ABSTRACT

In the years since the inception of blast vibration monitoring, the view of the practice has transformed from one of initial resentment and futility, to one of abject acceptance, and ultimately the current widespread acknowledgement of its absolute necessity. In an effort to remain compliant with increasingly stringent government regulations, project specifications and corporate reporting protocol, there has evolved a need within the blasting and vibration control industries for an accurate, timely and efficient method for the recording, reporting and dissemination of blast vibration data.

This paper provides a brief review of the reasons why vibration monitoring has become an essential and integral component of any successful blasting campaign. In order to accentuate the necessity of a vibration monitoring program this paper provides a specific sampling of current legislation and criteria from different areas across the globe. Additionally, appropriate industry standards are presented in detail with regards to equipment installation and programming to ensure that suitable data capture is achieved.

The future of vibration monitoring and reporting in the form of Autonomous Vibration Monitoring (AVM) systems is presented to demonstrate how wireless telemetry has emerged globally as a solution to provide more timely access to data for stakeholders and to minimize the legal exposure from violations of vibration limits. As this trend is likely to continue, the regulated vibration control industry is likely to see a continued shift in technology development to leverage wireless networks and the Internet to continue to improve data transfer, archiving and distribution.
Why Monitor?

With ever increasingly stringent legislation, an increase in public awareness specifically related to blasting operations, a decrease in separation distances between blasting projects and residential communities, and an increasing societal tendency towards litigation, the need for vibration monitoring has transformed from an additional benefit to an absolute necessity. A properly designed and administered vibration monitoring program offers the single best means of defending the mine, quarry or construction operation utilizing blasting against unsubstantiated or frivolous claims of damage.

In an effort to restrict adverse public response, many global regulators have adopted a policy of reduction in vibration limits, often to extremely conservative levels. Unfortunately, the complete elimination of vibration from our society is functionally infeasible, necessitating a compromise between the practicalities of blasting and the requirement to mitigate derivatives of blasting such as ground vibration and overpressure.

In recent years, there has been a dramatic increase in public scrutiny related to blasting operations. The internet has dramatically improved the ease with which the general public can gain access to information on a variety of topics, including blasting. While an informed and educated general public is often beneficial in dealing with public concerns related to blasting operations, the law societies of most countries have come to question the legal validity of what is colloquially known as “Google Research”. Misinformation, or the application of proper information analyzed by those unqualified to properly interpret that information, can often lead to increased hostility and decreased tolerance by neighbouring owners and operations.
Examples of Regulations currently in place

A substantial amount of research has been conducted with respect to the correlation of blast induced vibrations to observed damage. Of the research performed, the United States Bureau of Mines (USBM) Publication RI8507 represents one of the most thorough studies conducted specifically relating blast vibrations to scientifically observed damage. The USBM study concluded that particle velocity is the descriptor of choice when dealing with vibrations because of its superior correlation with the appearance of cosmetic cracking. On this basis, threshold damage criteria were established defining the lowest level vibration at which ground vibrations could be associated with the most superficial interior cracking of the type that develops in all homes independent of the imposition of external vibrations. Given the interdependence between vibration frequency and displacement (damage potential), the threshold limits established by the USBM incorporated both vibration amplitude and frequency (Refer to Appendix A graph).

To date, at particle velocities and associated frequencies below the limits established in USBM publication RI8507, damage as a result of blast induced vibrations has never been scientifically observed. Advancements in equipment and technology in the years since the original USBM study has confirmed the accuracy of the findings and demonstrated that changes in environmental conditions such as temperature and humidity have a far greater impact on structures.

The limits for vibration and overpressure from blasting operations in mines and quarries vary depending on the country, state, province or municipality in which the blasting is being performed. Despite the scientific support for the USBM findings, political will often directs regulators to limit vibrations even further in an effort to restrict adverse public response. Some select examples of local vibration and overpressure regulations are included in Appendix A.
Proper Monitoring Practices

Equipment Specifications

Typical best practices vibration monitoring equipment specifications are as follows:

- Capable of measuring both ground vibration and air overpressure.
- Capable of recording ground vibrations in three mutually exclusive orthogonal planes at a minimum sampling rate of 1000 samples per second.
- Capable of measuring ground vibration Peak Particle Velocity level up to 200mm/s minimum and a minimum frequency response of 2 – 100Hz.
- Capable of recording air overpressure in the linear scale at a minimum sampling rate of 1000 samples per second.
- Capable of measuring air overpressure levels up to 140dBL minimum and a minimum frequency response of 2 – 100Hz.
- Seismograph must be calibrated on a regular basis to a known standard, typically annually for most manufacturers.

Monitoring Program Design and Application

A properly developed monitoring program has two essential components – program design and program application. Failure to fully and properly execute either component will lead to inutile data. For the purposes of this paper, we have applied recommendations as developed by the International Society of Explosive Engineers (ISEE) Field Practice Guidelines for Blasting Seismographs 2009. While this guideline provides industry standard and best practice recommendations for monitoring, local legislation may require variations to specific monitoring practices.

Ground Vibration Monitoring

Sensor Placement

The objective of placing a sensor is to ensure that the blast induced vibration at the point of input into the structure is measured. As such, the sensor must be placed on the same side of the structure (house, commercial building, pipeline, etc.) as the blasting operations. In the event that no adequate location is found beside the monitored structure, the geophone should be placed at a point closer to the blasting operations than the closest structure. Once adequate ground conditions are established, the geophone should be installed with the longitudinal channel pointing in the direction of the blast and must be close to level.
Sensor Coupling

Sensor coupling is the methodology of physically attaching the geophone to the ground. The main goal of the coupling is to ensure that the geophone is responding in a similar manner to the substrate being monitored. According to the ISEE Field Practice Guidelines, the method of coupling the geophone to the monitored surface is dependent on the expected accelerations being produced by the induced blasting vibration. The generally accepted acceleration level where no coupling is required is less than 0.2g (1.96 m/s\(^2\)). Accelerations over this value can result in the decoupling of the sensor from the monitored substrate. If the expected acceleration is in the range of 0.2g (1.96m/s\(^2\)) to 1.0g (9.81 m/s\(^2\)) then the geophone must be buried, spiked, or attached to the substrate. If the acceleration is greater than 1.0g (9.81 m/s\(^2\)) then burial or firm attachment to the substrate is required.

When burying a geophone in the ground it is important to ensure that the soil composition is adequate to be able to firmly secure the geophone in place. Loose soil, such as arid soil or flower beds, should be avoided since it can lead to geophone movement and inaccurate readings. The geophone should be buried a minimum of eight (8) inches in stable ground and covered to allow for proper coupling. Spiking the geophone while buried or sandbagging the ground above the surface can assist proper coupling and lead to more accurate recordings.

In the event that a suitable location cannot be found in the ground to bury the geophone, either due to environmental constraints such as frozen or wet ground, or if the geophone is being placed in or on a structure, the geophone can be coupled or sandbagged on a solid surface. If a geophone is being installed in a residence or commercial building, the primary location should be the horizontal concrete slab in the basement. It should be noted that geophones installed on basement slabs typically record vibrations 25 – 50% lower than those recorded in the ground outside of the structure. The geophone can be either sandbagged on the slab, or if possible, bolted to the slab with the use of a concrete anchor and firmly tightened bolt.

If a sandbag is being used to couple the geophone, ensure that it is a sufficient size to cover the geophone and touch the ground surrounding the geophone at the same time. The bag should be filled with a minimum of 10lbs of dry sand or gravel. Never sandbag a geophone on top of grass, asphalt driveways or other areas that may skew the vibration readings. The combination of spiking and sandbagging will help to achieve better results when monitoring on soil.

Bedrock is also an appropriate place to install a geophone so long as the rock being monitored is part of a large rock mass and not an exposed boulder or rock. A geophone can be secured to bedrock either by bolting, or sandbagging.
Air Overpressure Monitoring

Microphone Placement

Much like a geophone, the microphone must be placed outdoors between the subject property and the location of the blast. A wind protector should be used in conjunction with the microphone in order to mitigate the effects of the wind on the overpressure reading. For air overpressure frequencies below 1000Hz the microphone orientation is not critical; however, since the air overpressure values are typically not known, and since environmental factors can create drastic variations in air overpressure readings, it is commonly accepted to install the microphone with the recording element facing the blast.

The microphone can be installed at any height, so long as it is not obstructed by the ground or other objects. It is important that the microphone has a direct line of sight, or as direct as possible in the given scenario, to the blasting operation and that there are as few objects as possible shielding the microphone from the source of air overpressure.

When installing a microphone near a commercial or residential structure, it is not good practice to position it against the flat portion of a wall. This can allow the wall to act as a reflective surface and could lead to a faulty reading, or could lead to the microphone recording the structural response to the overpressure rather than the true input overpressures. In order to attempt to reduce the amount of reflective interference that is recorded, the microphone should be placed at the corner of a building or well away from the flat portion of a wall.

Coupling of the microphone is not as detailed as with the geophone; however, a microphone should be firmly attached to a mounting point in such a manner that will keep it stationary. Use of a microphone stand or post is suggested. Objects such as tree branches, or other objects which can be affected by environmental forces should be avoided.
Seismograph Programming

Once the microphone and geophone are installed, a sensor test should be performed on the seismograph to ensure that all elements are functioning as per the manufacturer’s recommendations. The next step is to correctly program the seismograph to ensure that the blast is recorded properly. For the purposes of this report, we will make reference to the programming of an Instantel seismograph (Minimate Plus, Blastmate III). Other seismograph manufacturers produce seismographs with similar features.

Monitor Modes

In a Minimate Plus there are five different types of monitor modes to allow for a broad range of recording possibilities. The monitor modes are listed as follows:

1. **Single Shot Record Mode**

Use single shot record mode to record one event automatically. The Minimate Plus records the event, displays the results, and stops. No further recording occurs. Recording begins automatically when an event’s ground vibrations or air pressure exceeds the trigger level.

2. **Continuous Record Mode**

Use continuous record mode to record multiple events automatically. The Minimate Plus records an event, displays the results, and continues to monitor, ready to record subsequent events. The Minimate Plus records all events whose activity exceeds a preset trigger level.

3. **Manual Record Mode**

Use manual record mode if automatic triggering is unreliable, due to excessive wind or nearby vehicle activity, or to record the background noise level in the vicinity of a site.

4. **Histogram (Strip chart) Record Mode**

Use the histogram record mode for long term repetitious recording periods such as monitoring pile driving operations or if vibration intensities are anticipated to be very low. In this mode, the seismograph stores summary event information in intervals rather than in the real time continuous method used in the other record modes. The monitor samples data continuously at the chosen sample rate but only stores the relevant peaks for the given time interval. This reduces the data recorded to specific criteria only and greatly increases the monitor’s recording time. For each interval, the monitor calculates the maximum positive and negative peaks, the frequency of the largest peak, and up to two peak vector sums. For each channel, the maximum peak, its frequency, and the largest peak vector sum is calculated over the entire event.
5. **Histogram Combo Record Mode**

This mode creates a waveform during histogram recording if the signal exceeds the waveform trigger level. The waveform event is saved as a separate file while the histogram event file remains continuous.

**Programming Parameters**

Once the appropriate monitor mode is selected, the parameters of the seismograph must be set. Programming parameters allow for a seismograph to be adjusted to the specific blast monitoring application. The parameters for the various monitoring modes are as follows:

**Trigger Level**

The trigger level sets a threshold that must be exceeded by an event’s activity before the seismograph begins recording. The seismograph can be programmed to trigger from either the geophone or the microphone. Use caution when using the microphone as the trigger source since environmental factors such as rain and wind can result in false readings.

Use your judgment when setting the trigger level. You must set the level high enough so that the seismograph does not trigger on unwanted events such as nearby vehicle traffic. At the same time, you have to set the trigger level sufficiently low so that an event’s activity exceeds the trigger level and starts the seismograph recording process. A good starting point for a trigger level when triggering off of the microphone and geophone is 120dB(L) (20Pa) and 1.3mm/s (0.05in/s).

**Record Time**

The Record Time sets the length of time that the unit records a waveform. Once the record time has elapsed, the monitor stops recording. Two main factors to take into consideration when selecting a record time are blast duration and distance from the blast. A typical rule of thumb for choosing the appropriate record time is two (2) seconds longer than the duration of the blast plus one (1) second for every 335 meters (1000 ft) from the blast.

**Sample Rate**

The Minimate Plus offers three sample rates: a standard rate of 1024 samples per second, a fast rate of 2048 samples per second, and a faster rate of 4096 samples per second. Increasing the sample rate increases the accuracy of the waveform recording. For this reason, set the sampling rate according to the location of the seismograph or the standard transducer. For close–in monitoring, set the sample rate to 4096 samples per second. For far–field monitoring, set the sample rate to 1024 samples per second.
Aliasing occurs when a high–frequency signal appears as an erroneous low frequency signal because the waveform was sampled at too low a sampling rate. An anti-aliasing filter solves this problem by removing the high–frequencies before they can appear at lower frequencies.

The industry accepted sampling rate in most areas is 1000 samples per second; however, this value should be verified with local legislation to ensure proper compliance.

Notes

Proper notes are paramount to ensuring the accuracy of the data recorded on the seismograph and to provide substantiation in the event that the seismograph records come into question. Notes should be permanently affixed to the event, and not editable, to ensure the legal authenticity of the document. As a guideline, we recommend the following notes be included as a minimum: date, time, client, username, seismograph serial number, seismograph calibration date, location of seismograph, installation specifics, distance to blast, maximum load per delay, and total explosives.
Monitoring Program Applications

As previously noted, a perfectly designed monitoring program can be readily rendered useless if the application is not carried through as designed and with diligence and conscientiousness. Currently in many municipalities, it is generally not required that operators outsource vibration monitoring to independent outside parties. Provided the monitoring program receives the necessary attention, there is nothing technically wrong with such a policy. Unfortunately, more often than not, vibration monitoring is viewed internally as a nuisance task, often downloaded onto newer employees who may not have the time or expertise to perform the duties properly. Additionally, there is a general perception within the public that if the mine, quarry or construction operation is performing the monitoring internally, there is a bias which could result in alteration of the data. It has been our experience that outsourcing of the monitoring practice is preferred as this typically leads to improvements in administration of the program, increased reliability, a stronger legal position in the event of a dispute, reduction in liabilities and improved public relations.

In the past and still largely continued at present, vibration monitoring has typically involved the installation of seismographs with periodic manual downloading and reporting. The seismographs would either be installed for a limited period of time on the day of the blast, or alternatively, permanently installed and downloaded as required. While such a system was largely effective in accomplishing the required monitoring, it was open to some problems. Labour costs tended to be high depending on the number of monitors, location of the site and frequency of blasting. Additionally, for units permanently installed, equipment malfunctions could occur without realization until after the blast, leading to loss of data. Depending on contractual or regulatory requirements, reporting of data in a timely fashion often proved extremely difficult or infeasible. Fortunately, with the continued development of the internet and wireless communication systems, Autonomous Vibration Monitoring (AVM) systems are now available which provide a cost effective and efficient solution for future monitoring.
**Autonomous Vibration Monitoring**

In an effort to remain compliant with increasingly stringent government regulations, project specifications and corporate reporting protocol, there has evolved a need within the blasting and vibration control industries for a timely, efficient, automated method for the reporting and dissemination of blast vibration data. Additionally, there exists a need for the data acquired from the blasting operations to be widely available in an easily accessible format. This need has prompted a response in the form of the development of Autonomous Vibration Monitoring (AVM) systems. Coupling the ever advancing communications networks (PSTN, CDMA, TDMA, etc.) with the latest state-of-the-art digital seismographs, the AVM systems now have the ability to automatically handle all of the monitoring needs of a blasting contractor at the instant the blast is detonated.

While the use of AVM systems and web-based data distribution have seen limited application in recent years, their use has largely been limited to ‘mega-projects’ on which political pressures or project funding justified the associated costs and complexities. However, the ease of application of the latest generation of AVM systems now makes such monitoring and reporting protocols accessible to all contractors and for any project. This improved reporting protocol now carries with it a reduction in cost when compared to conventional attended monitoring.

The consequence of these developments to blast monitoring and blast design are significant, permitting the capability for the review and analysis of blast induced vibrations immediately following each blast. Employing the readily available vibration data, blast designs can be altered as required on a continuous and timely basis by professionals located worldwide. The benefits to large and complex blasting projects is well known in the form of improved efficiency and reduced costs. However, the latest AVM systems are now able to introduce the same efficiencies and cost savings on any style or size of project.

The use of telemetry in industrial monitoring applications employing both wired and wireless communication has garnered increasing attention in recent years. Modern digital seismographs, coupled with modern communication systems, now have the capability to automatically manage communications between the vibration monitors and a personal computer or database. This enables automatic download of any recorded data, either on a scheduled basis or as events occur, and distribution of this data to e-mail and text messaging devices.

With the AVM systems now available, vibration monitors can be installed within a matter of minutes with all subsequent communications handled over wireless cellular networks. Once the monitor is connected to the appropriate communication device, the third party monitoring firm can maintain full access to the monitor at all times. Implementation of photovoltaic solar panels permits a completely remote monitoring system. This allows a blasting company to have a virtual third party on site at all times handling all of the vibration data. For the purposes
of this report the BlastVibrations AVM system process is described. Other manufacturers produce AVM systems with similar features.

The BlastVibrations system was developed to permit comprehensive integration and information transfer between the online data and the seismograph recordings. Once a monitor records an event, the unit links to a central server over the land or wireless network to transmit the data for further processing. The seismographs continue to monitor without interruption, and are fully capable of triggering on subsequent events throughout the entire communication and download process (Figure 1).

![Figure 1 – Seismograph Telemetry](image)

**Data Processing**

Once the event data files are transmitted from the seismograph to the *Initial Processing Server (IPS)*, the server immediately processes the data and generates Extensible Markup Language (XML) and Windows Metafile Format (WMF) files to facilitate further data extraction and analysis. The IPS then requests a transfer of the events and associated files to the *Final Processing Server (FPS)* and verifies that the files have been transferred successfully. The FPS then converts the events into Graphics Interchange Format (GIF) and Portable Document Format (PDF) to permit online posting. Upon completion of processing, the FPS initiates and sends email and cellular text message files to notify activated stakeholders of the event and the readings.
All recorded data and process files are archived in the FPS database for future use and reference. The entire process, from recording of the waveforms to posting on the website is normally completed in a matter of minutes (Figure 2).

Figure 2 – Data Processing

**Web User Interface**

While telemetry provides the remote link between the vibration monitoring network and the user, and a central server introduces the technological capabilities necessary to augment processing capabilities (the final component necessary for full automation involved the application of the Internet to disseminate and archive data as it was generated). The latest AVM systems leverage the power of the Internet to simplify the monitoring and reporting processes and permit secure and reliable access to data from anywhere, at anytime. Secure web sites now provide ready access to both recent and historical monitored data, with supplemental information also available online depending on the complexity of the system.

The AVM systems incorporate a web-based Graphical User Interface (GUI) to provide access to event data through a password-protected website. This allows clients to choose who could, and who could not, have access to view the vibration data. The extent of information available to different viewers is scalable, permitting different users access to different levels of information as necessary.
The website provides a central data access point, allowing timely access to vibration data on password-protected web pages. Data is tabulated on the website by date, time, location, component velocities and event reports (Figure 3). Clicking on the event link opens a full event report in Hypertext Markup Language (HTML) format, detailing the full waveforms and associated data for all three monitoring axes.

The online data also includes the results of a Fast Fourier Transform (FFT) for the three component waveforms in the event that timely frequency analysis is required.

Once the events are imported into the website, convenient filters are provided to allow easy viewing of specific blast events (Figure 4). These filters make it possible to view events from a particular period in the blast history, sort the vibration levels to determine the maximum levels reached, view vibration results from single or multiple monitors, and more. The web-based application then provides one click access to vibration event reports. These reports can be viewed in HTML, PDF, or GIF format. PDF has become the standard in business for sharing published information on the Internet. PDF also produces high quality printed material. This allows the event reports to be easily viewed, downloaded and shared without compromising the image quality.

In addition to the filtering capabilities and listed view of the vibration data the web user interface contains an application called Interactive BlastVibrations Dashboard (Figure 5) which allows the user to see the results of past vibration data in a dynamic chart form. This service...
uses the power of Adobe Flex™. Adobe Flex™ is a highly productive, free open source framework for building and maintaining expressive web applications that deploy consistently on all major browsers, desktops, and operating systems. Using the Interactive Dashboard the user can quickly and easily statistically analyze the data to detect trends in blast results.

Figure 4 – Web-Based GUI

Figure 5 – Interactive Dashboard
In addition to viewing the data through secure websites, data can also be transmitted to the interested party via an email message, cell phone text message or a page to a standard pager. Blasters in the field have access to all seismograph data immediately following each blast by simply retrieving their cell phone messages (Figure 6).

Figure 6 - Sample text message event report
Underground Mining Operation Application

The versatility of the AVM system was demonstrated shortly following its initial development when an underground mining operation in Canada saw the same system as a solution to their current problems.

The challenges of mining under a residential community are numerous to say the least, especially when a private residential community exists a mere few hundred meters above the mining operations. At a Canadian underground mining operation, as blasting continued to approach the surface and the overlying properties, the vibration intensities were becoming of paramount interest to the community.

The homeowners in the community felt that regulated vibration limits were not being observed by the mine and that in recent years the blasting had deteriorated to the point where vibrations were considered unbearable. The residents demanded that the mine produce an accurate and legitimate vibration monitoring program to ensure that the prescribed limits were not exceeded and that their homes went unharmed. In an attempt to ensure the preservation of their property, the homeowners initiated a community action group targeting the mine and demanding steps be taken to alter the blasting operations. Overwhelmed by the barrage of complaints, the mine responded by forming a community liaison committee and began to hold quarterly meetings to provide the homeowners with a forum to discuss the mining operations in a more organized fashion. The homeowners demanded that vibration monitoring be placed at strategic locations around the community to ensure that the limits were observed. Additionally, they demanded immediate access to the vibration data so that they could verify the numbers for themselves, a request based in community distrust of the mining firm.

The mine found their solution in the form of the third party AVM system and proceeded to install numerous seismographs at strategic locations in the community to encompass all underground mining activity below the community. The seismographs were all installed on conventional landline modems to allow communication with the web-based application server. The homeowners were then provided with login ID’s allowing limited login privileges onto the BlastVibrations website.

A constant complaint that the mine had received was that the blasting was producing higher vibration levels today then in past years. In order to properly address this problem, the mine gathered all of their previously recorded electronic vibration data and uploaded them to the web-based application to allow the homeowners the opportunity to perform their own analysis and comparison between current and past vibration intensities, a comparison which confirmed that vibration levels were in fact decreasing year after year and consistently remained below the prescribed limits.

The mine’s main priority regarding blasting was to remain 100% compliant with the applicable vibration limits, and having the AVM system in place allowed the mine to determine when the
vibrations produced from the blasting operations were encroaching on the limits and allowed sufficient lead time to adjust the blast design accordingly.

This archival method also gave the mine a central storage location, viewable from anywhere in the world, thereby permitting mine officials, their advisors and agents access to the data on the BlastVibrations website for verification and analysis. The timely access to data and foundation for addressing public concerns has afforded the mine the opportunity to continue mining towards the surface while maintaining consistent regulation compliance and maintenance of public relations.
References


Ontario Ministry of the Environment, (1982), "Model Municipal Noise Control By-law ".


Australian and New Zealand Environmental Council, (September 1990), “Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration”


Pennsylvania Department of Environmental Protection, “Pennsylvania Code Title 25 Environmental Protection, Chapters 77, 86, 87, 88”
Appendix A

The following is provided as a sampling of the blasting regulations in various locales and is intended as a general reference document for blasting regulations. For a complete listing of the blasting regulations for the specific regions, please contact the appropriate regulatory body.

Ontario – Noise Pollution Control 119

**Concussion - Peak Pressure Level Limit**
If the person in charge of a blasting operation carries out routine monitoring of the peak pressure level, the peak pressure level limit for concussion resulting from blasting operations in a mine or quarry is 128dB(L).

**Vibration – Peak Particle Velocity Limit**
If the person in charge of a blasting operation carries out routine monitoring of the vibration the peak particle velocity limit resulting from blasting operations in a mine or quarry is 1.25cm/s
2.4.2 Noise and vibration during a blast

The operator of an active mine must monitor blasting operations (PPV, frequency of ground vibration, air pressure, patterns) during both the development and extraction phases of the operation. All records must be maintained on file for a minimum period of two (2) years. Vibration limits are established as follows:

a) Where there is no impact point (Receptor) within a radius of one kilometer around the mine site

• The maximum ground velocity allowed are shown in Table 6.

• For an open pit mine, the maximum air pressure at any house, if applicable, is 128 dB linear.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>PPV (mm/s)</th>
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<tbody>
<tr>
<td>1</td>
<td>12.7</td>
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<tr>
<td>15 &lt; Frequency ≤ 20</td>
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<td>20 &lt; Frequency ≤ 25</td>
<td>23.0</td>
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<td>25 &lt; Frequency ≤ 30</td>
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<td>30 &lt; Frequency ≤ 35</td>
<td>33.0</td>
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<tr>
<td>35 &lt; Frequency ≤ 40</td>
<td>38.0</td>
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<tr>
<td>Frequency &gt; 40</td>
<td>50.0</td>
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b) Where mining activities take place within one kilometer of a point impact (with the exception of a dwelling owned or leased to the owner or operator of the mine or a residential camp mining or artesian well belonging to the owner or the operator or serving a mining camp), the operator must install a ground vibration and air pressure monitoring network near homes or artesian wells (between one and three stations installed in the homes closest to the mine, unless a contrary opinion justifies a different location).

For an open pit:

• Maximum allowable PPV due to blasting operations recorded at the point of impact is 12.7mm/s

• The maximum threshold overpressure at any home is 128dB(L);

• If homes are present within one kilometer of such a mine, it is prohibited to blast between 7pm and 7am

For an underground mine:
• Between 0 and 100 meters deep, operating PPV due to blasting operations and recorded at the point of impact are shown in Table 7;

• When the operation of such a mine reaches a depth of 100 meters, the maximum PPV due to blasting operations and recorded at the point of impact cannot exceed 12.7mm/s;

• blasting performed between 7 pm and 7 am must be at regular times and the operator must notify the affected population located within one kilometre of such a mine of this time and any changes to the blasting schedule.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>PPV (mm/s)</th>
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<tbody>
<tr>
<td>Frequency ≤ 15</td>
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<td>15 &lt; Frequency ≤ 20</td>
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<td>20 &lt; Frequency ≤ 25</td>
<td>23.0</td>
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<tr>
<td>Frequency &gt; 25</td>
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**Manitoba – Mining and Minerals Act 1992**

44(2) No operator of a quarry shall permit any blasting at the quarry that emits sound exceeding the following limits when measured on adjacent property:

(a) Within 15 metres of a building maintained as a residence, 130 decibels linear peak sound pressure level;

(b) Within 15 metres of a building maintained for use other than as a residence, 150 decibels linear peak sound pressure level; and

(c) Where any person other than an employee of the operator is exposed to the sound, 140 decibels linear peak sound pressure level.

44(3) No operator of a quarry shall permit any blasting at the quarry that emits soil-borne vibrations exceeding the following limits when measured on adjacent property inside a building below grade or less than one metre above grade,

(a) For any building maintained as a residence, 12 millimetres per second peak particle velocity; and

(b) For any building maintained for use other than as a residence, 50 millimetres per second peak particle velocity.
2.1 Airblast Overpressure

2.1.1 The recommended maximum level for airblast overpressure is 115 dB(L).

2.1.2 The level of 115 dB(L) may be exceeded on up to 5% of the total number of blasts over a period of 12 months. However, the level should not exceed 120 dB(L) at any time.

2.1.3 The airblast overpressure values referred to in 2.1.1 and 2.1.2 apply when the measurements are performed with equipment having a lower cut-off frequency of 2Hz or less. If the instrumentation has a higher cut off frequency then a correction of 5dB(L) should be added to the measured value.

Equipment with a lower cut-off frequency exceeding 10Hz should not be used for the purpose of measuring airblast overpressure.

2.2 Ground Vibration

2.2.1 The recommended maximum level for ground vibration is 5mm/s PPV.

2.2.2 The PPV level of 5mm/s may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 10mm/s at any time.

2.2.3 Experience has shown that for almost all sites a PPV of less than 1mm/s is generally achieved. It is recognised that it is not practicable to achieve a PPV of this level at all sites and hence a maximum level of 5mm/s has been selected. However, it is recommended that a level of 2mm/s PPV be considered as the long term regulatory goal for the control of ground vibration.
Chapter 77: Noncoal Mining

77.564. Surface blasting requirements.

(f) Airblasts shall be controlled so that they do not exceed 133 dBL at a dwelling, public building, school, church or commercial or institutional structure, unless the structure is owned by the person who conducts the surface mining activities and is not leased to another person. The lessee may sign a waiver relieving the operator from meeting the airblast limitations of this subsection.

(1) Exceptions. The Department may specify lower maximum allowable airblast levels than those in this subsection for use in the vicinity of a specific blasting operation, if necessary.

(2) Monitoring. The operator shall conduct periodic monitoring to ensure compliance with the airblast standards. The Department may require an airblast measurement of a blast, and may specify the location of the requirements.

(i) In blasting operations, except as otherwise authorized in this section, the maximum peak particle velocity may not exceed 2.0 inches per second at the location of a dwelling, public building, school, church or commercial or institutional building or other structure designated by the Department. The maximum peak particle velocity shall be the largest of three measurements. The Department may reduce the maximum peak particle velocity allowed, if it determines that a lower standard is required because of density of population or land use, age or type of structure, geology or hydrology of the area, frequency of blasts or other factors.

(j) The maximum peak particle velocity limitation of subsection (i) does not apply at a structure owned by the permittee.

(k) When seismographs are not used to monitor peak particle velocity, the maximum weight of explosives to be detonated within any 8 millisecond or greater period may be determined by the formula $W = (d/50)^2$ where $W$ equals the maximum weight of explosives, in pounds, that can be detonated in any 8 millisecond period or greater, and equals the distance, in feet, from the blast to the nearest dwelling, school, church, commercial or institutional building. The development of a modified scale-distance factor may be authorized by the Department on receipt of a written request by the operator, supported by seismographic records of blasting at the minesite. If the peak particle velocity will exceed .5 inch per second with the adjusted scale-distance, § 77.562(d) shall be complied with prior to blasting at the adjusted levels.

(l) When a seismograph is required to monitor the peak particle velocity, a seismographic record shall be obtained for each blast.
(m) The use of a formula to determine maximum weight of explosives per delay for blasting operations at a particular site may be approved by the Department if the peak particle velocity of 2 inches per second required in this section would not be exceeded.

(n) The Department may require a seismographic record of blasts and may specify the location at which the measurements are taken.

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(e) Airblast shall be controlled so that it does not exceed the level specified in this subsection at a dwelling, public building, school, church or commercial or institutional structure, unless the structure is located on the permit area when the structure owner and lessee, if leased to another party, have each signed a waiver relieving the operator from meeting the airblast limitations of this subsection.

(1) The maximum allowable airblast level is 133 dBL.

(2) If necessary to prevent damage, the Department will specify lower maximum allowable airblast levels than those of this subsection for use in the vicinity of a specific blasting operation. The measuring systems used shall have a flat response of at least 200 Hz at the upper end. The Type 1 sound level meter shall use the slow response C- weighted network and shall meet American National Standards Institute (ANSI) S1.4-1971 specifications. The ANSI S1.4-1971 is incorporated by reference.

(3) The operator shall conduct periodic monitoring to ensure compliance with the airblast standards. The Department may require an airblast measurement of blasts, and may specify the location of the measurements.

(h) In blasting operations, except as otherwise authorized in this section, the maximum peak particle velocity may not exceed the values approved in the blast plan required by § 87.64 (relating to blasting plan) at the location of a dwelling, public building, school, church, commercial or institutional building or other structure. Peak particle velocities shall be recorded in three mutually perpendicular directions. The maximum peak particle velocity shall be the largest of any of three measurements. The Department may reduce the maximum peak particle velocity allowed, if it determines that a lower standard is required because of density of population or land use, age or type of structure, geology or hydrology of the area, frequency of the vibration or other factors.

(i) The maximum peak particle velocity limitation of subsection (h) does not apply at structures located on the permit area when the owner and lessee, if leased to another party, of the structure have each signed a waiver releasing the vibration limit. The waiver shall be clear,
knowing and specific. This waiver shall be submitted to the Department prior to the firing of a blast which exceeds the current vibration limit, as stated in this section or the blast plan.

(j) When seismographs are not used to monitor peak particle velocity, the maximum weight of explosives to be detonated within an 8 millisecond period may be determined by the formula \( W = \left( \frac{D}{D_s} \right)^2 \) where \( W \) equals the maximum weight of explosives, in pounds, that can be detonated in any 8 millisecond period or greater, \( D \) equals the distance, in feet, from the blast to the nearest dwelling, school, church, commercial or institutional building and \( D_s \) equals the scaled distance factor. The development of a modified scaled-distance factor may be authorized by the Department on receipt of a written request by the operator, supported by seismographic records of blasting at the minesite. The modified scaled-distance factor shall be determined so that the particle velocity of the predicted ground vibration will not exceed the prescribed maximum allowable peak particle velocity of subsection (n) at a 95% confidence level.

(k) When a seismograph is used to monitor the peak particle velocity, a seismograph record shall be obtained for each blast and within 30 calendar days become part of the blast record required in § 87.129 (relating to use of explosives: record of blasting operations). The seismograph record shall be analyzed by an independent party qualified in the analysis of seismic data.

(l) The Department may require a seismograph record of blasts and may specify the location at which the measurements are taken.

(m) The maximum ground vibration may not exceed the following limits at the location of a dwelling, public building, school, church or community or institutional building:

<table>
<thead>
<tr>
<th>Distance (D), from the blasting site, in feet</th>
<th>Maximum allowable peak particle velocity (V_{max}) for ground vibration, in inches/second(^1)</th>
<th>Scaled-distance factor to be applied without seismic monitoring (Ds)(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 300</td>
<td>1.25</td>
<td>50</td>
</tr>
<tr>
<td>301 to 5,000</td>
<td>1.00</td>
<td>55</td>
</tr>
<tr>
<td>5,001 and beyond</td>
<td>.75</td>
<td>65</td>
</tr>
</tbody>
</table>

\(^1\) Ground vibration shall be measured as the particle velocity. Particle velocity shall be recorded in three mutually perpendicular directions. The maximum allowable peak particle velocity shall apply to each of the three measurements.

\(^2\) Applicable to the scaled-distance equation of subsection (j).