepared in writing and shall be submitted to the Secretariat for a letter ballot of the ISEE Standards Committee. Interpretations shall be approved in accordance with Section G.

2) **Notification of Interpretations** - Notification of approved interpretations shall be sent in writing to the requester. Notification shall also be given to other users of the Standards through technical journals and other appropriate publications, e-mail, and/or the ISEE web site.

I. Metric Policy - ISEE accepts ANSI's Metric Policy which states that, "Units of the International System of Units (SI), the modernized metric system, are the preferred units of measurement in American National Standards."

J. Consideration of International Standards - The Committee shall take into consideration international standards and shall, if appropriate, base its Standard on international standards.

K. Public Review and Content - Proposals for new Standards or reaffirmation, revision, or withdrawal of existing Standards shall be listed in the Journal of Explosives Engineers and/or on the ISEE Web Site for comment. The Secretariat shall determine whether listing of proposed standards actions shall be concurrent with the final committee letter ballot and whether announcement in other suitable media is appropriate. All comments that are received shall be considered by the ISEE Standards Committee and the commenter shall be notified, in writing, of the Committee's decision/response.

L. Patent Policy - ISEE has adopted the ANSI Patent Policy, as outlined in ANSI Procedures for the Development and Coordination of American National Standards.

M. Correspondence

1) **ISEE Standards Committee Correspondence –** Correspondence from a Committee member to the entire membership of the Committee or any subcommittees shall be forwarded to the Secretariat for approval and distribution. All official Committee /subcommittee correspondence, including meeting notices, agendas, reports, and letter ballots, shall be distributed by the Secretariat. Copies of all other correspondence between ISEE Standards Committee members, relating to ISEE standards activities, shall be forwarded to the Secretariat.

2) **External Correspondence –** Inquiries relating to the ISEE Standards Committee and

Standards shall be directed to the Secretariat. ISEE Standards Committee members should advise individuals who contact them that responses to all inquiries are handled by the Secretariat.

N. Appeals

1) **Complaint –** Persons who have been or may be affected by any ISEE Standards Committee action or inaction shall have the right to appeal such action or inaction. The appellant shall file a written complaint with the Secretariat within 30 days after the date of notification of any action or at any time with respect to inaction. The complaint shall state that it is an official complaint, the nature of the objection, the procedures or the sections of the Standards that are at issue, the action or inaction at issue, and the specific remedial action(s) that would satisfy the appellant's concerns. Procedural complaints include whether a technical issue was afforded due process. Previous efforts to resolve the objections and the outcome of each shall be noted
2) **Response –** Within 30 days after the receipt of the complaint, the Secretariat shall respond in writing to the appellant, specifically addressing each allegation in the complaint to the extent possible. The Secretariat shall attempt to resolve, informally, the complaint of the appellant.
3) **Appeals Panel and Hearing –** If the Secretariat is unable to informally resolve the complaint, it shall appoint an appeals panel to hold a hearing on a date agreeable to all participants, with at least 15 working days notice. The appeals panel shall consist of three individuals who have not been directly involved in the dispute and who will not be materially affected by any decision made in the dispute. At least two members of the panel shall be acceptable to the appellant and at least two shall be acceptable to the Secretariat.
4) **Conduct of the Hearing –** The appellant has the responsibility of demonstrating improper action or inaction, the adverse effects therefrom, and the efficacy of the requested remedial action. The Secretariat has the responsibility to demonstrate that the Committee took all actions in question in compliance with these procedures.
5) **Decision –** The appeals panel shall render its decision in writing within 30 days of the hearing, based upon a preponderance of the evidence, stating its findings of fact and conclusions, with reasons therefore and citing the evidence. The Secretariat shall notify the appellant and the ISEE Standards Committee of the decision of the appeals panel, which shall be binding and final on all concerned.

O. Periodic Maintenance and Review – The Secretariat shall consider the periodic maintenance and review of standards no less often than every five years.

P. Revision to Procedures - Proposed revisions to these *Operating Principles and Procedures* should be written and submitted to the Secretariat along with rationale supporting the requested change. The Secretariat will present the proposed revisions to the Standards Review Council for review, consideration, and ultimate decision. Any approved revisions to these *Operating Principles and Procedures* will be effective upon publication (either electronically or in print format). The Secretariat shall be responsible for the interpretation of these *Operating Principles and Procedures*.

Adopted 7/04

Appendix B – Blast Vibration and Seismograph Section Proposal

Calibration Documentation Required for Blasting Seismographs

Revision K
July 21, 2015

1. Introduction

The objective of this document is to provide a standardized list of documentation requirements that are to be provided as part of the calibration process for a blasting seismograph. The requirements are intended to be a minimum requirement only, as some calibration facilities and manufacturers may choose to provide additional information. The contents of this document are to be included in the next revision of the Performance Specification for Blasting Seismographs standard.

The calibration documentation must provide evidence that each channel of the seismograph being calibrated meets or exceeds the ISEE Performance Specification for Blasting Seismographs, 2011 edition. To achieve this, the seismograph must be tested across the entire frequency range of 2 to 250 Hertz (Hz). The complete ISEE performance specification can be found on the ISEE's web site at www.isee.org. Below is an excerpt from this standard with the recommended changes:

Part ii. Ground Vibrations Measurement

Ground vibration sensor response characteristics should conform to the following minimum values:

Frequency range	2 to 250 Hz,
Accuracy	4 to 125 Hz, +/- 5% or +/-0.5 mm/sec (+/-0.02 in/sec), whichever is larger, 2 to 4 Hz and 125 to 250 Hz, +5% to -3 dB of an ideal flat response.
Phase response	Phase shift between 2.5 Hz to 250 Hz shall not cause an error of more than 10% to the maximum absolute value of two superimposed harmonic vibrations.
Cross-talk response	Less than 5% of the excited axis indication on either of the mutually perpendicular channels when excited at the natural frequency of the sensor or 10 Hz for sensors with a natural frequency greater than 250Hz.
Density of sensor	<150 lbs/ft3 (should be reported for user consideration).

Part iii. Air Overpressure Measurement

Air overpressure microphones should conform to the following minimum values:

Frequency range	2 to 250 Hz,
Accuracy	4 to 125 Hz +/-1 dB
	2 to 4 Hz and 125 to 250 Hz, +1 dB to -3dB
	2 and 250 Hz, -3 dB +/-1dB
Microphone seismic sensitivity	Microphone response to a mechanical vibration of 50 mm/s (2 in/s) at 30 Hz, from any angle, must be less than 40 dB below the maximum microphone output, or 106 dB whichever is lower.

Some of these specifications, like the cross-talk response, the sensor density and the microphone's response to mechanical vibration, will not change over time and therefore will generally be found on product specification sheets. However, the frequency, amplitude and phase responses will directly affect the accuracy of the recorded events and therefore must be checked as part of the calibration process.

The frequency, amplitude and phase responses are directly affected by the individual components used in the circuit design. These components may change, drift over time or could fail altogether, which could affect the response and accuracy of the blasting seismograph. To ensure each seismograph is performing as it was intended, the seismograph, its ground vibration and air overpressure sensors are to be calibrated on not less than an annual basis. As the calibration procedures are different for each manufacturer, it is recommended that the seismographs be returned to the manufacturer or a calibration facility authorized by the manufacturer for the annual calibration.

2. Documentation Required

The help ensure consistency the following documentation must be provided by the calibration facility for each blasting seismograph:

1) The As Found condition of the seismograph,
2) A list of the reference calibration equipment used during the calibration process,
3) The test signals used to verify the frequency, amplitude and phase response, along with the specific results for each channel based on these test signals,
4) A signed and dated calibration certificate for the blasting seismograph being calibrated.

The specific format of these documents may vary, however, the main content of each of these documents is outlined below.

2.1 As Found Report

The As Found report is to be produced prior to any adjustments or repairs of the equipment being calibrated. This report will measure and document the initial response of the seismograph and its sensors to a series of calibrated reference signals. This report can then be used to help assess the

validity of previously recorded events. The report should be dated and must clearly identify the specific sensor it is related to (ie serial number 12345 - Vertical channel). To help ensure consistency, it is recommended that the signals used to produce the As Found report be the same as the signals used during the final calibration process. Samples of a tabular As Found report can be found in Appendix 1 and the graphical As Found report in Appendix 2.

2.2 Reference Equipment

The reference equipment used during calibration is a critical aspect of the calibration process. All of the reference equipment must be calibrated on an annual basis and their traceable reference standard noted. The specific equipment used in the calibration process must be identified on the calibration certificate, along with its traceable standard. If the list of equipment is extensive, a test system identification number may be also used. The calibration records for the reference equipment should be made available to the end user upon request.

2.3 Calibration Test Signals and Results

To ensure full compliance to this ISEE specification, the amplitude and frequency response of each sensor and the phase response of the three ground vibration channels must be tested at enough points to verify their response across the entire ISEE specified frequency range of 2 to 250 Hz. The results of the frequency, amplitude and phase response tests can be provided in a tabular or graphical format. The minimum number of test points for the amplitude and frequency response can be found in Table 1 of Appendix 1. The phase response is used to measure the phase shift between the reference signal and the response of the ground vibration sensor being tested. This could be measured and recorded at each of the test points across the specified frequency range. However, the phase response can also be verified using specific amplitude and frequency measurements. As a minimum, using a mid-range amplitude and frequency response, like 30 Hz, as a reference, the frequency roll off at both the low and high frequencies can be verified against this mid-range response. This procedure is described in the "Measuring the phase response" section of Appendix 1.

NOTE: As this procedure to measure the phase response is based on the measured amplitude at 30 Hz, it is recommended that the final amplitude and frequency response table be completed prior to measuring the phase response. This will allow the seismograph, ground vibration and air overpressure sensors to be calibrated/adjusted, if required, prior to measuring the phase response.

When using the tabular method to document the amplitude and frequency, the reference signals must be documented along with the actual response of each of the sensors. The results must clearly indicate a pass or fail at each of the test points. Samples of the tabular reports can be found in Appendix 1, while samples of the graphical reports can be found in Appendix 2.

Any additional information that the calibration facility may want to include can be provided in a "Calibration Remarks" section of each report. As an example, if a calibration facility was to use an

electrical method or statistical analysis to verify specific ground vibration frequencies instead of shaking the sensor on a shake table, these notes should be included as Calibration Remarks. These notes must also be included or referenced on the calibration certificate. The calibration facility may also choose to include the technical justification for their alternative methods. As an example, the calibration certificate reads; This seismograph meets or exceeds the ISEE Performance Specification for Blasting Seismographs 2011 edition. Exceptions as noted.

Ground channel exceptions: The ground channels were electrical verified from 125 to 250 Hz.

Then somewhere in the documentation describe how the electrical testing was done or if the procedure has already been documented, indicate where the procedure can be found…… A signal generator was connected to the input of each ground channel and the amplitude response verified from 125 to 250 Hz or the electrical testing procedure can be found in test specification “ABC123”.

2.4 Calibration Certificate

The calibration certificate for a blasting seismograph should include at least the following items:

1) The serial numbers of the equipment being calibrated (seismograph, vibration and air overpressure sensors),
2) The model number and description of the equipment being calibrated,
3) The date the calibration was performed,
4) A list of reference equipment used to calibrate the seismograph,
5) The standard(s) that the reference equipment is traceable to,
6) A statement that the seismograph meets the ISEE 2011 specification (including any calibration remarks),
7) The name and signature of the technician who performed the calibration, 8) The tabular and/or graphical reports of the calibration results.

3. REFERENCE

1) ISEE Performance Specifications for Blasting Seismographs 2011 Edition
2) Mechanical vibration and shock measurement standard, DIN 45669-1

APPENDIX 1

Calibration Documentation with Tabular Results

When using the tabular method to ensure compliance to the ISEE Performance Specification for Blasting Seismographs 2011 Edition, the following tables must be completed. These tables will provide a consistent and repeatable set of test points for each blasting seismograph, its ground vibration sensor and the air overpressure microphone.

Ground Vibration Sensor

Some calibration facilities may choose to provide additional test points, however, the specific frequencies listed in Table 1 are the minimum test points required. It is recommended that the same table be used for the As Found and Final calibration results, to allow for a direct comparison of any adjustments or repairs made to the equipment.

Frequency	Reference Signal	Amplitude Response ☐ **As Found** or ☐ **Final Results**				
Hertz	Amplitude	Transverse	Vertical	Longitudinal	Tolerance	Pass/Fail
2					+5% to -3 dB	
4					+/- 5 % or +/-0.5 mm/sec (+/-0.02 in/sec) whichever is larger	
10					+/- 5 % or +/-0.5 mm/sec (+/-0.02 in/sec) whichever is larger	
30					+/- 5 % or +/-0.5 mm/sec (+/-0.02 in/sec) whichever is larger	
60					+/- 5 % or +/-0.5 mm/sec (+/-0.02 in/sec) whichever is larger	
125					+/- 5 % or +/-0.5 mm/sec (+/-0.02 in/sec) whichever is larger	
200					+5% to -3 dB	
250					+5% to -3 dB	

Table 1 Sample Ground Vibration Sensor Amplitude and Frequency Test Results

Calibration remarks: This is a sample of a tabular test report for the ground vibration sensor.

Measuring the Phase Response

This method of measuring the phase response is based on the frequency multiplication factors and amplitude percentages that were obtained from the amplitude versus frequency response graph of a velocity pick-up that has been damped by 70.7% as described in the DIN 45669-1 standard. Other procedures may also be acceptable, as long as documentation is provided to support that the procedure will show compliance with the ISEE Performance Specifications for a phase response between 2.5 and 250 Hz. The precision of all measured frequencies should be no larger than 0.1 Hz.

In this procedure, the signal used to drive the shake table will be adjusted to produce a 25.4 mm/s (1.00 in/s), 30 Hz signal from the calibrated and traceable reference sensor. If the shake table cannot be driven at 25.4 mm/s (1.00 in/s) for all frequencies, the drive signal can be lowered to an appropriate level. This procedure assumes the reference amplitude will remain the same for all of the following measurements.

With the ground vibration sensor mounted on the shake table, adjust the frequency and amplitude of the signal used to drive the shake table as described above. In Table 2, record the frequency and amplitude that the seismograph is reporting for this signal. This will be called reference frequency "F" and reference amplitude "A".

To verify the phase response for the low frequency roll off, maintain the same amplitude output from the calibrated reference sensor and lower the frequency of the signal driving the shake table to find the frequency where the amplitude reported by the seismograph drops to 0.707 of the "A" amplitude value. This frequency point will be called the "F1" frequency and cannot be greater than 2.0 Hz. Record the frequency and the amplitude of the "F1" value in Table 2.

Multiply the "F1" frequency value by 1.270 to obtain the value for the "F2" frequency. With the same amplitude from the calibrated reference, set the shake table frequency to the "F2" frequency. Record the frequency and amplitude values in Table 2. The amplitude should be 85% of the "A" amplitude value, +/- 10%.

Multiply the "F1" frequency value by 0.760 to obtain the value for the "F3" frequency. With the same amplitude from the calibrated reference, set the shake table frequency to the "F3" frequency. Record the frequency and amplitude values in Table 2. The amplitude should be at 50% of the "A" amplitude value, +/- 10%.

To verify the phase response for the high frequency roll off, maintain the same amplitude output from the calibrated reference sensor and increase the frequency of the signal driving the shake table to find the frequency where the amplitude reported by the seismograph drops to 0.707 of the "A" amplitude value. This frequency will be called the "F4" frequency and cannot be lower than 250 Hz. Record the frequency and amplitude of the "F4" value in Table 2.

Multiply the "F4" frequency value by 0.787 to obtain the value for the "F5" frequency. With the same amplitude from the calibrated reference, set the shake table frequency to the "F5" frequency. Record the frequency and amplitude values in Table 2. The amplitude should be at 85% of the "A" amplitude value, +/- 10%.

Multiply the "F4" frequency value by 1.316 to obtain a value for the "F6" frequency. With the same amplitude from the calibrated reference, set the shake table frequency to the "F6" frequency. Record

the frequency and amplitude values in Table 2. The amplitude should be at 50% of the "A" amplitude value, +/- 10%.

Examples of Measuring the Phase Response

The following examples provide results based on an F reference of 30 Hz, with amplitudes of 25.4,

25.25 mm/s, 1.00, 1.01 in/s and -3dB (0.707) frequencies of 1.6, 2.0, 250 and 255 Hz.

Metric Examples

For an F amplitude of 25.4 mm/s, an F1 frequency of 2.0 Hz and an F4 frequency of 250 Hz							
Reference	F3	F1	F2	**F**	F5	F4	F6
Frequency (Hz)	1.52	2.00	2.54	**30.00**	196.75	250.00	329.00
Amplitude (mm/s)	12.70	17.96	21.59	**25.40**	21.59	17.96	12.70

For an F amplitude of 25.25 mm/s, an F1 frequency of 1.6 Hz and an F4 frequency of 255 Hz							
Reference	F3	F1	F2	**F**	F5	F4	F6
Frequency (Hz)	1.22	1.60	2.03	**30.00**	200.69	255.00	335.58
Amplitude (mm/s)	12.63	17.85	21.46	**25.25**	21.46	17.85	12.63

Imperial Examples

For an F amplitude of 1.00 in/s, an F1 frequency of 2.0 Hz and an F4 frequency of 250 Hz							
Reference	F3	F1	F2	**F**	F5	F4	F6
Frequency (Hz)	1.52	2.00	2.54	**30.00**	196.75	250.00	329.00
Amplitude (in/s)	0.500	0.707	0.850	**1.00**	0.850	0.707	0.500

For an F amplitude of 1.01 in/s, an F1 frequency of 1.6 Hz and an F4 frequency of 255 Hz							
Reference	F3	F1	F2	**F**	F5	F4	F6
Frequency (Hz)	1.22	1.60	2.03	**30.00**	200.69	255.00	335.58
Amplitude (in/s)	0.505	0.714	0.859	**1.01**	0.859	0.714	0.505

The frequency and amplitude values for F1 to F6 will vary between units and between each of the ground vibration sensors. Therefore these values will need to be recorded for each of the individual ground vibration sensors.

It is also possible to use other multipliers of the F1 and F4 frequencies as long as they meet the requirements described in the DIN 45669-1 standard. Some of these multipliers and scale factors are listed below. This table also includes the multipliers and scale factors noted above.

F1 Multiplier	Scale F Amplitude By	F4 Multiplier
1.438	90%	0.696
1.270	85%	0.787
1.155	80%	0.866
1.000	70.7%	1.000
0.866	60%	1.154
0.812	55%	1.232
0.760	50%	1.316
0.661	40%	1.523

Other Frequency and Amplitude Multipliers

Frequency	Ground Channel ☐ **Transverse** ☐ **Vertical** ☐ **Longitudinal**			Tolerance	Pass/Fail
	Frequency (Hertz)	Amplitude (mm/s or in/s)	Deviation (%)		
Reference **F** (30Hz 25.4 mm/s)			N/A	N/A	N/A
F1 (0.707 x A)				F1 < 2.0 Hz	
F2 (1.270 x F1)				F amplitude x 0.85 +/- 10%	
F3 (0.760 x F1)				F amplitude x 0.50 +/- 10%	
F4 (0.707 x A)				F4 > 250 Hz	
F5 (0.787 x F4)				F amplitude x 0.85 +/- 10%	
F6 (1.316 x F4)				F amplitude x 0.50 +/- 10%	

Table 2 Sample Ground Vibration Sensor Phase Response Test Results (One Required for Each Channel)

Calibration remarks: This is a sample of a tabular test report for the phase response of the ground vibration channels. The table must be completed for each of the ground channels.

Air Overpressure Microphone

The air overpressure microphone can be verified by subjecting it and the calibrated and traceable reference microphone to specific frequency and amplitude signals. Some calibration facilities may choose to provide additional test points, however the specific frequencies listed in Table 3 are the

minimum test points required. It is recommended that the amplitude of the reference signal remain the same for each frequency tested. The same table should be used for the As Found and Final Results to allow for a direct comparison of any adjustments or repairs made to the equipment.

Frequency	Amplitude Response ☐ **As Found** or ☐ **Final Results**		Pass/Fail
Hertz	Reference input set to 127 dB	Tolerance	
2		-3 dB, +/-1dB	
4		+/-1 dB	
10		+/-1 dB	
30		+/-1 dB	
60		+/-1 dB	
125		+/-1 dB	
200		+ 1 dB to -3 dB	
250		-3 dB, +/-1dB	

Table 3 Sample Air Overpressure Sensor Frequency and Amplitude Test Results

Calibration remarks: This is a sample of a tabular test report for the air overpressure microphone.

APPENDIX 2

Calibration Documentation with Graphical Results

When using a graphical method to ensure compliance to the ISEE Performance Specification for Blasting Seismographs 2011 edition, the calibration facility must provide an amplitude versus frequency response for each of the ground vibration and air overpressure sensors as well as a phase versus frequency response for each of the ground vibration sensors. Exceeding the tolerance limit lines on any of the graphs will indicate a failure to meet the ISEE Performance Specification.

Ground Vibration Sensor

The amplitude versus frequency and phase versus frequency response data is obtained by comparing the output of the calibrated and traceable reference sensor to that of the ground vibration sensor being tested when they are excited at the same level. The recommended minimum number of data points for the amplitude versus frequency and phase versus frequency response graphs is 1 Hz resolution below 10 Hz, 10 Hz resolution from 10 to 100 Hz and 25 Hz resolution from 100 to 250 Hz. However, some calibration facilities may choose to provide additional data points to improve the resolution of the response graphs. The same response graphs should be used for the As Found and Final calibration results to allow for a direct comparison of any adjustments or repairs made to the equipment.

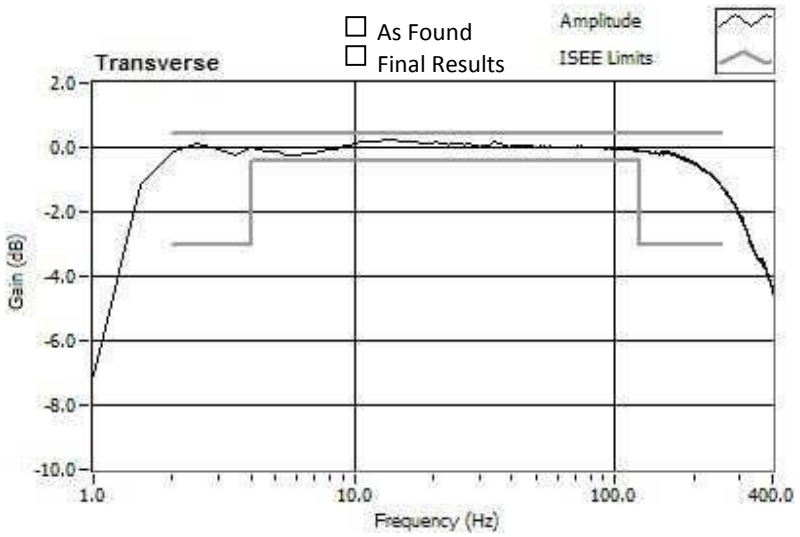

Figure 1 Sample Ground Vibration Sensor Amplitude versus Frequency Response Graph

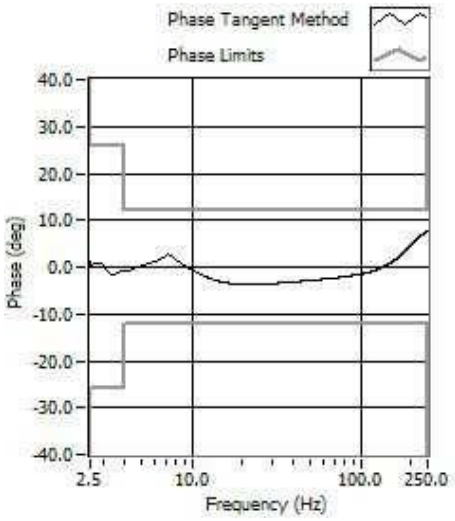

Figure 2 Sample Phase versus Frequency Response Graph

Calibration remarks: This is a sample of a graphical response for one of the ground vibration sensors.

Air Overpressure Microphone

The amplitude versus frequency response data is obtained by comparing the output of the calibrated and traceable reference sensor to that of the air overpressure microphone being tested when subjected to the same pressure source. The recommended minimum number of data points for the amplitude versus frequency response graphs is 1 Hz resolution below 10 Hz, 10 Hz resolution from 10 to 100 Hz and 25 Hz resolution from 100 to 250 Hz. However, some calibration facilities may choose to provide additional data points to improve the resolution of the response graph. The same response graphs should be used for the As Found and Final calibration results to allow for a direct comparison of any adjustments or repairs made to the equipment.

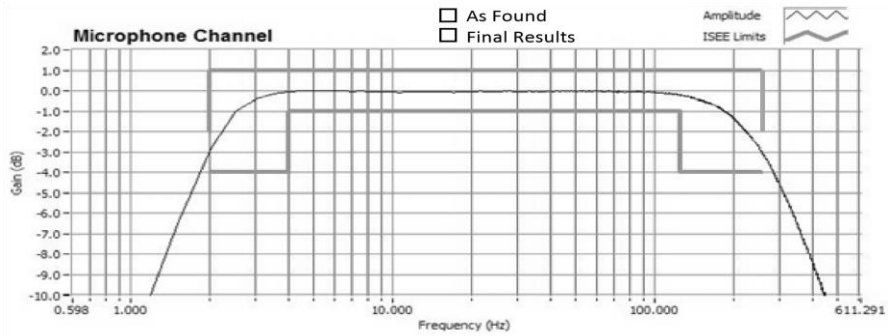

Figure 3 Sample Air Overpressure Sensor Graphical Test Results Amplitude versus Frequency Response Graph

Calibration remarks: This is a sample of a graphical response for the air overpressure channel.