MAXAM

Beyond Performance

RIOTRONIC X+ SYSTEM

User manual

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Version 1.1

Disclaimer:

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1. Safety

The RIOTRONIC X+ system consists of several components (Detonator, Logger, Remote, Blaster, Bus-line, Replacement connectors, Software, etc.) that will be accurately described in the following chapters.

The system is not only the respective hardware but the knowledge and way of working with it, both in blast design and in blast operation. That is why training is a crucial part in the use of the system. Every user must be properly trained and certified in its use. That includes the use of the equipment and the general safety rules of the blasting activity.

Some safety remarks that must be considered at any time are:

- RIOTRONIC X+ electronic detonators and the parts of the system are different than standard electric detonators. Therefore, it is not allowed to mix them together, or use electric blasting machines or testers with RIOTRONIC X+ electronic detonators, or RIOTRONIC X+ Blasters or RIOTRONIC X+ Loggers with electric detonators. The results of those actions will result in failure in the blast.
- Each electronic system is different, so it is not allowed to mix detonators and devices from different manufacturers or versions of the same systems.
- Follow standard blasting safety rules in the use of electronic initiation systems, in addition to the specific safety rules of the system.
- Never attempt to repair or manipulate system equipment and avoid using manipulated or failed equipment if it is detected.
- Respect the system limits in terms of the maximum number of RIOTRONIC X+ detonators per blast, per RIOTRONIC X+ Blaster and per RIOTRONIC X+ Logger.
- Follow the manufacturer´s instructions of use, and always use original bus-line and connectors to avoid system failures.
- Always start with an appropriate risk assessment of the blast.
- Always use approved devices and hardware when using RIOTRONIC X+ electronic detonators.
- Never connect a RIOTRONIC X+ detonator to any energy supply other than the RIOTRONIC X+ Logger and Blaster.
- Never connect conventional electric detonators and RIOTRONIC X+ detonators to the same circuit.
- Never connect conventional electric detonators to a RIOTRONIC X+ Logger or Blaster.
- Never use the RIOTRONIC X+ firing system unless you have been properly trained for its use.

- This equipment is not suitable for use in locations where children are likely to be present
- The battery cannot be replaced by the user. Please contact the RIOTRONIC technical team in case of issues
- The Remote, Blaster & Logger content licence-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's licence-exempt RSS(s). Operation is subject to the following two conditions: (1) These devices may not cause interference; (2) These devices must accept any interference, including interference that may cause undesired operation of the device.
- The Remote, Blaster & Logger 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 must accept any interference received, including interference that may cause undesired operation

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2. Introduction

The RIOTRONIC X+ system is a blasting system for electronic detonators comprised of the following:

• RIOTRONIC X+ Electronic detonator	• RIOTRONIC X+ Blaster
• RIOTRONIC X+ Logger	• RIOTRONIC X+ Remote
• Bus Line	• RIOTRONIC Blast design software

Figure 1. RIOTRONIC X+ System

The RIOTRONIC X+ system uses proprietary bi-directional communication between the RIOTRONIC X+ detonators and the RIOTRONIC X+ Blaster and the RIOTRONIC X+ Logger.

This type of communication between the RIOTRONIC X+ detonators and the units:

- Allows each RIOTRONIC X+ detonator to be programmed with a unique delay.
- Ensures that tests can be executed at the shot and from the firing station.
- Controls the energy of each RIOTRONIC X+ detonator up to the moment of firing.
- Reports any anomaly to the operator, identifying the type of problem and the RIOTRONIC X+ detonator involved
- Prevents initiation unless commanded by a RIOTRONIC X+ Blaster.

This technology makes it possible to control the precision of the firing sequence and allows overall supervision of a correctly implemented safety procedure for blasting.

2.1. RIOTRONIC X+ Detonator

The RIOTRONIC X+ detonator is an electronic detonator and it is the main part of the system. It consists of a connector, cable and an electronic detonator (Figure 2).

Figure 2. RIOTRONIC X+ Detonator

The RIOTRONIC X+ detonator´s main functions are:

- Receiving, analyzing and executing commands from the RIOTRONIC X+ Logger and Blaster.
- Carrying out a self-diagnosis when commanded by the RIOTRONIC X+ Logger or Blaster.
- Storing enough energy to remain self-sufficient during the firing phase.
- Storing the energy required to initiate the firing element at the programmed delay time.
- Generating the electrical impulse to initiate the firing element at the programmed delay time.
- Continuously analyzing its environment and carrying out safety procedures if necessary (e.g. if communication between the RIOTRONIC X+ Blaster and a RIOTRONIC X+ detonator is lost).

2.1.1. Detonator Technical Specifications

Parameter	Value
Water tightness	20 bars for 30 days
Operating Temperature	-30°C to +55°C
Storage Temperature	-40°C to +70°C
Detonator Strength	#8 cap strength
Tensile Strength	> 300N (67 Lbs)
Shelf Life	2 years (renewable depending on storage conditions)
Timing	Fully programmable from 0 to 14 000 ms with increment steps of 0,5 ms
ESD Resistance	Compliant to EN 13763-13 (25 KV)
EMC Resistance	Compliant to EN 13763-27
Traceability	Unique ID number
Wire	Copper clad steel core and High Abrasion Resistance Polyamide insulation

2.1.2. Label

The water-resistant label includes information regarding length, lot number, a unique traceable data matrix and the unique ID of the detonator (Figure 3).

Figure 3. RIOTRONIC X+ Detonator Label

2.1.3. Connector

The system uses a robust and glove friendly connector for extra reliability and effectiveness. The mechanical hinge allows it to be used over an extended temperature range (Figure 4).

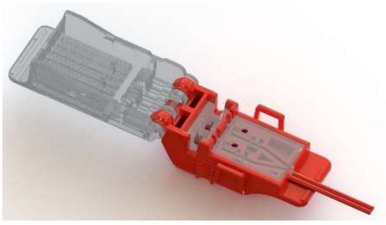


Figure 4. Connector

Always use a RIOTRONIC X+ bus line to connect several RIOTRONIC X+ detonators. If two or more rows needed to be connected to each other, use the corresponding replacement connectors. Put the cable in a flat position inside the connector and close it completely (Figure 5).

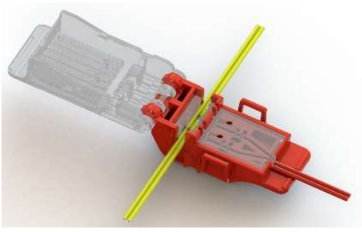


Figure 5. Bus line location inside the connector

The lid of the connectors has two positions when it is closed. When the RIOTRONIC X+ detonator is connected to the line the lid should be closed completely, until the second click is heard. It is recommended that the lid is only closed until the first click is heard while a bus line is not being used (both positions can be seen in figure 6). This will facilitate the opening of the connector later while still protecting it against dust and rocks.

Figure 6. Completely Closed and half-closed connectors

2.2. RIOTRONIC X+ Accessories

2.2.1. Safety key

The Safety key (RFID card, in Figure 7) is used to authenticate the operator of the RIOTRONIC X+ Blaster. RFID tag must be tapped on NFC antenna. Unique serial number from card is stored in Blaster's memory and Blaster's serial number is written in card's memory. Blaster is equipped with NFC communication antenna. NFC is used to communicate with Logger and read RFID card to blast authorization. NFC antenna is placed at the left side of front panel, just above the CHARGE key.

Figure 7. Safety key (RFID card)

2.2.2. Bus-line

The bus line (Figure 8) is used to connect separate RIOTRONIC X+ detonators as a network. Additionally, the RIOTRONIC X+ Logger can be used to program RIOTRONIC X+ detonators using this line and the RIOTRONIC X+ Blaster needs this line to charge and fire the detonators.

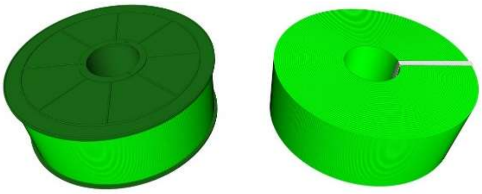


Figure 8. Bus line (With and without reel)

2.2.3. Charger

This equipment is used to charge the RIOTRONIC X+ Blaster (Figure 9).

Figure 9. RIOTRONIC X+ Blaster Charger

2.2.4. Replacement connector

If the bus-line or a RIOTRONIC X+ detonator wire is broken, use a replacement connector (Figure 10.) to reconnect the broken lines.

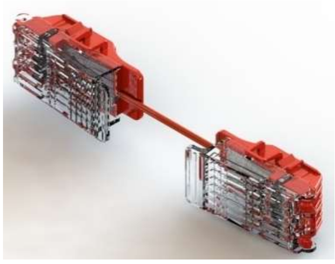


Figure 10. Replacement connector

2.2.5. Equipment-PC USB cable

It is used to transfer data between RIOTRONIC X+ Logger to a computer (Figure 11)

Figure 11. USB cable

2.3. RIOTRONIC SW software

RIOTRONIC SW is the Blast Design and Simulation software for RIOTRONIC electronic detonators developed by TAP (Technical Application Department of MAXAM Civil Explosives).

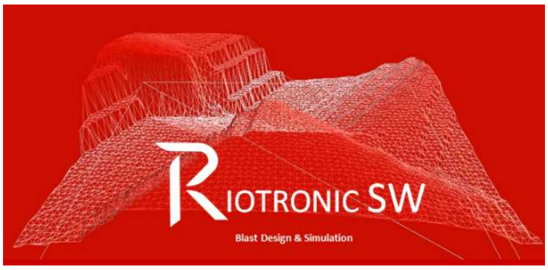


Figure 12. RIOTRONIC Software

RIOTRONIC SW is a 2D and 3D blast design and simulation software useful for surface blasting applications and for tunnelling blasting. It is composed of diverse modules that will help users in the task of designing a quality shot. This is aimed to attend MAXAM blasting activities and projects around the world with a compromise to provide tools and technology under the standard of TAP (Technical Applications).

3. Operation Procedure

When using RIOTRONIC X+ to carry out a blasting plan, the procedure of the operation is different compared to a conventional one. In this chapter, a general description of the whole operation in the application of the RIOTRONIC X+ system can be found.

3.1. General procedure for a blast using RIOTRONIC X+

The procedure described below provides a general idea about the steps and information that a RIOTRONIC X+ blast needs. Each part has a series of tasks that must be fulfilled.

3.1.1. Defining a blast plan

- Number of holes and number of RIOTRONIC X+ detonators.
- Timing of each detonator/borehole.
- Assignation of boreholes to each RIOTRONIC X+ Logger.
- Connection order or connection path.

3.1.2. Covering Risk Assessment

- Number of people and their function.
- Distance to the firing point.

3.1.3. Preparing the Equipment

Consider the following aspects regarding the equipment:

- Charge the batteries.
- Check the security key.
- Configure the RIOTRONIC X+ Loggers with the desired configuration:
  - Name of the blast.
  - Connection method.
  - Programming method.
- Configure the RIOTRONIC X+ Blaster.

3.1.4. Product distribution

- Distribute the corresponding number of RIOTRONIC X+ detonators per hole.
- Avoid impacts, friction, exposure to heat, naked light, electromagnetic radiation (including mobile phones), electrostatic charges.

- The boosters and RIOTRONIC X+ detonators must be separate from each other. Make sure they do not drop into the hole.

3.1.5. Priming, loading and stemming the hole

- Prime the holes using the wooden cylinder provided by MAXAM to uncoil the cable. Avoid twisting the line.
- Load and stem the holes avoiding friction between the cables and the collar of the borehole; using a protective tool if necessary.
- Keep the connectors closed to avoid moisture inside.
- Assure the cable in the collar of the hole.

3.1.6. Programming and connecting

- Choose the corresponding connection method:
  - In “Line mode”, connect the RIOTRONIC X+ detonator to the line and assign the corresponding time.
  - In “One-by-one” mode, connect each RIOTRONIC X+ detonator to the pins of the RIOTRONIC X+ Logger and assign the corresponding time.
- Wait for the message “Detonator Programmed” to go to the next one.
- Take note of the number of detonators in the blast plan in order to easily check any errors.
- It is recommended to write down the letter and number that are assigned to each detonator on the Logger. This will make it easier to identify detonators on the blast plan and their actual holes on the field.

3.1.7.Testing lines, detonators and connections

- Make sure to always use the RIOTRONIC X+ cable and the RIOTRONIC X+ bus wire in the connections.
- If a cable or a detonator is damaged out of the collar of the hole, use the replacement connectors to reconnect the broken lines.
- Proceed to test the lines, detonators and connections using the RIOTRONIC X+ Logger.
- Check the cables first, looking for short-circuits or open circuits.
- Measure the leakage using the RIOTRONIC X+ Logger.
- Use the RIOTRONIC X+ Logger to check the detonators for possible errors such as:
  - Unconnected detonators.
  - Unprogrammed detonators.
  - Faulty detonators.

3.1.8. Firing the blast

- Before firing the blast, recheck it (leakage, connected and missing detonators…) using the RIOTRONIC X+ Logger. If an error is found on these tests **do not** begin the blast procedure. Stop and solve the error first.
- **NEVER** use the Blaster to check the blast near the blast area. Use the Logger instead.
- Be sure that the blast area has been cleared and secured.
- Locate the firing point in a safe area and use a shelter or protection.
- Consider wind direction to avoid fumes from the blast.
- Proceed with the firing procedure:
    - Secure the firing line in order to avoid the RIOTRONIC X+ Blaster being dragged by the blast-generated movement.
    - Check the blast using the RIOTRONIC X+ Logger.
    - Get the security key.
    - Connect the RIOTRONIC X+ Blaster to the RIOTRONIC X+ Logger and download the data. If more than one RIOTRONIC X+ Logger has been used while programming, download data from each one.
    - Proceed with checking and charging.
    - Once the charging operation has been completed, make sure the area is clear and fire.
    - Wait inside the protection for at least one minute to avoid fly rock. Do not enter the blast area for at least five minutes after the blast.

3.1.9. Post blast inspection and solving cut-offs/misfires

- Make sure that fumes have disappeared.
- Check whether cut-offs or misfires have happened.
- If there are no irregular situations give the “All clear” order.
- If not, proceed with the misfire remediation procedure.
- In any case, always wait for at least FIVE minutes to step into the blast area after the blast.

3.1.10. Blast history/record download

- Download the blast history from both the RIOTRONIC X+ Logger(s) and the RIOTRONIC X+ Blaster(s).
- Keep them with the corresponding blast report.

3.2. Operating procedure

3.2.1. Blasting plan

It is important to use a blast plan, as this will ensure that all detonators will be correctly assigned their corresponding delay. This can prevent excessive ground vibration, poor fragmentation and fly rock caused by detonators detonating out of sequence.

RIOTRONIC SW is the Blast Design and Simulation software for MAXAM electronic detonators. It is composed of modules that will help in the design of a good shot.

It is essential to obtain blast site data before designing a blasting plan.

First, it is necessary to use 2D or 3D laser profiling to get bench profile data, which can be used as input to the RIOTRONIC SW, and then generate a bench in the software. Furthermore, it is needed to obtain the rock mass characterization, which can be used to predict fragmentation.

After gathering all the information that is needed, make a blast plan (Figure 13).

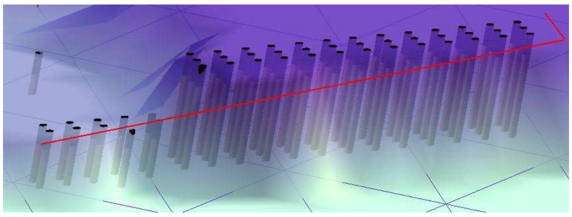


Figure 13. Blast design

Print this plan to provide the Drill and Blast Engineer the necessary information and timing of the blast holes.

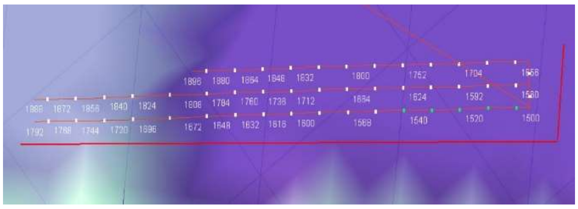


Figure 14. Delay plan

If it is needed, adjust burden and spacing to meet the fragmentation needs and control the vibration level by adjusting the delay time and MIC. Those should be done before carrying out the blast plan.

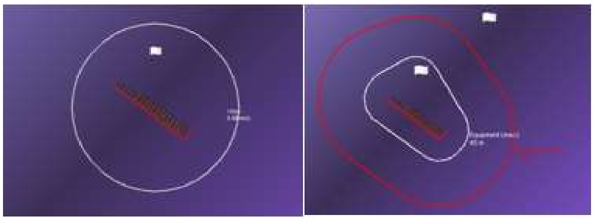


Figure 15. PPV and clearance prediction

Defining a clearance zone is also needed for safety consideration.

3.2.2. Detonator testing

Every RIOTRONIC X+ detonator should be tested before being used. The RIOTRONIC X+ detonator should be attached directly to the RIOTRONIC X+ Logger (Figure 16) before the testing option is chosen. If it is not done like this, the user will get a "no response" error screen.

Figure 16. Connection between a RIOTRONIC+ detonator and RIOTRONIC X+ Logger

Test one det is to perform self-testing procedure in single detonator. One detonator only should be connected before initiating this test.

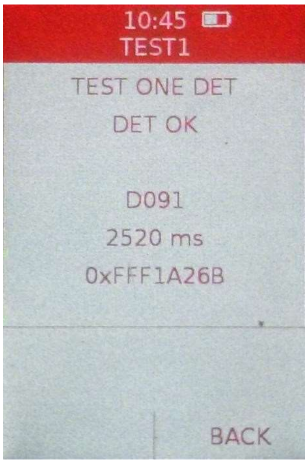


Figure 17. Test one det results

The result screen shows detonator's ID, delay time and sequence number actually stored in detonator's memory and self-test result (OK or not OK).

If detonator is OK, then BACK or F2 key leads to main menu. If there is any error, BACK or F2 key starts another test. MENU leads to main menu and CANCEL leads to programming. Once all RIOTRONIC X+ detonators have been checked, distribute them in the blast. Connectors should be closed after testing to avoid any damage caused by mud. There are more options in the test menu. They will be covered in Riotronic X+ Logger – user manual.

3.2.3. Risk assessment

A risk assessment of the whole blast operation should be performed as a first step, analyzing risks and making sure the operators have been appropriately tasked.

Risk Assessment at a broad operational level, and more specifically focusing on the management of blasting and explosives, provide guidance for dealing with the hazards and potential consequences of undesired outcomes and impacts. Specific risk assessments must also be carried out, identifying the hazards that could be presented by an individual shot, and the controls required at each stage of the blasting process. Operational risk assessments should also be conducted on a daily or shift change basis as relevant. Again, these exercises must be conducted by a representative group of stakeholders.

The main areas to consider include:

(a) Planning and design – Identifying the hazards and controls associated with specific blast types and ground conditions, and the potential impacts on subsequent mining activities, wall stability, environmental impact, downstream processing etc.;
(b) Bench preparation and demarcation – Identifying the hazards and controls associated with equipment and personnel working within the blast area, including broken ground, cavities, vehicle rollover, unsafe high-walls/low-walls, adverse slope and crest conditions, unauthorised access, water management and interaction with other mining processes;
(c) Priming, charging and stemming blastholes – Avoiding hazards associated with the snap/slap/shoot of signal tube downlines, unplanned detonation in elevated temperature and/or reactive ground, and flyrock/overpressure associated with overloaded or under-burdened holes;
(d) Blast clearance & shotfiring – Ensuring adequate blast clearance and controls are in place to prevent unauthorised access into the blast exclusion zone while blasting is in progress and until after the 'all clear' has been given. Identifying where post-blast

inspection of any critical areas is required, such as unstable wall conditions and misfires, and where physical barriers need to be established after the blast.

In some cases, additional risk assessments will be required for specific high risk processes, such as blasting in elevated temperature and/or reactive ground areas, blasting in areas with a known history of generating post-blast fume, working in areas with cracked and/or unstable ground conditions, working under steep walls or slopes, or working in areas with noxious gases such as carbon monoxide and nitrogen oxides, either on the bench or during re-entry after the blast. Consideration should also be given to any old underground workings in the vicinity.

While the above risk assessment stages are not all directly associated with on-bench blasting activities, the various hazards and controls must be understood by personnel working on-bench to ensure that potential consequences are understood for the complete process.

Operational or specific risk assessments of on-bench activities are best carried out at the work area, prior to the commencement of work (e.g. SLAM, Take5, JSA, etc.). When a formal risk assessment is carried out it must be approved in accordance with the relevant safety management systems and accepted and signed by all of the relevant parties involved in that blasting process prior to work being undertaken. (source: Code of Practice ON-BENCH PRACTICES FOR OPEN CUT MINES AND QUARRIES Edition 3 June 2019).

3.2.4. Priming

Traditionally, priming was done in two steps according to the following procedure: punching the detonator into an explosive cartridge or putting it in a booster and downloading the primer.

Special care must be taken to avoid any risk of damaging or breaking the cable. If any hole is cased with a PVC pipe, be aware of sharp edges that could damage the cables.

The following are general recommendations regarding priming. They do not take precedence over specific Work Procedures.

3.2.5. Reels

The bracket system is used to hold the connector during the priming. Leave the cables from the holes rather free, at least 1 m, avoiding strain that can generate breakages and, therefore, failures (Figure 18).

The reel has an integrated bracket for the connector and offers a quick release system for the RIOTRONIC X+ detonator. Use the wooden cylinder included with the reels for rapid uncoiling.

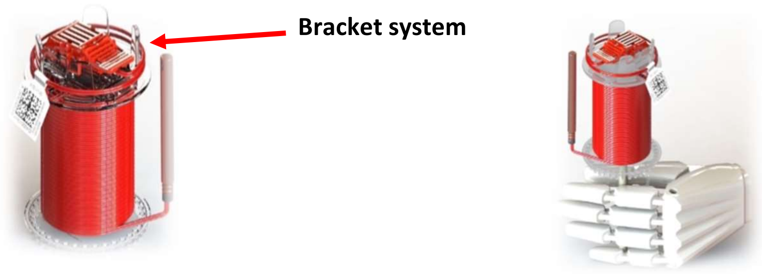


Figure 18. Bracket system

3.2.6. Packaged Explosives

Proceed as follows:

- Take the RIOTRONIC X+ detonator out of the coil drawing out about one meter of cable downline.
- If necessary, make a puncture in the cartridge using a non-ferrous spike.
- Push the RIOTRONIC X+ detonator into the cartridge so that the detonator stays centered in the explosive.
- When lowering the base charge, secure the downline around the cartridge with a half knot or plastic tape.

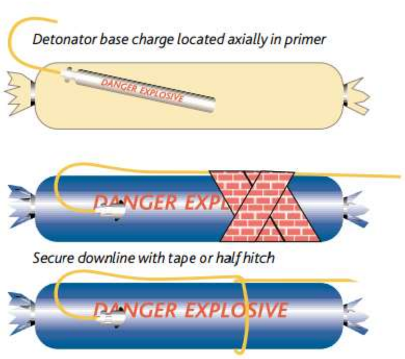


Figure 19. Priming with packaged explosives

3.2.7. Cast Booster

Proceed as follows:

- Take the RIOTRONIC X+ detonator out of the coil drawing out about one meter of downline.
- Insert the RIOTRONIC X+ detonator into its internal hole and draw it out the other side.

- Insert the RIOTRONIC X+ detonator fully into the stepped hole making sure the base charge does not protrude.
- Assure that detonators are secured in the booster. Use tape to secure them if necessary.
- For boosters with more than three holes, the hole with the RIOTRONIC X+ detonator should be the stepped one with a diameter a little greater than the detonator itself.

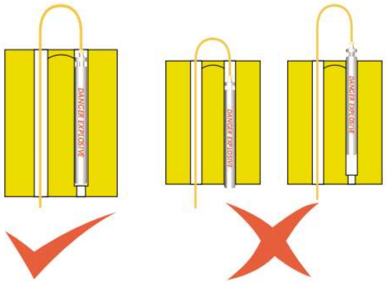


Figure 20. priming with Cast Booster

Find a stone of suitable size, bigger than the blast hole (Figure 21). Carefully wrap the down-line around it once. Place the stone with the down-line about half a meter from the collar of the hole. This procedure is done in order to avoid the possibility of the down-line being lost down an unloaded hole.

Figure 21. Line wrapped around a stone

3.2.8. Loading

The loading of explosives should be performed according to the blast plan data and following a standard blast procedure. Special care should be taken to mitigate damage to the cables.

3.2.9. Stemming

Engineers should perform an additional Leakage test of the RIOTRONIC X+ detonators, both before and after the stemming process, to check if some of the cables were damaged.

Figure 22. Connection of the Bus line to the RIOTRONIC X+ Logger

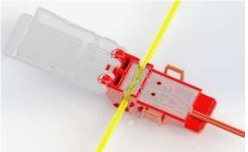


Figure 23. Twisted line inside the connector

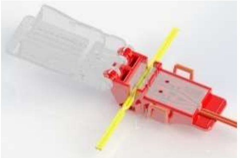


Figure 24. Twisted line before and after the connector

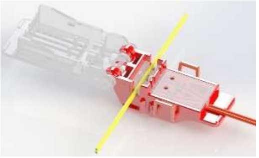


Figure 25. Bus line tilted causing a short circuit

3.2.10. Precautions during operation

- All personal involved in the operation must to wear all the protective equipment required for the task in accordance with the company and site requirements.
- Appropriate training package(s) for using the specific explosive systems deployed at the site, such as electric or signal tube delay detonators, detonating cord, electronic initiation systems, presplit products etc.

4. Best Practices

4.1. Before you proceed to the blast site, make sure that

- The equipment is fully charged and complete.
- The equipment is OK. Run self-test.
- The blast design is prepared, and a printout is available to use on site (waterproof paper, if necessary). Record the position of the BUS LINE wire on the blast plan and ensure logging track is logical.

The following check list is recommended to maximize safety during the operation:

- Charge the **batteries** of the equipment.
- Check the **security key (**RFID card**)** and the **communication cable**.
- Keep the Blaster **separated**.
- Configure the Logger with the desired **parameters**:
    - Name of the blast
    - Connection method
    - Programming method
- Configure the Blaster.
- Distribute the corresponding **number of detonators** per hole.

- The booster and the detonators have to be **kept apart** from each other. Make sure they cannot be **dropped** into the hole.
- Follow **general and specific rules** about the use of detonators and explosives.
- Only **trained personnel** should carry out these tasks.

While Priming, loading and stemming:

- Place the electronic detonator **inside** the booster/cartridge.
- Using a pole or another device, place the **primer in the hole**.
- Uncoil the cable making sure it is **not twisted** during the process. Also make sure the cable does not rub the collar or the wall of the hole during the priming process.
- **Loading-** For both packaged or bulk explosives, **avoid rubbing the cable**.
- **Stemming- Protect the cable** with a tool against sharp objects that could damage it.
- Keep the **connectors closed** to avoid moisture inside.
- Assure the cable in the **collar** of the hole.

REMEMBER Keep blaster/loggers OFF when not in use.

4.2. During logging

- Check the delay times against the blast plan frequently. If a wrong delay has been assigned or if there is any uncertainty, always check it and correct it immediately.
- Record the logging sequence on the blast plan.
- Any exception to the blast plan (i.e. hole blocked, detonator missing) should be recorded on the plan.

4.3. After logging

- Check the blast design against the logging list.
- Run DETONATORS TESTS.
- Run LEAKAGE.

Remember:

- Bus line must to have its ends isolated to prevent short cuts.
- Always use replacement connectors when necessary to joint between different branches to the main line or to substitute damaged connector in electronic detonators.
- Avoid RF sources nearby.

- Avoid electrostatic charges by wearing appropriate safety footwear able to discharge before handling electronic detonators.

5. System limits for the RIOTRONIC X+ Logger

The maximum quantity of detonators the Logger can test at a time is 500 per blasting plan, regardless of the length of the RIOTRONIC X+ detonator, as long as less than 1000 meters of BUS LINE are being used. In order to test 500 detonators at the same time they must all be part of the same blasting plan.

5.1. Positioning of RIOTRONIC X+ Loggers

Always position the RIOTRONIC X+ Logger near the RIOTRONIC X+ detonators which have been assigned the longest delay times. This ensures that the capacitors on these detonators, which need the highest voltage, are supplied with the maximum voltage.

The voltage drop to the end of the BUS LINE can be reduced by positioning the RIOTRONIC X+ Logger in the middle of the BUS LINE.

5.2. Connect – Reconnect the RIOTRONIC X+ Logger to the BUS LINE

If the RIOTRONIC X+ Logger is connected or reconnected to the BUS LINE, it must always be on the level of the main menu.

Once the RIOTRONIC X+ Logger is connected to the BUS LINE, it is recommended to run these tests:

- DETONATORS PROG
- LIST / EDIT DETS
- TEST LINE
- OHM
- TEST 1 DET
- LEAKAGE

5.3. Extension of BUS LINE wire

It is recommended to run **TEST LINE** after an extension of the BUS LINE wire and before the logging operation is continued to make sure the connection is good, and, therefore, the communication with the existing RIOTRONIC X+ detonators is still reliable.

Additionally, a **measurement of the current leakage** on the BUS LINE is recommended. Use the RIOTRONIC X+ Logger to do so. This way the operator is always aware of any restrictions on the length of BUS LINE, due to any leakage on the system.

5.4. System limits for the RIOTRONIC X+ Blaster

A single RIOTRONIC X+ Blaster can communicate and initiate a maximum of 500 RIOTRONIC X+ detonators. A network can be set up to increase that number of detonators to 2500. This network would consist of a master Blaster controlling 5 slave Blasters.

For any shot requiring more than 2500 RIOTRONIC X+ detonators, please contact TAP or your agent.

5.5. General planning for connection

Cross talk between BUS LINE circuits is only possible if the BUS LINE of different circuits is run in parallel and in proximity (less than one centimeter) over a long distance. To avoid cross talk between the BUS LINE of different RIOTRONIC X+ Logger circuits, each RIOTRONIC X+ Logger circuit must **always** be run separately. A distance of a few centimeters is enough to avoid cross talk between different circuits.

In quarrying or open cut operations, this is usually not a problem. In underground mining operations or tunneling, where the environment is much more confined, special efforts must be made to comply with this rule.

Therefore, follow these rules:

- Never run the RIOTRONIC X+ Logger circuits in parallel and near each other.
- Never put the RIOTRONIC X+ Logger and BUS LINE circuits in a bunch, wrapping them around pins in the side wall.
- Never run several RIOTRONIC X+ Logger circuits through a telephone or multi pair conductor cable.
- Always put the RIOTRONIC X+ Loggers in a safe place away from the blast. Ensure that the BUS LINE wire is not under tension.

5.6. Before shot

Always make sure all mine personnel is safe and the site is cleared before the RIOTRONIC X+ Blaster is connected to the bus line and the programming sequence is initiated.

In case the blast must be aborted either during or after programming the RIOTRONIC X+ detonators, **always** wait for at least FIFTEEN minutes before returning to the blast site.

5.7. Conditions for setting up a shot

Depending on special conditions (nature of the rock, presence of water in rock mass, drilling conditions, installation of charges ...), the operator may have to take extra precautions.

These conditions may include, for example:

- Abrasive rocks like quartzite, granite, gneiss, basalt, etc.
- The presence of water in general.
- Holes deeper than 20m.
- A sharp angle on the drill-holes (>15°).
- Collar pipe in the holes, especially when the collar pipe is removed before firing.
- Drill-holes which include large holes, pockets of earth and any other irregularities likely to make loading difficult and cause stress on the wires.
- Decked charges.

These conditions may lead to:

- Damage to the RIOTRONIC X+ detonator wires.
- Damage to the bus-line.
- Damage to the RIOTRONIC X+ detonators due to high dynamic pressure.

Potential results could be:

- Lack of communication or communication errors between the RIOTRONIC X+ detonators and the RIOTRONIC X+ Logger or Blaster.
- Electric current leakage.
- Partial misfires.

5.8. Limiting the risk of wire damage

To limit the risk of damaging the RIOTRONIC X+ detonator wires during the preparation and installation of the priming cartridge:

- Place the RIOTRONIC X+ detonator in the lower third of the priming cartridge, making sure that the wire does not pull excessively on the crimping assembly of the RIOTRONIC X+ detonator.
- Miners' knots increase the diameter of the cartridge and lead to weak points being exposed to abrasion along the inner walls of the drill holes. The knots limit the amount of play needed to allow the cartridge to slide down the hole easily.
- Use electrical tape to ensure that the RIOTRONIC X+ detonator wire is properly connected to the cartridge and that the wire is protected for the entire length of the priming cartridge.
- Lower the cartridge down carefully, by slowly un-spooling the RIOTRONIC X+ detonator wire and avoiding free fall.

- Keep the wires relatively tight when loading, blocking them with a stone or pulling on them lightly by hand. Loops should not be allowed to form inside the hole.
- If a hose is used, it is imperative to be cautious while inserting and retracting it to protect the RIOTRONIC X+ detonator wire.
- Cartridges should be sized to ensure that RIOTRONIC X+ detonator wires are protected from the hole or casing walls. When the collar pipe is removed after charging, care must be taken to avoid the wire getting coiled around the casing.

5.9. Limiting the risk of damaging the bus-line

In order to limit damage to the bus-line, especially when the terrain is rough, the following measures should be considered:

- Avoid walking on the line.
- Prevent vehicles from driving over the line.

5.10. Limiting the risk of transient pressure

A transient pressure pulse from the detonation of adjacent holes or adjacent decks within the same hole can adversely affect un-detonated explosives and the RIOTRONIC X+ detonators by pre-compression and dynamic shock which can result in a partial or total failure.

This phenomenon may be encountered in the following situations:

- When firing underground due to small distances between drill-holes.
- When firing on the surface due to a small distance between the drill-holes or the decked charges.
- When water is present in the rock, since it does not get compressed under pressure and it is a good medium for the propagation of shock waves (shock waves attenuation is therefore limited).
- When there is a natural fracture in the rock or soft geology.

6. Riotronic X+ Logger – User manual

This documentation considers following devices: 043-006-001 Logger X+.

6.1. General information

Logger is a device used to programming and testing the detonators. It is able to read the detonator's ID# and verify the detonator's condition. It can program detonator's delay time according to blasting pattern. Logger can also interchange programmed blasting patterns with Blaster or PC. It has also built-in special features, like auto-test function, Ohmmeter or Ammeter.

Figure 26. Riotronic X+ Logger

CAUTION! The document contains content not intended for the end user. The final user should receive the manual in a trimmed version.

6.2. Device outlook

6.2.1. Keypad

Logger is equipped with membrane keypad at the front. Each key has selectively backlight and only active keys are lighted.

6.2.2. Display

Logger is equipped with 3,5" LCD colour display.

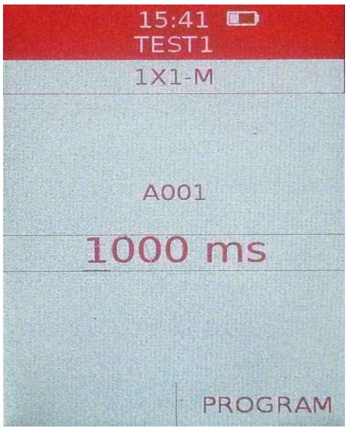


Figure 27. Display areas

Display is divided into three areas:

- Top bar area, where user can find information about time, battery status, NFC status and active pattern name,
- Main operation area, where are all information about currently performed operation, Function keys area, where current function of F1 and F2 keys is displayed.

6.2.3. Charging socket

Charging socket is placed at the bottom of Logger. It is used to connect the charger or external battery.

6.2.4. USB socket

USB socket is placed at the bottom of Logger. It is used to connect Logger to PC or Blaster.

Figure 28. Bottom view

6.2.5. Bus-line terminals

Bus-line terminals are placed at the top of Logger. They are used to connect the detonators directly or through the bus-line.

Figure 29. Top view

6.2.6. NFC antenna

Logger is equipped with NFC communication antenna. NFC is used to communicate with Blaster or read detonators RFID tags. NFC antenna is placed at the back of Logger's case. It is exact position is marked by the white rectangle.

Figure 30. Back view

6.2.7. Turning device on and off

To turn the device on press ON/OFF button and hold for about 3 seconds. Logger proceed with initial auto test. If PIN checking is enabled, enter PIN and press OK or F2 button. Logger starts with pattern list to pick the Active Pattern.

To turn the device off press ON/OFF button and then confirm with OK or F2 button. If ON/OFF button is pressed and held for longer than 3 second, Logger will be turned off without confirmation screen.

6.2.8. Active pattern

Active pattern is a pattern which Logger is working on. It is used to programming new detonators, for editing, listing and testing.

Choosing the active pattern is the first thing after turning the Logger on. It can be chosen from the list or user can create a new one. Selected pattern have to be confirmed with OK or F2 button.

To create a new pattern * NEW PATTERN * item should be chosen from the end of the list. The name of the new metric can be maximal 8 letters long. There can be up to 100 patterns stored in the Logger.

Active pattern name is shown in second line at the top of the display.

6.3. Programming detonators

Programming the detonators is the main function of the Logger. As soon as the active pattern is chosen, Logger goes to programming the next detonator.

Programming detonators can look different depending on chosen connection mode and delay mode.

Connection mode can be:

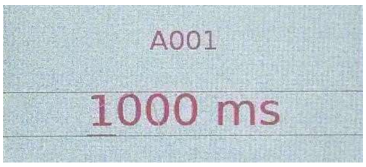
- One by one (1 x 1) – in this mode only one detonator can be connected to the Logger.
- Bus (||) – in this mode Logger is connected to the bus-line and every next detonator is connected to this bus together with all detonators connected previously.
- NFC (NFC) – in this mode detonator's ID is read from RFID tag.

Delay mode can be:

- Manual (M) – delay time for each detonator have to be entered manually.
- Incremental (++) – delay time for each detonator is suggested according to increments defined for pattern.
- No delay (#) – only detonator's ID is read, delay time have to set up later.
- PC (PC) – for patterns created by PC software delay time for each detonator is suggested according to pattern file.

Connection mode and delay mode can be changed in settings menu.

6.3.1. Manual mode



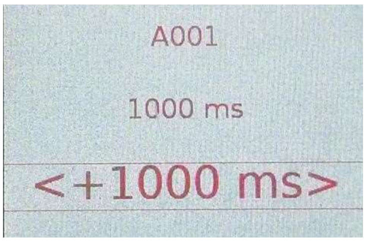
Detonator's number in pattern with logger's ID letter

Delay time

Figure 31. Manual programming screen

In manual programming mode there are two information on the screen: detonator's number and delay time. User can switch between them using up and down arrows. Delay time can be entered using numeric keys. Detonator's number can be entered with numeric keys or changed with left and right arrows. When Delay time is entered for specific detonator, OK or F2 button have to be pressed to program connected detonator.

6.3.2. Incremental mode



Detonator's number in pattern with logger's ID letter

Delay time

Delay time increment

Figure 32. Incremental programming screen

In incremental programming mode there are three information on the screen: detonator's number, delay time and delay increment. User can switch between them using up and down arrows. Increment can be changed used left and right arrows. Once user left the increment field, it disappears, and screen looks like in manual mode. When Delay time is set, OK or F2 button have to be pressed to program the connected detonator. When the detonator is programmed, time increment field is back for next detonator.

The number and value of increments can be set in settings menu.

6.3.3. No delay mode

Detonator's number in pattern with logger's ID letter

Figure 33. No delay programming screen

In no delay programming mode there is only detonator's number on the screen. and delay time. User can only press OK or F2 button to "program" connected detonator. In this mode only detonator's ID is read and stored with pattern. Delay time can be set later for whole pattern and massive programming can be performed.

6.3.4. PC mode

In PC programming mode there are two information on the screen: detonator's number and delay time. This mode is similar to manual mode, but the delay time for each detonator is suggested according to the pattern. User can change the delay time using numeric keys. OK or F2 button have to be pressed to program connected detonator.

6.4. Main menu

After pressing the MENU button, main menu is displayed on the screen. User can change item with up and down arrows and press OK or F2 to enter to next menu level. Pressing CANCEL leads back to detonators programming.

6.4.1. Test one det

Test one det is to perform self-testing procedure in single detonator. One detonator only should be connected before initiating this test.

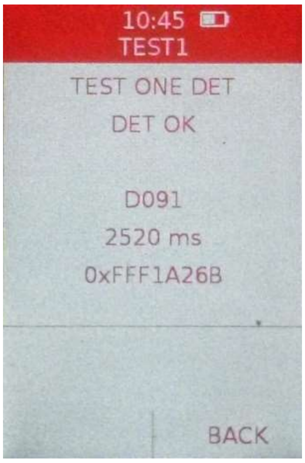


Figure 34. Test one det results

The result screen shows detonator's ID, delay time and sequence number actually stored in detonator's memory and self-test result (OK or not OK).

If detonator is OK, then BACK or F2 key leads to main menu. If there is any error, BACK or F2 key starts another test. MENU leads to main menu and CANCEL leads to programming.

6.4.2. Test range

Test range is to test connection with detonators in only part of pattern. Before test is initiated number of first and last detonator in the range need to be entered. Then OK or F2 initiate the test. In this test each detonator in the range is checked if it is connected and programmed for correct delay time. If programmed delay time is different from pattern, detonator is reprogrammed.

As the result, quantity of OK (including reprogrammed) detonators, missing (not connected to the Bus-line) detonators and error detonators (with wrong time, which cannot be reprogrammed) is displayed. If there are any missing or error detonators, detailed information can be displayed using up and down arrows and OK or F2 keys.

If there are no errors BACK and F2 buttons leads to main menu. In other case BACK key starts another test.

6.4.3. Test pattern

Test pattern is to test connection with detonators in the active pattern. Bus-line should be connected to the Logger before initiating this test. In this test each detonator in the range is checked if it is connected and programmed for correct delay time. If programmed delay time is different from pattern, detonator is reprogrammed. At the end, Logger is checking if there are any extra detonators connected to the Bus-line.

As the result, quantity of OK (including reprogrammed) detonators, missing (not connected to the bus-line) detonators, error detonators (with wrong time, which cannot be reprogrammed) and extra detonators is displayed. If there are any missing, error or extra detonators, detailed information can be displayed using up and down arrows and OK or F2 keys.

If there are no errors BACK and F2 buttons leads to main menu. In other case BACK key starts another test.

6.4.4. Test leakage

Test leakage is to measure the current consumed by bus-line with detonators. The result is displayed in mA.

6.4.5. Test resistance

Test resistance is to measure the resistance between line terminals. The result is displayed in kΩ.

6.4.6. List dets

List dets is to list all detonators in active pattern. To navigate in the list up, down, left and right arrow keys can be used. F2 key allows to check detailed information about each detonator. The detonator can be edited or deleted then.

6.4.7. Transfer data

Transfer data is to send or receive patterns to and from Blaster or another Logger.

6.4.8. Send

Pattern to send must be selected on the list and then confirmed with OK or F2 key. There is additional warning to confirm if:

- pattern wasn't tested or didn't passed all tests,
- pattern includes no delay detonators,
- not all detonators were programmed in pattern from PC.

Empty patterns are not listed to send.

Next step depends on medium chosen in transfer settings.

For USB there will be message to connect USB cable. In this moment USB cable should be connected to the Blaster. If Blaster waits for transmission transfer will be started immediately. Connecting USB cable earlier my cause entering to mass storage mode. Logger-Logger transmission can be only realised by NFC.

For NFC there will be message to align NFC device. Logger should be placed on Blaster's NFC antenna or put to another Logger's back to start the transmission.

6.4.9. Receive

Receiving pattern have to be confirmed with OK or F2 key. Logger will start receiving by NFC regardless from the option set up in transfer settings. Logger should be put to another Logger's back to start the transmission.

6.4.10. Program range

Program range is to set or change delay time in a part of pattern. This is specially to set delay time of no delay detonators, but it works also with detonators with delay time already set. To use program range function user has to set first and last detonator in active pattern, initial delay and increment. Pressing OK or F2 will change the delay time in pattern only. To transfer this change to detonators test range or test pattern functions have to be used.

6.5. Settings

Settings menu is to change setting of Logger listed below.

Figure 35. Settings menu

6.5.1. Active pattern

Active pattern is a pattern which Logger is working on. It is used to programming new detonators, for editing, listing and testing. Here another pattern can be loaded from list or new pattern can be made.

Delete pattern

User can delete pattern from Logger's memory. Pattern have to be pointed using arrow keys and F2 key. Deleting must be confirmed then by pressing F1 key.

6.5.2. Connection mode

Connection mode can be changed here.

6.5.3. Delay mode

Delay mode can be changed here.

6.5.4. Transfer settings

Transfer method can be chosen between wireless (NFC) and wired (USB). This setting affects only to sending data to Blaster. Receiving is always by NFC.

6.5.5. System

This is to enter to system settings submenu.

Figure 36. System submenu

6.5.5.1. System info

Displays Logger's serial number, firmware version, date of last battery changes and revision.

6.5.5.2. Clean memory

It is to delete all patterns from Logger's memory.

6.5.5.3. PIN settings

It is to change user or admin PIN. To change admin PIN, it must be entered when the device is starting.

PIN can be from 1 to 8 digits long or empty. If user PIN is empty, Logger will not ask for PIN on start.

Admin PIN can be entered as old PIN, when user PIN is changed.

6.5.5.4. Time and date

Current time and date can be set there.

6.5.5.5. Device ID

Each logger is defined by ID. ID is a letter from A to F. Logger's ID is stored in detonators while programming. It can be helpful when many Loggers are used in the same time on blasting site.

6.5.5.6. Language

Language can be changed there.

6.5.5.7. Brightness

Display brightness can be changed. The value can be set by left and right arrow key or entered with numeric keys. OK or F2 key have to be pressed to store the value.

6.5.5.8. Auto off timer

Auto off timer can be set with the value between 1 and 60 minutes. If no key is pressed within this time Logger will be automatically turned off. Value 0 means auto off timer function is disabled.

6.5.5.9. Buttons beep

If this function is on, there is a beep signal with every key pressed. If this is off, beep signal is only for important notifications.

6.6. PC connection

Logger can be connected to PC with USB cable. Its internal memory can be accessed as mass storage device then.

Logger should be turned on after USB cable is connected to PC. Mass storage mode will be started. If Logger was already turned on before it also starts Mass storage mode.

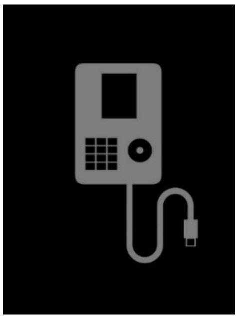


Figure 36. Mass storage mode screen

Before disconnecting USB cable, it is important to dismount drive in PC operation system. When USB cable is disconnected Logger automatically is turned off.

6.7. Battery charging

Current battery level is displayed on top bar of display.

To charge the battery dedicated power supply has to be connected to CHARGE socket at the bottom of Logger. Logger automatically starts charging and suitable message will be displayed. There is no possibility to use Logger while charging.

Figure 37. Battery charging screen

When charging is finished, user will be informed. Charger may be unplugged. Logger will be automatically turned off.

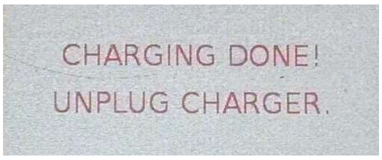


Figure 38. Charging done message

6.8. Firmware uploading

To change the firmware, file FIRMWARE.BIN have to be placed inside BOOT folder of the internal.

Logger's memory. FIRMWARE.BIN file have to be encoded using device's serial number.

To copy this file to Logger regular PC connection (if old firmware is working) or bootloader mode can be used.

To start bootloader mode Logger must be turned off first. Then up and down arrow keys have to be pressed and hold while ON/OFF is pressed to turn the device on. Logger starts in bootloader mode, shows bootloader version, device's serial number and allow to connect USB cable to copy the file. After copying the file Logger have to be unmounted from the PC system and turned off. When turned on again Logger looks in BOOT folder for new firmware. If the file is OK and encoded with correct serial number, Logger will change content of the firmware flash memory and the file will be renamed to FLASH.BIN.

6.9. Service menu

To get access to Service menu, user PIN must be set first. After Logger is turned on, service PIN **62926082** must be entered instead of user PIN. Service PIN is fixed and cannot be changed. There is a second stage of authorisation – token checking. There are four digits displayed on the screen. Another four digits must be entered. Token digits must be calculated according to the algorithm below:

- First two digits have to be multiplied and then third and fourth digit have to be added. The result gives first two digits of token.
- Digits three and four have to be multiplied and then first and second digit have to be added.

The result gives third and fourth digit of token.

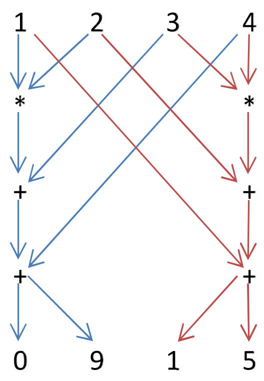


Figure 39. Token calculation algorithm

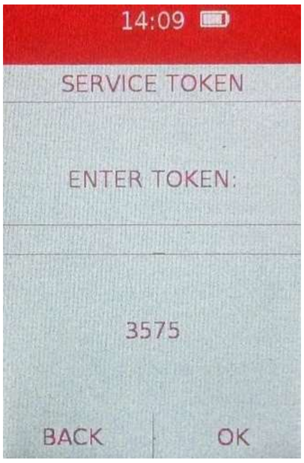


Figure 40. Token checking screen

This enables hidden Service menu as the last item of settings.

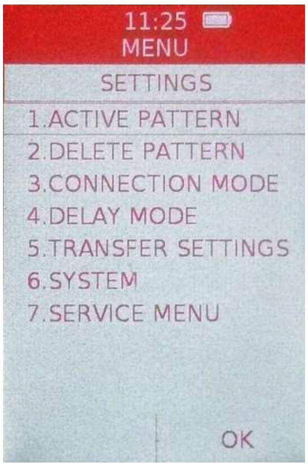


Figure 41. Settings with Service menu enabled

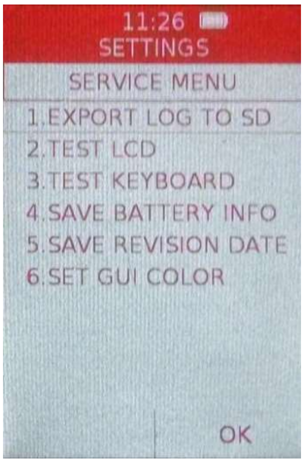


Figure 42. Service menu

6.9.1. Export log to SD

History log is created in a hidden part of memory. It cannot be changed or erased. With this option the content of this hidden log is exported to .xml file and copied to that part of memory, which can be accessed as mass storage.

6.9.2. Test LCD

To test LCD whole screen is filled with one colour. Colour can be changed with OK key in following sequence: red, green, blue, white, black. BACK key lead back to Service menu.

6.9.3. Test keyboard

This option allows to test keys and backlight. At the beginning all keys are lighted. When any key is pressed, its name is displayed and its backlight is off. All keys can be tested, but ON/OFF still leads to turning off question screen and BACK leads back to Service menu.

6.9.4. Save battery info

It is to set the date of last battery change, which is visible in system info screen.

6.9.5. Save revision date

It is to set the date of revision, which is visible in system info screen.

6.9.6. Set GUI colour

GUI colour schemes can be changed. Following schemes are available:

- Yellow – yellow letters on black background,
- White – white letters on black background,
- Lime – light green letters on black background,
- Aqua – cyan letters on black background,
- Khaki – khaki letters on black background,
- Red – red letters on white background,
- Pink – pink letters on white background,
- Green - green letters on white background,
- Blue - blue letters on white background.

6.10. Restarting the device

In case if device hangs, it could be restarted by pressing and holding any three keys (except ON/OFF) for longer than 4 seconds.

6.11. Troubleshooting

Problem	Possible cause	Action
Logger won't start	Very low batter level	Connect battery charger
Error "OPEN LINE"	Bus line or detonator is disconnected	Connect Bus line or detonator and try again
Error "SHORT LINE"	Bus-line is shorted	Remove the short circuit and try again
Error "PIN ERROR"	Entered PIN is incorrect	Try to enter user or admin PIN again
NFC transfer won't start	NFC antennas are not aligned	NFC sending and receiving antennas must be precisely aligned

6.12. Technical specification

Parameter	Value
Dimensions	125 x 219 x 37 mm
Operation temperature	-15°C, +55°C
Charging temperature	0°C, +40°C
Storage temperature	-20°C, ÷ +50°C
Charging supply voltage	10÷12 V DC
Battery voltage	7,2V
Battery capacity	5,2Ah
Battery type	Li-Ion
Display type	LCD
Display size	3,5"
Display resolution	320x480
Maximal Bus-line length	**1000 m**
Number of supported detonators	**up to 500**
Bus-line voltage	10,5 V

Maximal line current	65 mA
Dust and Water Resistance Level	IP 67

7. Riotronic X+ Blaster – User manual

This documentation considers following devices:

- 043-007-001 Blaster X+ WiFi
- 043-007-002 Blaster X+ RF868
- 043-007-003 Blaster X+ RF915

7.1. General information

Blaster is a device used for:

- import data from the Logger(s),
- verify the entire blasting, looking for current leakage, extra or missing detonators,
- programming the delay time in detonators,
- communicate with other Blasters or Remote control device.

Figure 43. Riotronic X+ Blaster

CAUTION! The document contains content not intended for the end user. The final user should receive the manual in a trimmed version.

7.2. Device outlook

7.2.1. Keypad

Blaster is equipped with membrane keypad at the front panel. Each key has selective backlight and only active keys are lighted.

7.2.2. Display

Blaster is equipped with 3,5" LCD colour display.

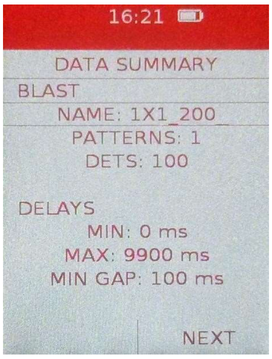


Figure 44. Display areas

Display is divided into three areas:

- Top bar area, where user can find information about time, battery status, NFC status and blasting name,
- Main operation area, where are all information about currently performed operation, Function keys area, where current function of F1 and F2 keys is displayed.

7.2.3. Charging socket

CHARGE/LINK socket is placed at the left side of Blaster's front panel. It is used to connect the charger or external battery. There is also RS485 interface used to communicate with other Blasters or Remote control device.

7.2.4. USB sockets

Blaster is equipped with two USB sockets. The bigger one, USB1 is a USB host type A socket. It is used to connect flash drive or Logger. Smaller one, USB2 is a micro USB device socket. It is used to firmware upload.

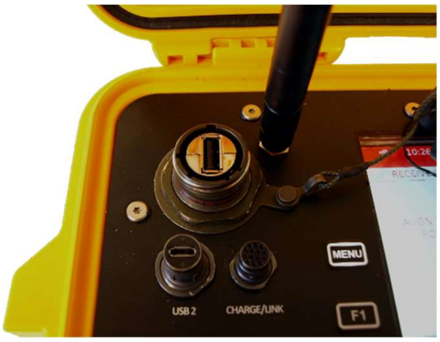


Figure 45. USB and charge sockets

7.2.5. Communication antenna socket

Blaster is equipped with remote communication modem. Depending on version it could be WiFi modem or RF modem (868 MHz or 915 MHz). Socket for remote communication antenna is placed on the left side of front panel, just to the right of USB1 socket.

Appropriate antenna should be connected before remote communication is started.

7.2.6. Firing line terminals

Firing line terminals are placed at the right side of front panel. They are used to connect the detonators through two-wire firing line.

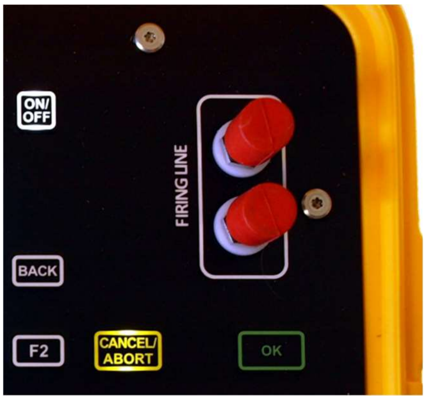


Figure 46. Firing line terminals

7.2.7. NFC antenna

Blaster is equipped with NFC communication antenna. NFC is used to communicate with Logger and read RFID card to blast authorization. NFC antenna is placed at the left side of front panel, just above the CHARGE key.

Figure 47. NFC antenna

7.2.8. Turning device on and off

To turn the device on press ON/OFF button and hold for about 3 seconds. Blaster proceed with initial auto test. If PIN checking is enabled, enter PIN and press OK or F2 button. Blaster starts with Logger connection screen to download the pattern.

To turn the device off press ON/OFF button and then confirm with OK or F2 button. If ON/OFF button is pressed and held for longer than 3 second, Blaster will be turned off without confirmation screen.

7.2.9. Receive data

Blasting procedure starts with receiving data from Loggers. Depending on settings it can be by NFC (wireless) or USB (wired).

To transfer data by NFC ***Transfer data / Send*** option have to be chosen on Logger and pattern must be selected. Then Logger should be put on the Blaster and NFC antennas should be aligned. Transfer will start automatically.

If USB transfer is set, ***Transfer data / Send*** option have to be chosen on Logger and pattern must be selected. Then USB cable should be connected between Logger and Blaster's USB1 socket. Then OK or F2 key should be pressed.

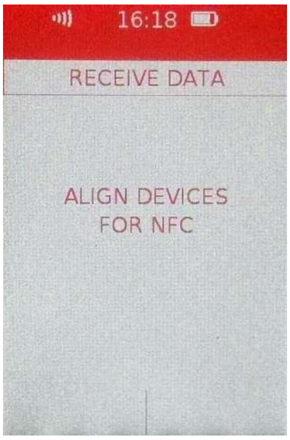


Figure 48. Receive data through NFC

When receiving is finished, another pattern can be transferred and combined in one blast.

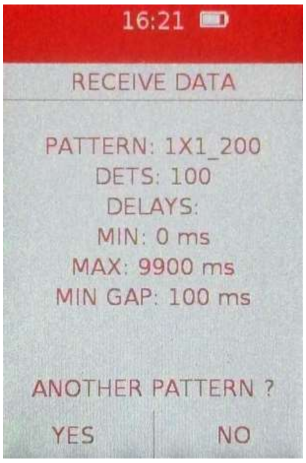


Figure 49. Pattern received

If there are no other patterns to transfer blast summary will be displayed. Name of the blast can be changed there.

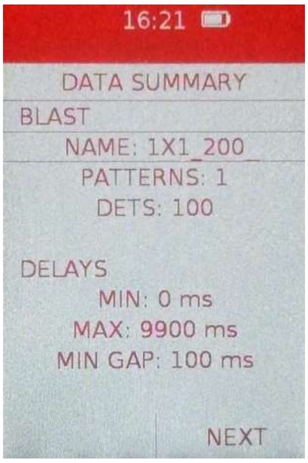


Figure 50. Blast summary

7.2.10. Test blast

Before blast can be initiated firing line have to checked. First, all detonators from transferred patterns are checked if they are connected to the line and programmed with correct delay time. If the delay time is wrong, Blaster tries to reprogram them. At the end Blaster search for extra detonators connected to the firing line. Detonators can be counted to one of following categories:

- OK – detonator is present and programmed with correct delay time,
- MISSING – detonator is not connected to firing line,
- ERROR – detonator is connected, but cannot be programmed with correct delay time, EXTRA – additional detonator connected to firing line.

If there are not only OK detonators, there is warning. Detailed information can be checked using up and down arrow keys and OK or F2 key. F1 key is to continue, then it must be confirmed with F2 key.

If there are only OK detonator, F2 or OK key should be pressed.

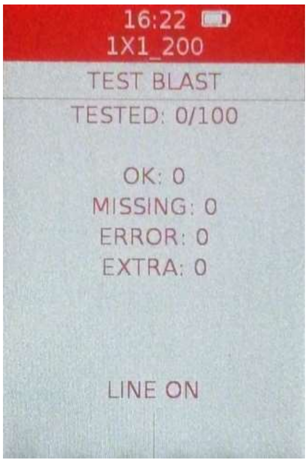


Figure 51. Test blast

7.3. Blast procedure

At the beginning of blast procedure, type of control must be chosen. It could be:

- Local – blast will be initiated on the Blaster, where firing line is connected.
- Remote – blast will be initiated on Remote control device.

F1 or F2 key should be pressed.

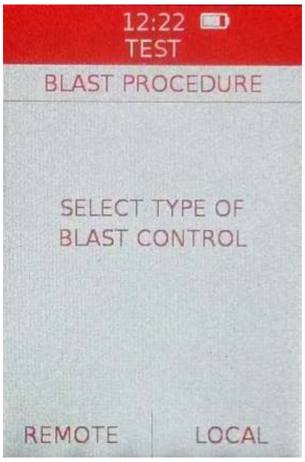


Figure 52. Type of blast control

7.3.1. Local

If local blast control was chosen, user has to be authorised. RFID card have to be put on NFC antenna.

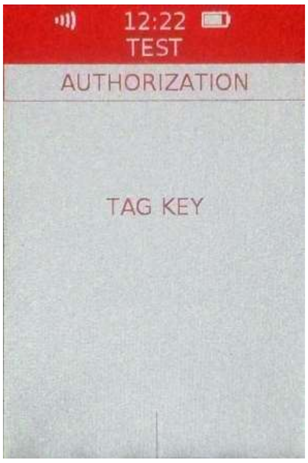


Figure 53. Authorisation

After authorisation detonators are ready to charge. CHARGE key has to be pressed.

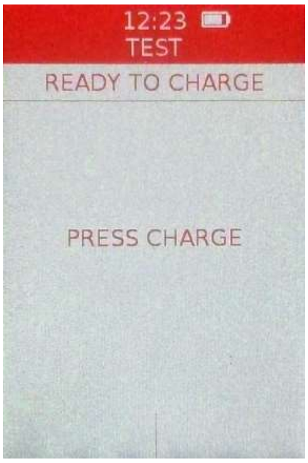


Figure 54. Press charge

After that charging and calibration procedure is started.

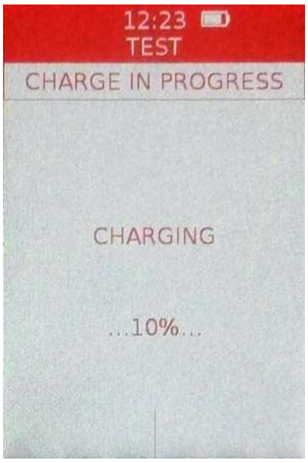


Figure 55. Charge in progress

When detonators are charged, there are 10 minutes to initiate the blast by pressing and holding CHARGE and FIRE keys simultaneously for 2 seconds.

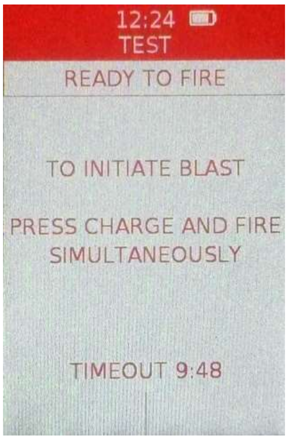


Figure 56. Ready to fire

After initiation Blaster can be turned off with F2 key. F1 key leads to receiving new data.

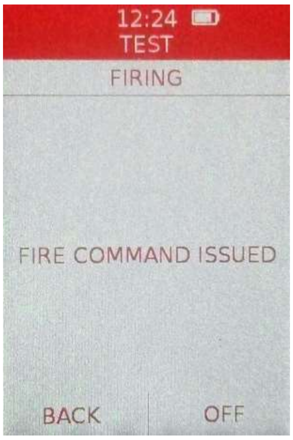


Figure 57. Fire command issued

7.3.2. Remote

If remote blast control was chosen, Blaster have to be connected to Remote control device. Remote device RFID card should be put on NFC antenna or Remote serial number should be entered with numeric keypad and confirmed with OK key.

Figure 58. Connecting with Remote control device

Communication method (wireless or wired) chosen in Remote type in settings menu will be used.

Remote blasting has to be also started on Remote control device.

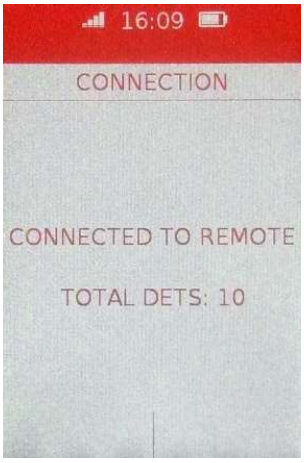


Figure 59. Blaster connected to Remote control device

When connection is established, all further operations are controlled by Remote device. Only ON/OFF and CANCEL/ABORT keys are active to abort blasting.

Figure 60. Remote fire command issued

After firing, Blaster can be switched off by Remote device or from local keypad. Another blasting may also be started with BACK of F1 key.

7.3.3. Menu

Main menu will be displayed when MENU key will be pressed. MENU key is active only if connected detonators are not charged.

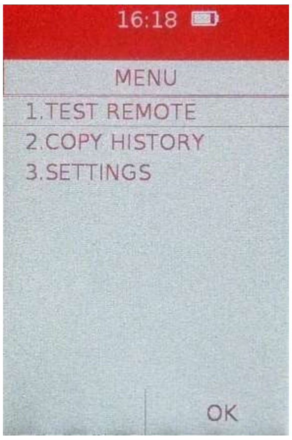


Figure 61. Main menu

7.3.4. Test remote

Test remote is to test communication between Blaster and Remote-control device. To test communication, serial number of Remote device must be entered or Remote card must be put on NFC antenna. Test remote must be also started on Remote.

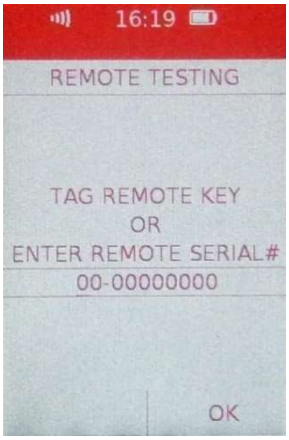


Figure 62. Remote test - connection setting

After connection is established Blaster show signal strength and packet success ratio.

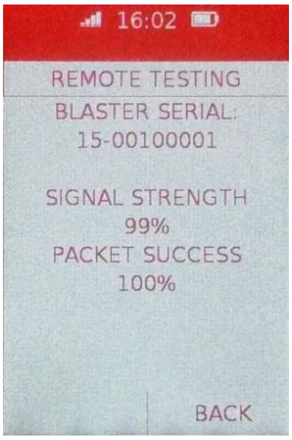


Figure 63. Remote test - results

7.3.5. Copy history

History log is created in a hidden part of memory. It cannot be changed or erased. With this option the content of this hidden log with all information important for user is exported to .xml file and saved on USB flash memory.

7.4. Settings

Settings menu is to change setting of Blaster listed below.

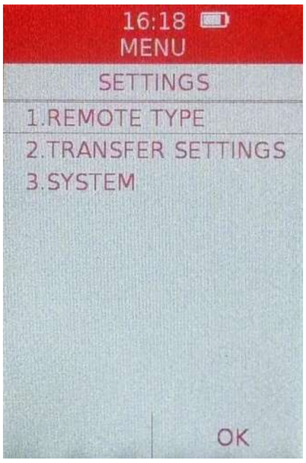


Figure 64. Settings menu

7.4.1. Remote type

There are two methods of connection with Remote control device: using wireless modem (WiFi or RF) or RS485 cable. Preferred connection type can be set here.

7.4.2. Transfer settings

Transfer method can be chosen between wireless (NFC) and wired (USB). This setting affects only to sending data to Blaster. Receiving is always by NFC.

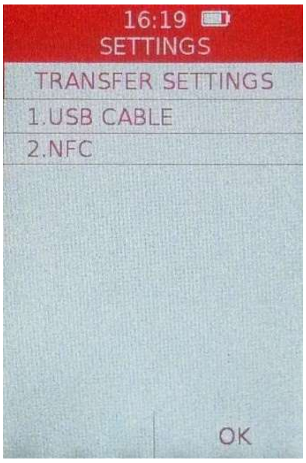


Figure 65. Transfer settings

7.5. System

This is to enter to system settings submenu.

Figure 66. System submenu

7.5.1. System info

Displays Blaster's serial number, firmware version, date of last battery change and revision.

7.5.2. PIN settings

It is to change user or admin PIN. To change admin PIN, it must be entered when the device is starting.

PIN can be from 1 to 8 digits long or empty. If user PIN is empty, Blaster will not ask for PIN on start.

Admin PIN can be entered as old PIN, when user PIN is changed.

7.5.3. Time and date

Current time and date can be set there.

7.5.4. Language

Language can be changed there.

7.5.5. Brightness

Display brightness can be changed. The value can be set by left and right arrow key or entered with numeric keys. OK or F2 key have to be pressed to store the value.

7.5.6. Buttons beep

If this function is on, there is a beep signal with every key pressed. If this is off, beep signal is only for important notifications.

7.5.7. Reset WiFi

This option is to reset WiFi modem to default configuration. It is used to enable direct connection between Blaster and PC and set new WiFi configuration.

When this option is chosen WiFi modem will create Access Point with network called ***MAXAM_B_XX***, where XX are last two digits of its serial number. PC should be connected to this network. Password is ***MAXAMWIFI***. Web browser should be started and ***192.168.12.100*** should be entered in the address bar. Login page should be opened.

Figure 67. Login page to WiFi configuration

Default user name is ***admin*** and password is ***admin***. Login button should be pressed. Configuration page will be opened.

Figure 68. WiFi configuration page

CAUTION! GPIO Control, Serial Setting and User Information must not be modified. Changes in those sections may block the modem.

Usual to configure network connection ***S2W Setting & Scan network*** option is used.

In Step 1 Mode should be set to ***Station Mode*** and Protocol to ***UDP Server***. Then Setting button should be pressed to confirm and Next_Step to go to Step 2.

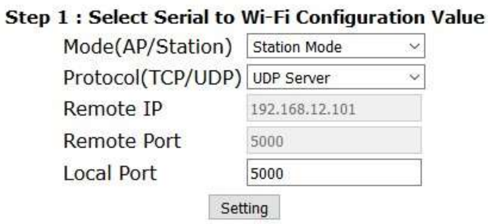


Figure 69. WiFi configuration - Step 1

In Step 2 mode should be set to DHCP or STATIC. In case of static, IP address, gateway and mask must be set. Then Setting button should be pressed to confirm and Next_Step to go to Step 3.

Figure 70. WiFi configuration - Step 2

In Step 3 all accessible networks are listed. Button Join button have to be pressed next to preferred network name. User may be asked for password then. After confirming, modem is restarted with new configuration. Web browser may be closed.

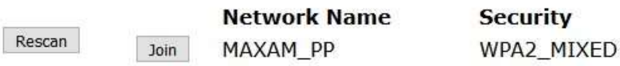


Figure 71. WiFi configuration - Step 3

7.6. Battery charging

Current battery level is displayed on top bar of display.

To charge the battery dedicated power supply has to be connected to CHARGE/LINK socket at the Blaster's front plate. Blaster automatically starts charging and suitable message will be displayed.

There is no possibility to use Blaster while charging.

Figure 72. Battery charging screen

When charging is finished, user will be informed. Charger may be unplugged. Blaster will be automatically turned off.

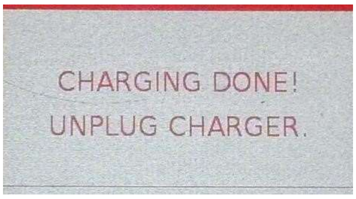


Figure 73. Charging done message

7.7. Firmware uploading

To change the firmware, file FIRMWARE.BIN have to be placed inside BOOT folder of the internal.

Blaster's memory. FIRMWARE.BIN file have to be encoded using device's serial number.

To copy this file to Blaster bootloader mode must be used. To start bootloader mode Blaster must be turned off first. Then up and down arrow keys have to be pressed and hold while ON/OFF is pressed to turn the device on. Blaster starts in bootloader mode, shows bootloader version, device's serial number and allow to connect USB cable to copy the file.

After copying the file Blaster have to be unmounted from the PC system and the USB cable have to be disconnected (Blaster will be automatically turned off). When turned on again Blaster looks in BOOT folder for new firmware. If the file is OK and encoded with correct serial number, Blaster will change content of the firmware flash memory and the file will be renamed to FLASH.BIN.

7.8. Service menu

To get access to Service menu, user PIN must be set first. After Blaster is turned on, service PIN **62926082** must be entered instead of user PIN. Service PIN is fixed and cannot be changed. There is a second stage of authorisation – token checking. There are four digits displayed on the screen. Another four digits must be entered. Token digits must be calculated according to the algorithm below:

- First two digits have to be multiplied and then third and fourth digit have to be added. The result gives first two digits of token.
- Digits three and four have to be multiplied and then first and second digit have to be added.

The result gives third and fourth digit of token.

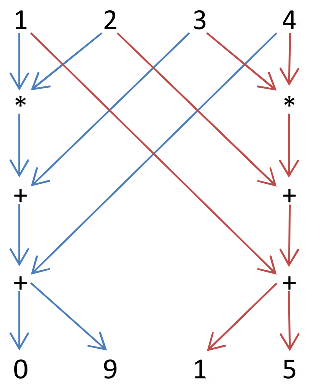


Figure 74. Token calculation algorithm

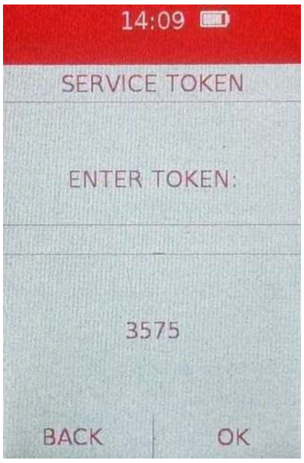


Figure 75. Token checking screen

This enables hidden Service menu as the last item of settings.

Figure 76. Settings with Service menu enabled

Figure 77. Service menu

7.8.1. Tag read

This is to pair RFID card with Blaster. When this option is chosen, RFID tag must be tapped on NFC antenna. Unique serial number from card is stored in Blaster's memory and Blaster's serial number is written in card's memory. Up to 3 cards can be paired with Blaster.

7.8.2. Export dev log

History log is created in a hidden part of memory. It cannot be changed or erased. With this option the content of this hidden log in full version with all developer information is exported to .xml file and saved on USB flash memory.

7.8.3. Test LCD

To test LCD whole screen is filled with one colour. Colour can be changed with OK key in following sequence: red, green, blue, white, black. BACK key lead back to Service menu.

7.8.4. Test keyboard

This option allows to test keys and backlight. At the beginning all keys are lighted. When any key is pressed, its name is displayed, and its backlight is off. All keys can be tested, but ON/OFF still leads to turning off question screen and BACK leads back to Service menu.

7.8.5. Save battery info

It is to set the date of last battery change, which is visible in system info screen.

7.8.6. Save revision date

It is to set the date of revision, which is visible in system info screen.

7.8.7. Set GUI colour

GUI colour schemes can be changed. Following schemes are available:

- Yellow – yellow letters on black background,
- White – white letters on black background,
- Lime – light green letters on black background,
- Aqua – cyan letters on black background,
- Khaki – khaki letters on black background,
- Red – red letters on white background,
- Pink – pink letters on white background,
- Green - green letters on white background, Blue - blue letters on white background.

7.9. Restarting the device

In case if device hangs, it could be restarted by pressing and holding any three keys (except ON/OFF) for longer than 4 seconds.

7.10. Troubleshooting

Problem	Possible cause	Action
Blaster won't start	Very low batter level	Connect battery charger
Error "OPEN LINE"	Bus line or detonator is disconnected	Connect Bus line or detonator and try again
Error "SHORT LINE"	Bus-line is shorted	Remove the short circuit and try again
Error "PIN ERROR"	Entered PIN is incorrect	Try to enter user or admin PIN again
NFC transfer won't start	NFC antennas are not aligned	NFC sending and receiving antennas must be precisely aligned

7.11. Technical specification

Parameter	Value
Dimensions	300 x 249 x 119 mm
Operation temperature	-15˚C ÷ +55˚C
Charging temperature	0˚C ÷ +40˚C
Storage temperature	-20˚C ÷ +50˚C
Charging supply voltage	10÷12 V DC
Battery voltage	7,2V
Battery capacity	20,8Ah
Battery type	Li-Ion
Display type	LCD
Display size	3,5"
Display resolution	320x480

Maximal Bus-line length	1000 m
Number of supported detonators	**up to 500**
Bus-line voltage	10,5 V and 20,5 V
Maximal line current	65 mA and 300 mA
Dust and Water Resistance Level	IP 67

8. Riotronic X+ Remote – User manual

This documentation considers following devices:

- 043-008-001 Remote X+ WiFi
- 043-008-002 Remote X+ RF868
- 043-008-003 Remote X+ RF915

8.1. General information

Remote is a device used for communicating with Blasters for remote blast initiation.

Figure 78. Riotronic X+ Blaster

CAUTION! The document contains content not intended for the end user. The final user should receive the manual in a trimmed version.

8.2. Device outlook

8.2.1. Keypad

Remote is equipped with membrane keypad at the front panel. Each key has selective backlight and only active keys are lighted.

8.2.2. Display

Remote is equipped with 3,5” LCD colour display.

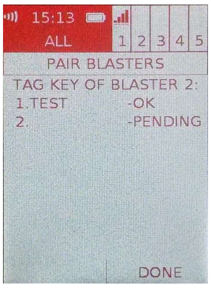


Figure 79. Display areas

Display is divided into three areas:

- Top bar area, where user can find information about time, battery status, NFC status and blasting name,
- Main operation area, where are all information about currently performed operation, Function keys area, where current function of F1 and F2 keys is displayed.

8.2.3. Charging socket

Charging socket is placed at the bottom of Remote. It is used to connect the charger or external battery.

8.2.4. USB sockets

USB socket is placed at the bottom of Remote. It is used to firmware upload.

Figure 80. USB and charge sockets

8.2.5. Communication antenna socket

Remote is equipped with remote communication modem. Depending on version it could be WiFi modem or RF modem (868 MHz or 915 MHz). Socket for remote communication antenna is placed on the top of Remote.

Appropriate antenna should be connected before remote communication is started.

Figure 81. Communication antenna socket

8.2.6. NFC antenna

Remote is equipped with NFC communication antenna. NFC is used to read RFID card for blast authorisation. NFC antenna is placed at the back of Remote's case. It's exact position is marked by the white rectangle.

Figure 82. NFC antenna

8.3. Turning device on and off

To turn the device on press ON/OFF button and hold for about 3 seconds. Remote proceed with initial auto test. If PIN checking is enabled, enter PIN and press OK or F2 button. Remote starts with Blasters connection screen pair the devices.

To turn the device off press ON/OFF button and then confirm with OK or F2 button. If ON/OFF button is pressed and held for longer than 3 second, Blaster will be turned off without confirmation screen.

8.4. Pairing Blasters

To pair Blaster with Remote Blaster's authentication card should be put to Remote's NFC antenna. Blaster will be added to the list and Remote will try to communicate with it using medium chosen in Remote Type setting. When communication is established, blasting name will be read and displayed on the list with connection status. Up to five Blasters can be added.

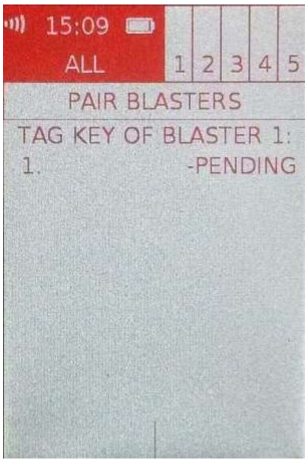


Figure 83. Remote waits for pairing Blasters

When all Blasters are added to the list, then OK or F2 key should be pressed to proceed.

Figure 84. Blaster properly paired

On the next screen also number of detonators for each Blaster is displayed. When all Blasters are properly connected blast procedure can be started by pressing OK or F2 key.

Figure 85. Remote is ready to start blast procedure

8.5. Blast procedure

To enter to blast procedure user must be authenticated by putting Remote's card to NFC antenna.

Figure 86. Authentication

After positive authentication system is ready to charge the detonators. To start that CHARGE key must be pressed.

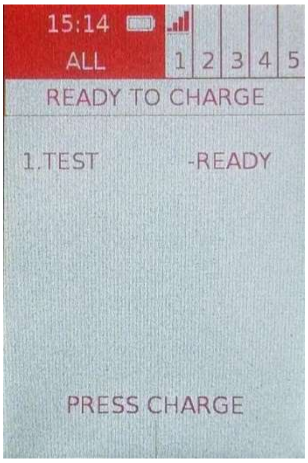


Figure 87. Ready for charging the detonators

Charging and calibration progress is displayed as a list of all Blasters. Detailed screen of each Blaster can also be show. To switch between Blasters ←B and B→ keys should be used.

In case of any errors user should switch display to Blaster with error and then proceed as in local blasting on Blaster.

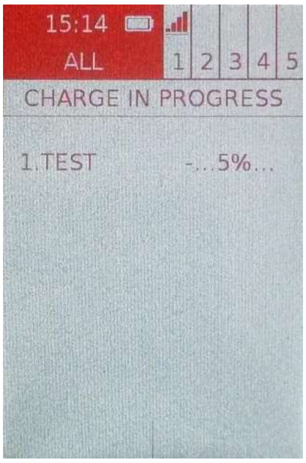


Figure 88. Summary view for all Blasters

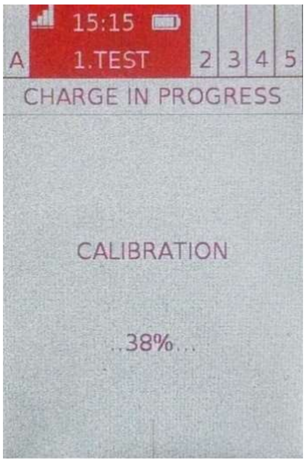


Figure 89. Detailed view of Blaster 1 screen

If all detonators are properly charged and calibrated Remote is ready to fire. To initiate the blast CHARGE and FIRE keys must be pressed simultaneously for about five seconds. In this time communication status will be confirmed and fire command will be sent Blasters.

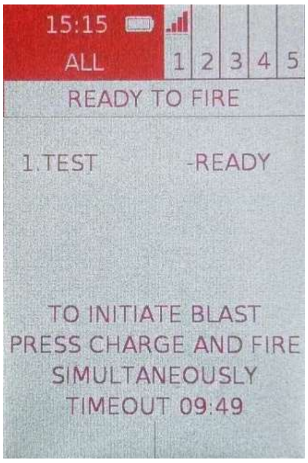


Figure 90. Ready to fire

After firing summary screen will be displayed with confirmation, that all Blasters fired.

Figure 91. Fire command issued

Remote go back then to pairing new Blasters by pressing BACK or F1 key. It can also be switched off by pressing F2 key. In this case all paired Blasters will be also switched off.

8.6. Menu

Main menu will be displayed when MENU key will be pressed. MENU key is active only if detonators connected to paired Blasters are not charged.

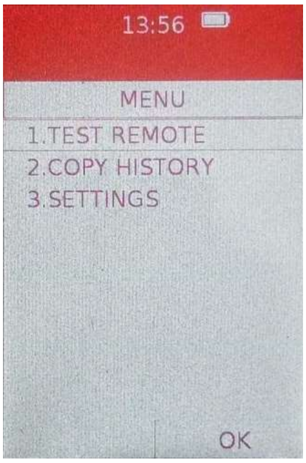


Figure 92. Main menu

8.6.1. Test remote

Test remote is to test communication between Remote and Blasters. At the beginning tested Blasters must be paired with Remote. To do that, Blasters' cards must be put to Remote's NFC antenna. Up to five Blasters can be added to the list. Then OK or F2 key must be pressed to start testing. Remote test must be also started and configured on Blasters.

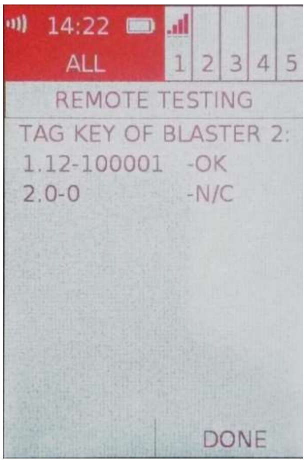


Figure 93. Remote test - connection setting

Testing may be stopped with F2 key. F1 key is used to switching between signal strength information and packet success ratio.

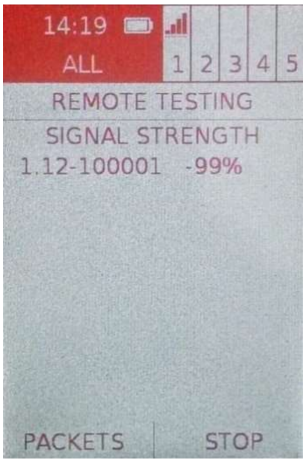


Figure 94. Remote test – results

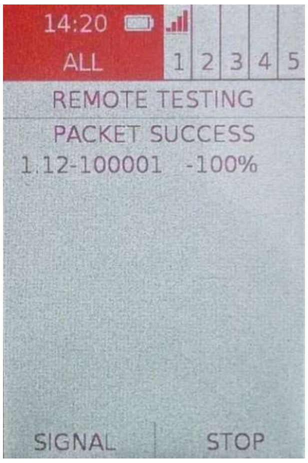


Figure 95. Remote test – results

8.6.2. Copy history

History log is created in a hidden part of memory. It cannot be changed or erased. With this option the content of this hidden log with all information important for user is exported to .xml file and copied to part of flash memory accessible as mass storage device.

8.6.3. Settings

Settings menu is to change settings of Remote listed below.

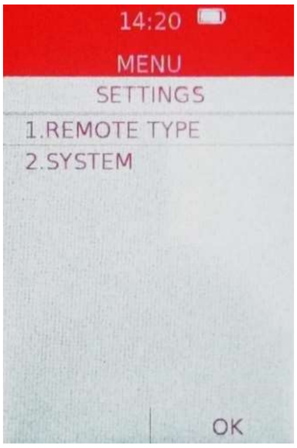


Figure 96. Settings menu

8.6.3.1. Remote type

There are two methods of connection with Remote control device: using wireless modem (WiFi or RF) or RS485 cable. Preferred connection type can be set here.

Figure 97. Remote type

8.6.3.2. System

This is to enter to system settings submenu.

Figure 98. System submenu

8.6.3.3. System info

Displays Remote's serial number, firmware version, date of last battery changes and revision.

8.6.3.4. PIN settings

It is to change user or admin PIN. To change admin PIN, it must be entered when the device is starting.

PIN can be from 1 to 8 digits long or empty. If user PIN is empty, Logger will not ask for PIN on start.

Admin PIN can be entered as old PIN, when user PIN is changed.

8.6.3.5. Time and date

Current time and date can be set there.

8.6.3.6. Language

Language can be changed there.

8.6.3.7. Brightness

Display brightness can be changed. The value can be set by left and right arrow key or entered with numeric keys. OK or F2 key have to be pressed to store the value.

8.6.3.8. Buttons beep

If this function is on, there is a beep signal with every key pressed. If this is off, beep signal is only for important notifications.

8.6.3.9. Reset WiFi

This option is to reset WiFi modem to default configuration. It is used to enable direct connection between Remote and PC and set new WiFi configuration.

When this option is chosen WiFi modem will create Access Point with network called MAXAM_R_XX, where XX are last two digits of its serial number. PC should be connected to this network. Password is MAXAMWIFI. Web browser should be started and 192.168.12.100 should be entered in the address bar. Login page should be opened.

Figure 99. Login page to WiFi configuration

Default user name is ***admin*** and password is ***admin***. Login button should be pressed. Configuration page will be opened.

Figure 100. WiFi configuration page

CAUTION! GPIO Control, Serial Setting and User Information must not be modified. Changes in those sections may block the modem.

Usual to configure network connection ***S2W Setting & Scan network*** option is used.

In Step 1 Mode should be set to ***Station Mode*** and Protocol to ***UDP Server***. Then Setting button should be pressed to confirm and Next_Step to go to Step 2.

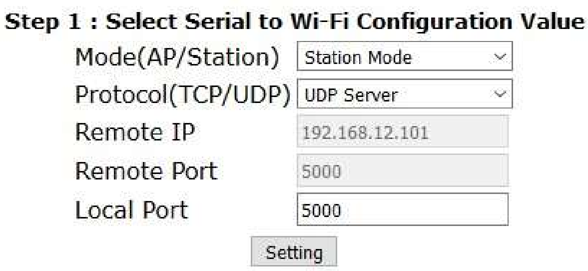


Figure 101. WiFi configuration - Step 1

In Step 2 mode should be set to DHCP or STATIC. In case of static, IP address, gateway and mask must be set. Then Setting button should be pressed to confirm and Next Step to go to Step 3.

Figure 102. WiFi configuration - Step 2

In Step 3 all accessible networks are listed. Button Join button have to be pressed next to preferred network name. User may be asked for password then. After confirming, modem is restarted with new configuration. Web browser may be closed.

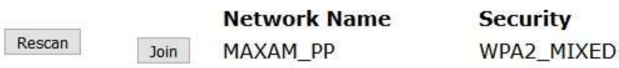


Figure 103. WiFi configuration - Step 3

8.7. PC connection

Remote can be connected to PC with USB cable. Its internal memory can be accessed as mass storage device then.

Remote should be turned on after USB cable is connected to PC. Mass storage mode will be started.

If Remote was already turned on before it also starts Mass storage mode.

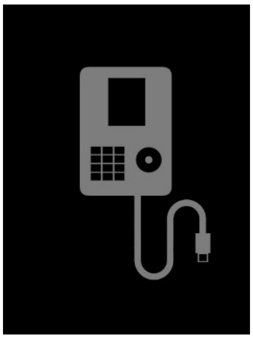


Figure 104. Mass storage mode screen

Before disconnecting USB cable it is important to dismount drive in PC operation system. When USB cable is disconnected Remote automatically is turned off.

8.8. Battery charging

Current battery level is displayed on top bar of display.

To charge the battery dedicated power supply has to be connected to CHARGE socket at the bottom of Remote. Remote automatically starts charging and suitable message will be displayed. There is no possibility to use Remote while charging.

Figure 105. Battery charging screen

When charging is finished, user will be informed. Charger may be unplugged. Remote will be automatically turned off.

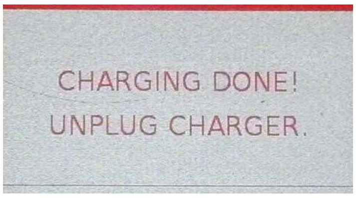


Figure 106. Charging done message

8.9. Firmware uploading

To change the firmware, file FIRMWARE.BIN have to be placed inside BOOT folder of the internal.

Remote's memory. FIRMWARE.BIN file have to be encoded using device's serial number.

To copy this file to Remote regular PC connection (if old firmware is working) or bootloader mode can be used.

To start bootloader mode Remote must be turned off first. Then up and down arrow keys have to be pressed and hold while ON/OFF is pressed to turn the device on. Remote starts in bootloader mode, shows bootloader version, device's serial number and allow to connect USB cable to copy the file. After copying the file Remote have to be unmounted from the PC system and turned off. When turned on again Remote looks in BOOT folder for new firmware. If the file is OK and encoded with correct serial number, Remote will change content of the firmware flash memory and the file will be renamed to FLASH.BIN.

8.10. Service menu

To get access to Service menu, user PIN must be set first. After Remote is turned on, service PIN **62926082** must be entered instead of user PIN. Service PIN is fixed and cannot be changed. There is a second stage of authorisation – token checking. There are four digits displayed on the screen. Another four digits must be entered. Token digits must be calculated according to the algorithm below:

- First two digits have to be multiplied and then third and fourth digit have to be added. The result gives first two digits of token.
- Digits three and four have to be multiplied and then first and second digit have to be added.

The result gives third and fourth digit of token.

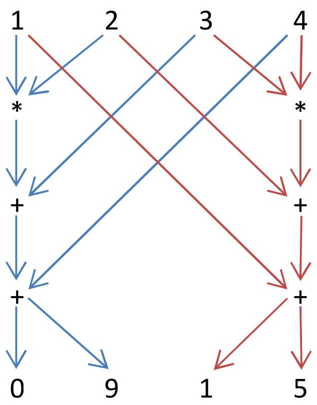


Figure 107. Token calculation algorithm

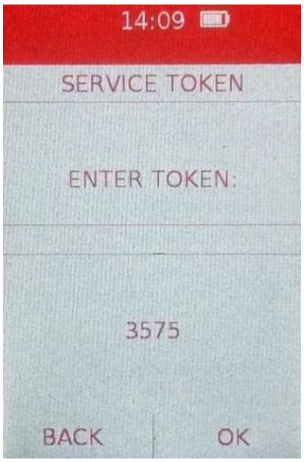


Figure 108. Token checking screen

This enables hidden Service menu as the last item of settings.

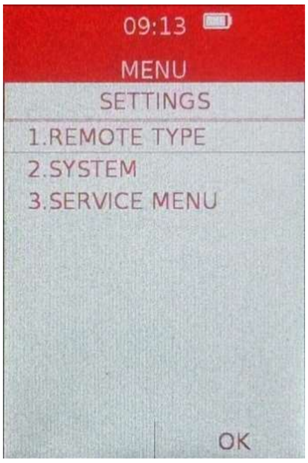


Figure 109. Settings with Service menu enabled

Figure 110. Service menu

8.10.1. Tag read

This is to pair RFID card with Blaster. When this option is chosen, RFID tag must be tapped on NFC antenna. Unique serial number from card is stored in Blaster's memory and Blaster's serial number is written in card's memory. Up to 3 cards can be paired with Blaster.

8.10.2. Export dev log

History log is created in a hidden part of memory. It cannot be changed or erased. With this option the content of this hidden log in full version with all developer information is exported to .xml file and copied to that part of memory, which can be accessed as mass storage.

8.10.3. Test LCD

To test LCD whole screen is filled with one colour. Colour can be changed with OK key in following sequence: red, green, blue, white, black. BACK key lead back to Service menu.

8.10.4. Test keyboard

This option allows to test keys and backlight. At the beginning all keys are lighted. When any key is pressed, its name is displayed, and its backlight is off. All keys can be tested, but ON/OFF still leads to turning off question screen and BACK leads back to Service menu.

8.10.5. Save battery info

It is to set the date of last battery change, which is visible in system info screen.

8.10.6. Save revision date

It is to set the date of revision, which is visible in system info screen.

8.10.7. Set GUI colour

GUI colour schemes can be changed. Following schemes are available:

- Yellow – yellow letters on black background,
- White – white letters on black background,
- Lime – light green letters on black background,
- Aqua – cyan letters on black background,
- Khaki – khaki letters on black background,
- Red – red letters on white background,
- Pink – pink letters on white background,
- Green - green letters on white background, Blue - blue letters on white background.

8.11. Restarting the device

In case if device hangs, it could be restarted by pressing and holding any three keys (except ON/OFF) for longer than 4 seconds.

8.12. Troubleshooting

Problem	Possible cause	Action
Remote won't start	Very low batter level	Connect battery charger
Error "PIN ERROR"	Entered PIN is incorrect	Try to enter user or admin PIN again

8.13. Technical specification

Parameter	Value
Dimensions	125 x 219 x 37 mm
Operation temperature	-15°C, +55°C
Charging temperature	0°C, +40°C
Storage temperature	-20°C, +50°C
Charging supply voltage	10, 12 V DC
Battery voltage	7,2V
Battery capacity	5,2Ah

Battery type	Li-Ion
Display type	LCD
Display size	3,5”
Display resolution	320x480
Dust and Water Resistance Level	IP 67

9. Annex

9.1. Rules of thumb in blasting design Recommendations for timing

Some of the basic 'rules of thumb' for designing timing in quarrying are noted below. In each situation, local site conditions will determine what the optimal timing should be. MAXAM recommends that a competent blasting engineer, who is familiar with the ground conditions, performs all timing design. Explosive rock interactions happen very fast. When an explosive goes off in a drill hole in hard rock, the first thing that happens is that the blast hole expands. This very rapid expansion causes compression and shear waves to travel out through the rock at high speed. Depending on the rock type the compression wave can travel at speeds between 2000 and 4000 meters per second. When this compression wave hits joints, the face, or other faults, it is reflected as a tensile wave causing cracking to occur. The high-pressure gases then travel into the rock mass, opening up existing cracks and extending them. Crack propagation in hard rock is thought to travel at between 300 and 600 meters per second.

How does this affect timing in hard rock quarries? If the cracks from one blast hole are travelling at a speed of 450 meters per second, they will reach the next hole in the row in around 13 milliseconds (assuming a six-meter spacing). It is thought that, in order to promote the best fragmentation, the next hole should fire before it is unburdened by the hole firing before it.

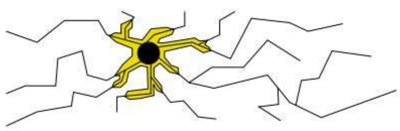


Figure 111. Crack propagation in a blast

In fact, a relationship between timing along the row and fragmentation is thought to look like the following (Figure 112).

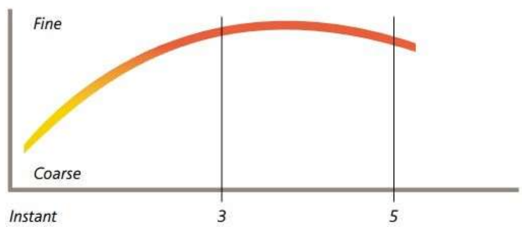


Figure 112. Relation between timing and fragmentation

In hard rock, the best fragmentation is observed between three and five milliseconds per meter. If the blast pattern has a five-meter spacing, the optimal delay is expected to be between 15 and 25 milliseconds. Variations in rock type and geology will change this rule.

In very hard ground, the optimum delay may be as fast as one or two milliseconds per meter.

Whilst timing along the row (intra-row or inter-hole timing) has the greatest effect on fragmentation, timing between rows is also important. If the timing between rows is too short there is not enough time for the rock in the previous row to move. The effect of this is that the ground movement tends to be up, fragmentation is reduced, the rock pile becomes 'tight' and heavy to dig and more of the explosive energy is directed back into the remaining face causing over break. For general quarry blasting, the delay between rows should be at least 15 milliseconds per meter of burden. For example, if the burden is 4.5 meters, the delay between rows should be at least 67 milliseconds. Again, in very hard, brittle rock, which responds quickly to explosives, this time may be reduced. If the timing between rows is too long, the row fired will have time to settle before the next row fires. This would be like firing a face with the previous blast only half dug out and would reduce the likelihood of secondary fragmentation by flying rock fragments smashing into one another. It is up to the person in charge.

One of the major benefits of using the RIOTRONIC X+ System is the ability to change timing by increments to optimize the process. The first step in any blast timing optimization program is to fire a couple of shots using the same planned timing as if the previous system (non-electrics or electrics) was still being used. Quite often you will see a better blast just because of the accuracy of the RIOTRONIC X+ detonators.

The table below contains a series of recommended delay times:

V rock (m/s)	Burden (m) 2.6		Burden (m) 2.8		Burden (m) 3		Burden (m) 3.2		Burden (m) 3.4		Burden (m) 3.6		Burden (m) 3.8		Burden (m) 4	
	Interhole	Interrow	Interhole	Interrow	Interhole	Interrow	Interhole	Interrow	Interhole	Interrow	Interhole	Interrow	Interhole	Interrow	Interhole	Interrow
1500	16	47	17	50	18	54	19	58	20	61	22	65	23	68	24	72
1725	15	45	17	49	18	52	19	56	20	59	21	63	22	66	24	70
1950	15	44	16	47	17	51	19	54	20	57	21	61	22	64	23	68
2175	15	42	16	46	17	49	18	52	19	56	21	59	22	62	23	65
2400	15	41	16	44	17	47	18	51	19	54	20	57	21	60	22	63
2625	14	40	15	43	17	46	18	49	19	52	20	55	21	58	22	61
2850	14	38	15	41	16	44	17	47	18	50	20	53	21	56	22	59
3075	14	37	15	40	16	43	17	46	18	48	19	51	20	54	21	57
3300	14	36	15	38	16	41	17	44	18	47	19	49	20	52	21	55
3525	13	34	14	37	15	40	16	42	17	45	19	48	20	50	21	53
3750	13	33	14	36	15	38	16	41	17	43	18	46	19	48	20	51
3975	13	32	14	34	15	37	16	39	17	42	18	44	19	47	20	49
4200	13	31	14	33	15	35	16	38	17	40	17	42	18	45	19	47
4425	12	29	13	32	14	34	15	36	16	39	17	41	18	43	19	45
4650	12	28	13	30	14	33	15	35	16	37	17	39	18	41	19	44
4875	12	27	13	29	14	31	15	33	16	36	16	38	17	40	18	42
5100	12	26	13	28	13	30	14	32	15	34	16	36	17	38	18	40
5325	11	25	12	27	13	29	14	31	15	33	16	35	17	36	18	38
5550	11	24	12	26	13	28	14	29	15	31	15	33	16	35	17	37
5775	11	23	12	25	13	26	13	28	14	30	15	32	16	33	17	35
6000	10	21	11	22	12	24	13	26	14	27	14	29	15	30	16	32

Recommended delay times based on Burden values

Rock properties	specific gravity (g/cm3)	density (kg/m3) Solid rock	density (kg/m3) broken rock	p-wave velocity m/s	Uniaxial Compressive Strength (MPa)	Tensile strength (Mpa)
Limestone	2.4 - 2.9	2643	1682	2500-6000 546000	10 - 245	6 - 25

Table 1 Properties of limestone

A rough calculation might be as follows:

Burden =3.8 meters.

To find the optimum inter-row timing in our ground, assuming that the rock needed to explode is limestone, read the tables above. The optimal delay time with 3.8 meters can be 17/18/19/20/21ms.

The delay time changes should not be big, as it could end up causing significant problems, including greater air blast and over break. The recommended way is to move towards where the expected result is in steps. Change the intra-row delay by a few milliseconds and see what the effect is. The reason for doing the initial calculation is not to obtain the optimal timing, but to give the direction in which the timing should be moving towards. The following is an example of the shots fired in a typical hard rock quarry where the optimal timing was thought to be 18/46 and the site was currently using 17/42 non-electrics.

- 1st blast with RIOTRONIC X+ product, timing = 17/42
- 2nd = 17/43 Not much of a difference
- 3rd = 18/43 More throw. Fragmentation a bit more uniform
- 4th = 19/44 More throw. Fragmentation about the same but air blast up a bit
- 5th = 18/43 About the same as the 3rd trial
- 6th = 19/45 Not much change
- 7th = 17/46 Possibly a bit more throw
- 8th = 19/43 Rock pile a bit higher
- 9th = 17/48 Loss of some power trough. Digging a bit tighter
- 10th = 17/46 About the same as the 7th trial.

So, after a controlled program of 10 blasts this site could optimize its blast timing at 17/46 without having to expose themselves to any radical changes.

9.2. Air blast and vibration

9.2.1. Air blast

This can be a tricky one. It depends on where the air blast is coming from. The first thing to do is to look at an air blast trace and work out where the maximums are coming from. There are three main sources of air blast peak:

9.2.2. Face Bursting

If holes are under burdened, explosive gases can vent into the atmosphere at a higher pressure than normal. This will cause air blast. This cause of under burdening may be short drilled burdens or excessive timing along the front row. Short drilled burdens may be fixed by implementing a controlled face and a blast hole-surveying program. If timing along the row is too great, an earlier firing hole may open up the face around the next hole causing air blast. In this case, moving to faster times along the row can help. The following air blast trace (Figure 113) indicates face bursting, although examination of a blast video would also be helpful.

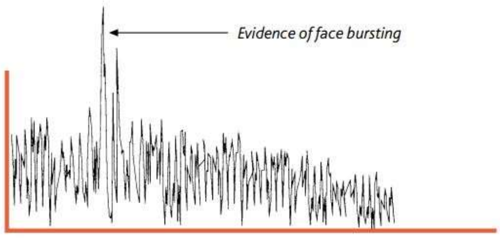


Figure 113. Air blast trace from a blast suffering from face bursting

9.2.3. Piston Effect

The movement of a large volume of rock from a quarry face will push the air in front of it like a piston. The following trace indicates this (Figure 114).

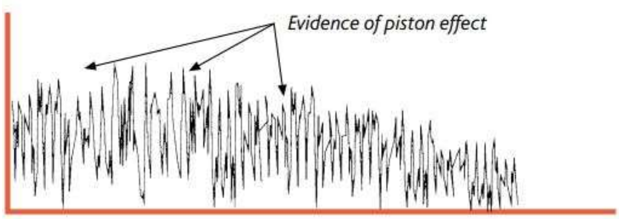


Figure 114. Air blast trace from a blast suffering from piston effect

In this situation slowing down the times along the face may help to reduce peak air blast.

9.2.4. Lead holes

The first few holes to fire often cause the highest air blast. This is thought to be because they are working the hardest and have no free faces developed by the holes beside them. In some situations, it has been seen that firing the first couple of holes a bit slower can significantly reduce peak air blast. For example, if the optimal timing was 18/55, the first couple of holes could be timed at 25/30 milliseconds between them. The following air blast trace shows signs of lead hole peaks (Figure 115).

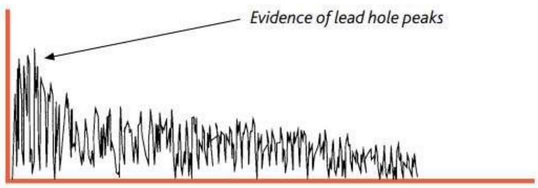


Figure 115. Air blast trace from a blast suffering from lead hole peaks

9.2.5. Vibration

The change from pyrotechnic detonators to RIOTRONIC X+ detonators will make a difference to ground vibration simply because of the much greater accuracy. Holes will fire at the designed timing separation rather than a spread of times around the chosen delay. In decking operations, a single deck per delay can be fired with confidence. The eight-millisecond window that has crept in as an industry standard should be looked at with caution. Depending on the ground conditions and the distance from the blast to the monitoring point the optimum window may range from 4 to 40 milliseconds. The following graphic illustrates the decrease in vibrations over time after a blast (Figure 116).

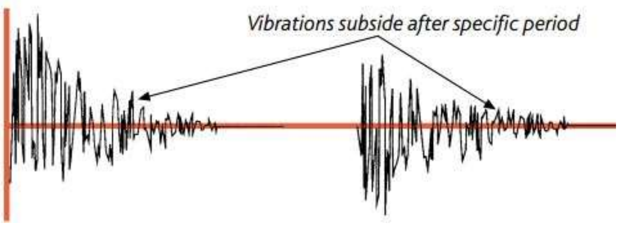


Figure 116. Vibration over time after a blast

9.2.5.1. The method of signature hole

Figure 117. Analysis using MAXAM software

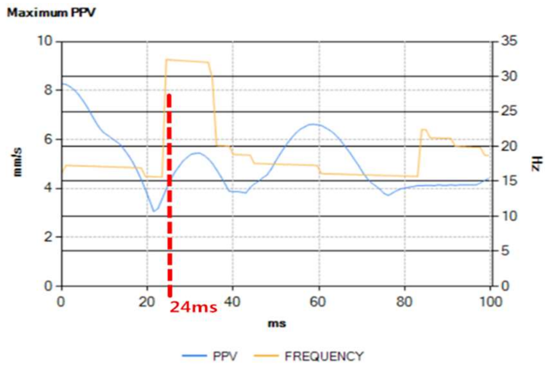


Figure 118. Relationship between PPV, delay time and frequency

Based on analysis of the signature hole, the minimum PPV and maximum Frequency is generated by an inter-hole interval of close to 25ms (Figure 118). The inter row timing should be chosen trying to avoid overlapping with holes located on the previous line.

9.3. Blast Design Parameters

Initiation is not everything and the electronic detonator will not solve all problems. The drilling and explosive parameters must also be properly controlled to achieve the best results.

The main variables that a blast designer must consider are as follows:

- Blast-hole diameter
- Excavation depth (bench height)
- Angled blast-holes
- Burden and spacing
- Blast-hole pattern
- Subdrilling
- Explosives distribution

- Stemming
- Overburden material

A set of rules of thumb will be developed for these key parameters based on blast-hole diameters.

9.3.1. Blast-hole Diameter

Drilling and blasting costs generally decrease with an increase in blast-hole diameter. This provides the incentive to maximize diameters. However, given the same Powder Factor, the larger patterns associated with larger diameter blast-holes will give poorer fragmentation and hence, higher digging, hauling and crushing costs. This is especially the case in rocks that are strong and massive or contain widely spaced sub vertical joints.

Big Holes + Big Patterns = Lower Costs + Big Rocks

Fragmentation will be poor in places where a large percentage of the natural (i.e. joint bounded) blocks do not contain a blast-hole. This also applies to large "boulders" or pods of hard ore in soft waste material where there are no explosives in the vicinity of the hard material. This will tend to reduce digging rates and increase wear, downtime and maintenance cost for digging, hauling and crushing equipment.

In places where the selected blat-hole diameter is small, the costs of drilling, priming and initiating will be high. The charging, stemming and tying operations in these blasts are also more time consuming and labor intensive. The disadvantages of small diameter blast-holes outweigh the fragmentation benefits of slightly lower powder factors.

As a blast designer you will often be constrained by the capability of the available drill equipment. However, one bit size up or down may have a measurable effect on cost performance.

An enormous range of blast-hole diameters can be drilled in rock, with numerous drill bit designs available for different rock types and drilling equipment. Blast-hole diameters drilled in most open-cut mines and quarries vary from 57 mm to 311 mm, with an almost continuous range of sizes in between.

Some of the most common diameters are:

- 76, 89, & 102 mm in quarries, with "button bits" and "top hammer" rigs,
- 115, 140, & 165 mm in metal mines, using "down-the-hole hammer" drills,
- 270 & 311 mm for coal overburden, with "tricone" bits and "rotary" rigs,

- 150 mm for drilling coal seams, using simple rotary "auger" drills, and
- 229, 251, & 311 mm in iron ore mines, with "tricone" bits and "rotary" rigs.

Hole Diameter Rules of Thumb #1

Excellent energy distribution can be achieved by using blast-hole diameters (mm) equal to the bench height (m) multiplied by 8 to 15.

$$d = (8 \text{ to } 15) \times BH$$

Where: d = Hole Diameter in mm

BH= Bench Height in meters

The smaller the hole diameter the better the explosive energy distribution throughout the rock mass.

9.3.2. Bench Height

Excavation depth (bench height) is arguably the most basic of blast parameters, and yet it is often overlooked. Bench height is usually dictated by either existing mine planning and designs or the available excavation equipment or methods.

If there is some flexibility available regarding bench height, the choices between lower and higher benches may be influenced by the following:

- Bench preparation and infrastructure costs are reduced with increased bench height
- Overall drilling, manpower and explosives costs are reduced with increased bench height
- Drill deviation increases with increased bench height
- Blasting control and ore dilution/losses are increased with increased bench height

In shallow trenches, the cost efficiency of ripping often exceeds that of drilling and blasting. The cost efficiency of drilling and blasting decreases very rapidly as the excavation depth falls below about two meters.

9.3.3. Burden and Spacing

The burden and spacing relationship between blast-holes is the basis of blast pattern design in surface mining. Typically, the study of the ability of the explosive column to shoot the burden is the start point of any pattern design.

Burden and spacing designs are influenced by:

- Design powder factor
- Blast-hole diameter
- Rock mass properties (and particularly, the properties of the strongest, most massive rock penetrated by blast-holes)
- Required fragmentation, displacement and muck pile looseness required (these being strong functions of the type of digging equipment employed)
- Geometry of the block to be blasted

Rule of thumb #2:

Burden lies in the range of 24-36 diameters.

In places where the rock is strong and either massive or blocky, conservative values of burden and spacing should be selected. When blasting weak or closely fissured rocks, on the other hand, satisfactory results are obtained by using larger blast-hole patterns. In benches that consist of thick beds of both strong and weak rocks, burden and spacing are restricted by the fragmentation produced in the strongest or most massive bed encountered.

As the length (along the face) to width (normal to the face) ratio of a blast block decreases below about 1.0, the blast becomes a trench type shot, a blast in which progressive relief of burden and the required degree of muck pile looseness are less likely to be achieved.

To overcome this potential problem, burden and spacing in ramp blasts should be smaller than in blasts that shoot to a long sub vertical face.

All too often, burden and spacing are rounded off to the nearest meter or half meter for convenience when it comes to marking out. In nearly every situation, the best pattern is not 'to the nearest half meter'. For example, the optimum pattern for a blast is found to be 7.6 m x 9.8 m, but the mine operator wants it simple so he opts for an 8 m x 10 m pattern. This produces unacceptable muck piles, so he tries a 7 m x 9 m pattern. This results in excellent digging, but his costs have increased significantly. Lower costs could be achieved by using "non-standard" dimensions.

In areas where the burden is too large, explosion gases find it difficult to break the burden rock and heave it towards the face. Consequently, high pressure gases from the explosion tend to be bottled up within blast-holes for excessive periods of time.

This over confinement of gases causes:

- excessive backbreak
- ground vibration
- reduced fragmentation
- reduced muck pile looseness & diggability

Special attention should be paid to the positions of front row blast-holes. If the burden on front row charges is excessive, the rock will not move sufficiently to allow rock in subsequent rows to blast optimally and the blast will be a disaster.

If the burden is too small, energetic explosive gases burst rapidly through the face causing noise, air blast and, in some cases, fly rock. If air blast is to be controlled, the burden distance should be at least 20 blast-hole diameters.

Changes in burden tend to affect fragmentation, muck pile looseness and the presence of toe much more rapidly than any changes in spacing. If blasting results are good and it is decided to try a larger pattern, it is preferable to increase spacing rather than burden. If the current pattern is already quite elongated, however, it may be necessary to keep spacing constant and increase burden by a sensible amount (10% maximum). With any trial blast, it is important that the muck pile is completely removed and the cost efficiency of digging assessed before the next blast is drilled out.

It is most important that once burden and spacing have been selected, every blast-hole is collared in the correct place and drilled at the correct angle and direction of dip and to the correct depth. There is a very good argument for every blast-hole being pegged out by a surveyor. Optimum blasting results cannot be achieved by stepping out of a blast-hole pattern.

Main Points - burden

- General rule of thumb for burden is 24-36 blast-hole diameters.
- Burden and Spacing are controlled by blast-hole diameter, rock properties, required fragmentation, muck pile looseness and layout of the block to be blasted.
- Excessive burden causes poor fragmentation, poor movement, toe and excessive ground vibration.
- Insufficient burden causes air blast, fly rock, and poor fragmentation between blast-holes and it wastes the explosive´s energy.
- Burdens can be changed in a blast to provide better relief in deep blasts (reduce burdens as you move to the back of the blast with more than 15 rows from front to

back) and to reduce costs in throw blasting (increase burdens after first five to six rows as these will not throw because of the material in front.)

9.3.4. Blast-hole Pattern (Staggered v Square)

One of the most common questions asked of blast design is "What is the advantage of staggered patterns over square patterns?". Square patterns are simple to mark out and often the end result seems to be the same. However, there is both an academic argument and considerable experience to show that fragmentation, productivity and profitability are greater with staggered patterns compared to square or rectangular patterns. The difference increases with higher values in the strength of the rock mass.

Use square patterns in trenches and narrow benches where the simpler geometry is a significant advantage, otherwise, use staggered patterns.

A staggered pattern has every second row 'offset'. This can give a better explosives distribution but is dependent on the Spacing to Burden ratio.

The S:B ratio chosen will be based on:

- Rock strength
- Rock condition
- Ore body type (massive or small pods/vertical or horizontal)
- Required movement of material (throw or sit)

In general, lower ratios (<1) are used in paddock blasting or choke blasting to fragment and give muck pile looseness. High ratios (>1.2) are used to throw or 'cast' material as in overburden removal for draglines in large open cut coal mines.

Rule of thumb #3:

Begin the design with staggered patterns and a burden to spacing ratio of 1:1.15

If the burden to spacing ratio is too high, the material midway between back row blast- holes may remain intact, especially near bench floor level, creating toe problems for the next blast.

For burden to spacing ratios that are too low or, in the extreme case where the spacing is significantly less than the burden, premature splitting between blast-holes in the row and early loosening of the stemming may occur. Both these effects encourage the premature release of gases to the atmosphere and overbreak is usually considerable.

This loss of heave energy detracts from overall breakage and large slabs are often found in the muck pile.

Although the mechanical efficiency of staggered patterns exceeds that of square or rectangular patterns, the difference in blasting results decreases with a decrease in the strength of the rock mass. In weak or closely fissured rock the difference in blasting results may not be noticeable.

Main Points - blast-hole pattern

- Staggered patterns are more economical than square or rectangular patterns in strong rock.
- There is little difference in blast result in weak, highly fissured rock.
- Burden to spacing ratio varies from 1: 1 up to 1: 1.5 but it may go higher depending on rock structure, orientation and required blast result.

9.3.5. Subdrilling

Subdrilling or subgrade is the length of blast-hole drilled beneath bench floor level below the required floor of the excavation.

Subdrilling is carried out to ensure explosives are placed below the bench floor level to assist with floor grade control. The correct amount of subdrilling is critical to the entire operation. Too little subdrilling and digging becomes difficult, floor grades will be poor and tear on equipment will be increased. Too much subdrilling and drilling is adversely affected due to excessive preconditioning of the next bench down.

Note that if there is a weak or valuable horizon at grade (such as when blasting to coal) the blast holes will be drilled to finish above the grade line. This is the opposite of subgrade and it is known as 'Standoff'.

The optimum amount of subdrilling depends on:

- Strength and density of the rock mass
- Diameter and inclination of blast-holes
- Type of explosive and, more particularly, the energy generated per meter of blast-hole
- Mean inclination of the face and the effective toe burden distance
- Location of primers in the charge.

Rule of thumb #4:

Subgrade = 8-12 blast-hole diameters

Subgrade = 8-12 blast-hole diameters for surface blasting operations. (Remember that rules of thumb are just that, an initial first pass estimate).

In strong, massive rocks, subdrilling of about 8D is usually found to be satisfactory. But subdrilling as high as 12D may be necessary in front row blast-holes in places where vertical blast-holes shoot to relatively high or shallow dipping faces.

A Subdrilling below 8D can usually be employed satisfactorily in places where:

- the rock is weak or contains well developed sub-horizontal fissures
- blast-holes are inclined significantly to the vertical
- a high energy per meter of blast-hole can be generated

Even when there is no change to blast hole diameter, subdrilling may have to be increased with any increase in burden distance or blast-hole spacing.

Standoff is generally designed in the range of 4 to 8 diameters as the damage below the toe of a blast hole is limited.

Main Points - subdrilling

- subdrilling is required to keep good floor grade control
- The general rule of thumb for subdrilling is between 8 and 12 blast-hole diameters
- Excessive subdrilling will precondition the next bench and cause high vibration. Insufficient subdrilling will cause toe and floor grade degradation.

9.3.6. Explosives Distribution

The distribution of explosives along a blast-hole should be consistent with:

- the bench height
- the physical properties of the rock mass
- the amount of fragmentation, displacement and muck pile looseness desired
- the need, if any, to control noise, air blast and overbreak.

Single and continuous charges should be used in most blast-holes. As blast-hole length increases towards a certain critical value, so should charge length and charge weight. Blast-holes having a length exceeding this critical value should contain two deck charges rather than a continuous charge. The critical blast-hole length increases with the effective strength of the rock. It is important to ensure that the length of any explosive charge (other than pocket charges used for breaking collar rock) is at least 20 hole diameters.

Explosives distribution is very dependent on the rock mass to be blasted. If a single bed of strong massive rock lies within relatively weak/soft materials, a high energy fully coupled charge should be placed in that part of the blast-hole within the strong rock. In weaker material, a lower energy charge should be located both below and above the strong bed.

If poor fragmentation is causing problems in the collar area, a small pocket charge can be located centrally within the stemming column. The size of this pocket charge should be sufficiently small to prevent excessive air blast, fly rock and overbreak, but large enough to help break any massive blocks which lie alongside the stemming. A cheaper and easier alternative is to increase the uncharged length and reduce stemming by the introduction of an air deck.

Main points –explosive distribution

- Explosive column length should be at least 20-hole diameters for effective distribution.
- Change the distribution of the explosives for soft rock, cavities, insufficient burden or excessive toe burden.
- Explosives distribution should be called energy distribution.
- Pocket charges may be used in the stemming to break up strong collar rock.

9.3.7. Stemming

The function of stemming is to contain the explosion gases to assist in fracturing rock, heave and to reduce blast nuisances such as air blast and fly rock. For a given blast, this means burden and/or spacing can be increased significantly if a suitable type and quantity of stemming is being used.

Good stemming provides both inertia (weight of the stemming) and, more importantly, frictional resistance (locking of angular rocks/grains) to contain the high-pressure gases following a detonation. For this reason, water, mud and fine drill cuttings are ineffective forms of stemming as they only rely on inertia to contain the gases.

The general rule for the size of stemming to be used is 10% of the blast-hole diameter.

i.e. for a 208mm blast-hole, the stemming material should be approximately 20 mm in size. The maximum stemming size, regardless of the size of the blast hole, is about 25 mm, as anything larger than this tends to damage the initiation down lines.

Stemming length increases if the blast-hole diameter increases.

Rule #5

Stemming length is 20 - 30 blast-hole diameters.

In strong, massive rock, stemming length may be kept short to ensure good breakage at the collar, but not induce excessive air blast or fly rock. Small pocket charges may be used if required. In weak rock, stemming lengths can be increased to take advantage of the weaker material in the collar area breaking.

It should also be remarked that the stemming length should be longer than the burden to promote forward movement rather than upward movement. If upward movement is required, the stemming length may be less than the burden but should generally not be less than 0.8 times the burden to contain fly rock, air blast and cratering of blast-holes (energy is released too easily and does not work on rock between blast-holes).

Relatively long stemming columns should also be used for any front-row blast-hole that has an inadequate burden alongside the top of the charging order to prevent fly rock and air blast. Such conditions are common if vertical blast-holes are drilled alongside faces that are high or shallow dipping. Pocket charges can also be applied in such front-row blast-holes. A longer stemming column can be used in back-row blast-holes to reduce overbreak.

Main Points - stemming

- The general rule of thumb for stemming length is 20-30 diameters.
- Insufficient stemming length will cause air blast and fly rock out the top of the blast.
- Excessive stemming will cause poor fragmentation in the collar region.
- Stemming particle size should be approximately 10% of the blast-hole diameter up to a maximum of 25 mm as a general rule. Material over 25 mm may damage the initiation downline.

9.3.8. Primer placement

A bench blast design must also include details of priming. Blasting results are affected by the type and number of primers used and their positions in blast-holes. If a single primer is used inside each blast-hole, it is usually placed just above the toe. This ensures that the detonation starts in a position that is well confined so that explosion gases cannot easily escape. Explosive energy can then be effectively used to break rock near the toe. If a single primer is placed near the collar, the charge could blow out quickly because the detonation starts close to the stemming material.

If there is a layer of hard rock between weaker materials, the primer can be placed within the tougher rock. This could assist to break the hard rock, and may also prevent charges from easily blowing out through the weaker material.

Several primers may also be used in each blast-hole, for many different reasons. Multiple primers provide "insurance" in long blast-holes, and are desirable if the rock contains cracks or faults that could cut off charges during the blast. Extra primers are also recommended if explosives are likely to be damaged after charging (e.g. by water).

9.4. Influence of blast timing on fragmentation and heave

Whilst the blast mechanism is an extremely complex event with many unmeasured factors, it is possible to significantly alter the outcome of a blast by changing the initiation timing. This is not to say that timing will fix a poorly drilled pattern or compensate for poor explosive performance. However, in a correctly drilled and loaded pattern, the application of consistent timing with appropriate, well-chosen delays will significantly enhance performance.

Assuming there is standard bench geometry, the overall timing can be considered as being comprised of two timing elements - the timing between holes along the row and the timing between rows. The time between holes within the row is known as the intra-row or spacing timing and the time between rows is known as the inter-row or burden timing.

It is reasonable to consider that the intra-row delay has the dominant influence on fragmentation and the inter-row delay has the dominant influence on heave or throw. This is simplifying matters - however, it helps to reach a good first estimate which can be fine-tuned in the field. When actual firing times are considered for optimization, it is necessary to refer to timing in terms of milliseconds per meter of burden or spacing for a particular hole. This enables generalizations to be made about blast performance in certain rock types irrespective of the blast geometry.

9.4.1. Spacing timing influence on fragmentation

For extremely brittle hard rocks the intra row delay should be reduced as the response time of the rock mass is reduced. In contrast, a porous, plastic, highly jointed rock mass will require more time between detonations of adjacent blast holes.

If the intra-row delay is made very short (consider the extreme case of firing a row of holes instantly), preferential cracking will occur between holes in a row resulting in increased forward movement and reduced fragmentation.

In places where the intra-row delay is made too long, blast-holes function individually with reduced fragmentation and movement. This is due to the relaxation of blast induced cracks in the burden rock of the adjacent blast-hole, which then both stop the development of radial cracks from the blast-hole firing and act as escape paths for explosive energy.

The optimum spacing timing will be such that all radial cracks from the first blast-hole have developed as far as possible, and explosive gases have started to move the burden rock of that blast-hole away from the face. The second blast-hole then “sees” only the correct burden of rock, still stressed due to the energy of the first blast-hole, with all blast induced cracks still tight, allowing new cracks to pass through into the solid rock on the other side.

9.4.2. Burden timing influence on heave

To achieve maximum throw in multiple row blasts, timing between the rows must be long enough that previously fired material is well away and does not hinder the forward movement of the mass about to be fired. Consider the extreme case of firing all rows together; in this case, only the front row will see a free face forward, for all the remaining rows the bench will effectively be the free face.

This puts a lower limit on the inter-row delay below which choking of the blast will occur with restricted forward movement and a possible increase in over break and vertical heave. This minimum time is variable depending on the response time of the rock mass.

Increasing the burden timing to excessively long inter-row delays does not have an added effect on performance. In fact, excessive inter-row delays will limit throw due to displaced rock mass coming to rest against the face hindering further movement.

If the case of the ‘optimum’ timing for the rock being blasted is being considered, then the front row blast-hole will have fired, and will just have started to move away from the face, so that the next row only sees one burden of unbroken rock.

The timing should not be so long that relaxation can occur in the burden rock. When the next row of blast-holes is fired, the moving burden will not be confined by the row in front and the rows of blasted rock will maximize forward movement. The combination of spacing and burden timing elements is often described as “relief”. Unless there is a strong reason not to do it, initiation timing will have a constant relief throughout the blast. This promotes optimal timing and consistent results across the blast. Blast sequencing programs will show the blast timing as “relief” in milliseconds per burden meter and can be used to apply consistent timing.