BMM® System Manual

Monitoring Procedures

Solutions to Reduce Ore Loss and

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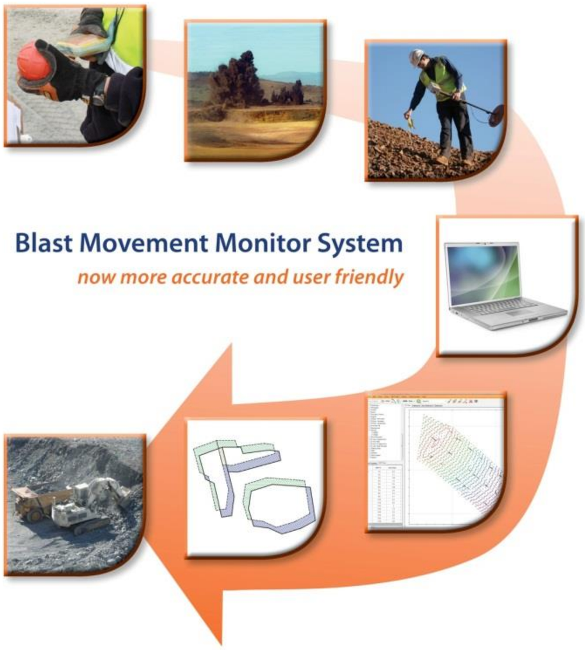
1 INTRODUCTION

The Blast Movement Monitor (BMM®) System consists of directional transmitters placed within the blast volume prior to blasting, which are then located after the blast with a special detector. The data is then processed with purpose-designed software. The system is applicable to all open cut mines and is easy to use — designed for routine use by site personnel.



- Each BMM® is activated, programmed and installed before blasting.
- A special detector is used to locate each BMM® after the blast. Data is downloaded to accompanying software that calculates the movement vectors and then summarises and archives the results.
- Ore boundaries can then be redefined to reflect the measured movement of the blast and therefore enable accurate ore control.

Detection of the BMM®s after blasting is generally the most difficult part of the entire process to learn due to its practical nature. Good tuition and experience are the greatest assets for any practical activities. For example, it would be very difficult to learn to ride a bicycle by reading a manual because there is no sensory experience. Similarly, a new BMM® System operator needs to get a feel for what the changing signal strength is indicating and how to move the *Detector*. This can only be obtained by actually doing it. This manual does not replace first-hand tuition from an experienced operator and it should be used to supplement that practical training to accelerate the process of developing experience. It includes:

- Planning the monitoring locations
- BMM® installation procedure
- The correct technique for locating BMM®s
- Depth calibration procedure
- Potential hazards.

This manual covers how to use the BMM® System as a whole. The detailed description of the *Detector* and *Activator* are covered by the respective equipment manuals.

ⓘ There are Quick Reference Guides available for download from the VIP-Zone on the BMT website. These are step-by-step procedures for monitoring a blast and processing the data. New users should print and refer to them regularly until the procedures are familiar.

2 PLANNING THE LOCATION OF BMM®S

2.1 Introduction

The two main reasons for monitoring blast movement are to improve grade control and to understand blast movement dynamics. In practice, the objective of many blasts will be a combination of both. The data requirement of each is different so the decision process of where to install the BMM®s will also be different. Regardless of the main reason for monitoring, there are operational constraints that must always be followed. The objective of this section is to provide guidelines to help with this decision process to maximise the value of using the BMM® System.

As with any new activity, the best advice to new users is to commence conservatively. Plan the BMM® locations to make detection easier until experience is gained. This can be achieved by selecting appropriate depths, Multi-ID BMM®s (colours), separation distances and locations within the pattern. For example, the BMM®'s signal gets weaker as the depth increases and therefore is harder to locate and requires greater separation from BMM®s of the same colour. Concentrate at about mid-bench to begin with before investigating the movement in other parts of the bench. The exception to this is for multi-pass (flitch) mining where it is important to monitor different levels.

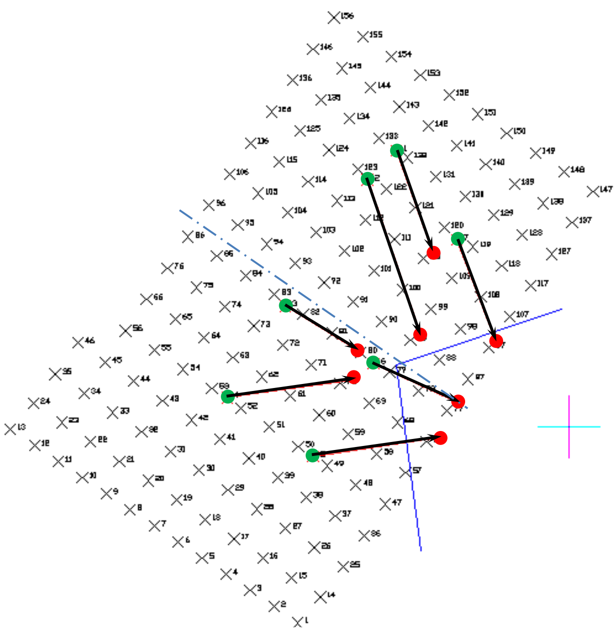
The number of BMM®s installed depends on many factors but the primary question is, "*If a BMM is placed at a certain location, will it lead to a more accurate post-blast delineation of an ore boundary and therefore more ore?*" The decision factors include:

- Grade
- Price of mineral
- Cost of monitoring
- Ore/waste boundary condition – structural vs. disseminated
- Movement variation
- Size and shape of ore polygons
- Orientation of ore polygons
- Isolated vs. contiguous ore polygons
- Bench height

2.2 BMM® Separation

There are four Multi-ID BMM®s available, each identified by a colour; orange, yellow, red, and green. Each Multi-ID BMM® emits a different signal and therefore can be identified separately by the *Detector*. Therefore, it is possible to install more than one BMM® per hole and/or place BMM®s close together – assuming they are of a different colour. If there is inadequate separation between adjacent BMM®s of the same colour, they may be impossible to locate. There are a few simple rules that should be followed when designing separation distances between BMM®s of the **<u>same colour</u>**.

- If they are installed at similar depths, the separation should be a factor of 2–3 times the depth. Deeper BMM®s require greater separation.
- If there is a large difference in depths of the BMM®s, the separation must be 3-4 times the depth of the deepest BMM® (maximum 30 m). For example, an orange BMM® that is 2 m deep should be at least 25 m away from an orange BMM® that is 8 m deep.
- When planning BMM® locations and installation depths, remember to take into account the planned movement direction and distance within the blast. BMM®s with adequate separation at the installation stage, may actually move towards each other and end up too close after the blast. The blast plan shown is an actual blast where this occurred and several BMM®s could not be located after the blast. The green and red dots are the pre and (expected) post-blast BMM® locations respectively.



2.3 BMM® Location for Grade Control

When planning the location of BMM®s specifically for the purposes of grade control, ***think ahead to what will be critical for translating the ore polygons***. The main aim is to locate the BMM®s as close as possible to the ore boundaries to reduce the error associated with interpolating the ore is translated away from the measured vector. This therefore reduces the overall ore loss and dilution. To achieve the best result, planning BMM® locations should take into account the following factors.

1. High grade ore – ore loss and dilution will have a greater economic impact on higher value zones, therefore definition of the correct boundary of high grade polygons will have a higher priority than lower grade polygons.
2. Ore boundary conditions – the worst case is high grade adjacent to waste and the mineralisation is structurally controlled, i.e. sharp cut-off.
3. Proximity to other BMM®s of the **same colour** after the blast – consider the expected movement distance and direction (use the planned initiation timing contours) to ensure BMM®s don’t end up within the minimum separation distance if they move towards each other (refer to Section 2.2).

4. Depth – Horizontal displacement varies with depth and is typically D-shaped with the maximum occurring adjacent to the explosive column, i.e. in the lower half of the bench. Ore loss is more costly than dilution so it is important to maximise the recovery of the mineral, especially for high-grade ore polygons.
    a) For single-pass excavation, it is recommended to install the BMM®s below the top of the explosive column because this region is typically most representative of the majority of the bench height. This is typically close to the **mid-bench level** but could be adjusted under certain circumstances. Contact a BMT consultant if you want to know more.
    b) For multi-pass (flitch) mining, the movement of different flitches are likely to be different. Therefore plan to have BMM®s in each flitch. It may be feasible to combine movement vectors from different flitches under certain circumstances but contact a BMT consultant to discuss this.
5. Close to ore polygon vertices – during the ore translation process, it is the vertices of the polygons that are going to be moved.
6. Small, isolated ore polygons (surrounded by waste) – these have the potential for the greatest **percentage** of ore loss and dilution (up to 100%). If the polygon is very small and a single BMM is planned to be near it, install a BMM® inside the ore polygon so all edges are similar distance from that vector.
7. Polygon boundaries that are oblique to expected movement are more important than parallel boundaries.
8. Concentrate most of the BMM®s in the body of the blast, away from edge-effects, unless there is an important ore boundary close to an edge.
9. Survivability of the BMM®s – Install halfway between blast holes to maximise the distance between BMM®s and any explosive. See Section 2.5.
10. Impact on drill and blast operations – for ease of drilling monitor holes and explosive truck access, holes drilled within the rows of blast holes will have the least impact on drill and blast operations. See Section 2.5.
11. It is important for the person responsible for defining the post-blast ore polygons to understand the 3-dimensional movement in various regions of the blast. Therefore, while most BMM®s will be installed specifically to adjust ore boundaries, it is recommended that some should also be used to gain an understanding of movement in all regions of the blast. This is important because it is not practical to measure movement everywhere, so this knowledge will often be used to supplement the measured movement.

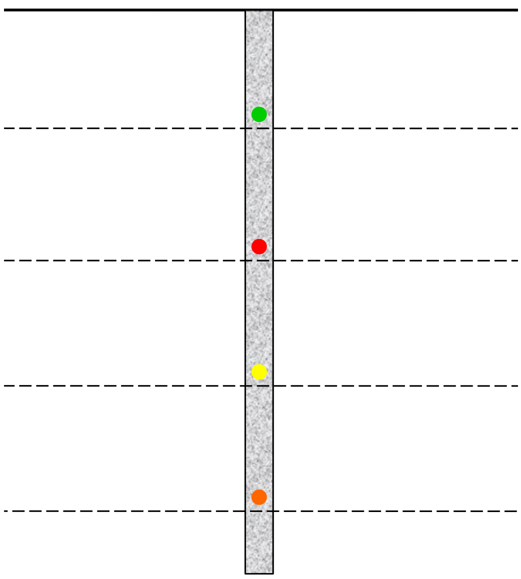
2.4 BMM® Location for Blast Dynamics

BMM®s can be installed in certain locations specifically to understand blast dynamics. The movement data can still be used to translate ore polygons for ore control, but this may be a lesser priority when deciding where to install the BMM®s. Outcomes of these results include:

- Determining optimum flitch digging heights for a multi-pass mining operation
- The relationship between powder factor and horizontal movement
- Quantify the variability of movement
- Quantifying the movement profile
- Understanding the movement dynamics in different zones.
- Optimising blast designs, such as sub-drill and timing.

It is important to recognise that there are a number of zones within a blast pattern where the movement is known to be different to other zones. These include close to all edges (within 2-3 blast holes from any edge, including the initiation centreline) and the body (away from edge-effects). It is only valid to compare similar data, and depending on the specific objectives, BMM®s may be concentrated in the body or distributed through all zones. The body zone represents the greatest volume of most blasts so it is generally more important to understand and monitor this zone, but the edges are arguably more interesting and provide unique challenges for grade control. Regardless, the data will need to be filtered to compare like with like.

The horizontal and vertical components of the 3D movement are both important to ore loss and dilution, but to varying degrees depending on the orebody. It is therefore important to gather a good spread of data throughout the depth of the bench to gain an understanding of the horizontal movement profile, i.e. the shape in section. For multi-pass (flitch) mining operations, this information will enable a determination of the optimum flitch digging levels. The diagram on the right shows an example of installing multiple BMM® at the base of each flitch for a four-pass mining operation (the dashed lines represent the pre-blast flitch levels). Several holes in a blast could have BMM®s installed in this way, but the separation rule must still be applied to BMM®s of the same colour.



- Concentrate on the body of the blast.
- Ideally, select blast(s) with similar rock along the entire length.
- Ensure the same initiation timing for all locations. If the blast has to be initiated with a V, then the centreline of the V must be more than 3 rows from any BMM® and the same timing on each side of the centreline.
- Select the depths to give a complete coverage of the bench height, including sub-drill.

Since blast movement is quite variable, one of the most important criteria when planning a project to gain an understanding of blast dynamics, is to control the variables. For example, the size and shape of patterns (bigger is better), initiation timing (delays and tie-up), rockmass, explosive, hole diameter, and front face condition. This will minimise the variation and enable more specific conclusions to be drawn from the results. Although we can plan for predictability within a blast, there are also several factors that are difficult to control or out of the blast designer's control. These factors could include:

- Change in material characteristics — rock type, structures, oxidation state
- Inconsistent mass of explosive being loaded into each hole
- Variation between batches of explosive
- Variability of explosive delays.

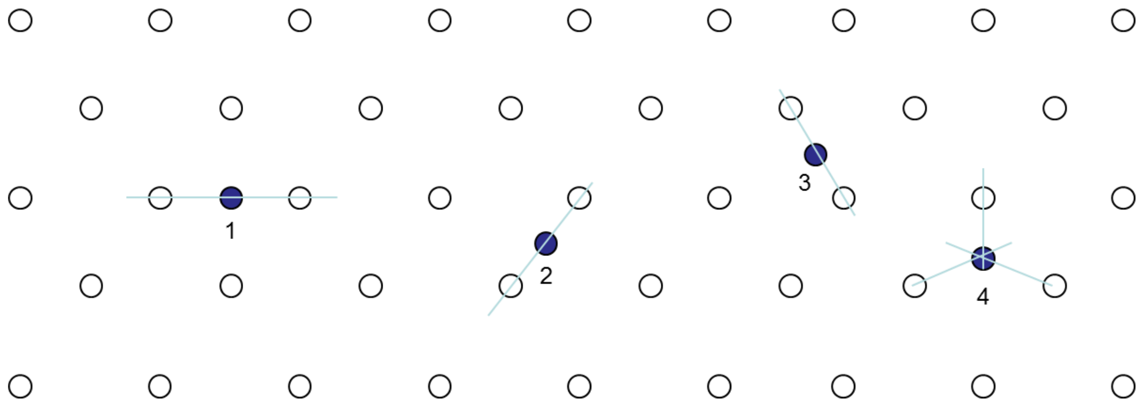
Therefore it is valuable to quantify and understand the variability when interpreting results and tests can be configured specifically to investigate this. To understand the amount of variability within a blast, the following guidelines are recommended.

- All monitoring holes within the body of the blast.
- Install the BMM®s at the same depths in every hole – use multiple BMM®s per hole as required.
- Conduct a number of blasts to quantify variability at different depths — at least one in the stemming and explosive zones respectively. Depending on the scope of the study, it may be advantageous to either do these blasts with the same depth as used in the 3D movement tests or to select different depths.

2.5 Monitoring Holes

When deciding the location and depth of a monitoring hole in the blast pattern, consideration needs to be given to its position to ensure the BMM® has the greatest chance of survival.

To minimise the chance of BMMs being destroyed, it is very important to get them as far from a blasthole as possible. The maximum distance from a blast hole is shown at position 4 in the diagram below (equidistant between blast holes). However, this location can be less convenient to drill and may suffer cave-in due to equipment driving through the drilled pattern. Positions 1-3 may be better from a production perspective (half way between blast holes). Whichever position you choose, it is important to get it close to mid-way between blast holes.



Below are some further suggestions relating to monitor hole placement and hole depth.

- There is no need to drill monitor holes to the same depth as blast holes. Only drill to just below where you want to install the deepest BMM® in that hole (if more than one). Holes that are deeper than necessary waste drilling resources plus it takes time and effort to back-fill them before installing the BMM®s.
- It is often a good idea to put something in the hole collars to prevent them from filling or collapsing as equipment moves around the bench. Gasbags are best but traffic cones can also be effective.
- Communication with the shot crew is important. Ensure monitor holes are clearly marked so that the hole is not stemmed or loaded with explosive accidently. Drill and Blast should be aware of the importance of correct placement of the monitoring holes within the blast pattern.

2.6 Monitoring Hole Diameter

The BMM®s are 98 mm diameter so it is possible to get them into a 102 mm (4″) hole but only if the ground is competent and the hole is clean. The minimum recommended hole diameter for effective installation is 115 mm (4.5″).

3 BMM® Installation

3.1 Introduction

Installation of the BMM®s is arguably the easiest of the monitoring tasks and with good planning and communication with the drillers and blasters, it can be done very efficiently, with little impact on existing workloads.

The BMM®s have a limited transmission time so it is critical to know the blast time. The signal from each BMM® is constant for about 10–12 hours and then begins to decrease and finally stops after about 36 hours. The signal strength is used to calculate the depth, so the depth, and hence the vertical displacement, will only be accurate if it is located within the 10–12 hour window. To provide more flexibility, there is the ability to program the BMM®s to start transmitting up to 36 hours in the future. See Section 3.3 for more information on this topic.

The limited transmission time and the fact that a BMM® can't be switch off once activated, means planning and communication with the drill and blast department is critical. One must be reasonably certain of the blast time **before** installing BMM®s into a blast. Installing the BMM®s as close as possible to the scheduled blast time minimises the chance that the blast will be delayed.

3.2 Installation Procedure

Installation of the BMM®s consists of five basic steps:

i. Measure the depth of the hole
ii. Activate the BMM®
iii. Drop the BMM® into the hole
iv. Read the signal strength and record the BMM®s details on the blast plan
v. Backfill the hole.

WARNING ***The BMM® cannot be switched off once activated with the BMM On button.***

ⓘ The *Detector* will be affected by electromagnetic interference from certain equipment and vehicles. This usually manifests as unusually erratic signal strength ('noisy') and/or elevated signal strength on the *Detector*. There is a usually little interference once in the pit, unless a source is close to the *Detector*. Known sources in the pit include: survey GPS controller (if very close to the LCD), some vehicles (a few metres) and electric shovel power cable (~10 m). There are no issues with mobile/cell phones.

Make sure you have all required equipment before departing to the pit.

- *Detector* and *Activator*
- BMM®s — take 1-2 extra
- Tape measure with weight suitable for measuring the depth of the monitor holes
- Map of blast pattern and planned BMM® locations
- Pencil or pen — to write on map
- BMM® Mesh Bags — if wet holes are expected (see Section 3.4)
- Shovels — to backfill holes if required

ⓘ The easiest way to carry the BMM®s and ancillary equipment around the pattern is with a bucket, tool-carry or similar container with a handle.

Below is the BMM® installation procedure. For detailed information about using the *Activator* or *Detector*, refer to the respective user manuals.

a) Locate the first monitoring hole and check depth.
   - If the hole is deeper than the planned depth then backfill to the required depth.
   - If the hole is wet, refer to the wet hole procedures in Section 3.4.

b) Turn on the *Remote Processing Module (RPM)* by pressing the button on top of the unit.

c) Turn on the *Controller* by pressing the ***Power*** button.
   - Enter the "Blast Name".
   - Select ***Install.***

d) Choose the correct BMM® colour you are going to install in the monitor hole.

e) Record the following details onto the blast plan.
   - BMM® number (as per the *Controller*)
   - Colour of the BMM® to be placed in the hole
   - Measured depth

f) Turn on the BMM® *Activator* by pressing the ***Power*** button.
   - If no *Delay* time (delayed start-up) is required, leave display zero.
   - If *delayed start-up* is required, please consult the applicable BMM® Activator Manual for instructions.

ⓘ If the *delayed start-up* is selected, when the BMM® is turned on it will transmit for 15 minutes, before going to 'sleep', giving enough time to take a signal reading (and a Depth Calibration if required).

g) Hold the *Activator* close to the BMM® and press the ***BMM On*** button to start the BMM® transmitting.

> **WARNING** ***Any BMM®s within range of the Activator will turn on (safe distance is 2 m). Once a BMM® is on, it cannot be turned off.***

h) The red LED on the *Activator* will flash when the BMM® is transmitting close to the *Activator*. As a double check, move the BMM® out of range and then back into range of the *Activator*. If the BMM® is not transmitting, try a different activator angle and press ***BMM On*** button again. Try several times if necessary. If the BMM® will not activate, identify with marking pen, and use another BMM®.

i) Drop the BMM® into the hole.

j) On the *Controller*, select the colour of the BMM® and check that the BMM® number is correct. If not, use the '▼' and '▲' keys to correct the BMM® ID number and select the correct BMM® colour by cycling through BMM® colour button.

k) Enter the measured hole depth into the *Controller*.

l) Place the *Detector's* receiver disc directly over the hole at bench level and use the bubble level get it horizontal.

ⓘ It is important that the level at which the reading is taken is approximately the same level that the surveyors will pick up. If accurate depth is important and it is not possible to get the receiver to bench level due to drill cuttings, then ensure the hole depth is measured from the level of the receiver and also remember to adjust the surveyed elevation accordingly.

m) Press ***Store Reading*** on the touch screen to take a reading. Make sure the *Detector* is kept still while ***Please wait.....*** message is displayed.

ⓘ Before taking the signal reading, get into the habit of reviewing the displayed data – Range, BMM® number, colour, and signal. With experience, you will know approximately what the range should be at various depths. For example, if the hole is 8 m deep and the display is showing Range 3 then the BMM® is not at the bottom of the hole or a BMM® in the bucket is transmitting. If the display is static on Range 1, then the Controller and/or RPM may be locked and need to be reset. If it is displaying Range 12, then the BMM® is probably not transmitting (unless it is a very deep hole).

n) It is recommended that inexperienced operators write the displayed range and signal strength on the plan. Experienced operators should review the display and record any unusual behaviour.

o) Repeat all steps for all BMM®s.

p) Once all BMMs have been installed, exit the installation mode on the controller then switch off the *Controller* and RPM. The data is stored for later downloading.

3.3 Delayed Start

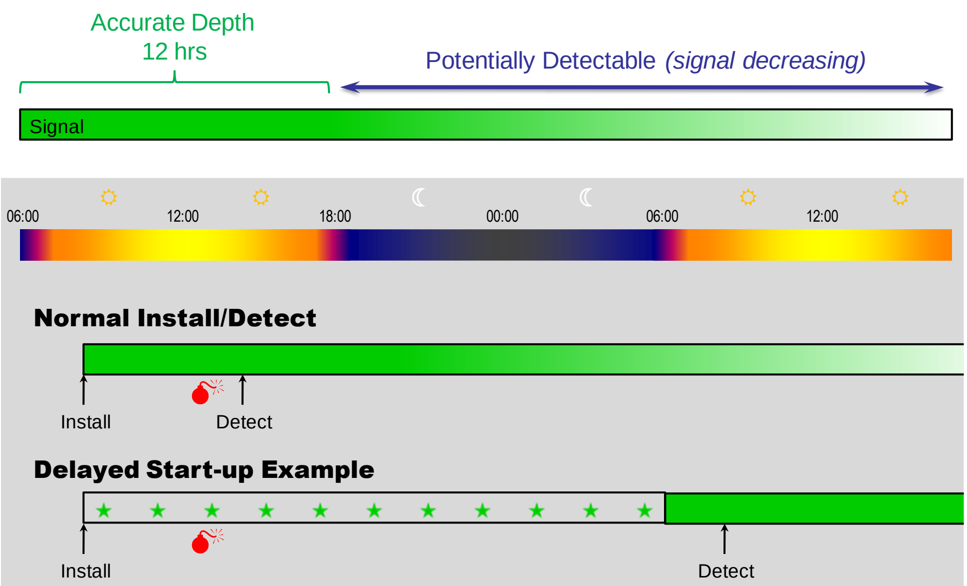
The delayed start extends the 12-hour time window that the BMM®s must be detected to obtain accurate depth. There are several situations where the delayed start will be used to program the BMMs to switch on some time in the near future. For example:

- Cannot access the muckpile immediately after the blast due to a regulated safe settling period when blasting through underground workings.
- Late afternoon blast means end of shift and/or fading light.

- The shot-firer wants to limit access to a loaded and/or tied-up pattern

Under normal circumstances, it is recommended that the BMM®s be installed and located the same day to minimise the chance of blast delays after the BMM®s have been installed and in this case, the delayed start-up is not required. Installation the day prior to blasting is possible but once activated, the delay cannot be cancelled nor changed. It is another opportunity for error that should only be used if necessary.

The diagram below shows an example of how the delayed start could be used. The top strip represents the signal from the BMM® – it is constant for 10–12 hours and then decreases. The second strip represents a time line starting at 06:00. The common procedure is to install in the morning for a lunchtime blast and then find the BMM®s soon after the blast. With the delayed start-up, the BMM®s can be installed on the morning of the blast with an appropriate delay to wake up the following morning when they can be located. This scenario would be used if there are underground workings that must settle for a period before accessing the muckpile.



3.4 Wet Holes

Some special procedures are required when installing BMM®s into wet holes to ensure the BMM® sinks to the desired depth and stays there. The bulk density of the BMM® is about 1.2 g/cm³ which could be less than the water that is in the holes. If the density of the water is greater than the density of the BMM®, then it will float. This could be caused by a high concentration of suspended solids (very muddy water) or hyper-saline water.

The easiest way to sink the BMM® into the wet hole is to use a small amount of rock to increase its weight and density. BMT supplies mesh bags to make this process quick and easy and the procedure is set out below.

ⓘ Steel, Iron or Lead is not to be used as weight material in the mesh bag as it will interfere with the BMM® system.

1. Place an amount of rock into the base of the mesh bag. This could be a single rock of suitable size or a handful of stemming as per the photo. The rock must be no larger than the BMM® if it is being installed in a small hole.
2. Place the BMM® onto the top of the rock and tie a knot in the mesh bag to stop the BMM® and rock from falling out.
3. Prior to placing the BMM® into the monitoring hole, ensure you have completed the Installation procedures as detailed in section 3.2.
4. Place the weighted BMM® into the monitor hole with the rock below the BMM®.
5. Allow sufficient time for the BMM® to reach the bottom of the hole before storing data.

ⓘ Monitor the descent with the detector. The displayed signal strength will stop decreasing when it reaches the bottom.

6. Once the Detector data has been stored, backfill the monitor hole as per standard procedures. If the water is very muddy, drop 1-2 additional suitable sized rocks into the hole prior to backfilling with stemming to ensure the BMM® stays at the bottom of the hole.

3.5 Test Button on the Activator

Test **should <u>not</u> be used under normal circumstances**. The only function it does is check that a BMM® will switch on – it does not perform any additional testing of the BMM® or the Activator. It circumvents the fact that once a transmitter is switched on normally, it cannot be switched off. In Test mode, the BMM® will transmit for about five seconds and then switch off – ready for normal use. It is used during manufacture and testing, and is not recommended for general use since it adds an unnecessary process that takes time and where something could go wrong.

WARNING ***The earlier Test Mode was configured differently and there may still be some of these BMM®s at sites. For these, the transmitter is on for a few seconds and off for a few seconds – cycling indefinitely. If this early Test Mode is initialised, then it <u>must be deactivated</u> before the BMM® can be activated normally (see the Activator manual for the procedure).***

4 BMM® DETECTION

4.1 Introduction

There is no substitute for experience when it comes to locating the BMM®s. This section provides some basic techniques to get you started and fast-track that experience. When working on a reasonably flat, well fragmented muckpile, the BMM® signal is reasonably easy to locate but as the terrain gets steeper and rougher, locating the BMM® gets more challenging. In this situation, the key is to take your time, use the technique specified and double check that you have located the correct position (see Section 4.5).

One of the challenges for new users is to know what is a real signal from a BMM and what is just environmental interference. You are looking for a signal that rises reasonably quickly and consistently – unless the depth of the BMM® is approaching the limit of the *Detector*'s capability. As you gain experience, you will sense when the signal is not right. As an analogy, you may be stumbling around in the foothills instead of climbing the mountain. Usually, when you find the mountain it will be obvious. As a general rule, ***if you are not sure if you have located the 'real' signal, then you probably haven't!***

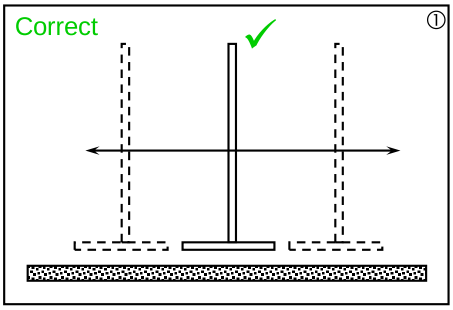
Following is a list of things to keep in mind when conducting a search:

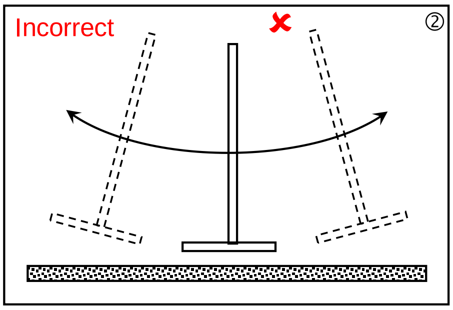
a) Where do you expect the BMM®s to be? Use your plan from the installation stage nd there is also a GPS (low precision) map accessible on the detector.

b) What signal strength do you expect? If you have been locating other similarly installed BMM®s on say, Range 5 and you think you are close to the BMM® but on Range 12 then the chances are, you are not at the right location — keep looking.

c) If you are working on the side of a slope, you may be detecting the side of the field and the interaction between the receiver and the field at this location is different to when you are well above the level of the source.

4.2 Orientation of the Detector

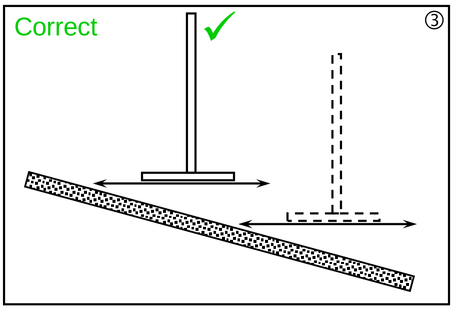


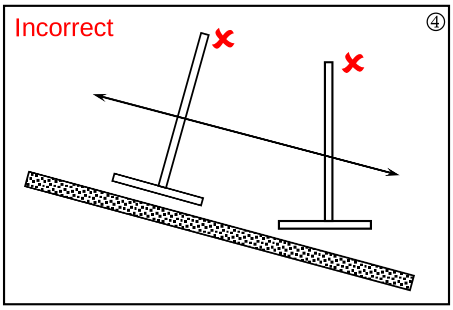


The signal strength measured by the *Detector* is determined by the distance from the transmitter and the angle between the *Detector Coil* and the field lines radiating from the transmitter. The peak signal will be when the *Detector* is directly above the transmitter with the coil horizontal.

One variable can be eliminated by keeping the coil horizontal at all times as in diagrams ① and ③. This is critical when conducting the final pin-pointing and recording the ultimate signal strength, although it is not necessary to be perfect when conducting the initial traverse of the muckpile to get close to the BMM®.

When working on a slope, the *Detector* must still be moved horizontally so it is necessary to 'staircase' up or down the slope as shown in diagram③. It may only be possible to sweep about 1 m for each step. The technique shown in ④ is incorrect because the constantly changing elevation will dominate the change in the horizontal position.





ⓘ The signal changes more quickly from moving the detector vertically compared with horizontally.

For example, if you start at the lower position of diagram ③ and the signal increases as the *Detector* is moved towards the muckpile, and continues to increase until it hits the surface, then it indicates the BMM® is further towards the left. Step up the slope, moving the *Detector* up and away from the muckpile to overlap the lower pass. The signal strength will decrease initially because you lifted the detector further away from the BMM® in the vertical direction. Take note of the signal strength and move towards the left. The signal should increase, at least initially, so continue until you either hit the face with the coil again or it begins to decrease.

If the signal did not increase then the peak may be close to the previous 'step' so move half the distance down the slope and sweep to locate the peak. Clearly, this is more challenging and will take longer than working on a flat surface so take your time and check the final position carefully.

4.3 Detecting Procedure - Locating the Peak Signal

As discussed previously, the detection of the BMM®s after blasting is generally the most difficult part of the entire process to learn due to its practical nature. A BMM® System operator needs to get a feel for what the changing signal strength is indicating and how to move the Detector. This procedure manual does not replace first-hand tuition from an experienced operator and it should be used to supplement that practical training to accelerate the process of developing experience.

ⓘ When searching for the peak signal, you are only interested in a relative change of the signal strength, not the actual signal strength number. At all times…Is the signal increasing or decreasing?

In practice, the procedure is:

a) Turn on the *Remote Processing Module (RPM)* by pressing the button on top of the unit.

b) *Turn* on the *Controller* by pressing the ***Power*** button.

- Select the "Blast Name" from the pull down menu.
- Select ***Detect.***

c) Set the range to a suitable value – usually 8-10.

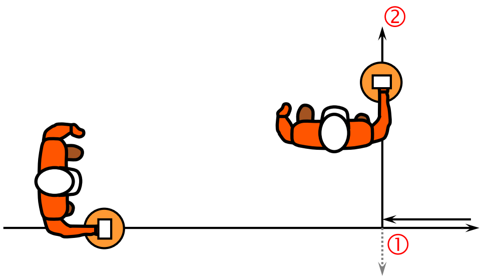
d) Select the BMM® colour that you are searching for. This information is contained on the blast plan created during installation.

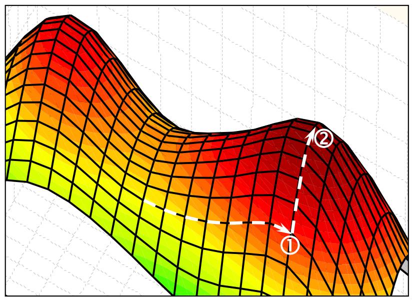
ⓘ As a general rule, start a search by walking along a slope, i.e. approximately constant elevation rather than up or down a slope. More area can be scanned in a short time because it is slow to "staircase" up and down a slope. Once the maximum is found along the slope, you will only have to go up or down once to get close to the peak.

e) Find a BMM® signal.

- Before you can pinpoint a BMM®, you have to get within range. Therefore, your initial objective is to just locate a signal.
- You will not pick up a signal until you are within about 15 - 20 m of the BMM® so keep this in mind when planning your search path.
- To quickly locate the general vicinity of a BMM®, walk an approximately straight line and approximately constant elevation if possible (e.g. along a slope rather than up it), towards where you think a BMM® will be (or was).
- The signal strength will rise very quickly as you approach the BMM®, unless it is close to the limit of the *Detector*.

f) As you get closer to the signal, it will probably be necessary to **decrease the range** to maintain the signal at a level that does not overload the detector.



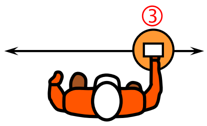


g) BMM® Signal located

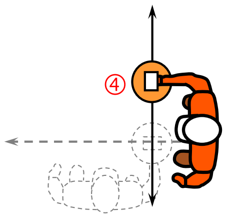
- When a signal is detected, keep going straight in that direction until the signal decreases.
- **Always** walk 2-3 m **past** this first peak to be sure it is not the "phantom peak" (discussed in Section 4.6).
- Back up to about where the maximum was. You are now at location ① in the diagram to the right.

- Don't spend too much time getting the precise location of this peak. At this stage you are just trying to find the approximate location of the peak, so ± 1 m is good enough.
- Turn 90° and move the *Detector*. If the signal decreases you are going the wrong way so walk in the opposite direction, towards the increasing signal strength. Walk forward until the signal starts to decrease. Return to the peak (location ②).
- You are now close to the BMM® and it is time to pinpoint the location.

h) Stand still and move the *Detector* across your body in a straight line **at constant elevation** (refer to Section 4.2) to locate a maximum value (location ③).



i) Turn 90° and repeat the scan technique to locate the maximum signal strength in that direction (location ④).



j) Repeat steps (d) and (e) until you are confident that you have located the peak.

k) Place the receiver coil level on the ground, at the location of the peak signal. Review the display – Is the Range realistic for the expected depth? Is the BMM letter correct? Is the peak validated? (see Section 4.5) If satisfied, press ***Store Reading*** to record the signal. Hold it still while the *Detector* displays ***Please wait...*** A different tone will sound when complete.

l) Mark the location with a suitable marker (stake, flag, paint, etc.) and write the BMM letter (from the *Detector*), on the marker. **This letter must be recorded when the point is surveyed**.

m) Repeat until all transmitting BMM®s have been located – one or more may fail during the blast.

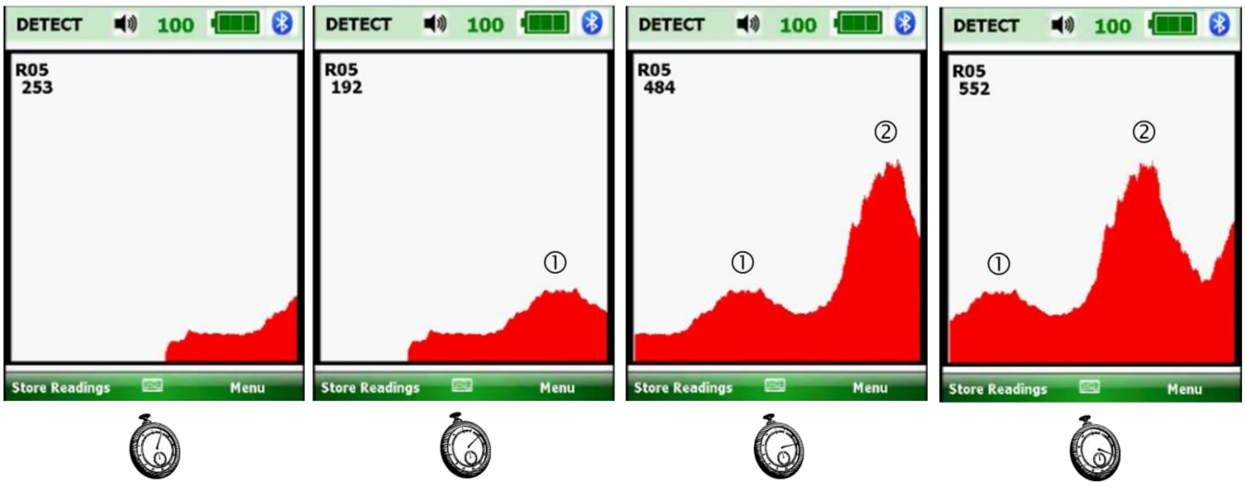
n) Switch the *Controller* and *RPM* off when complete – the data is stored for later downloading.

4.4 Graphical Display

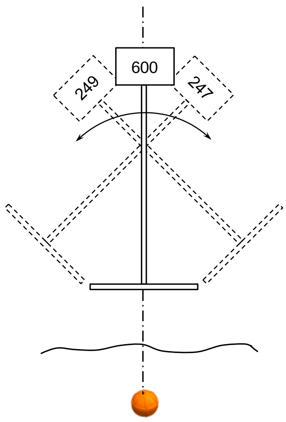
The graphical representation of the signal strength on the *Controller* is designed to be more intuitive and easier to use than looking at a 4-digit number that is constantly changing. This is because all of our senses are analogue – we don't process digital data as efficiently as analogue information. If the signal was perfectly stable then it wouldn't be too bad but environmental interference means that there will constantly be some random fluctuation of the signal and the more it fluctuates, the more difficult it is for an operator to "process" the numeric data to determine whether that average is going up or down.

The most efficient search procedure, set out in this manual, is based on simply knowing whether the signal is increasing or decreasing, and indeed, looking for the point where it changes from increasing to decreasing. The graphical display clearly shows these humps, even if the signal is very "noisy" with a lot of random interference from the environment. Below is an introduction to the graphical display.

- New signal data constantly enters at the right edge of the screen and old data gets pushed left. It shows a brief history of the signal so the peaks and troughs are clearly evident. The image below is four snapshots of the screen at different time, with the most recent screen on the right.
- The height of the red area is proportional to the signal strength.
- Points ① and ② in the diagram below could be what you might see at ① and ② in the diagram in Section 4.3.
- There are a number of steps that can be taken to increase the vertical resolution of the graph and hence make the peaks more obvious. This will be necessary for deeper BMM®s (weaker signals).
  - Set the graph to be full-screen (shown here) by touching the graph.
  - Zoom into the top of the red "signal". There are four zoom levels accessed by pressing "5" on the keypad. The Range # will be highlighted while zoomed. Press "0" on the keypad to return to normal.



4.5 Validating the Peak

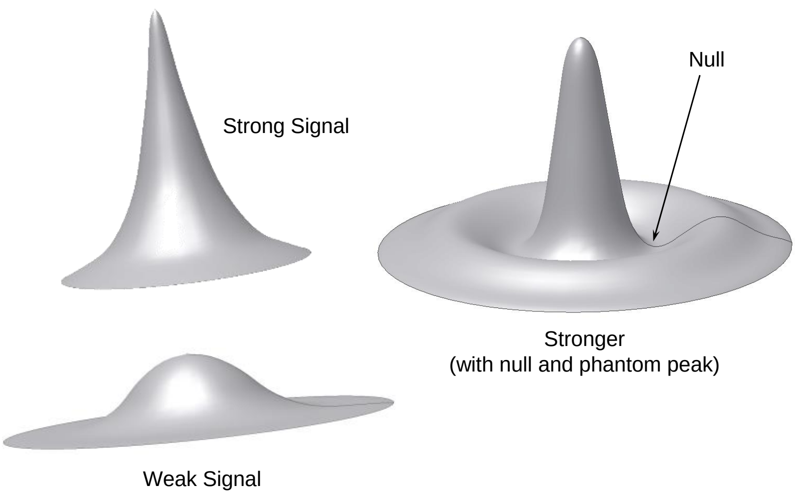


As stated previously, the maximum signal strength is when the *Detector*'s receiver is directly above the BMM® and horizontal. Therefore, when you believe you have located this point, it can be validated by slowly rotating the *Detector* about the vertical axis. If you are indeed directly above the BMM®, the signal will decrease in every direction and it will be symmetrical (within reason). If it increases at all in any direction, then you are **not** directly above the BMM®, so keep looking. This procedure should be carried out for each BMM®.

4.6 Sample Field Shapes

The diagrams below are representations of the signal strength (z-axis) measured on a horizontal surface above a BMM®, where the BMM® is directly below the peak in each case. Three sample shapes are provided for discussion.

- When a BMM® is relatively close to the surface, the signal will be strong (top-left). There is no mistaking this signal when it is encountered and the peak can be determined very accurately (in the order of centimetres).
- The shape of the signal gets broader (flatter) as the depth of the BMM® increases (bottom-left) such that the signal changes less as the detector moves, i.e. have to move it further to see a significant change in the signal. These can be more challenging to locate and less accurate.
- The shape on the right occurs when the BMM is less than about 5 m below the surface and the detector is on a reasonably high range. It is easy to mistake the low "phantom peak" for the real one and it is important for new users to be able to know when they on the "phantom peak" rather than the real peak because it can waste a lot of time and potentially mark the BMM® in the wrong location. With experience, it is relatively easy to identify this scenario but will catch inexperienced operators, particularly if the muckpile is steep and/or rough. The "phantom peak" is characterised by the following features:
    - It is not symmetrical. As you move towards the centre, it decreases faster than it increases.
    - The signal strength is several orders of magnitude less than the real one, i.e. a couple of ranges higher on the detector.
    - It drops to a null (background noise only) between the peaks.
    - The signal rises very quickly from the null point.
    - While standing at the phantom peak, if you rotate the *Detector* to validate the location (Section 4.5), the signal will rise for at least one direction.
    - The distance from the phantom peak to the base of the real peak is about 5 m so if in doubt, take another few steps in the original direction (the null is about one step away).

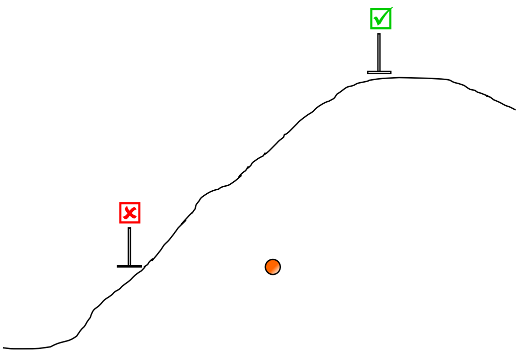


4.7 Procedures to Improve Efficiency

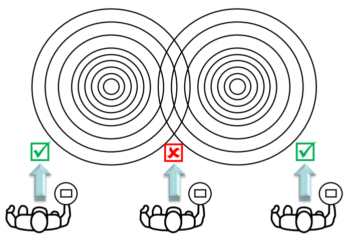
This section is aimed at the user that is comfortable with the basic techniques covered by the previous section of the manual. It summarises a few techniques that have been established from experienced users so that the BMM® detection process can be completed efficiently and maximise the benefits from using the *BMM® System*.

When arriving at the muckpile, take a moment to review the terrain with respect to the expected location of the BMM®s and plan an efficient search route. It is time well spent because it will minimise the time spent looking for the BMM®s. Below are some general guidelines.

- **Always traverse perpendicular straight lines** to minimise the detection time. Start by walking at a safe pace while periodically glancing at the signal strength or listening to the beeper, to check whether it is increasing. By following the simple procedure set out in section 4.2, two perpendicular lines are usually sufficient to get within 1-2 m of the BMM®. Now stand and sweep the *Detector* across one's body to pinpoint the BMM®.
- When working on slopes, start the search by walking along the slope at approximately constant elevation and the first maximum signal will determine where to begin going up or down the slope, which is slow due to the staircase technique (Section 4.2). If feasible, be above the BMM® (see diagram at right) because the signal can be unusual when at a similar elevation as the BMM®.



- Start searching for a new BMM® with the *Detector* set to a range that is to 2–3 ranges above what is expected to be the final range. For example, if the *Detector* was on range 7 when the BMM® was installed, then begin searching on range 9 or 10. Similarly, if the BMM® was installed close to the surface and the installation range was 2, then begin detection on range 5 or 6. Adjust with experience.
- If the same coloured BMM®s are close such that the signals are likely to overlap significantly, try and approach from the outside of the target BMM®.
- Start at an end of a blast pattern, especially for long, narrow blasts.



4.8 Common Mistakes by New Users

- When doing the initial walk looking for a signal, even though there is no signal evident, they frequently stop and move the *Detector* to each side or rotate the *Detector looking for a signal*. If you have just walked 10 m and seen no signal increase, then moving it a metre to the right is unlikely to help – keep walking.

- Walking in a random path searching for a signal. Always walk approximately straight lines.
- If the signal increases when the *Detector* is rotated, it does not necessarily point at the BMM®.
- When doing the final accurate location – within a metre:
    - Move the *Detector* across the body from side to side, not away from the body (you can't move it far enough).
    - Move the *Detector* in a straight line across the body, not an arc.
    - Keep feet firmly on the ground. If you take a step (or shuffle) to reach further, it is likely that your elevation of the detector will change.
    - Always turn your body 90° and stand firm, to scan the perpendicular direction. The objective is to scan a '+' not a '⊥'.

5 DEPTH CALIBRATION

5.1 Overview

The received signal strength decreases as the distance from the transmitter increases. This relationship is used to calculate the post-blast depth of the BMM® from the measured signal strength. The measured signal strength will be affected primarily by:

- *Detector*
- Transmitter
- Rock type — the difference between rock types at a site is usually relatively small except if there are iron-rich minerals.
- Electromagnetic interference – normally not a problem on the blast (see Section 3.2).

A depth calibration should be conducted for each site to provide a site-specific relationship and then repeated if any of the above items change significantly. BMT will notify users if equipment changes require a new calibration.

5.2 Procedure

While it is possible to do this with one person, it is much more efficient with two – one to hold the measuring tape and the second to use the *Detector*. The following procedure can be used as a guide.

a) Locate a suitable hole — ideally, at least as deep as the maximum depth that will be monitored (including swell).

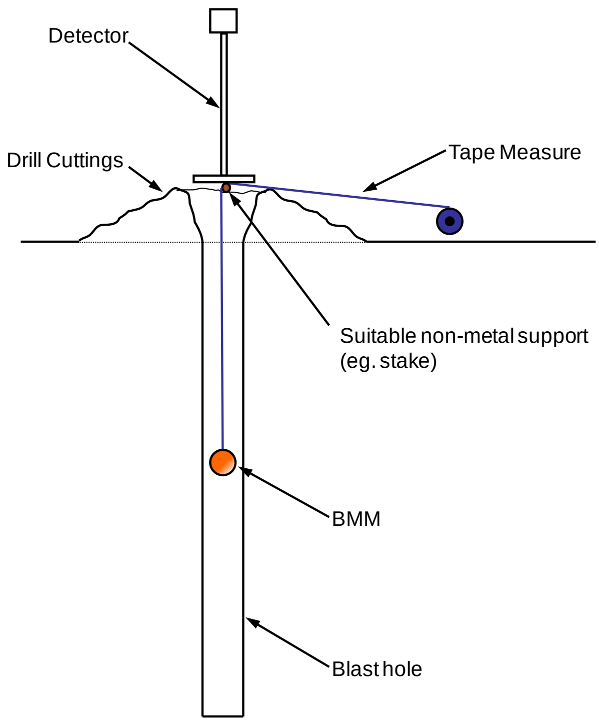
b) Place a non-metallic pole across the **centre** of the hole to form a stable reference point to take measurements, e.g. shovel handle or stake.

c) Attach the end of a measuring tape to a BMM®, e.g. self-tapping screw or tape.

d) Start the detector and on the Controller's home screen, select *Menu > Depth Calibration*.

e) Type the name, initial depth and increment into the relevant boxes and press *OK*. Suitable increments are 1 m for higher benches or 0.5 m for lower benches.

f) Lower the BMM® into the hole to the starting depth, typically 1 m.



g) Select *Store Reading* on the *Controller* to record data.

h) Lower BMM® by increment amount and record data. Repeat until the bottom of the hole.

ⓘ If there is no holes deep enough to cover the expected maximum, including heave, the depth can still be calculated, albeit with a very small decrease in the accuracy. The Depth Calculation algorithm can project beyond the measured calibration set or another, larger calibration set can be used.

5.3 Using the Data

The Depth Calibration data is used in the *BMM Explorer* software to calculate the post-blast depth of each BMM®. Refer to the software manual for more information.

6 POTENTIAL HAZARDS

Monitoring blast movement with the *BMM® System* can be conducted safely if the correct procedures are followed. Each operation is unique and a Job Safety Analysis (JSA/JSEA) should be conducted to establish safe operating procedures for **your** operation.

The following items can be used to guide this process:

- A blasted muckpile is likely to have unstable slopes, loose rocks of various sizes, uneven ground and cavities. There is a risk of personal injury due to falling, tripping and rock impact.

- ➾ Move slowly and look where you are going. It is <u>not</u> necessary to concentrate on the *Detector* screen while moving. While doing the initial pass across the muckpile, move at a safe pace while listening to the beeper and **periodically glancing** at the signal strength on the display, stopping to adjust the range as necessary, until you get close to the location of the BMM® and begin to 'pin-point' it. At this stage you should be standing still (or at least moving very slowly) so the hazard is managed. Using the BMM® *Detector* is no more hazardous than surveying or marking out ore polygons.
- ➾ Be aware of your surroundings at all times.
- ➾ Take care when working below potentially unstable rocks.
- ➾ Be careful stepping on rocks that may be unstable and roll under-foot — test it if in doubt.
- ➾ Maintain a safe distance from pit edges — it is better to lose a BMM® than lose your life!

- Always wear appropriate Personal Protective Equipment when installing or locating the BMM®s. Lace-up safety boots with good ankle support is especially important when walking on the post-blast muckpile. Drills or other noisy equipment will often be nearby so hearing protection may also be required.
- Follow the site procedures for accessing a blast pattern, especially if explosive loading has commenced.
- If the monitoring holes are backfilled manually, use correct shovelling technique to avoid back injury.
- View the blast from a safe location as directed by the blast controller.

<u>Using BMM®s Near Electric Detonators</u>

<u>Electric</u> detonators are potentially susceptible to initiation from radio frequency radiation so there are regulations to ensure their safe use. The measured output power of the BMM®'s transmitter is calculated to be approximately 0.003 watt or 3 mW (EIRP). They must be used in accordance with the relevant regulations in the jurisdiction where they are being used. For example, according to Australian Standard, *AS 2187.2--2006, "Explosives--Storage and Use, Part 2: Use of Explosives"*, the safe distance to maintain between a BMM® and an <u>electric</u> detonator is **<u>20 m</u>** (see relevant table below).

Note: This does not include <u>electronic</u> detonators since they are intrinsically safe from electro-magnetic fields.

TABLE 11

SINGLE SOURCE SAFE DISTANCES FOR ELECTRIC DETONATORS SUBJECT TO RADIO FREQUENCY RADIATION (See Note 1)

Description of equipment	Frequency range	Maximum transmitted power	Safe distance (see Note 3) m
Radar	>5 GHz	100 kW peak	500
Radar	1 to 5 GHz	6 MW peak 50 kW continuous work	800
Radar	0.2 to 1 GHz	6 MW peak 50 kW continuous work	1500
SHF: radio relay	≥3 GHz	20 W	80
VHF: radio relay	0.3 to 3 GHz	20 W	150
UHF: fixed installation: broadcast	≥ 0.3 GHz	5 MW	600
UHF: movable (see Notes)	≥ 0.3 GHz	50 kW	150
VHF: fixed, broadcast	30 to 300 MHz	50 kW	900
VHF: movable	30 to 300 MHz	5 kW	150
HF: broadcast	3 to 30 MHz	500 kW	1000
MF: broadcast	0.3 to 3 MHz	500 kW	1000
LF: broadcast	30 to 300 kHz	500 kW	500
VLF: broadcast	<30 kHz	200 kW	100
Mobile radio (see Note 7)	Any frequency	100 to 500 W	40
Mobile radio (see Note 7)	Any frequency	10 to 100 W	20
Mobile radio (see Note 7)	Any frequency	<10 W	20
Mobile phones	800 to 2100 MHz	0.125 to 2 W	20
Microwave ovens or high-frequency ovens (providing there is no significant r.f. leakage)			No hazard outside the equipment
Civil aircraft equipment. All types at maximum permitted power.			50

NOTES:

1 Table 11 sets out recommendations for safe distances for blasting from electromagnetic radiation when electric detonators are being used to detonate explosive charges. These distances may not apply under desert and marine conditions, where special shotfiring methods adopted may give rise to worse hazard. If two or more significant field sources are superimposed at the firing site a safety assessment should be carried out.

2 If there are two or more significant transmitting sites radiating powers in excess of 50 kW, each within 3000 m (see also Note 3 of the firing site, then a detailed site assessment should be undertaken.

3 The tabled distances do not necessarily apply to transmitters utilizing 'troposcatter'.

4 The distances apply directly in the case of standard commercial detonators with leads unwound or partially unwound during normal handling and when connected into firing circuits. The distances are from the transmitter to the nearest point of the proposed firing circuit.

5 This Table may require amendment as further information on radiation sources becomes available.

6 'Movable' implies vehicle-borne equipment, which requires erection of a portable aerial for operation.

7 'Mobile' implies capable of operation whilst vehicle is moving (seagoing vessel radios should not be assumed 'mobile' in this context).

All BMM®s comply with part 15 of the FCC rules. Operation is subject to the following two conditions: (1) These devices may not cause harmful interference, and (2) These devices must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

DISCLAIMER

Every effort has been made to ensure the procedures set out in this manual will ensure the best possible results from the Blast Movement Monitoring System. However *Blast Movement Technologies* makes no guarantee that all BMM®s will be located after a blast because this is influenced by many factors beyond our control.

Please read all relevant operating manuals prior to using the *BMM® System*.

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