British Columbia Blasters' Handbook

WORKSAFEBC

About WorkSafeBC

At WorkSafeBC, we're dedicated to promoting safe and healthy workplaces across B.C. We partner with workers and employers to save lives and prevent injury, disease, and disability. When work-related injuries or diseases occur, we provide compensation and support injured workers in their recovery, rehabilitation, and safe return to work. We also provide no-fault insurance and work diligently to sustain our workers' compensation system for today and future generations. We're honoured to serve the workers and employers in our province.

Prevention Information Line and contact information

We provide information and assistance with health and safety issues in the workplace.

Call the information line 24 hours a day, 7 days a week to report unsafe working conditions, a serious incident, or a major chemical release. Your call can be made anonymously. We can provide assistance in almost any language.

If you have questions about workplace health and safety or the Occupational Health and Safety Regulation, call during our office hours (Monday to Friday, 8:05 a.m. to 4:30 p.m.) to speak to a WorkSafeBC officer.

If you're in the Lower Mainland, call 604.276.3100, or toll-free at 1.888.621.7233 (621.SAFE) in Canada.

Health and safety resources

You can find our health and safety resources at worksafebc.com/forms-resources. Printed copies are available for some resources and can be ordered from worksafebcstore.com.

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WorkSafe BC

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Introduction

Blasting and explosives have long been used in British Columbia. Over time, they have proven to be valuable in mining, construction, road building, avalanche control, seismic, and oil-and-gas applications.

The use of explosives comes with risk and has caused serious injuries and fatalities. As a result of these incidents, in 1951 the Workers' Compensation Board was empowered to establish a blasting certification program. The program's goal was to ensure that persons engaged in blasting activities have the necessary skills and knowledge to safely handle explosives.

Today, any person who wants to conduct an industrial blasting operation (other than in a mine) must be a holder of a valid blasting certificate issued by WorkSafeBC.

This handbook is designed as a study guide for those who wish to be examined for a WorkSafeBC blasting certificate. It can also be used as a reference for certified blasters currently working in the industry and for blasting company employers and owner/operators.

Key changes in this edition

This edition of *British Columbia Blasters' Handbook* includes new chapters on the following:

- General health and safety requirements (Chapter 1)
- Common injuries and health and safety hazards in blasting operations (Chapter 2)
- Blast design (Chapter 10)
- Electronic initiation systems (Chapter 21)
- Remote firing systems (Chapter 22)
- Avalanche control (Chapter 23)

This edition has been revised extensively to reflect changes in blasting technology and in a number of laws and regulations, including the Occupational Health and Safety Regulation. Learning objectives appear at the start of each chapter, and the updated glossary should be useful to readers. In most cases, if a term is set in italics in this handbook, it is defined in the glossary. And the appendixes have been revised to include information on blast design patterns, trench patterns, blast design calculations, and other topics.

Wording in this handbook

In this handbook, the word "must" indicates a requirement that's specified in a law or regulation. The word "should" indicates a recommended action that will improve workplace safety even though it's not required.

This handbook doesn't replace the Occupational Health and Safety Regulation

This handbook is meant to give you a basic understanding of your health and safety requirements, but you should also refer to the Regulation to ensure you're meeting your legal responsibilities for workplace health and safety. You can find a searchable version of the Regulation and its accompanying guidelines and policies at worksafebc.com/searchable-regulation.

Part 1:
Programs and documentation

Chapter 1: General health and safety requirements

Learning objectives

- Identify employer, supervisor, and worker responsibilities related to general workplace safety when planning and conducting blasting operations.
- Explain workers' right to refuse unsafe work.
- Describe WorkSafeBC blasting certification requirements and qualifications for new and existing workers as well as trainers.
- Explain blaster requirements for continued professional development.
- Describe workplace health and safety program requirements.
- Identify how to manage health and safety risks.
- Describe the purpose of a health and safety program and its components.
- Discuss the role of ongoing education and training in blasting operations.
- Describe supervisor responsibilities for training workers under their supervision.
- Describe the purpose and goal of workplace inspections.
- Describe how to conduct an inspection and what to inspect.
- Explain the minimum requirements for providing first aid at blasting operations.
- Describe the role of personal protective equipment (PPE) as a last line of defence in a health and safety program.
- Describe what PPE workers may need to use and why.
- Distinguish between worker and employer responsibilities related to limb and body protection.
- Describe the purpose and function of health and safety meetings.
- Explain the purpose of an emergency response plan.
- Discuss the reason for maintaining statistical data and health and safety records.
- Describe the purpose of incident investigations and how they are conducted.

Responsibilities

Everyone in the workplace has health and safety responsibilities, including employers, supervisors, and workers.

Employers

General workplace safety

Employers have the following responsibilities:

- Ensure the health and safety of workers at the worksite.
- Identify workplace *hazards*, and assess the risks of injury associated with those hazards.
- Remedy any workplace conditions that are hazardous to workers' health or safety.
- Write safe work procedures, and implement risk controls.
- Provide workers and supervisors with the information, instruction, training, and supervision necessary to ensure their health and safety.
- Keep written records of training (detailing who, what, and when).
- Establish and maintain an occupational health and safety program, including a written health and safety policy and a procedure for incident investigations.
- Support supervisors, safety coordinators, and workers in their health and safety activities.
- Take action immediately when a worker or supervisor reports a potentially hazardous situation.
- Initiate immediate investigations into incidents.
- Provide adequate first aid facilities and services.
- Provide and maintain personal protective equipment (PPE), clothing, and devices as required.
- Ensure that workers are made aware of:
    - All known or reasonably foreseeable health or safety hazards to which they are likely to be exposed by their work.
    - Their rights and duties under B.C.'s *Workers Compensation Act* and Occupational Health and Safety Regulation.
- Ensure that workers follow the requirements of the Act and the Regulation, and that they have access to these documents.

WorkSafeBC provides a free OHS Regulation app for iOS and Android devices. For more information, search for "OHS Regulation app" on worksafebc.com.

Planning and conducting blasting operations

Employers also have specific responsibilities for planning and conducting *blasting operations.*

An employer must ensure that all activities of a blasting operation are planned and conducted in a manner consistent with the Regulation and recognized safe blasting practices. This requirement also applies to every person who has knowledge and control of any particular activity in a blasting operation.

The planning must:

- Include procedures for identifying and addressing potential *misfires.*
- Include any exposure controls required by Part 5 or 6 of the Regulation.
- Identify any work activities or conditions at the workplace where there is a known or reasonably foreseeable risk to persons or property.
- Be completed before work begins on the relevant activity.
- Be documented.

If changes to workplace activities or conditions create risks to people or property, then the written plan must be updated as soon as practicable to identify and address those risks. The updated written plan must be readily available to workers.

In the Regulation

The Regulation defines practicable as "that which is reasonably capable of being done."

Employers must also do the following:

- Assign work only to competent workers.
- Ensure that workers engaged in loading, unloading, or transporting *explosives* are trained in the following:
  - The proper means for handling the explosives.
  - The hazards of mishandling or fire.
  - The procedures to follow in the event of a fire or *explosion*.

In the Regulation

If a worker is or may be exposed to potentially harmful levels of certain substances (e.g., silica dust, asbestos), the employer must ensure that a risk assessment is conducted by a qualified person. The employer must also ensure that an exposure control plan (ECP) is developed and implemented. An ECP is required under section 5.57 of the Regulation and must meet the requirements of section 5.54 of the Regulation.

Supervisors

Supervisors have the following responsibilities:

- Ensure the health and safety of workers under their direct supervision.
- Know the requirements of the Regulation that apply to the work they're supervising.
- Ensure that workers under their direct supervision are informed about all hazards in the workplace and that they comply with the Regulation.
- Consult and co-operate with the joint health and safety committee (or worker health and safety representative, if applicable).
- Co-operate with WorkSafeBC and its officers.

Workers

Workers have the following responsibilities:

- Take reasonable care to protect their health and safety and that of others who may be affected by their actions.
- Comply with the Regulation and other legal requirements.
- Follow established safe work procedures.
- Use any required PPE.
- Refrain from horseplay or similar conduct that may endanger others.
- Don't work if impaired (for example, by drugs or alcohol).
- Report accidents and other incidents (such as near misses) to the supervisor.

- Report to the supervisor or employer any of the following:
  - A hazard that might endanger others.
  - A problem with protective equipment or clothing.
  - A violation of the Regulation or other legal requirements.
- Co-operate with the joint health and safety committee (or worker health and safety representative, if applicable).
- Co-operate with WorkSafeBC and its officers.

Refusing unsafe work

As a worker, you have the right to refuse unsafe work. In fact, you must not carry out (or cause to be carried out) any task you have reasonable cause to believe would create an undue hazard to the health and safety of any person.

If you discover an unsafe condition or believe you're expected to perform an unsafe act, you must immediately report it to a supervisor or your employer. A supervisor or employer who receives such a report must investigate the matter immediately. If there is an unsafe condition, it must be corrected without delay.

Sometimes a supervisor or employer may not agree that a task is dangerous. In this case, sections 3.12 and 3.13 of the Regulation describe the steps to be followed.

Workers must not be disciplined for refusing to perform tasks they have reasonable cause to believe are dangerous. You may be assigned other work at no loss in pay while the reported unsafe condition is being investigated.

Certification requirements

In B.C., initial or new blasting certifications are issued for a period of two years. When a certificate expires, the *blaster* must write and pass another blasting exam to be recertified. Renewal blasting certifications are issued for a period of up to five years. WorkSafeBC may apply restrictions to any blasting certification as needed.

Under section 21.8 of the Regulation, each candidate for a blaster's certificate must:

- Be at least 18 years of age.
- Forward written proof acceptable to the examining officer that:
  - The candidate has taken a minimum of 8 hours of training relating to the safe handling of explosives.
  - The candidate has passed a background check.
  - The candidate has one of the following:
    - At least 6 months of experience in blasting operations as an *assistant* to a blaster.
    - The knowledge, qualifications, and experience to make the candidate competent to handle explosives.

Before attempting to write or rewrite a blasting exam, applicants must be knowledgeable about Part 21 of the Regulation as well as this handbook. Other important material can be found in the following:

- Explosives manufacturers' technical data sheets (TDSs)
- The federal *Transportation of Dangerous Goods Act* and Regulations
- The federal *Explosives Act* and Regulations
- The B.C. *Motor Vehicle Act* and Regulations

For more information on blaster certification, including documentation requirements, see the Blaster certification webpage at worksafebc.com.

For information on certification for mining operations, contact the B.C. Ministry of Energy, Mines and Low Carbon Innovation.

Qualifications for trainers

The blaster(s) providing training to a candidate should:

- Have a minimum of two years' experience within the same class qualification
- Have no certificate suspensions within the past two years
- Be competent and knowledgeable in the endorsements held

For more information on qualifications for trainers, including documentation requirements, see OHS Guideline 21.8.

Continuing professional development

Every year during the term of a blaster's certificate, the blaster must receive at least six hours of continuing professional development relating to best practices in blasting. Professional development can be obtained through the International Society of Explosives Engineers (ISEE) or other organizations. For more information on professional development requirements and topics, see OHS Guideline G21.8.1.

Health and safety program

Under the Regulation, employers must develop and implement an effective health and safety program for their workplace. They must also train workers and supervisors in relevant sections of the program.

A health and safety program helps ensure a safe, productive workplace by describing specific tasks and responsibilities for many different aspects of an employer's operation. An effective health and safety program for any workplace must include the following:

- A written occupational health and safety policy that:
  - States the employer's commitment to health and safety.
  - States the program's objectives.
  - Defines the responsibilities and roles of the employer, supervisors, and workers.
- Written safe work procedures and emergency response procedures.
- Instruction and supervision of workers.
- Regular worksite inspections. (The definition of "regular" depends on the conditions and number of shifts for each individual site.)
- Regular health and safety meetings.
- Accident investigation procedures.
- Records and statistics.
- A joint health and safety committee or worker health and safety representative, if required. (For more information, see "Regular health and safety meetings" on page 29.)

Remember that every worksite is different. Although these general elements may be common to health and safety programs across the province, employers cannot expect to copy a program from another worksite. Instead, they must develop and implement a health and safety program unique to their own operation.

Managing health and safety risks

Identifying hazards and controlling the risks associated with them help keep workers safe from injury. There are three steps to managing health and safety risks:

1. Identify the hazards.
2. Assess the risks.
3. Control the risks.

1. Identifying hazards

As an employer or supervisor, you should identify and eliminate hazards during the planning phase of a project. You can also identify hazards by doing workplace inspections. Consider the following when identifying hazards:

- Assess the equipment, materials, and tools workers are using. Consider how workers will be using them.
- Analyze the design, layout, and conditions of the work areas.
- Observe how workers are doing their tasks.
- Encourage workers to take part in hazard identification.

2. Assessing risks

Once you've identified hazards, assess the risks associated with them. Try to determine how likely an incident is and how serious it would be.

3. Controlling risks

After you've identified hazards and assessed the risks, look for ways to control each hazard without delay. If possible, eliminate the hazard entirely.

If that's not practicable, control the risks as much as possible. For example, it may not be practicable to eliminate noise when using a drill. Instead, the employer must implement a hearing conservation program. This includes:

- Educating workers about the noise hazards
- Ensuring workers wear hearing protection when working with or near drills
- Ensuring hearing tests are conducted

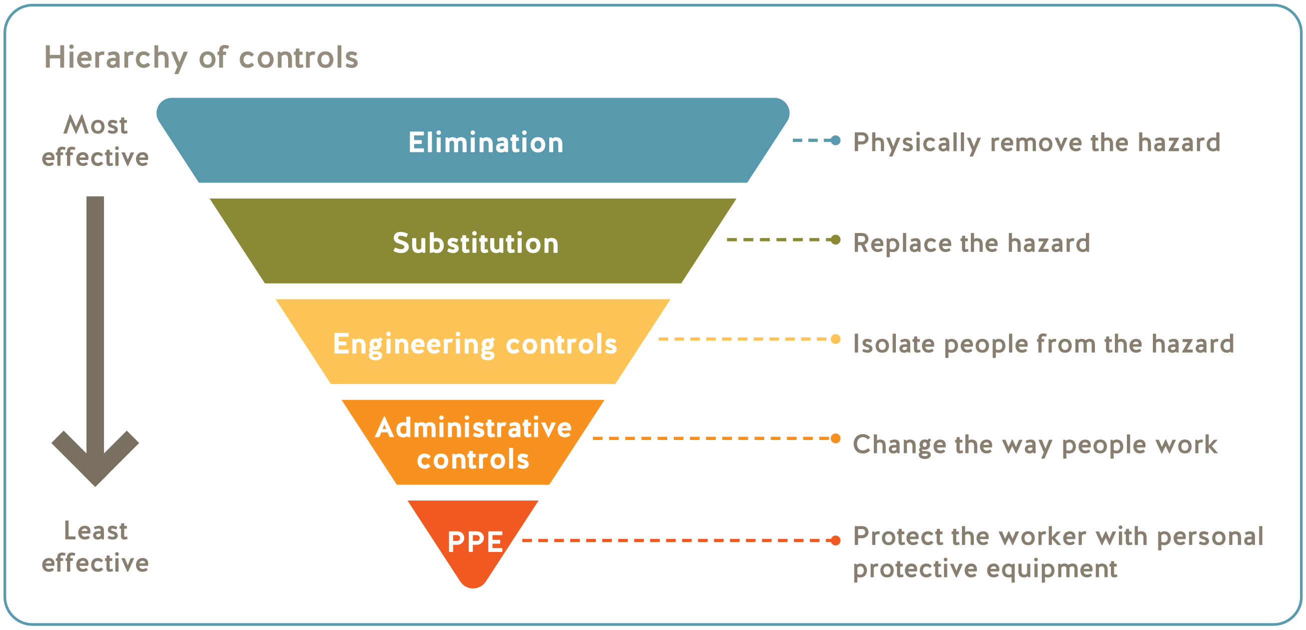
For more information on hearing conservation programs, see Part 7 of the Regulation.

Hierarchy of controls

Some types of controls are more effective than others, although it may not always be practicable to use the more effective solution. Whenever possible, though, you must implement controls in the following order:

1. Eliminate the hazard.
2. Substitute a safer alternative.
3. Use engineering controls.
4. Use administrative controls.
5. Use PPE.

Controls from most effective to least effective



Note that while the controls are listed in order of effectiveness, you must consider all four remaining types of controls if you can't eliminate the hazard. They often work best in combination.

For example, when drilling rock or using products containing crystalline silica, you may need to use several of the following to control the hazard effectively:

- Engineering controls (e.g., vacuum systems and wetting controls)
- Administrative controls (e.g., exposure control plans, work procedures, signage, enclosures, and work area arrangements)
- PPE (e.g., respiratory protection, protective clothing or suits, and gloves)

References

Refer to the following for more information.

Regulation

- Section 3.16(2), Basic requirements
- Sections 4.13, 4.48, and 4.49, Risk assessment
- Section 6.6, Assessment and classification
- Sections 6.59.1 and 6.112, Risk assessment

Web

Webpages at worksafebc.com:

- Managing risk
- Controlling risks

Orientation, education, training, and supervision

An occupational health and safety program should describe the type of education and training that will be provided to workers and when it will be provided. For example, workers should receive instruction in the safe work procedures they must follow when performing hazardous tasks. Workers should also be instructed about site hazards and trained in the use of emergency equipment and procedures.

Employers should ensure that, before starting work, young or new workers receive a health and safety orientation and training specific to the workplace. A young worker is any worker under age 25.

References

Refer to the following for more information.

Regulation

- Sections 3.1 to 3.3, Occupational health and safety programs
- Sections 3.22 to 3.25, Young or new workers

Publication

Creating and Managing a Healthy and Safe Workplace

Web

Young & new workers

Checklist

Young and New Worker Orientation Checklist

Orientations and ongoing education

At the end of the hiring process, employers need to make sure that new or young workers get off to a good start. Orientations are important because they provide an opportunity to establish health and safety guidelines and requirements before a worker starts at a new job or location. Health and safety education is an ongoing process.

Employers need to provide instruction to workers whenever there are changes in the workplace, such as a new work process or piece of equipment. The person conducting the orientation should know the workplace well and understand all the items on the orientation checklist.

Topics an orientation should include

Orientations must occur on the first day of employment, before work begins. Workers must not perform any tasks until the orientation is complete. Orientations should include the following:

- Direction that workers should not perform any task they're not trained to do safely
- Encouragement to ask questions whenever workers are unsure of anything
- An introduction to the joint committee or worker health and safety representative
- Information on who the direct supervisor will be and the supervisor's contact information

In addition, workers should be informed of the following:

- Employer and worker rights and responsibilities, including reporting unsafe conditions and refusing unsafe work
- Workplace health and safety rules
- Potential hazards, such as falling objects, working around heavy equipment, vibration, and silica exposure
- Procedures for working alone or in isolation
- Procedures for workplace violence
- Bullying and harassment policy
- Required PPE
- Locations of first aid facilities and how to summon first aid
- How to report illnesses and injuries
- Emergency procedures
- Workplace Hazardous Materials Information System (WHMIS) requirements that apply to their tasks
- Contact information for the joint health and safety committee (or worker health and safety representative, if applicable)

Employers should provide young or new workers with additional orientation and training if the worker isn't able to perform work tasks safely or the worker asks for more training.

Ongoing education

Ongoing education is an important part of worker education and training. One example of ongoing education is the tailgate meeting. Tailgate meetings are brief safety talks where, in as little as five minutes, workers can learn about workplace health and safety topics and ask questions. The following table suggests examples of topics that managers or supervisors could discuss during tailgate meetings in blasting operations.

Tailgate meetings help workers learn about health and safety topics and ask questions.

Tailgate meeting topics

Topic	Things to consider
Shop	Grinders, tools, hoses, ropes, drill rods, stairs, fire exits, emergency equipment, documents (e.g., seismograph records, work orders, inspection logs, TDSs)
Vehicles	Maintenance, fluids, tires, interior, powder boxes, locks, placards
Fire protection	Fire extinguishers, plastic backpack extinguishers (piss cans), water access
Hazardous materials	Flammables, grout, expanding grout, fuel, antifreeze, motor oil, disposal
First aid	Eyewash, first aid supplies, attendants
PPE	Hard hats, safety glasses, gloves, hearing protection, respirators, harnesses, lifelines
Drills/rigs	Loose clothing hazards, falling objects, blind spots, rollover protective structures (ROPS), winches, bight, maintenance, condition of drill rods, rotation of drill rods, drill rod retrieval, mud collars, slips, drill log, whip checks, high-pressure air hoses, fittings, repairs
Hand drilling	Working around heights, body positioning, gauging drill rod bits; mud collars, slips, broken rods, oilers, high-pressure air hoses, whip checks, fittings, hose repairs
Compressors	Maintenance, pressurized air safety, valves, hoses, safety shut-off, whip checks
Hand tools	Air guns/drivers, grinders, gas saws, scaling bars, jacks, grease guns
Magazines	Log books, cleanliness, organization, security, locks
Environment	Proximity to lakes, streams, and ocean; environmental impact
Site preparation	Tree removal, danger tree removal; scaling by hand or machine, installing rock fences
Blast site	Blast mats, hooks, cables, equipment, heavy equipment, seismographs, hoses; site management, communication, hand signals
Walkways and roads	Ramps, vehicle ways, tag lines, footpaths
Support equipment	Aerial lifts, cranes, scaffolds, ladders, work platforms
Work process	Working safely, using PPE, following safe work procedures

Training

All workers need supervised, hands-on training in how to safely perform their tasks before starting a job. The following three steps describe a general procedure supervisors can follow when training new workers.

1. Prepare the worker

- Explain the job in detail, including any safety precautions or required PPE.
- Encourage the worker to ask questions. Take the time to answer them fully.

2. Train the worker

- Demonstrate and describe specific procedures, including all safety precautions.
- Go through procedures at normal speed, then repeat them slowly while the worker asks questions.
- Watch the worker perform procedures until the worker can do them exactly as required.
- Answer any questions or repeat any key points that the worker may have missed.
- Keep written records of training. Document who was trained, when they were trained, who did the training, and what the training included.

3. Check progress and observe the worker on the job

- Monitor new workers to ensure they're maintaining safety standards.
- Make unscheduled checkup visits. As the worker progresses, make visits shorter and less frequent.
- Correct unsafe work habits.
- Reinforce and recognize good work habits.

Supervision

If you're directing another worker, you're a supervisor. Supervisors are responsible for ensuring the health and safety of workers under their supervision. Supervision includes the following:

- Explain the hazards of the job.
- Instruct new workers in safe work procedures. Document the instruction.
- Ensure that workers have been trained for their assigned tasks, including safety precautions and safe work procedures. Document this training.
- Ensure that safety equipment and PPE are used when required and maintained in good working order. Document safety equipment and PPE maintenance.
- Ensure that workers handle and store all materials safely.
- Instruct new workers on how to report safety hazards and on their right to refuse unsafe work.
- Enforce health and safety requirements.
- Implement risk controls for identified hazards.
- Correct unsafe acts or conditions that you observe or that workers bring to your attention. Document any steps taken.
- Monitor worker safety behaviours and well-being.
- Set a good example in areas such as following safe work procedures and using PPE.

Workplace inspections

Employers need to correct hazards they observe from day to day. They also need to set aside time for regular workplace safety inspections. And they need to control any hazards found during inspections. It's far better and less costly to prevent incidents than to deal with their consequences. Because safety inspections are preventive in nature, they're an important part of an occupational health and safety program.

When to inspect

Workplace inspections need to be done at intervals appropriate to the risk to prevent unsafe working conditions from developing. An inspection must also be done when a new process has been added or after an incident. Inspection is an ongoing task because the workplace is always changing.

References

Refer to the following for more information.

Regulation
Section 3.5, General requirement (for workplace inspections)

Publication
Safety Inspections Workbook

Who should inspect

Inspections should be conducted by a supervisor and a worker who are familiar with the work process. If possible, a member of the joint health and safety committee (or the worker health and safety representative, if applicable) should be involved.

How to inspect

During an inspection, the goal is to identify unsafe conditions and acts that could result in an incident so that risk controls can be implemented. If you're carrying out an inspection, follow these guidelines:

- Use a checklist to ensure the inspection is thorough and consistent with previous inspections.
- Ask yourself what hazards are associated with the tasks you're observing or that would be performed in the work area.
- Observe how workers perform tasks. Do they follow safe work procedures and use PPE as required?
- Ask workers about the hazards associated with their tasks and how they safely perform the tasks.
- Talk to workers about what they're doing. Ask about safety concerns.
- Record any unsafe actions or conditions that you observe.
- Keep inspections on file for two years.

At first, inspections may seem slow and difficult. But over time, they'll become much easier. They'll also help make the health and safety program more effective.

Use a checklist to ensure the inspection is thorough.

What to inspect

A few examples of things to inspect include the following:

- Buildings, structures, and grounds
- Excavations
- Tools, equipment, and machinery
- Work methods and practices

However, there are different ways of approaching safety inspections, depending on the objectives of your health and safety program. For example, inspections can focus on the most common tasks workers perform or on a specific issue addressed by the program, such as ergonomics.

Check whether workers are following safe work procedures. For example, consider the following:

- Is drilling equipment in proper working order and inspected for safety prior to use?
- Are workers using appropriate respirators and hearing protection devices and wearing them properly?
- Are *drill holes* (also known as bore holes) checked to ensure they are unobstructed and the correct depth?

After the inspection

Employers and supervisors need to follow these guidelines:

- Remedy serious hazards or unsafe work practices immediately. For example, if you find cable that is damaged or frayed, immediately remove it from service and repair or replace it. Some repairs and modifications may require design and approval from the equipment manufacturer or a professional engineer.
- Prioritize other, less serious hazards, and assign someone to remedy each one.

- Follow up on any actions that will take time to complete (for example, purchasing new equipment).
- Communicate your findings and plans to workers using your safety board or the joint health and safety committee.
- Keep a record of inspection results and timelines for when you plan to fix identified issues. This is a good practice that shows due diligence.

First aid

All workplaces must meet the first aid requirements in Part 3 of the Regulation. Effective first aid treatment can reduce the severity of work-related injuries. This will help minimize the financial costs associated with extensive medical treatment or the need to replace employees who are unable to work.

All blasting operations must keep a first aid kit on site, and many will also need at least one first aid attendant. The type of kit and the first aid attendant requirements depend on the number of workers and the travel time to the nearest hospital.

For more information on first aid requirements, see the "Occupational first aid" sections of Part 3 of the Regulation.

Personal protective equipment (PPE)

Personal protective equipment should be the last line of defence in a health and safety program. Before considering PPE, employers should first try to eliminate or minimize the risks using other means. For example, they should explore using less-hazardous chemicals or modifying work processes or equipment. If PPE is required, employers must ensure that it's available to all workers who need it.

Workers in blasting operations are exposed to many types of risks. Some types of PPE are essential for all workers working in a blasting environment. It is crucial that each worker is properly trained, and in some cases certified, in the use of PPE. Workers must use the PPE according to their training.

Hearing protection devices

Workers in blasting operations are regularly exposed to high levels of noise. These noise levels have the potential to cause permanent hearing damage. Most rock drills operate at 130 *decibels*, so hearing damage can occur in just seconds.

As a worker, you must wear a hearing protection device (HPD) that provides enough protection from noise. It must be the right size for you and be comfortable, and you must wear it properly. Make sure to wear your HPD before exposure to hazardous noise, and remove it only after leaving the hazardous-noise area. Your HPD must also allow you to communicate if you need to.

Because workers in blasting operations are exposed to hazardous noise, your employer must take steps to protect your hearing. These steps include supplying you with adequate hearing protection, arranging annual hearing tests, and reducing workplace noise. (For more information on employer requirements related to hazardous noise, see "Noise" on page 42.)

For more information on hearing protection devices, see the publication *Hear for Good: Preventing Noise Exposure at Work* at worksafebc.com.

Respirators and silica exposure

Workers in drilling and blasting operations are regularly exposed to silica dust. Silica is the basic component of sand and rock. It is found in concrete, masonry, sandstone, and most rock. Drilling and blasting these materials without proper controls produces fine silica dust that workers may inhale.

When silica dust builds up in the lungs, workers are at risk of developing a serious lung disease called silicosis. Silicosis is irreversible and can lead to death.

The key to silica disease prevention is to prevent the dust from getting into the workplace air. Silica dust is usually controlled with water and dust collectors. However, these methods may not provide full protection, so workers need to wear respirators.

A worker wears a half-facepiece respirator, hearing protection, and other PPE while drilling.

The type of respirator required for working around silica dust while drilling or blasting can only be determined through a risk assessment. Key factors in the assessment include the concentration of silica dust in the air generated during the work and the duration of the workshift. The protection required may range from a half-facepiece respirator with P100 filters to a full-facepiece powered air-purifying respirator.

All respirators with tight-fitting facepieces must be checked to make sure they fit properly. When it fits properly, this type of respirator forms a good seal on your face. Every time you put your respirator on, you must do a seal check for fit. In addition, when you are first fitted with your respirator, you will do a fit test, which must be repeated at least once a year. The fit-testing results and the rationale for respirator selection must be documented in the employer's respirator program.

For more information on respirators and respirator programs, see the publication *Breathe Safer* at worksafebc.com.

Fall restraint and fall arrest

Falls from heights, even at relatively low elevations, can result in serious injuries. The proper use of fall protection equipment — in addition to planning, supervision, and training — can reduce or eliminate the risk of falling.

A personal fall protection system is a worker's fall-restraint system or fall-arrest system. The key components of these systems include a safety belt or full body harness, a lanyard, a lifeline, and other connecting equipment. Together, these components secure the worker to an anchor or a horizontal lifeline system.

A fall-arrest system stops a worker's fall before the worker hits the surface below. A fall-restraint system is a system to prevent a worker from:

- Falling from a work position, or
- Travelling to an unguarded edge from which the worker could fall

Workers must use fall protection systems when they could fall from a height of 3 m (10 ft.) or more, or where a fall from a lesser height could result in serious injury.

For more information on fall-restraint and fall-arrest systems, see the Fall protection webpage on worksafebc.com.

Safety headgear

Employers must take steps to eliminate or minimize the risk of head injury from thrown or falling objects. If employers can't eliminate or reduce the risk to a level that protects worker safety, they must require workers to wear safety headgear (e.g., hard hats).

A worker wears a hard hat and other PPE while drilling.

Workers must use chin straps on safety headgear when they are:

- Climbing or working from a height of more than 3 m (10 ft.), or
- Exposed to high winds or other conditions that may cause loss of the headgear

For more information, see the Safety headgear webpage on worksafebc.com.

Safety footwear

The following requirements apply to safety footwear:

- It must be designed, constructed, and made of material that's appropriate for the protection required.
- It must allow the worker to work safely.
- It must meet an applicable standard, as required by the Regulation — for example, safety footwear with a CSA Group green-triangle symbol.

Employers may be required to conduct a workplace evaluation to determine if and what type of safety footwear is required for the work task and location. For more information, see sections 8.22 and 8.23 of the Regulation.

High-visibility clothing

High-visibility clothing, such as vests, helps reduce the risk of workers being hit by vehicles or machinery. Employers are responsible for providing workers with high-visibility clothing.

For information on choosing and safely using this apparel, see sections 8.24 and 8.25 of the Regulation.

Eye and face protection

Drilling results in airborne hot rocks and chips that can easily injure a worker's eyes or face.

Workers must wear eye and possibly face protection where hazards involving the eyes or face exist or are created as a result of conditions or activities in the area. Face protection protects the full face from injury. It's considered a secondary safeguard to protective eyewear. Where face protection is required (e.g., when using a chainsaw or gas chop saw), workers must wear it over eye protection.

Eye and face protection must fit properly and provide adequate side protection.

Employers are responsible for providing eye and face protection. For more information, see sections 8.14 to 8.18 of the Regulation.

Limb and body protection

In general, workers are responsible for providing their own general-purpose gloves and clothing necessary for protection against the natural elements. However, if specialized gloves or other limb and body protection are necessary to protect against injury or disease — for example, when workers are exposed to petroleum, silica, nitroglycerine, or other hazardous substances — the employer must provide them.

For more information, see the Gloves and Limb & body protection webpages on worksafebc.com and sections 8.19 to 8.21 of the Regulation.

Regular health and safety meetings

Good communication among employers, supervisors, and workers on health and safety issues is vital for the success of a health and safety program. Hold regular monthly meetings with workers to discuss health and safety matters.

At your meetings, focus on identifying and correcting hazardous conditions or tasks and making health and safety a priority in your workplace. Keep a record of each meeting, including what was discussed and who attended. Post meeting minutes for everyone to read.

Bring the following to each meeting:

- The latest inspection report
- Any incident reports completed during the past month
- Any new safe work procedures
- The minutes for last month's meeting

Joint health and safety committees

Joint health and safety committees help create safer work environments by recommending ways to improve workplace health and safety and promoting compliance with the Regulation and the Act.

Workplaces that regularly employ 20 or more workers must establish and maintain a joint health and safety committee. ("Regularly employ" means to employ for at least one month, whether full-time or part-time.) The committee must include at least four members — usually two employer representatives and two worker representatives — and must have monthly meetings. For more information, see the publication *Handbook for Joint Health and Safety Committees* on worksafebc.com.

Worker health and safety representatives

Workplaces that regularly employ more than 9 and fewer than 20 workers are usually required to have at least one worker health and safety representative rather than a joint health and safety committee. These representatives act as advisors and work co-operatively with employers and workers to identify and resolve workplace health and safety issues. During health and safety meetings, the representative should raise any issues that workers have mentioned since the last meeting.

Emergency response plans

Blasters should be prepared to respond to emergencies, such as fires, explosions, chemical spills, or natural disasters. If an emergency occurs, you will need to make quick decisions to minimize injuries and damage. Such decisions are easier if employers have already developed an emergency response plan as required by regulations.

How to develop and implement an emergency response plan

Follow these guidelines:

1. List all possible events (for example, serious injuries, fires, explosions, and natural disasters, such as severe weather and earthquakes).
2. Identify the major consequences associated with each event (for example, casualties, equipment damage, or facility damage).
3. Determine the necessary measures to deal with and recover from those consequences (for example, first aid, notification of medical authorities, rescue, firefighting, and employee management).
4. Determine what resources will be required (for example, medical supplies or rescue equipment).
5. Store emergency equipment where it will be accessible in an emergency.
6. Ensure that workers are trained in emergency procedures and shown where equipment is stored.
7. Establish a muster point. Ensure that all workers know the muster point location and what to do after evacuating. If the company has multiple sites, there should be a muster point for each one.
8. Hold periodic drills to ensure that employees will be ready to act if an emergency occurs. Evaluate each drill's effectiveness, and identify areas for improvement.
9. Communicate the plan to everyone involved.

Note

For more information on emergency planning and preparedness, visit the following webpages:

- Emergency response assistance plans (Transport Canada)
- Emergency management in B.C. (B.C. government)

Emergency circumstances

If emergency action is required to correct a condition that poses an immediate threat to workers, the following requirements apply:

1. Only those qualified and properly instructed workers necessary to correct the unsafe condition may be exposed to the hazard.
2. Every possible effort must be made to control the hazard while this is being done.

Records and statistics

Employers are required to keep health and safety records and statistics on file. Written records and statistics can help with the following:

- Identify trends for unsafe conditions or work practices so you can take steps to correct these potential hazards.
- Provide material for education and training.
- Provide documentation in case a WorkSafeBC officer requests it, or if an incident occurs and you need to prove that you did all you could reasonably do to prevent it.

Documentation

Maintain records and statistics, such as the following:

- Health and safety program reviews, to track the progress of your program.
- Worker orientation and training records, to ensure that workers are getting the education and training they need.
- Inspection reports, to provide historical information about hazards your business has encountered and how you've dealt with them.
- Monthly meeting records, to monitor how promptly and how well action items have been carried out.
- *Magazine* inspection and inventory log documents, to ensure safety and inventory control. (Inspect and review weekly.)
- Emergency response plan, to ensure all contact information is up to date. (Check monthly.)
- Security plan and worker-screening documents. (Once a year, ensure these are valid as required by Natural Resources Canada.)
- Transportation of dangerous goods shipping documents, to ensure they are accurate and current.
- Vehicle inspection forms or checklists, to ensure maintenance is up to date.
- Seismograph records (if applicable), to ensure *ground vibration* is kept within acceptable ranges.
- TDSs, to ensure workers have access to information about the explosives they are using. (Ensure these are current and readily available.)
- WHMIS program documents, to ensure workers have the information they need to protect themselves when working with hazardous products.
- Incident investigation reports, to identify which hazards have caused incidents and how they were controlled.
- First aid records, to provide injury statistics that will help prioritize health and safety efforts.
- Confined space entry permits, to control access to confined spaces.
- Equipment maintenance records, to ensure maintenance is kept up to date.

Employers should review these documents periodically to ensure they are accurate and up to date.

Statistics that may be of value to your operation include the following:

- Number of incidents and injuries each year
- Number of workdays lost each year
- Cost to your business from workplace injuries each year

Incident investigation

Incident investigations help determine the causes of an incident so employers can take steps to ensure it won't happen again. Employers are required to immediately investigate any incident that involves the following:

- Serious injury or death of a worker
- A major structural failure or collapse
- A major release of a hazardous substance
- Fire or explosion with potential for serious injury
- A *dangerous incident* involving explosives, whether or not there is personal injury
- Minor injury or no injury but with the potential for causing serious injury (for example, a near miss)
- Injury requiring medical treatment

Employers aren't required to investigate motor vehicle accidents that occur on public streets or highways. The RCMP or local police generally investigate such incidents.

References

Refer to the following for more information.

Act

Sections 68 to 73, Employer accident reporting and investigation

Publication

Reference Guide for Employer Incident Investigations

Form

Employer Incident Investigation Report (EIIR) — search for "EIIR" on worksafebc.com and look for the link to "Employer Incident Investigation Report (Form 52E40)."

Incidents

An incident is an accident or other occurrence that resulted in or had the potential for causing a death, injury, occupational disease, or damage to equipment or property. Incidents include the following:

- Accidents in which a worker is injured or killed
- Accidents in which no one is hurt but equipment or property is damaged
- Near misses

Near misses

A near miss is an incident in which there is no injury or damage but that could have resulted in an injury or death, or damage to equipment or property. Near misses may indicate hazardous conditions or acts that need to be corrected.

The terms "incident" and "accident" are often used interchangeably, but the preferred term is incident because it includes near misses as well as accidents.

Participants

Everyone has a role to play. Workers must report incidents to their supervisors. Owners, employers, or supervisors must initiate incident investigations promptly. If possible, investigations should include at least one employer representative and one worker representative who is knowledgeable about the workplace operations. If your company has a joint health and safety committee, involve them in hazard identification, inspections, and incident investigations.

Goals

As much as possible, an investigation must do the following:

- Determine the causes of the incident.
- Identify any unsafe conditions, acts, or procedures that contributed to the incident.
- Find ways to prevent similar incidents.

Examples of incidents requiring investigation

The following are examples of incidents employers would need to investigate:

- Any injuries or fatalities involving explosives
- Injuries, property damage, or near misses due to *fly rock*
- *Air blast* or excessive vibration that causes structural damage in a nearby residential neighbourhood
- The discovery of abandoned explosives

How to conduct an investigation

Interview witnesses and the people involved in the incident, even if they weren't present at the incident. For example, you may need to interview a supervisor who gave instructions at the start of the shift or a trainer who previously instructed the workers involved.

Questions to ask

The investigation should answer the following questions:

- Who was involved or injured?
- What were the causes?
- When did it occur?
- Where did the incident happen?
- Why was an unsafe act or condition allowed?
- How can similar incidents be prevented?

To help remember these questions, you can think of them as the "5 Ws and 1 H" questions or Who-What-When-Where-Why-and-How.

Factors to consider

Usually there are several factors that cause or contribute to an incident. Try to identify as many causes as possible. Factors to consider when investigating an incident include the following:

- Unsafe or defective equipment
- Unsafe acts or conditions
- Poor housekeeping
- Physical hazards
- Poor planning
- Poor instruction
- Unsafe work practices
- Unusual or unfamiliar work conditions
- Personal factors

Reporting incidents and injuries to WorkSafeBC

Employers must immediately report serious incidents to WorkSafeBC by phone. To report a serious incident, call 604.276.3100 in the Lower Mainland or 1.888.621.SAFE (7233) toll-free in Canada.

Reference

Refer to the following for more information.

Publication

Guide to Completing an Employer Incident Investigation Report (EIIR)

Serious incidents

Serious incidents include the following:

- Serious injury or death of a worker
- A blasting accident causing personal injury
- A major structural failure or collapse
- A major release of a hazardous substance
- Fire or explosion with potential for serious injury
- A dangerous incident involving explosives, whether or not there is personal injury

For information on reporting dangerous incidents in blasting operations, see Chapter 15, "Post-blast hazards and requirements."

Form 7

If a worker is injured, the employer must submit an Employer's Report of Injury or Occupational Disease (Form 7) to WorkSafeBC within three days to initiate a claim. You can also submit the file online. Go to worksafebc.com and search for "Form 7."

Form 7 is required in the following situations:

- A worker is injured and loses consciousness.
- A worker is sent for medical treatment by a first aid attendant or supervisor.
- A worker has an injury or disease that needs medical treatment.
- A worker is going to get medical treatment or has already received medical treatment for an injury or disease.
- A worker is (or claims to be) unable to do his or her job because of an injury or disease.
- An artificial limb, eyeglasses, dentures, or hearing aid is broken in an incident.

Filing an investigation report

WorkSafeBC has developed an Employer Incident Investigation Report (EIIR) template employers can use to create all four reports that may be required following an incident in the workplace. This template will help employers collect all the necessary information and reduce the work associated with completing separate reports.

For a copy of this template and a guide on how to complete it, search for "EIIR" on worksafebc.com. Look for the link to "Employer Incident Investigation Report (Form 52E40)."

All EIIRs must be submitted to WorkSafeBC within 30 days. Depending on the incident, WorkSafeBC may require a preliminary investigation within 48 hours of the incident. You can submit EIIRs using one of the following methods:

- Use the online EIIR upload portal. Go to worksafebc.com and search for "EIIR upload portal."
- Fax 604.276.3247 in the Lower Mainland or 1.866.240.1434 toll-free.
- Mail it to WorkSafeBC, PO Box 5350, Stn Terminal, Vancouver, BC V6B 5L5.

Chapter 2:

Common injuries and health and safety hazards in blasting operations

Learning objectives

- Identify the three most common blasting and drilling claims.
- Distinguish between exposure and transport claims.
- Describe types of musculoskeletal injuries (MSIs) often presented in drillers and blasters.
- Identify machinery and equipment hazards in blasting and drilling environments.
- Identify risk factors associated with drilling.
- Identify employer requirements to minimize MSIs in the workplace.
- Identify employer requirements to reduce the risk of hearing loss in workers exposed to noise above the noise exposure limit.
- Describe the different noise levels that can occur from equipment or events and through job position.
- List steps in the hierarchy of controls to reduce risks associated with airborne contaminants (e.g., silica dust).
- Describe factors that contribute to impairment in the workplace.
- Explain worker and employer responsibilities related to impairment in the workplace.
- Discuss methods to discourage improper conduct at the worksite.
- Identify potential risks and associated strategies to reduce the risks when blasting or drilling.

Overview

This chapter provides an overview of the most common injuries in blasting operations. It also describes the main blasting-related and other hazards, and discusses how to reduce the risks. Good blast-site management is crucial for eliminating or minimizing safety issues on a site.

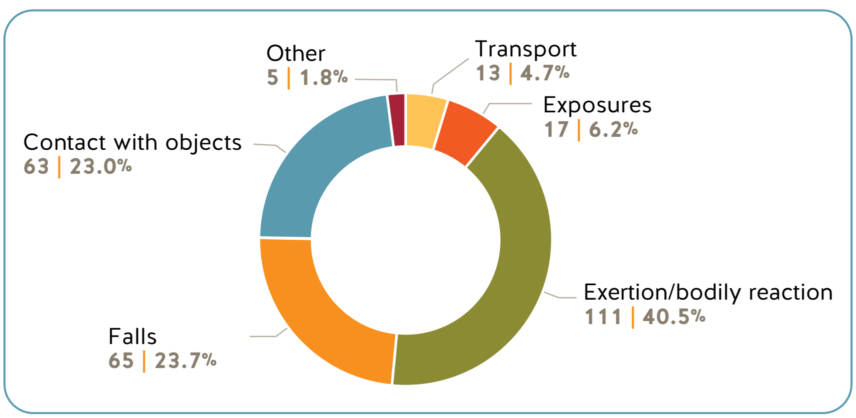
Most common injuries among blasters and drillers

The following chart is based on WorkSafeBC accident statistics for blasters and drillers over a 10-year period.

The top three (i.e., most common) injury claims among blasters and drillers involve the following:

1. **Exertion/bodily reaction**, which includes strains, sprains, and other musculoskeletal injuries or MSIs. These injuries are typically caused by overexertion (e.g., from moving heavy objects such as rocks and equipment, lifting tools and explosives, and climbing slopes). For more information on MSIs, see "Overexertion and repetitive movement" on page 40.
2. **Falls**, which include sprains and strains, fractures, dislocations, and other injuries. These injuries are caused by falls on snow or ice, falls from trucks or rocks, falls down slopes, and slips and trips on rocks and gravel. For information on reducing the risk of falls, see "Fall restraint and fall arrest" on page 26 and "Safety footwear" on page 27.
3. **Contact with objects**, which includes amputations, fractures, eye injuries, burns, concussions, cuts, and other injuries. Some of these injuries are caused by being caught between objects such as pipes, rocks, and equipment. Others are caused by being struck by objects such as drills, tools, and rocks. For more information, see "Contact with machinery or equipment" on page 41.

Injury claim counts by accident type among blasters and drillers over a 10-year period



"Exposures" claims include hearing loss, silicosis (a lung disease caused by inhaling silica dust), and illness caused by exposure to nitroglycerine (NG) products. "Transport" claims include injuries related to equipment such as excavators and drilling machines, as well as to motor vehicle accidents.

Health and safety hazards

Overexertion and repetitive movement

Drillers and blasters typically do a lot of bending, lifting, carrying, twisting, and hoisting. These movements can involve overexertion or be repetitive. In some cases, these movements can result in sprains, strains, hernias, and other musculoskeletal injuries (MSIs). MSIs account for roughly one-third of all workplace injury claims accepted by WorkSafeBC.

MSI risk factors

The factors that contribute to the risk of MSI are called risk factors. A risk factor is something that may cause or contribute to an injury. Risk factors for MSI include force, duration, working position, vibration, repetition, and contact stress. There can be two or more risk factors at the same time, increasing the risk of injury.

Employers must identify risk factors that may expose workers to a risk of MSI, assess those risks, and determine and implement appropriate risk controls. See "Managing health and safety risks" starting on page 13.

References

Refer to the following for more information.

Regulation

- Sections 4.46 to 4.53, Ergonomics (MSI) requirements

Publications

- *Preventing Musculoskeletal Injury (MSI): A Guide for Employers and Joint Committees*
- *Understanding the Risks of Musculoskeletal Injury (MSI): An Educational Guide for Workers on Sprains, Strains, and Other MSIs*

Web

Webpages at worksafebc.com:
- Sprains & strains
- Lift/lower calculator

Worker education

Employers must ensure that workers who may be exposed to a risk of MSI are educated to identify the risks related to the work. Workers should also learn how to recognize early signs and symptoms of MSIs and their potential health effects.

Contact with machinery or equipment

Unguarded or inadequately safeguarded machinery and equipment are hazards in any workplace that uses powered equipment. Every year, physical contact with machines and powered equipment causes a significant number of injuries, including amputations, and may also result in workplace fatalities. Most of these incidents can be prevented by effective safeguarding procedures and training.

For more information on safeguarding, see the Safeguarding webpage on worksafebc.com.

Vibration

Vibration is a risk factor for a number of conditions, including injuries to the fingers, hands, and back. Two types of vibration hazard can affect workers: hand-arm vibration and whole-body vibration.

Hand-arm vibration occurs when vibrating objects such as power tools send vibration through the hands and arms. Whole-body vibration occurs when vibrating surfaces where a worker stands or sits send vibration throughout the body.

In a blasting operation, hand-operated pneumatic rock drills (also known as jackhammers, sinker drills, or pluggers) used for drilling small-diameter drill holes expose workers to high levels of hand-arm vibration or whole-body vibration, depending on how the drill is handled.

Hand-operated pneumatic rock drills expose workers to high levels of hand-arm vibration or whole-body vibration, depending on how the drill is handled.

Other risk factors can increase the likelihood of injury from vibration, including the following:

- Working in cold, damp environments
- Increased grip force
- Using a vibrating tool for long periods

Employers must conduct risk assessments for musculoskeletal injuries (MSIs) in the workplace, and eliminate or minimize the risks. Employers must also educate and train workers about MSI risks in the workplace. For more information, visit the Vibration webpage on worksafebc.com.

Noise

Workers in blasting operations are often exposed to noise that can permanently damage hearing. If workers are exposed to noise that goes over noise exposure limits, employer requirements include the following:

- Develop and implement an effective noise control and hearing conservation program.
- Investigate options for engineered noise control. Implement one or more of those options to reduce noise exposure to or below the exposure limits.
- Post warning signs for noisy areas.
- Provide hearing protection. Make sure it fits each worker and can be worn effectively. Typically, you'll need to provide a variety of hearing protection devices. For more information, see "Hearing protection devices" on page 25.
- Ensure that workers wear hearing protection as required.
- Make sure workers are provided with an initial hearing test within the first six months and at least once a year after the initial test.

Employers should also make sure workers have their "hearing test card." Workers should carry their cards at work.

The program and hearing protection must meet the requirements of the applicable standard. For more information on what's required in a hearing conservation program, see Part 7 of the Regulation.

Potential noise hazards in blasting operations

Equipment or event	Noise-level range Eight-hour (or equivalent) exposures
Excavator	75–86 dBA (inside cab); 90–102 dBA (outside cab)
Air compressor	90–97 dBA
Excavator-mounted hydraulic breaker	95–105 dBA (inside cab); 105–125 dBA (outside cab)
Pneumatic and hydraulic rock drills	100–120 dBA
Hand-operated pneumatic rock drills (also known as jackhammers, sinker drills, or pluggers)	100–120 dBA
Air horn	130–145 dBA (at 1 m or 3 ft.); 100 dBA (at 30 m or 100 ft.)
Explosion	140–160 dBC (peak)

Job position	Noise-level range Eight-hour (or equivalent) exposures
Excavator operator	80–87 dBA
Blaster	93–96 dBA
Driller	93–98 dBA

If a worker is or may be exposed to potentially harmful levels of noise, or if information indicates that a worker may be exposed to more than 82 decibels (dBA L_{ex}), the employer must measure the noise exposure.

If workers are exposed to noise that exceeds noise exposure limits, the employer must ensure they have their hearing tested every year to monitor the effectiveness of hearing protection. You can find a list of authorized industrial audiometric (hearing test) facilities at worksafebc.com.

Breathing hazards

Workers may be at risk of breathing in airborne contaminants such as silica dust. Employers must assess the workplace for breathing hazards and control worker exposure to these hazards.

If elimination isn't practicable, follow the remaining steps in the hierarchy of controls: substitution, engineering controls, administrative controls, and PPE. In many cases, you'll need to use a combination of these controls to keep worker exposures as low as reasonably achievable. See “Managing health and safety risks” on page 13.

If you can't reduce dangerous air contaminants to safe levels, you must provide your workers with training and appropriate respirators. You must also ensure they use the respirators as they were trained. Respirators must meet and be used in accordance with the requirements of a standard acceptable to WorkSafeBC and the employer's respirator program.

For more information, see sections 8.32 to 8.45 of the Regulation and the WorkSafeBC publication *Breathe Safer*.

Impairment

Impairment means being unable to perform optimally because of diminished physical or mental capacity. The most common causes of impairment in the workplace are fatigue and substance use.

Fatigue is the state of feeling tired, weary, or sleepy. It can result from lack of sleep, prolonged mental or physical work, or extended periods of stress or anxiety.

Substance use includes the use of illicit or prescription drugs, alcohol, cannabis, or any other substance that causes impairment.

Risk controls

Employers can reduce the risk of incidents by following these guidelines:

- Develop a written impairment policy for your workplace. Ensure workers understand the policy and expectations.
- Train supervisors on your policy. They shouldn't be expected to recognize specific effects of substances but should be able to assess acceptable performance and behaviour.
- Limit overtime hours so workers don't work excessively long shifts.

Workers must tell their supervisor or employer if their ability to perform assigned work safely is impaired for any reason. If you are physically or mentally impaired, don't keep working if your impairment could create a risk for you or anyone else.

Employers must not assign impaired workers to activities where impairment may create a risk. Employers must also not knowingly allow workers to remain at work while their ability to work safely is affected by alcohol, a drug, or another substance or condition.

References

Refer to the following for more information.

Regulation

- Section 4.19, Physical or mental impairment
- Section 4.20, Impairment by alcohol, drug or other substance

Web

Webpages at worksafebc.com:

- Substance use & impairment in the workplace
- Fatigue impairment

Horseplay and similar conduct

A person must not engage in any improper activity or behaviour at a workplace that might pose a hazard to themselves or anyone else. This includes horseplay, practical jokes, unnecessary running or jumping, and similar conduct. Improper activity or behaviour must be reported and investigated. Employers should put in place written rules prohibiting horseplay and similar conduct, and then enforce those rules.

Flying material

Flying material (e.g., fly rock) can cause serious injuries, fatalities, and property damage. Fly rock has been known to travel great distances, and the blaster must take into account worst-case scenarios.

At the time of *detonation*, the *blaster of record* must be absolutely certain that the area is completely clear and access to the *blast site* is controlled. A predetermined plan must be prepared for safeguarding all workers and the public prior to the *blast*. Since many incidents are caused by flying material, the plan must emphasize precautions related to fly rock. Precautions include using sound blast designs, good *loading* practices, and security procedures. For more information, see Chapter 10, “Blast design”; Chapter 13, “Priming and loading explosives”; and Chapter 14, “Controlling the effects of a blast.”

Fly rock thrown from a poorly controlled blast damages a vehicle.

Electrical storms

If there is any sign of thunder or lightning storm activity, all *blasting activity* must be suspended. In addition, the *danger area* must be cleared and guarded if explosives are present at the blast site. These actions are required regardless of the types of explosives or initiation systems being used.

Some blasters may have the misconception that electrical storms are not a threat when non-electric initiation systems are used. But a lightning strike can *initiate* any explosive.

For more information, see “Securing the area surrounding a blast” on page 161 and “Electrical storms” on page 296.

Chapter 3: Legal and jurisdictional requirements

Learning objectives

- Identify legal requirements regarding possession, use, handling, storage, and disposal of explosives as per laws, regulations, and bylaws.
- Identify key sections of the *Criminal Code* with respect to penalties for negligence and improper possession of explosives.
- Describe the purpose of the *Explosives Act* and Explosives Regulations.
- Identify key sections of the *Explosives Act* with respect to penalties for trespassing in or around explosives magazines, abandoning explosives, and other illegal acts.
- Discuss federal and provincial laws and regulations for transporting dangerous goods.
- Describe the power of provincial authorities, laws, and regulations related to explosives, mining operations, and other blasting operations.
- Explain the relationship between civil law and personal injury and/or damage to property caused by explosives.
- Explain the principle of strict liability.

Overview

A blaster is expected to know and comply with all legal requirements governing the possession, storage, transportation, handling, use, and disposal of explosives. These requirements are detailed in laws, regulations, and bylaws.

Explosives fall under several jurisdictions, and some legal requirements may overlap. Complying with one requirement doesn't relieve a person from the obligation to comply with other requirements. And it's crucial to stay current with any changes in these requirements.

Legal requirements governing explosives

The federal, provincial, local, and civil legal requirements that govern explosives and blasting in British Columbia are as follows.

Federal laws and regulations

Criminal Code

The *Criminal Code* is primarily concerned with criminal activities. The Code sets out severe penalties for negligence and improper possession of explosives.

Key sections of the Code that may affect the blaster of record include the following:

- Under section 79, "Every one who has an explosive substance in his possession or under his care or control is under a legal duty to use reasonable care to prevent bodily harm or death to persons or damage to property by that explosive substance."
- Under section 82 (1), "Every person who, without lawful excuse, makes or has in their possession or under their care or control any explosive substance is guilty of
  a) an indictable offence and liable to imprisonment for a term of not more than five years; or
  b) an offence punishable on summary conviction."

Explosives Act and Regulations

The *Explosives Act* and the Explosives Regulations govern the classification, importation, manufacture, possession, sale, storage, and transportation of explosives. Section 18 of the *Explosives Act* prohibits trespassing in or about an explosives magazine. Section 20 sets out severe penalties for anyone who abandons explosives or who causes a fire or explosion in or near a magazine or a vehicle that carries explosives.

The *Explosives Act*, Explosives Regulations, and Magazine Standards are administered by the Explosives Regulatory Division (ERD) of Natural Resources Canada. Reports of theft, or questions about the *Explosives Act* and Regulations, should be directed to the local ERD branch office.

Up-to-date information on the *Explosives Act* and Regulations can be found on Natural Resources Canada's Explosives Regulations webpage.

Screening requirements

Part 8 of the Explosives Regulations sets out the screening requirements for people who have access to high hazard explosives.

Division 1 sets out the requirements for people who intend to manufacture, store, transport, import, or export high hazard explosives. Division 2 sets out the duties of authorized persons to control access to high hazard explosives. It also sets out the requirements for obtaining letters of approval.

What is a high hazard explosive?

Part 8 of the Explosives Regulations states that the term "high hazard explosive" refers to:

- Military explosives or law enforcement explosives (type D)
- High explosives (type E)
- Initiation systems (type I)

Transportation of Dangerous Goods Act and Regulations

The federal *Transportation of Dangerous Goods Act* regulates the transportation of dangerous goods, including explosives, by air, sea, rail, and road. The Act also governs the Canadian government's response to security incidents involving dangerous goods.

The Transportation of Dangerous Goods Regulations set out the safety requirements for transporting dangerous goods.

For more information on transporting explosives, see Chapter 8, "Transportation of explosives."

Provincial laws and regulations

Motor Vehicle Act and Regulations

British Columbia's *Motor Vehicle Act* and Regulations apply to all motor vehicles operating on public highways in the province.

Section 206 of the Act requires that any vehicle transporting explosives "must be equipped with not less than 2 fire extinguishers, filled and ready for immediate use, and placed at a convenient point on the vehicle."

Mines Act and Health, Safety and Reclamation Code

The *Mines Act* and the Health, Safety and Reclamation Code for Mines in British Columbia govern the certification of blasters and the storage, transportation, and use of explosives on mining property in the province.

WorkSafeBC does not have jurisdiction over mines. For information on blasting certification to work in B.C. mines, visit the Certifications page of the Ministry of Energy, Mines and Low Carbon Innovation.

Workers Compensation Act and Occupational Health and Safety Regulation

The *Workers Compensation Act* and the Occupational Health and Safety Regulation govern the certification of blasters and the handling, storage, transportation, and use of explosives within the inspectional jurisdiction of WorkSafeBC. WorkSafeBC administers the Act for the provincial government. WorkSafeBC also sets and enforces the Regulation.

Part 21 of the Regulation sets out requirements specific to blasting operations. In addition to the requirements noted above, Part 21 covers the following:

- General requirements (e.g., dangerous incident reports, blasting logs, and authority to blast)
- Drilling

- Loading
- Initiation systems
- Returning to the blast site
- Misfire procedures
- Specialized blasting operations

Other parts of the Regulation and the Act cover the following:

- Core requirements that apply to all workplaces (e.g., rights and responsibilities, building and equipment safety, emergency preparedness, and ergonomics)
- General requirements for higher-hazard operations (e.g., chemical safety, confined space entry procedures, guarding of machinery, and the use of mobile equipment)
- Requirements specific to other industries or activities

Local requirements

Some municipalities and districts in B.C. have bylaws and regulations that govern the handling, storage, transportation, and use of explosives within their jurisdiction. To obtain a permit required by some local governments, proof of blasting experience and insurance coverage is often needed. In some cases, pre-inspection of buildings is required.

Pre-inspection of buildings may be required to obtain local permits.

Civil law

Civil law governs the relationship between individuals. Any personal injury or damage to property caused by explosives may result in a civil suit against the persons responsible, including the blaster of record.

A fundamental principle of civil law is duty of care. The persons responsible for explosives must take all reasonable precautions for the prevention of personal injury or damage to property. Precautions would include adequate guarding and control of flying material (e.g., fly rock).

Where explosives are involved, the principle of strict liability may be applied. This means that in case of injuries or property damage caused by explosives in blasting operations, the blaster of record may be held liable to a greater degree than other workers or the employer.

Part 2:
About explosives

Chapter 4:
Theory of explosives

Learning objectives

- Describe the characteristics that make an explosive unique.
- Compare and contrast pure chemical (or molecular) explosives and chemical mixture explosives.
- Identify common types of explosives used in blasting.
- Describe detonation and deflagration.
- Identify the most common effects of rock blasting.
- Discuss the properties of commercial explosives.
- Explain the concepts of strength and energy as related to explosives.
- Describe velocity of detonation (VOD) and its principles.
- Discuss density and its importance to blasters.
- Describe the characteristics and behaviour of toxic gases in blasting operations.
- Discuss how temperature and water exposure can affect the performance of explosives.
- Explain the specific criteria for selecting an explosive.
- Explain conditions in which cartridge explosives should be used.
- Define dead pressing and conditions in which it is likely to occur.
- Define sympathetic propagation or detonation.
- Identify conditions in which misfires could occur.

Overview

Blasters must understand the basic theory of explosives and the tools of the blasting trade. This includes knowing the characteristics, effects, and properties of commercial explosives, as well as the general and specific criteria for selecting an explosive.

Characteristics

Consider the three characteristics that make an explosive unique:

- Method of initiation (what sets it off or *initiates* the reaction)
- Composition (what it consists of)
- *Detonation* or *deflagration* (what happens when it is initiated)

Method of initiation

An explosive is designed to be initiated by the shock effect of a *detonator* or another explosive. Many explosives are sensitive to heat, friction, and impact. For these reasons, they should be protected from effects that could cause premature or accidental detonation.

Composition

An explosive is a type of chemical that detonates when shock, heat, or impact is applied.

Some explosives are pure chemicals that have a unique, consistent molecular structure. These chemical compounds typically include carbon (C), hydrogen (H), nitrogen (N), and oxygen (O) within each molecule. Examples of pure chemical (or molecular) explosives include the following:

- *PETN* (used in *detonating cord* and detonator base charges)
- *TNT* (used with PETN to make *cast boosters* or on its own)
- HMX (used in *shock tube*)
- *Lead azide* (used in detonators)

Other explosives come in the form of chemical mixtures. Chemical mixtures are combinations of fuels and oxidizers. Examples of mixtures include ammonium nitrate and fuel oil *(ANFO)* and *emulsions*. The more thoroughly the fuel and the oxidizer are mixed together, the higher the energy output. Other ingredients can be added to further affect overall performance. For example, guar can be added for water resistance (such as in water-resistant ANFO or WR) or aluminum for increased energy.

Explosives manufacturers make chemical mixtures for reasons such as the following:

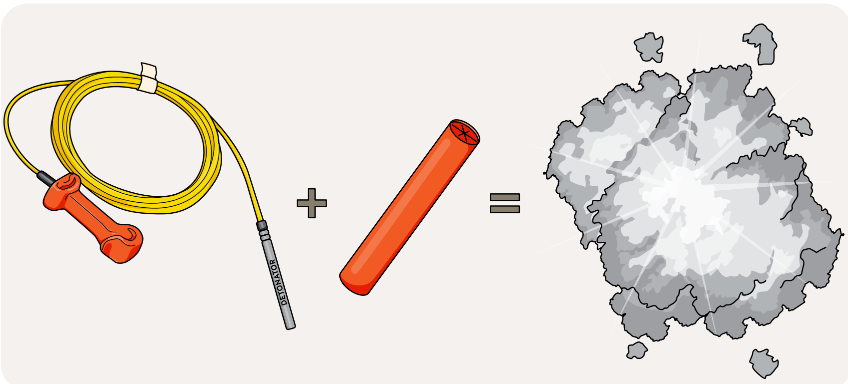
- To make an explosive from two non-explosive compounds
- To achieve proper oxygen balance (the ratio of oxygen to fuel in the explosive)
- To change chemical properties (such as toxicity)
- To change physical properties (such as *density*)
- To change explosive properties (such as *velocity* of *detonation*)
- To change explosive forms (shaped, plasticized, rubberized, etc.)

Mixtures give manufacturers the ability to make hundreds of types of explosives. The two types most common in drilling and blasting are ANFO and slurries (typically in the form of emulsions).

Detonation

Detonation is an explosive reaction that moves through an explosive at a velocity greater than the speed of sound.

Upon detonation, most commercial explosives are capable of producing gases with temperatures ranging from 1 600 to 3 800°C (3,000 to 7,000°F) and pressures ranging from 1 379 000 to 103 425 000 kPa (200,000 to 1,500,000 psi).



Method of initiation + Explosive = Detonation

Deflagration

Deflagration is an explosive reaction, such as a rapid combustion, that moves through an explosive at a velocity less than the speed of sound.

Effects

In most applications, detonation of commercial explosives produces a *shock wave* and a sudden release of heat and explosive gases.

Explosives used in rock blasting typically have four common effects:

- *Fragmentation* of material (breaking up the rock)
- Displacement of material (moving the rock)
- Vibration of ground
- Concussion (air blast)

The gas pressure released in an explosion is the main cause of fragmentation and displacement of rock, as well as vibration of ground. Gas pressure can also increase the concussion, depending on the site conditions.

The shock wave produced by an explosive is not a major cause of fragmentation, displacement, or vibration. However, the shock wave may have an effect on the concussion in rock blasting, depending on the site conditions.

In non-blasting applications, such as breaching walls or welding metals, the explosive shock wave is useful and often required.

Explosives are used in many industries for specialty applications. A few examples include the following:

- Plasticized or rubberized explosives are used to harden metals in the explosive forging of railway frogs. (A railway frog is the point where two rails cross as part of a switch.)
- Electrical line workers use explosive connectors to fuse high-voltage transmission lines together.
- A shaped charge (as in a perforator) is designed to cut or penetrate metal or rock.
- A special crimping technique uses the heat and pressure of an explosive to bond metal pipes together.
- Some explosives used in pyrotechnic work (special effects) create a flash effect.

Properties

Each commercial explosive has a unique combination of properties. To determine whether or not an explosive is suitable for a specific application, a blaster needs to understand its properties. Always refer to the manufacturer's technical data sheet for proportions and specifications.

Depending on the application, a blaster should consider the following properties when selecting an explosive:

- Strength (energy)
- Velocity of detonation (VOD)
- Density
- Toxic gases
- Sensitivity
- Temperature
- Water resistance

Strength (energy)

Strength is the amount of energy produced by a unit weight or volume of an explosive (typically, 1 gram or 1 cubic centimetre). It expresses the capacity of an explosive to perform work.

Strength may be a convenient yardstick for comparing various explosive products, but there is no recognized standard for measuring strength. The classic measurements based on nitroglycerine (NG) explosives (e.g., *dynamites*) do not accurately reflect the relative energy output of non-NG explosives. For this reason, strength alone may not be a reliable basis for comparing products.

Many blasters compare explosives by the amount of energy in unit weight or volume. Strength is defined as the thermomechanical heat of an explosive's reaction. Strength is measured in calories per gram (cal/g).

The energy produced by an explosive is ultimately determined under actual blasting conditions. Several techniques can be used to obtain a relative comparison and estimate of blast performance. The four main indicators of strength are as follows:

- Absolute weight strength
- Absolute bulk strength
- Relative weight strength
- Relative bulk strength

Absolute weight strength

Absolute weight strength (AWS) measures the heat of reaction (explosion) available in each gram of explosive (i.e., cal/g).

Absolute bulk strength

Absolute bulk strength (ABS) measures the heat of reaction available in each cubic centimetre of explosive (i.e., cal/cc).

Relative weight strength

Relative weight strength (RWS) measures the heat of reaction per unit weight of an explosive compared to the energy of an equal weight of standard ammonium nitrate and fuel oil (ANFO). The RWS is the ratio of the AWS of an explosive to the AWS of ANFO. The RWS shows how much energy per gram the explosive has relative to ANFO.

Relative bulk strength

Relative bulk strength (RBS) measures the heat of reaction per unit volume of an explosive compared to the energy of an equal volume of standard ANFO at a given density. The RBS is the ratio of the ABS of an explosive to the ABS of ANFO. The RBS shows how much energy per cubic centimetre an explosive has relative to ANFO.

Note

An explosive's energy rating is normally published by the manufacturer. Each manufacturer may use a different formula or code to rate its products. Be cautious with ratings of different products, since they are only meaningful if they come from the same manufacturer.

Velocity of detonation (VOD)

Velocity of detonation is the speed at which the shock wave (also known as a detonation wave) travels through a column of explosives. Each type of explosive has a maximum or ideal VOD that depends on the explosive's composition and density. During detonation, higher-VOD explosives, such as detonating cord, tend to create a greater shock wave. Lower-VOD explosives, such as ANFO, tend to create more gas pressure.

The VOD of most commercial explosives ranges from 1 500 to 7 500 m (5,000 to 25,000 ft.) per second. The VOD is an important tool to ensure that the explosive works properly. For example, if an explosive is rated to fire at 2 000 m/s and instead fires at 1 500 m/s, the explosive is likely not detonating properly.

A lower-than-expected VOD suggests that problems have occurred with the explosive either in manufacturing or in use. These problems often result in the formation of toxic gases upon detonation. These gases apply less pressure on the blast-hole walls, resulting in poor blast performance. And a low VOD won't pressurize the hole instantaneously, which leads to breakage (i.e., shattering of rock) before all the explosive detonates. This results in reduced blast-hole pressure and blast underperformance.

Blasting with *black powder* (or other deflagrating explosives) is most likely to result in this breakage-before-pressurization problem. The risk can be reduced by shortening the length of explosive *charges*. This allows the entire charge to burn before breakage occurs.

In most applications, a VOD below 2 000 m (6,560 ft.) per second may not produce the desired results. In specialty applications, such as secondary blasting (*mud capping*) and perforating (shaped charges), a higher VOD is necessary to produce the desired effect.

The following table shows the VOD of various explosives.

Velocity of detonation by type of explosive

	Velocity of detonation	
Type of explosive	Metres per second	Feet per second
ANFO	4 200	13,780
NG dynamite	4 300–7 700	14,108–25,262
Emulsion	5 000	16,400
TNT	6 900	22,338
PETN	8 400	27,560
HMX	9 400	30,840

Density

Density (or specific gravity) is a measurement of the weight/volume ratio of an explosive to an equal volume of water. Water has a density of 1 gram per cubic centimetre. Explosives with a specific gravity less than 1 are lighter than water. Those with a specific gravity greater than 1 are heavier than water. Most explosives have densities between 0.6 and 1.7.

Blasters should consider density when determining the most appropriate blast-hole charge. Since higher-density products have more explosive in a given volume, they have a greater potential for breakage (i.e., for shattering rock). This is because an increase in density leads to an increase in the volume of gas produced following a blast.

Density or specific gravity by type of explosive

Type of explosive	Density or specific gravity
Poured ANFO	0.8–0.9
Pneumatically loaded ANFO	0.8–1.0
Heavy ANFO	1.1–1.4
Cartridged slurry	1.1–1.3
Bulk slurry	1.1–1.6
Gelatin dynamite	1.0–1.7

Toxic gases

An explosive detonation can produce *toxic gases*, including carbon monoxide and oxides of nitrogen. Carbon monoxide is colourless and odourless. Oxides of nitrogen have an orange-brown colour. Both types of gases tend to hover in the atmosphere. Blasters must not enter or allow others to enter the worksite until these gases have disappeared.

In surface blasting operations, gases and *fumes* (very fine particulates) quickly disperse to the atmosphere. In confined areas, such as underground workings, exposure to these contaminants can be minimized with low-fume explosives and effective ventilation systems.

ANFO and emulsions are designed to produce much lower amounts of toxic gases than many other types of explosives. However, even ANFO and emulsions can generate toxic gases in some cases. Examples of such situations include errors in manufacturing, loss of confinement, or, for ANFO, water in the *blast hole*.

Sensitivity

Sensitivity is a measurement of how easily an explosive can be initiated by an external force such as a detonator, a primer, or a projectile impact. An explosive with high sensitivity may detonate when the shock wave from a nearby hole reaches it.

In some cases, blasters may also need to consider the explosive's packaging and stability (i.e., during handling or long-term storage).

Temperature

Temperature can affect how explosives respond and perform. For example, dynamites can become quite hard or frozen under very cold conditions. However, they can still be reliably used and fired successfully.

Packaged emulsions can also freeze at cold temperatures, but they may fail to detonate, even after being allowed to warm up.

ANFO does not suffer performance issues as long as it remains dry. But it can break down if it is often exposed to wide temperature changes during storage.

Water resistance

Water resistance is the ability of an explosive to withstand exposure to water without losing sensitivity or efficiency. The level of resistance depends on the following:

- The composition of the explosive product
- The product's packaging
- The environmental conditions to which the product is subjected

Some manufacturers describe water resistance in general terms. Others specify how long a product may be exposed to water and still detonate. Such descriptions are guidelines only. Water resistance can be significantly affected by the following:

- Water depth and movement
- Damaged wrappings
- Exposure to cold temperatures

General criteria for selecting an explosive

Under normal use, explosives should do the following:

- Remain intact during the period of storage
- Not freeze or break down chemically (dissociate) under normal temperatures
- Be suitably packaged for the intended use
- Be safe to handle, transport, and store
- Remain sensitive
- Detonate properly on initiation

Explosives should function at their ideal velocity of detonation. They should also have the following other properties:

- Adequate strength for the intended use
- Sufficient release of high temperature and gases
- Suitable density for the particular application
- Adequate water resistance
- Minimal toxic gases, particularly in confined areas

Specific criteria for selecting an explosive

Explosive selection is a critical part of every blast. In construction blasting applications, choosing the right explosive product should be based on the risk level and the site conditions, not the cost.

The following recommendations for explosive selection are based on site conditions. The explosive products covered include packaged and bulk explosives. Packaged explosives include packaged *blasting agents* (such as ANFO/WR) and *cartridge* explosives (such as emulsions and dynamites). Bulk explosives include pumped blasting agents or emulsions.

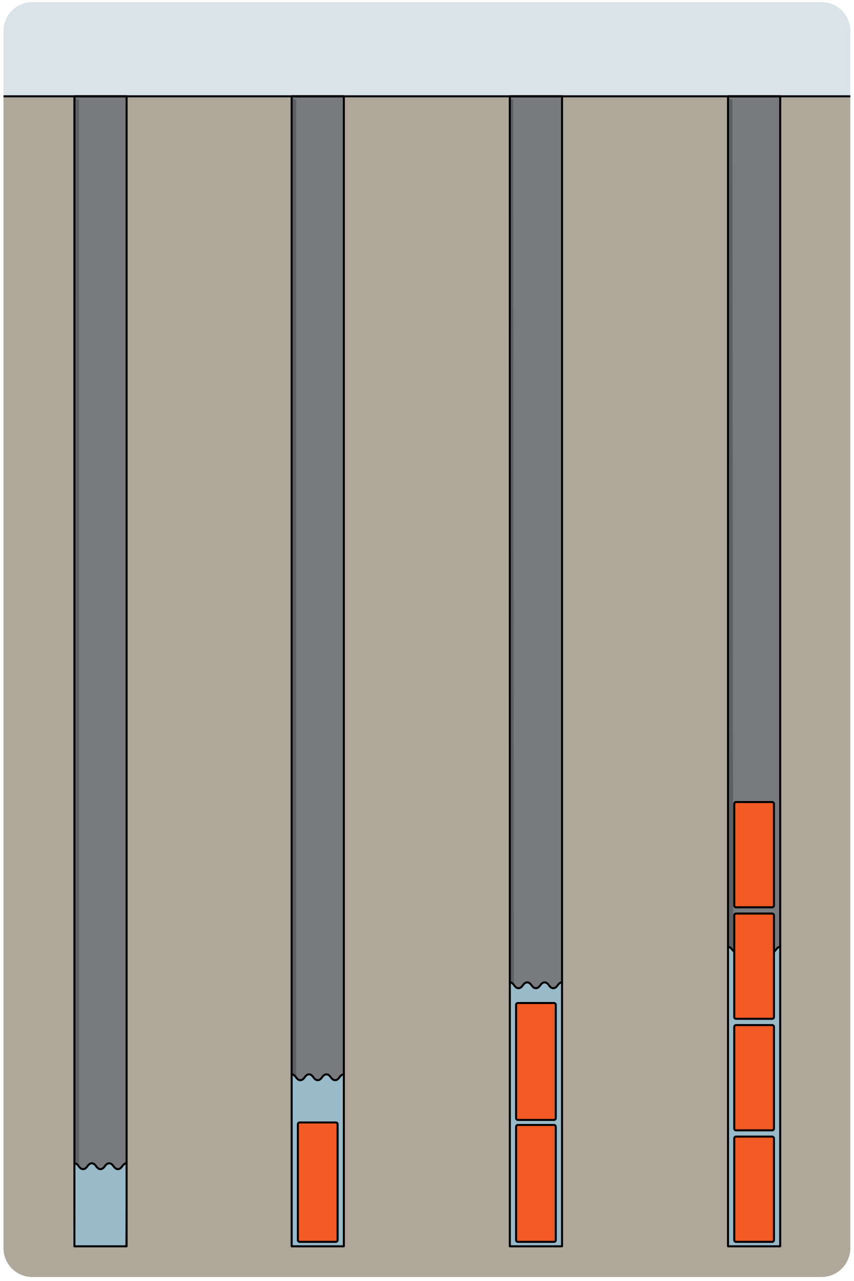
Explosives for surface blasting

Before the start of a blasting project, only limited geological information is typically available. Groundwater conditions and fractures in the rock are largely unknown until drilling begins. The blaster should communicate with the driller and select the correct explosives and loading methods for each and every hole.

When the rock is fractured or contains significant voids and soft seams, cartridge explosives should be used. Cartridge explosives are better controlled (i.e., contained by their packaging), which helps avoid overloading. When pouring blasting agents (such as ANFO or WR), it's easy for the *prills* to find their way into fractured rock or soft seams and voids. This means it's easy to load far too much blasting agent, which causes avoidable and unnecessary risks. For this reason, using ANFO in such situations should never be considered.

When blast holes contain water, cartridge explosives should be used. In some cases, such as in solid rock, blasters can use cartridges to displace low levels of water in a blast hole (see drawing on next page). Once the water reaches its highest level and the remainder of the hole is dry, the blaster can determine whether to top up the hole with ANFO. However, wet holes (i.e., holes that are full or mostly full of water) must be dewatered and remain dry to use ANFO/WR because water renders these products useless.

In projects that require maintaining good control over blast effects (such as *backbreak* and ground vibration), use a packaged product. If such control is not required, then cartridge explosives, bulk explosives, and ANFO are all practical choices.



In some cases, such as in solid rock, blasters can use cartridges to displace low levels of water in a blast hole.

What can go wrong

Dead pressing

Dead pressing is the failure or underperformance of an explosive when its density increases past a point at which it can reliably detonate.

Dead pressing can occur with less-sensitive explosives such as ANFO and emulsions. But it does not commonly occur with more-sensitive explosives such as dynamites.

Explosives such as ANFO and emulsions are sensitized (i.e., made to initiate more easily) by a reduction in their density. Manufacturers typically achieve this reduction by inserting air into the explosives. This allows the explosives to sustain a detonation.

Dead pressing often occurs when charges are spaced close to each other, especially if the blast holes are wet. The detonation of the nearby explosives may increase the density by expelling the air. This can lead to dead pressing.

Sympathetic propagation

Some types of explosives are so shock sensitive that the explosive in one charge will initiate as a result of the detonation of a charge in a nearby hole. The term *sympathetic propagation* or *sympathetic detonation* is sometimes used to describe such initiation.

Sympathetic propagation may occur with some explosives over considerable distances, depending on the following:

- The type of material being blasted
- The type of explosive
- The size of the charge
- The distance between charges
- Other factors, such as the presence of water

Under most conditions, individual charges should independently detonate at set delay intervals, not sympathetically propagate.

ANFO, emulsions, and water gels are at very low risk of sympathetic propagation. Typically, even two emulsion cartridges separated by several inches in a blast hole will not set each other off. For this reason, if a blaster does not properly load emulsions, and gaps are left between cartridges, misfires will occur. Sensitive explosives, such as dynamites, are at much higher risk of sympathetic propagation.

Chapter 5: Types of explosives

Learning objectives

- Describe high explosives, their properties, and storage requirements.
- Explain the properties of water-gel explosives.
- Describe the properties of emulsions.
- Describe blasting agents, their properties, and storage requirements.
- Explain the role of priming in blasting and consequences of under-priming.
- Describe the relationship between low explosives and deflagration.
- Explain common misconceptions and limitations regarding propellants.

Overview

Explosives can be obtained in packages and in bulk and are classified as either high or low explosives.

High explosives

A *high explosive* has a very high rate of reaction, high pressure development, and the presence of a shock wave upon detonation.

Dynamites (1.1D)

Dynamites are explosives that contain liquid nitrate esters. The most common nitrate ester used is "NG," which is a mixture of nitroglycerine and nitroglycol. NG has the ability to:

- Withstand freezing temperatures
- Mix with other ingredients to reduce its sensitivity
- Be packed into cartridges after mixing

Gelatinizing agents in dynamites promote water resistance. Antacids promote stability in storage.

Dynamites are *detonator-sensitive*, which means they can be initiated by detonators or detonating cord. Most dynamites develop a high velocity of detonation (VOD) that tends to create a greater shock wave.

Dynamites must be treated with caution due to the following:

- Skin contact with NG or inhalation of NG vapours may cause a "powder headache." Wearing non-permeable gloves (e.g., nitrile gloves) when handling dynamites can reduce the risk. Refer to the explosive's technical data sheet for more information on appropriate personal protective equipment to wear when handling the product.
- Exposure to moisture and temperatures in excess of 50°C (122°F) causes the composition of dynamites to break down.

- Accumulations of NG liquid (sweat) from the cartridges are very sensitive to accidental initiation.
- Most dynamites can be initiated easily and produce intense heat.
- When the temperature exceeds 200°C (392°F), dynamites can explode.

Dynamites are usually available in cartridge form. A paper wrapper prevents contact with the NG and protects the dynamite from moisture and contaminants. Cartridges are designed to maintain rigidity while being loaded into drill holes and to compress readily when *tamped*. For seismic and underwater blasting, cartridges made of heavy paper or plastic tubing are used. These materials allow for greater water resistance and protection from the elements.

Stability

Dynamites are stable under normal conditions. They may explode when subjected to fire, supersonic shock, or high-energy projectile impact. The risk of explosion is higher when dynamites are confined or in large quantities.

Water-gel explosives (1.1D)

Water-gel (also known as slurry) explosives contain *ammonium nitrate* (AN), which acts as an oxidizer. The AN is mixed with fuels, metal particles, and sensitizers. (Water gels do not contain NG.) The resulting explosive can be initiated by a high-strength detonator or a *booster*.

Water gels have a jelly-like consistency, are high density (1.1–1.5), and can be loaded into wet holes. They come in bulk or in sausage-like packing stapled shut on both sides.

The explosive in water-gel products is suspended in a thickened medium (gel) to protect it from external water. Many water gels have lower strengths and VODs than dynamites. But water gels are more stable and are highly water resistant.

Stability

Water-gel explosives can be initiated by extreme levels of shock, friction, or mechanical impact. As with all explosives, water gels should be handled and stored with care and must be kept clear of flames and excessive heat.

Emulsions (1.1D and 1.5D)

An emulsion explosive is a dispersion of minute droplets of ammonium nitrate oxidizer salt solution suspended in oil. Emulsifying agents prevent the separation of solution and oil in an emulsion. A bulking medium, in the form of gas bubbles or micro balloons, is added for density control. The more air that is added, the more sensitive but less powerful the blend becomes. Emulsions may also contain solids, such as aluminum, to enhance power.

Emulsions have varying consistencies, ranging from pumpable liquid to stiff putty. However, a grease-like consistency is the norm. Emulsions are also very water resistant.

Emulsions can come in bulk or packaged form. They are available as either detonator-sensitive or non-detonator-sensitive.

Emulsions are much safer to handle than other high explosives such as dynamites. There is no possibility of getting NG headaches from touching or smelling emulsions.

At low temperatures, emulsions may lose sensitivity. Consult manufacturers' technical data sheets for use and priming recommendations.

Stability

Emulsions are stable under normal conditions. They may explode when subjected to fire, supersonic shock, or high-energy projectile impact. The explosion risk is higher when emulsions are confined or in large quantities. The oxidizer increases the burning rate of combustible materials.

Blasting agents (1.5D)

A blasting agent is an explosive that is insensitive to a high-strength detonator. Blasting agents are composed of ammonium nitrate. They also contain various other sensitizing fuels that are generally not detonator-sensitive.

Blasting agents are relatively inexpensive. Due to their low sensitivity, they are stable and safe to store, transport, and use. Most are not water resistant. Exposure to moisture can result in poor rock breakage, misfires, or noxious fumes (oxides of nitrogen).

A high-energy primer is required to initiate blasting agents. Under-priming may result in excessive fumes, poor fragmentation, and misfires.

Ammonium nitrate and fuel oil (ANFO) and water-resistant ANFO (WR) are the most common blasting agents. They consist of a mixture of dry ammonium nitrate (AN) and *fuel oil* (FO) in a bulk weight ratio of 94% AN to 6% FO. Aluminum granules may be added to the mixture for extra energy. To mix ANFO, the written approval of the Chief Inspector of Explosives (Canada) is required. WR is used when there is a possibility of moisture, but it is not waterproof and should never be used in wet holes.

Blasting agents are either dry (free-running) or slurry products. Most dry types of ANFO mixtures have no water resistance, so a plastic *liner* (sock) may be required for wet holes. Dry products are generally supplied in bulk or packaged in bags with oil- and water-resistant liners. When free-pouring ANFO, follow the manufacturer's recommendations for the minimum diameter of the drill hole. These will vary between suppliers.

Stability

Blasting agents are insensitive but pose a mass explosion hazard when stored in large quantities. That's because the strong oxidizing effect of AN increases the burning rate of combustible materials. Shock, friction, fire (or other sources of ignition), and the strong oxidizer may cause fires or explosions.

Low explosives

Most *low explosives* are solid, combustible materials that decompose rapidly but do not normally detonate. This action is known as *deflagration*. Deflagration is an explosive reaction such as a rapid combustion that moves through an explosive at a velocity less than the speed of sound.

Black powder (1.5S)

Black powder is a low-explosive mixture of potassium nitrate, charcoal, and sulfur. It has no water resistance, is sensitive to heat sources and friction, and is highly flammable when dry. Upon initiation, it burns rapidly (deflagrates) with no shock wave. This produces a heaving rather than shattering action.

Black powder is used in fireworks, special-effect devices, and the (non-shattering) production of marble and slate. In finer grades, it is the core of safety fuse.

Propellants (1.4S2)

A propellant is a low-explosive mixture of a range of chemicals (e.g., nitrocellulose and ammonium nitrate) that varies between products and manufacturers. Propellants are sold in hard, water-resistant cartridges of various diameters and weights with igniters installed.

Propellants are used for breaking boulders (depending on their size), other rock, and concrete. Propellants may be effective for specialty uses (such as in sensitive marine environments). However, they can be costly and inefficient for blasting bedrock.

There is a common misconception that propellants produce less ground vibration, air blast, and fly rock than high explosives in surface-blasting operations. But in fact, propellants produce almost the same values of ground vibration and air blast (based on scaled distance) and fly rock as high explosives. In addition, propellant cartridges have a limited range of diameters and weights that can't be altered. This limits the blaster's ability to make adjustments.

For information on storage requirements for propellants and other high-hazard special purpose explosives, see sections 255 to 265 of the federal Explosives Regulations.

Chapter 6:
Handling explosives

Learning objectives

- Describe how (and how not) to handle explosives.
- Explain the separation requirements for explosives, detonators, and blasting accessories.
- Recognize the meaning and structure of factory, vendor, and user numbers.

Handling requirements

Employers and blasters must ensure that explosives are handled in accordance with the manufacturer's instructions. These instructions and technical data sheets must be readily available to workers at a worksite where explosives or *blasting accessories* are used.

The following handling requirements apply to most explosives:

- Never use explosives unless at least one of the following applies:
  - You are completely familiar with safety procedures for using the explosives.
  - You are under the direction of a qualified blaster.
- Ensure that explosives are *attended by* a competent person, except when they are stored in a locked magazine.
- Never store or keep different explosives in the same package.
- Never prime a charge in an area where explosives are stored.
- Never handle a detonator together with another type of explosive, except when priming a charge.
- Always keep electric detonators *shunted* or short-circuited, except during the testing or use of the detonators.
- Never investigate the contents of a detonator. Never pull wires, safety fuse, shock tube, coupling devices, plastic tubing, or detonating cord out of any detonator or delay device.
- Keep explosives a safe distance away from flammable materials or open flames.
- Never fight fires involving explosives. Remove yourself and all other persons to a safe location and *guard* the area.
- Never handle explosives during an *electrical storm* (i.e., if thunder or lightning is present). When a storm approaches, stop all blasting operations, move all persons to a safe distance, and guard the area. This applies to both surface and underground operations.
- Do not drop or throw explosives.
- Do not expose explosives to excessive impact or friction.
- Never allow loaded firearms or shooting near explosives, magazines, or vehicles loaded with explosives.
- Never use sparking metal tools when handling explosives.
- Never use sparking metal tools to open packages of explosives.
- Never put explosives in your pockets or other parts of your clothing.
- Always keep explosives away from food, eyes, and skin. Flush areas of contact with large quantities of water.
- Do not remove the protective casing or wrapper from any explosive (except for dry, free-running blasting agents).

- A blaster or another qualified person must examine stained, damaged, or deteriorated explosives. If the defect is slight, the explosives may be used, but only with new explosives as a primer. If the explosives are unfit for use, they must be destroyed in a safe manner and in accordance with the *Explosives Act* and Regulations.
- Never use explosives that have been soaked in water, even if they now appear to be dried out.
- Do not bury or abandon explosives. Unused explosives must be returned to a container or magazine, or disposed of as recommended by the manufacturer. (See Chapter 9, "Disposing of explosives.")

A worker reviews a technical data sheet for an explosive.

Separation of explosives

When explosives are handled, transported, stored in a magazine, or kept at a worksite, they must be kept separate from other materials. Such materials include drill rods, metal tools, and oily rags.

Explosives must also be kept away from sources of contamination, heat, or impact. And explosives, detonators, and some blasting accessories must be kept or stored separately. Blasting accessories include products that do not explode but are commonly used to set off a detonator.

The following figure outlines the separation requirements for explosives, detonators, and blasting accessories. The items in each group must be kept away from items in the other groups.

Separation of explosives, detonators, and blasting accessories

Explosives

- Dynamites
- ANFO/WR
- Cast boosters
- Detonating cord
- Water gels and emulsions
- Propellants
- Black powder

Detonators

- Electric detonators
- Electronic detonators
- Shock tube detonators
- Safety fuse assemblies
- Detonating connectors

Blasting accessories

- Blasting machines
- Pull-wire lighters
- Galvanometers
- Thumper/mushroom starters
- Shot shell shooters/ pen starters
- Safety matches

Factory, vendor, and user numbers

Under the federal Explosives Regulations, the outer packaging of explosives must be permanently marked to identify ownership. On most packaging, a printed strip or label records ownership.

Ownership is identified with letters and numbers as shown in the following table. The *X*'s are placeholders for numbers.

Factory, vendor, and user numbers

Number	Identification
F1-XXXXXX/E	Factory number
VXXXXXX/E	Vendor number
UXXXXXX/E **(or Z or Y)**	User number

The first (left-hand) space of the identification area contains the "F" or factory number of the manufacturer. The next space usually contains the "V" or vendor number of the original seller of the explosive.

Before releasing any explosives or detonators, the vendor marks the next space with the identification number of the vendor or user taking possession of the explosive. The "U" (user) number identifies the person who has purchased the explosives. The user must not sell the explosives and must protect them from theft.

The vendor must properly identify a person before that person takes possession of explosives. The purchaser must have an approval letter from the Explosives Regulatory Division of Natural Resources Canada or an equivalent document (e.g., a FAST card, a NEXUS card, or a Firearms Possession and Acquisition Licence). A criminal record check is required as part of the application process for these documents.

The identification number of the last vendor or user to possess the explosives must be marked on the outer packaging. The person who opens a case of explosives must mark the inner cartons, packages, or spools with the appropriate identification numbers. This person must also update the inventory on the opened box and in the magazine log.

Chapter 7:
Storage of explosives

Learning objectives

- Identify the federal rules and regulations for magazines and storing explosives inside them.
- Identify the types of licensed facilities for manufacturing, selling, distributing, or storing explosives.
- Describe the responsibilities of the licensee related to an explosives magazine.
- Discuss the requirement to ensure someone is in charge of every explosives magazine.
- Describe the most common type of explosives magazine used in the blasting industry.
- Identify requirements that apply to the contents of an explosives magazine.
- Explain the importance of maintaining an explosives magazine inventory.
- Explain signage requirements where explosives are stored.
- Describe how to determine safe locations for explosives magazines.
- Describe how to protect explosives magazines from fire and lightning.
- Explain the federal and OHS Regulation requirements regarding maintenance and organization of an explosives magazine.

Overview

Explosives must be stored in a safe, secure facility to protect them from theft, damage, and contamination. The rules for magazines and storing explosives inside them are set out in the federal *Explosives Act* and Explosives Regulations. People with access to magazines need to be familiar with these requirements.

A pair of magazines

About licensed magazine storage

A licensed facility is a magazine for which a licence has been issued by the Explosives, Regulatory and Business Services Branch of Natural Resources Canada. There are three types of licensed facilities:

- A **factory site**, from which the licensee is authorized to manufacture, sell, or distribute explosives
- A **vendor magazine**, from which a vendor is authorized to sell or distribute explosives
- A **user magazine**, usually under the control of a blaster, in which a user is authorized to store explosives for use in a blasting operation

The terms of the licence will specify the location, maintenance, operation, safeguards, and permitted contents of the magazine. These terms must be strictly adhered to. The licensee must do the following:

- Prohibit entry by unauthorized persons.
- Ensure that everyone who accesses the magazine has an approval letter from the Explosives Regulatory Division of Natural Resources Canada or an equivalent document (e.g., a FAST card, a NEXUS card, or a Firearms Possession and Acquisition Licence).
- Prohibit matches, flammable materials, and iron or steel tools in and around the magazine.
- Keep the interior dry, cool, well-ventilated, organized, clean, and free of grit.
- Monitor the behaviour of persons in or near the facility.
- Have a written security plan and a fire safety plan. These can be two separate documents or one combined document.
- Ensure magazine key security, which includes a written key-control plan.
- Keep an accurate inventory of the magazine contents.
- Report all theft to the Explosives Regulatory Division of Natural Resources Canada and to local police.
- Have a magazine surveillance program in place and approved by Natural Resources Canada.

Ensuring a person is in charge of each magazine

The federal Explosives Regulations do not require a certified blaster to be responsible for storage. However, the magazine owner or employer must ensure someone is designated as being in charge for every magazine. That person is often a blaster. The employer must also designate a person to attend explosives when they are not stored in a locked magazine.

Requirements for magazines used for unattended overnight storage

Type 4 magazines are the most common example used in the blasting industry. They are walk-in style, licensed buildings used to store explosives overnight.

To store explosives, this type of magazine must be constructed according to the requirements of National Standard of Canada CAN/BNQ 2910-500 Explosives — Magazines for Industrial Explosives. This standard, published by the Standards Council of Canada and the Bureau de normalisation du Québec, is amended from time to time as security requirements change.

The standard provides the specifications for the following:

- Materials to be used
- Door design
- Locking systems
- Heating, cooling, and insulation
- Ventilation
- Bullet resistance of the walls
- Electrical systems
- Interior finish
- Surveillance

Magazine exterior


Magazine interior

Types of magazine licences

A general user magazine licence (also called a type U) is required when storing explosives for commercial use.

A vendor magazine licence (also called a type V) is needed if either of the following apply:

- Blasting explosives and other types of industrial explosives are being sold.
- Any amount is kept by the vendor in storage magazines.

Contents of magazines

The following requirements apply to the contents of magazines:

- Clean up spills of explosives promptly. In case of a spill of a deteriorated explosive, follow the product manufacturer's recommendations for cleanup.
- Store only explosives that are permitted under the magazine's licence.
- Other materials and equipment may be stored in the magazine only if they are required for operations (e.g., handling explosives) in the magazine and they don't increase the risk of an ignition.
- Rotate stocks of explosives so the oldest explosive in a magazine is used first. Consult with the manufacturer to ensure that the recommended storage time for the explosives is being followed.
- Never store detonators with other explosives.
- Never store any sparking metal in a magazine.
- Never use explosives that appear to have deteriorated. Consult the manufacturer for proper disposal or use.
- Never exceed recommended storage conditions and temperatures for explosives. Check with the manufacturer.
- Never perform any type of operation in a magazine other than inspection, inventory, or bringing in or taking out explosives.

Maintaining a magazine inventory

The operator of a licensed explosives-storage facility must maintain an accurate record of the explosives stored. This record is known as a magazine log book. All records of any magazine must be kept until two years after the last date mentioned in the log. For any explosives received or issued, the operator must record the following information:

- The quantity
- The brand name
- The cartridge size
- The date received and issued

If a magazine contains open boxes of cartridge explosives, an accurate stick count must be maintained in the magazine logs and should be written on each box.

Sample magazine log for explosives

Magazine number: ______________ Explosive limit: ______________

Date received	Date issued	Brand name and cartridge size	Stock or quantity			Signature
			In	Out	Balance	

Sample magazine log for detonators

Magazine number: ______________ Explosive limit: ______________

Date received	Date issued	Detonator type and length	Stock or quantity			Signature
			In	Out	Balance	

Posting warning signs for magazines

A site where explosives are kept or stored must be identified by warning signs. The signs must be easily seen, but they should not attract undue attention. In the interests of security, the less publicity as to what is stored at the site, the better. Position signs so that a bullet passing directly through them will not strike the magazine.

A federal explosives inspector may set out requirements for the placement and wording of warning signs. The signs should not be visible from a public road.

Signs typically display wording similar to the following:

DANGER
KEEP OUT

DANGER
NO TRESPASSING
NO SMOKING
NO MATCHES

Determining safe locations for magazines

National Standard of Canada CAN/BNQ 2910-510 Explosives — Quantity Distances is used to determine the proper separation distances between a magazine and its surroundings.

A site where explosives are kept or stored must be located a safe distance from the following:

- Inhabited buildings
- Public roads
- Passenger railways
- Travelled waterways
- Other places frequented by people
- Power lines
- Transmitting antennas
- Sites storing hazardous materials

The minimum distance a storage facility must be located from such areas depends on the quantity of explosives.

Table C.2 in the National Standard of Canada CAN/BNQ 2910-510 Explosives — Quantity Distances lists the minimum distances in metres. These distances may be adjusted at the discretion of a federal explosives inspector. Greater distances should be selected whenever possible.

Locate the storage site at the base of a high bank or in a grove of trees. This will hide the site from view and reduce the likelihood of lightning strikes.

Keep explosives a safe distance from electrical transmission lines. This means maintaining a minimum separation as set out in the quantity-distances standard mentioned above.

Protecting magazines

Explosives must be protected from fire and lightning. Do not allow smoking or the use of e-cigarettes in or around a magazine.

To reduce the risk of fire, keep the area within 8 m (26 ft.) of a storage area or facility clear of dry grass and other combustible materials.

Never allow any lighters, matches, smoking, open flames, or other sources of ignition or volatile materials within 15 m (50 ft.) of a magazine.

If a fire occurs near a storage facility or involves an explosives magazine, evacuate all personnel at least 800 m (0.5 mi.) away. Never attempt to extinguish burning explosives.

On the approach of and during a thunderstorm, close all storage facilities and keep a safe distance from explosives.

Magazine maintenance

Under the Occupational Health and Safety Regulation, the employer must ensure that a magazine is kept clean, dry, and organized. A well-organized magazine makes it easy to select, issue, and inventory explosives. Uncovered boxes and loose cartridges, spools, and detonators are not to be kept in a magazine.

Cases of explosives in a magazine must not be piled higher than allowed by the magazine licence issued under the federal *Explosives Act*. The "stack line" is often indicated in the magazine, as shown below. The employer must also ensure that the quantity of explosives stored in a magazine does not exceed the amount allowed by the licence.

Before performing any repairs on the inside or outside of a magazine, all explosives must be removed.

Stack line in a magazine

Chapter 8: Transportation of explosives

Learning objectives

- Identify federal and provincial acts and regulations that apply to transporting explosives.
- Explain how explosives are classified under the federal *Transportation of Dangerous Goods* (TDG) *Act*.
- Describe the training and certification requirements for workers who load, unload, or transport explosives in vehicles.
- Explain how safety marks, such as labels and placards, help to identify dangerous goods and the hazards they pose.
- Discuss compatibility grouping and when explosives may be transported together.
- Identify transport container requirements for commercially packaged explosives.
- Explain fire extinguisher requirements for vehicles transporting explosives.
- Describe inspection and maintenance requirements for vehicles used to transport explosives.
- Identify the requirements for loading and unloading of explosives being transported.
- Explain the rules authorized operators must follow while explosives are in transit.
- Describe the procedures for reporting a release of explosives during transportation.
- Describe the procedures to report loss or theft of explosives.
- Identify the purpose and contents of an emergency response assistance plan (ERAP).

Laws and regulations governing transportation of explosives

Transportation of explosives by road, rail, air, and water is governed by the federal *Transportation of Dangerous Goods* (TDG) *Act* and Regulations and the *Explosives Act* and Regulations.

Transportation of explosives on a worksite is governed by WorkSafeBC's Occupational Health and Safety Regulation.

Always follow federal and provincial laws and regulations concerning transportation.

Classification of explosives under the TDG Act

Under the TDG Act, dangerous goods belong to one of nine classes. Explosives are Class 1.

Each type of explosive has the following:

- A United Nations (UN) number of four digits
- A class number (1)
- A division number (1.1 to 1.6)
- A compatibility group letter

Divisions

Class 1 (explosives) has the following six divisions:

- Class 1.1, mass explosion hazard (e.g., dynamite, TNT)
- Class 1.2, fragment projection hazard (e.g., some forms of ammunition, bombs, and grenades)
- Class 1.3, fire hazard, along with a minor blast or projection hazard (e.g., rocket propellants, commercial-grade fireworks)
- Class 1.4, no significant hazard; explosion effects are largely confined to the package (e.g., fuses, igniters, consumer fireworks)
- Class 1.5, very insensitive but with a mass explosion hazard (e.g., some blasting agents)
- Class 1.6, extremely insensitive with no mass explosion hazard

Compatibility group letters

The compatibility group letter indicates which explosives can be transported and stored together. For a complete description of the 13 compatibility groups for Class 1 explosives, see Appendix 2 of Part 2 of the TDG Regulations.

Explosives from compatibility groups B (mostly detonators) and D (mostly blasting explosives) must not be stored together.

Note
For more information on classification of explosives, see sections 2.9 to 2.12 of the Transportation of Dangerous Goods (TDG) Regulations.

Training and certification of drivers and helpers

Under section 21.7 of the Occupational Health and Safety Regulation, a worker engaged in loading, unloading, or transporting explosives in a vehicle must be trained in the following:

- The proper means for handling the explosives
- The hazards of fire and mishandling explosives
- The procedures to follow in the event of a fire or explosion

Drivers and persons handling, offering for transport, or transporting explosives must have a certificate, issued by the employer, stating the worker has received adequate TDG training. A person is adequately trained in TDG if the person has a sound knowledge of all the following topics:

- Types of placards, labels, signs, numbers, and other safety marks; what they mean; and when and where to display them
- A thorough knowledge of the control and emergency features for all handling equipment used in the day-to-day activities of the job
- Safe practices on the loading and transportation of dangerous goods
- The proper selection and use of means of containment (i.e., packaging or containers) for dangerous goods
- Documentation for shipping dangerous goods
- Emergency response assistance planning
- Shipping names
- Reporting requirements

Self-employed persons who have reasonable grounds to believe that they are adequately trained and who will perform duties to which the training relates must issue to themselves a signed training certificate.

Workers who are not trained can handle, offer for transport, and transport dangerous goods as long as they perform those activities in the presence of and under the direct supervision of a person who holds a TDG training certificate in accordance with Part 6 of the TDG Regulations.

TDG training certificates are valid for 3 years and include transportation by ATVs, vessels, snowcats, and snowmobiles. For aerial operations, certificates are valid for 2 years. The pilot and the blaster of record are required to have TDG certificates. The employer must keep copies of the certificates.

Safety marks

Safety marks help workers to quickly identify dangerous goods and the hazards they pose. A safety mark can be:

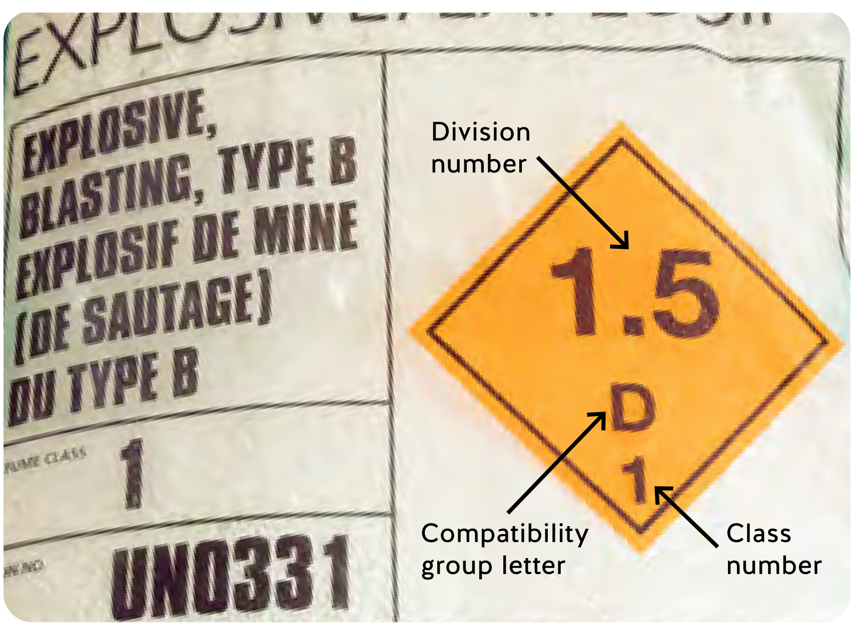
- A placard
- A label
- A sign
- An orange panel
- A word
- An abbreviation
- A letter
- A number
- A mark
- Any combination of the things listed above

This section focuses on labels and placards.

The type of safety mark required depends on the size of the container and the classification of the dangerous goods. In general, if the container is 450 L or less (known as a small means of containment), a label is required. If the container is more than 450 L (a large means of containment), a placard is required. The class of dangerous goods determines the type of label or placard needed. Explosives are Class 1, and placards are required on all vehicles that carry high explosives.

Labels

Labels are small hazard-warning signs that must be displayed on one side of any small means of containment (such as UN-approved plastic bags or fibreboard boxes of explosives). Under the TDG Regulations, labels must show the class of the explosive, the division number, and the compatibility group letter.



A TDG label on a bag of explosives

Placards

Vehicles transporting explosives must display appropriate large hazard-warning placards. Placards must show the following:

- The class and hazard division numbers of the explosive being transported
- The compatibility group letter of the explosive

Placards must correspond to the highest-hazard explosive being transported.

Placards are placed before explosives are loaded on the truck and removed when there are no explosives on board. An orange TDG placard must be displayed on all four sides of a vehicle while the vehicle contains explosives.

A truck with a TDG placard

There are special rules for placarding vehicles transporting mixed loads of explosives with different hazard ratings and/or compatibility groupings (such as detonators and explosives). The following table shows examples of placards required for various types of explosives. For more information on placarding rules, see Part 4 of the TDG Regulations.

Types of placards required for various types of explosives

Types of explosives	Label required	Placard required
Detonator-sensitive explosives, boosters, detonating cord	1.1D	1.1D
Blasting agents UN 0331 or UN 0332 (ANFO, detonator-insensitive slurries, water gels, or emulsion explosives)	1.5D	1.5D
Mixed loads of dynamite or detonator-sensitive explosives (1.1D) and ANFO (1.5D)	1.1D & 1.5D	1.1D
Detonators and detonating delays	1.1B	1.1B
Mixed loads of blasting explosives (1.1D) separated from detonators (1.1B) in limited quantities, per the federal Explosives Regulations	1.1B & 1.1D	1.1D
Fuses, igniters, consumer fireworks	1.4B	1.4B
Electric propellants, shock tube lead-in line, shock tube surface delays	1.4S	None

Usually only the placard for the explosives with the lowest division number (i.e., the most-hazardous explosives) must be displayed, except in the following cases:

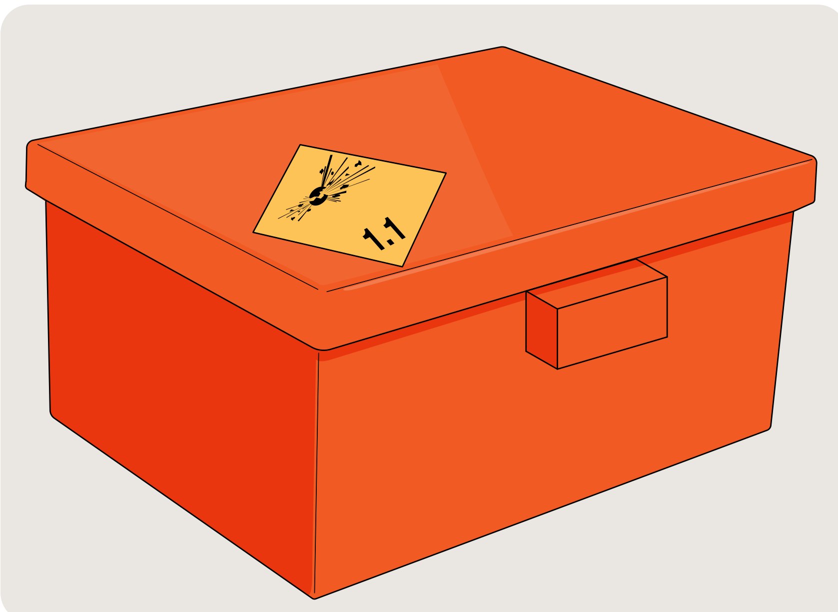
- When explosives included in Class 1.2 (e.g., some forms of ammunition, bombs, and grenades) and Class 1.5 are transported together, the placard for Class 1.1 must be displayed.
- When explosives included in Class 1.4 and Class 1.5 are transported together, the placard for Class 1.5 must be displayed.

Compatibility groups

Explosives of the same compatibility grouping may be transported together, provided there is no increase in the probability of an accident or in the magnitude of the effects of such an accident. Section 5.7 of the federal TDG Regulations contains a compatibility chart that shows which divisions of explosives may be transported together.

Transport container requirements

Commercially packaged explosives must be in plastic bags and fibreboard boxes that comply with National Standard of Canada CAN/CGSB-43.151, Packaging, Handling, Offering for Transport and Transport of Explosives (Class 1). This standard is published by the Canadian General Standards Board and is updated from time to time. To stay in compliance with this standard, keep explosives in their original packaging from the manufacturer.



An example of a container suitable for carrying explosives on a vehicle. This container must be locked and fixed to the vehicle.

Many vehicles used to transport explosives are equipped with fixed compartments (powder boxes) or tanks for this purpose. Leaving packaged explosives unsecured in the back of a vehicle or covering them with a tarpaulin is unacceptable.

The part of the vehicle where explosives are carried must be:

- Separate from the passenger compartment of the vehicle
- Fully enclosed, locked, and fire resistant
- Free of any combustible or abrasive materials
- Free of any fire-producing devices or materials

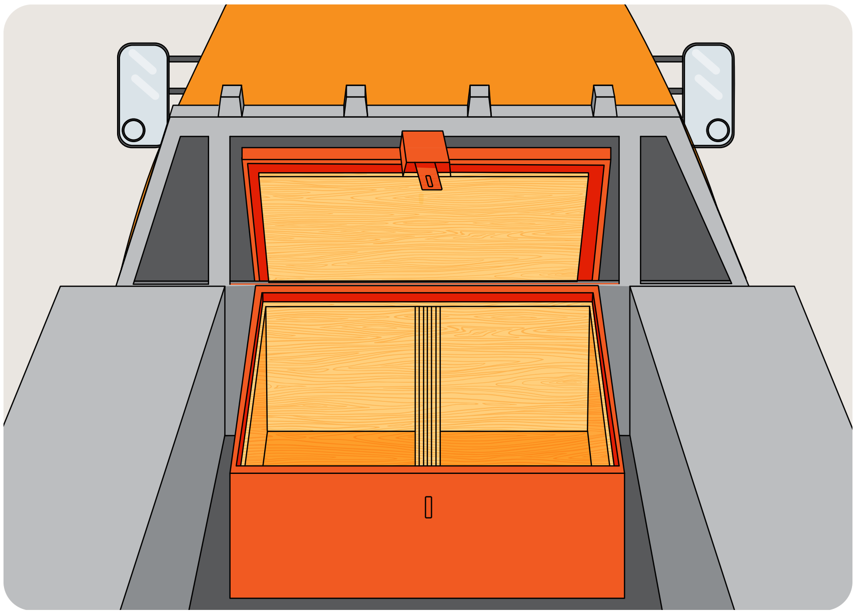
The Explosives Regulatory Division of Natural Resources Canada requires that containers or compartments be constructed of steel or aluminum with walls made from:

- An outer cladding of 6 mm (¼ in.) metal
- An inner lining of 12 mm (½ in.) plywood or equivalent non-sparking material

These inner lining materials protect the explosives from abrasion and contact with iron or steel surfaces. Explosives must be kept separate from items such as drill rods, metal tools, oily rags, other combustibles, detonators, and other initiating devices.

Detonators must be kept separate from other explosives in a vehicle so that the explosion of one or more detonators will not initiate any of the other explosives. The detonators must be in a completely enclosed container or compartment that protects them from detonation in the case of fire for at least one hour. There must be no access to the detonators from inside the cargo compartment of the vehicle.

Explosives and detonators may be transported in the same vehicle provided they are effectively separated. Any separation or barrier is acceptable, as long as it is supported by test data showing that the detonators will not initiate the rest of the explosives.



The powder box with thick partitions shown here is suitable for transporting both explosives and detonators.

Boxes constructed with a 150 mm (6 in.) thick plywood barrier can still be used if they totally enclose the detonators. The barrier must extend at least 150 mm (6 in.) above the highest level to which explosives are packed.

Special precautions must be taken when the vehicle is equipped with a radio transmitter. Electric detonators must be in a closed metal container, electrically bonded to the vehicle, and lined with wood or other approved material such as rubber or felt. The *leg wires* must be kept folded and shunted, and the radio transmitter must be switched off whenever the container is open.

Fire extinguisher requirements

A vehicle transporting explosives in British Columbia must be equipped with at least two fire extinguishers that have a rating of at least 4-A:40-B:C. Each must be fully charged, in working order, and readily accessible for use. The fire extinguishers must be in separate locations on the vehicle so that at least one is accessible in the event of a fire.

The extinguishers are intended for putting out fires on or near the vehicle. Do not attempt to extinguish burning explosives. Most explosives create their own oxygen supply and are not readily extinguished. Also, impact or shock may cause them to detonate. If the fire is near explosives or detonators, remove everyone from the danger area and keep it guarded until the fire burns out and the area has cooled.

Pre-loading inspections of vehicles

Vehicles used for transporting explosives must be inspected and maintained in accordance with the vehicle manufacturer's recommendations.

Before loading explosives on a vehicle, inspect the vehicle to ensure it is in good working order. Good working order means the following:

- The brakes and steering are working properly.
- The electrical wiring is insulated and secured.
- The chassis, engine, pan, and bottom of the body are clean and free from oil and grease.
- The vehicle is fully serviced and contains enough fuel.
- The fuel tank and feed lines are in good condition and have no leaks.
- The vehicle does not contain flammable materials such as paper, rags, and fuel containers.
- Fire extinguishers are fully charged, in working order, and readily available for use.

Containers for explosives must have the following characteristics:

- No exposed iron or steel on the inside
- A lid with a suitable lock
- A secure location in or on the vehicle

Other requirements include the following:

- Do not carry explosives on trailers.
- Do not carry explosives on a semi-trailer unless the semi-trailer is:
  - Equipped with power brakes operable from the tractor cab.
  - Attached by fifth wheel.
- Ensure that tires are not worn smooth or visibly defective.

Unless these pre-loading requirements are satisfied, the vehicle must not be used to transport explosives. The blaster should document the vehicle inspection for due diligence.

Loading and unloading explosives

Explosives must not be moved unless appropriate arrangements have been made to safeguard the explosives at the destination. The operator of the vehicle must do the following before receiving the shipment of explosives:

- Give the owner of the shipment notice of the time at which the operator is prepared to deliver.
- Receive confirmation from the owner of the shipment that the owner is prepared to receive the shipment at or about the time specified in the notice.

A worker loads explosives into a vehicle.

A person engaged in transportation of explosives must have been instructed in, and must observe, all safety precautions. While explosives are being loaded or unloaded, the following precautions must be taken:

- Smoking, open flames, and vaping are not permitted within 15 m (50 ft.) of an explosive, a *day box*, a magazine, or a vehicle containing explosives.
- Smoking, open flames, and vaping in or while attending any vehicle carrying or containing an explosive are prohibited.
- Turn the ignition off and apply the parking brake. If extreme cold and wind conditions might reasonably cause difficulty in restarting the engine, it may be left running.
- Handle explosives in a safe, orderly manner. An accidental fall may cause detonation.
- Do not drop, throw, or otherwise mishandle explosives.
- Distribute the load evenly between the load-bearing axles of the vehicle.
- Do not load in excess of 80% of the vehicle's rated capacity, commonly known as gross vehicle weight (*GVW*), except as permitted by the Explosives Regulations.

Rules while in transit

Only the driver and persons assigned to assist in handling explosives are permitted on a vehicle transporting explosives.

A vehicle or mobile equipment containing explosives must be attended by a qualified person at all times. Often, the blaster assumes or is assigned this responsibility, including operating the vehicle.

The authorized operator must:

- Have a valid driver's licence. A driver with an N is restricted to travelling with one passenger and having zero alcohol.
- Be at least 18 years of age.
- Be at least 21 years of age when transporting more than 2000 kg (4,409 lb.) of explosives.
- Have an approved emergency response assistance plan (ERAP) as required by the TDG Regulations. However, a copy of the ERAP inside the vehicle is not mandatory. (For more information on ERAPs, see page 114.)
- Possess documentation required by the Explosives Regulations and the TDG Regulations (such as a TDG training certificate and shipping documents).

When operating a vehicle transporting explosives, the following requirements apply:

- Follow dangerous goods routes. If there are no dangerous goods routes, the driver must, if possible, avoid routes that pass through densely populated areas.
- Drive in a safe manner, consistent with prevailing road and weather conditions.
- Do not drive near a fire.
- Stops at places where public safety would be endangered must be avoided.
- The vehicle must not be stopped unnecessarily or for a longer period than is reasonably required.
- Only refuel a vehicle carrying explosives when the ignition is shut off, and in a location where danger to workers or the public is minimized.
- The driver and any person assisting the driver must not carry alcohol or another performance-diminishing substance for their personal use.
- A person who is under the influence of alcohol or another performance-diminishing substance must not be in or attend a vehicle that contains explosives. However, people who have taken a prescription drug may be in or attend a vehicle containing explosives if they have medical proof that they need the drug and that it will not impede their ability to function safely.

In the case of a mechanical breakdown of a vehicle transporting explosives, the following requirements apply:

- The driver must ensure that minor repairs to the vehicle are done at the location of the breakdown only if doing the repair work will not increase the likelihood of an ignition.
- The work is done by a person who understands the hazards to which they could be exposed.
- Major repairs are allowed only when the explosives have been transferred to another vehicle or a place at least 300 m (985 ft.) from any inhabited premises, and placed under proper security.

When approaching a railway crossing with an automatic signal device, reduce the vehicle's speed and ensure that the crossing is safe before proceeding. If a railway crossing is without an automatic signal device, bring the vehicle to a complete stop and proceed only when the way is clear.

Before crossing any main highway, bring the vehicle to a complete stop and proceed only when the way is clear and safe.

When a vehicle carrying or containing explosives is to be parked overnight, the place where the vehicle will be parked must:

- Not be used for any other purpose that may involve any substance likely to cause explosion or fire
- Be away from homes and buildings that contain flammable materials

For more information on requirements for overnight parking, see sections 199 and 200 of the federal Explosives Regulations.

Reporting a release of explosives

In case of a release (spill) or anticipated release of any amount of explosives during transportation, the person in charge of the explosives at that time must make an emergency report to the local authorities. In B.C., these authorities are:

- 911 (or the local police)
- Emergency Management BC (1.800.663.3456)
- The Canadian Coast Guard (1.800.889.8852), in case of a release involving a vessel

The emergency report must be made as soon as possible after the release.

What is an anticipated release of explosives?

An anticipated release of explosives means that:

- A motor vehicle accident has occurred.
- The boxes that hold the explosives have been damaged.
- No explosives have been released from the boxes.

What an emergency report must include

An emergency report must include the following information:

- The name and contact information of the person making the report
- The date, time, and location of the release
- The mode of transport used
- The shipping name or UN number of the explosives
- The quantity of explosives that was in the means of containment (container or packaging) before the release
- The quantity of explosives estimated to have been released
- If applicable, the type of incident leading to the release (e.g., a collision, rollover, derailment, overfill, fire, explosion, or load-shift)

In addition, the blaster's employer must do the following:

- Immediately report the release to WorkSafeBC.
- Submit a written report of the release to WorkSafeBC within 48 hours.

After making an emergency report

If a release results in a death, injuries requiring medical attention, a facility or road closure, or an evacuation, the person in charge of the explosives must submit a release report to the following:

- CANUTEC, Transport Canada's emergency response agency, at 1.888.CANUTEC (1.888.226.8832) or 613.996.6666
- The consignor (shipper) of the explosives
- A Vessel Traffic Services Centre or a Canadian Coast Guard radio station, in case of a release involving a vessel

After a release report has been made, a 30-day follow-up report must be submitted to the Director General of the federal TDG Directorate.

For detailed information on reporting requirements, visit Transport Canada's Reporting requirements webpage.

In addition, regardless of whether a release report is required for CANUTEC, the person in charge of the explosives should do the following as soon as possible:

- Call the emergency response assistance plan (ERAP) implementation phone number listed on the shipping document.
- Notify CANUTEC that the ERAP has been implemented.

For more information on ERAPs, see page 114.

Loss or theft of explosives

Any loss or theft of explosives must be reported as soon as possible to:

- CANUTEC at 1.888.CANUTEC (1.888.226.8832) or 613.996.6666
- A Natural Resources Canada inspector at 613.995.5555

A loss or theft report must include the following information:

- The name and contact information of the person making the report
- The names and contact information of the consignor (shipper), the consignee (receiver), and the carrier
- Information as to whether the explosives were lost or stolen
- The shipping name or UN number of the lost or stolen explosives
- The quantity of the lost or stolen explosives
- A description of the means of containment (container or packaging) containing the lost or stolen explosives
- The approximate date, time, and location of the loss or theft

Any loss or theft of explosives should also be reported to the local police.

For more information on reporting requirements in case of loss or theft of explosives, see sections 8.16 and 8.17 of the TDG Regulations.

Emergency response assistance plan (ERAP)

An emergency response assistance plan (ERAP) describes what needs to be done in case of an accident or other incident during the transportation of explosives or other dangerous goods.

An ERAP describes things such as:

- Procedures to follow
- Who needs to be contacted and how
- What equipment needs to be used and how to get it to the site

An approved ERAP is used to help emergency workers in their response to an accident.

An ERAP is required when transporting explosives or other dangerous goods in specific quantities and under certain conditions. Part 7 of the TDG Regulations sets out those quantities and conditions and describes the ERAP application, approval, and implementation process.

For more information on ERAPs, visit Transport Canada's Emergency response assistance plans webpage.

Chapter 9:
Disposing of explosives

Learning objectives

- List the critical information employers and workers need to know with respect to the proper disposal of explosives.
- Recognize the signs of damaged and deteriorated explosives.
- Describe how to safely destroy deteriorated or defective explosives by detonating or burning them.
- Describe how to manage degraded dynamite and nitroglycerine contamination caused by sweating.
- Discuss methods to manage degraded emulsion, water-gel, and ammonium nitrate-based explosives.
- Describe how to manage abandoned or buried explosives and the consequences of mismanaging them.
- Describe what must be done with explosives equipment before disposing of it.

What employers and workers need to know

Any person who owns or possesses explosives has a legal responsibility to properly dispose of them. Surplus explosives in good condition may be returned to a storage facility or the supplier. Damaged or deteriorated explosives must be destroyed safely.

Every blaster must:

- Recognize and know the causes of damage and *deterioration*.
- Understand the dangers involved.
- Understand safe procedures for disposing of the more common types of explosives.
- Understand their duty to report abandoned explosives.

Always manage deteriorated or damaged explosives with special care. They may be more hazardous than explosives in good condition.

Always dispose of explosives in accordance with applicable federal, provincial, and local laws, regulations, and bylaws. This includes following all requirements related to packaging, marking, and transportation of explosives.

Never reuse any packaging of explosives. Empty original, disposable packaging must be destroyed safely or as recommended by the manufacturer.

Damage and deterioration

Deterioration can alter the composition or properties of an explosive. Exposure to moisture and extreme temperatures is the main cause of deterioration. Fuels and solvents can also cause deterioration. Some products deteriorate with age, but many retain their composition and properties for several years when stored in a dry, well-ventilated area.

If the protective shell or wrapping is damaged or removed and the product comes in contact with water or chemicals, the deterioration process will speed up. Many explosives will become insensitive and not perform as intended. However, detonators and nitroglycerine (NG) explosives that have deteriorated are extremely dangerous to handle or use.

Damaged or deteriorated products should be clearly identified and kept separate from serviceable explosives. The area in which deteriorated products are stored, handled, or destroyed must be kept clear of hazards.

Signs of damage include broken, stained, or crushed packaging, and liquid leaking from the outer wrappings of explosives. Other signs of damage include unexploded, used detonators and detonators with damaged wires or tubing. Using such detonators can result in accidental detonation, misfires, poor breakage, and excessive fumes. The authorization of a federal explosives inspector must be obtained before transporting any degraded explosives.

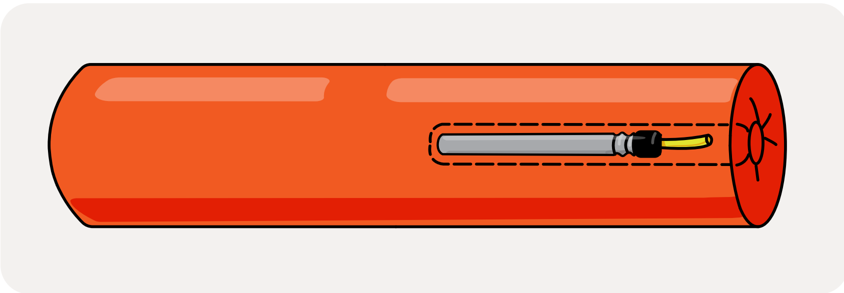
Disposal procedures

Explosives or blasting accessories that have deteriorated, or are believed to be defective, must not be used. They must be handled and disposed of in a safe manner in accordance with the federal *Explosives Act* and Regulations.

Destruction by detonation

In many cases, the best way to destroy deteriorated explosives is to place them in a blast hole (under the *collar* or stemming) with other explosives and initiate the other explosives. This should be done as part of a planned blasting operation.

If the explosives are still in good condition, small quantities of explosives can be added in the blast hole.



A deteriorated detonator is embedded in a stick of dynamite in preparation for destruction by detonation.

Special care must be taken to not mix different types of explosives. This helps to avoid contamination or incompatibility between the explosives to be blasted and the explosives to be destroyed.

Disposing of deteriorated explosives in a blast may only be done if the explosives:

- Can be safely handled, placed, and used
- Are initiated with a fresh primer
- Will detonate reliably with the desired effects
- Will be placed by a certified blaster trained in disposal

Destruction by burning

Another option is to destroy deteriorated explosives by burning them. This requires a licence or certificate issued by the Explosives Regulatory Division of Natural Resources Canada.

There is always a chance of an explosion when burning deteriorated explosives. For this reason, a remote location must be chosen so that no damage to property or injury to people will result.

During burning operations, every precaution must be taken to ensure that:

- Approved procedures are in place and workers have been properly trained.
- No detonators of any kind are among the deteriorated explosives to be burned. The presence of even one detonator or a metallic object will probably lead to detonation. Carefully examine deteriorated dynamite, detonating cord, cast boosters, and safety fuses for the presence of detonators. Destroy detonators separately.
- At any given time, only one type of explosive is to be burned.
- The explosives and their packaging are not confined or burned in such a way that they can become confined (e.g., in incinerators or barrels).

Scrap or deteriorated explosives must be packaged according to the federal Transportation of Dangerous Goods Regulations before they are transported to a destruction site.

The burning of explosives may contribute to pollution, particularly when ammonium nitrate-based and water-gel explosives are involved. Consult the B.C. Ministry of Environment and the local government before proceeding.

Dealing with degraded dynamite and nitroglycerine contamination

NG-based explosives, such as the dynamites, may “sweat.” This sweating is the exudation (slow, steady discharge) of nitroglycerine. Sweating greatly increases an explosive’s sensitivity to friction.

Storing NG explosives in a hot, moist atmosphere greatly increases sweating. But sweating can occur even under good storage conditions. Beads of nitroglycerine form on the outside and ends of cartridges. Over time, the exuded nitroglycerine soaks into the bottom and lower sides of the cases, staining them noticeably. The sweating may be observed earlier on cartridges in open cases.

In either event, the cartridges in all packages should be examined. If the cartridges are still serviceable, they should be taken for early use. They should be issued only if the person receiving them understands their condition. If the sweating observed is so great that the cartridges are unserviceable, they should be destroyed in accordance with the manufacturer’s recommendations.

The authorization of a federal explosives inspector must be obtained before transporting degraded NG explosives. These explosives can be very sensitive to shock and friction. For this reason, specific procedures must be followed for packaging and transportation.

Where nitroglycerine exudation has occurred to the point where the liquid has seeped from the cases to the floor, special decontamination procedures must be performed. Contaminated wooden battens, duckboards, and false floors should be removed from the magazine and burned. **Caution: Nitroglycerine-contaminated wood can explode when burned.** Any free, liquid nitroglycerine must be removed with sawdust or absorbents. The contaminated absorbents must then be burned by following special procedures recommended by the manufacturer. Make sure the floor is perfectly dry before storing other explosives on it.

Dealing with degraded emulsion, water-gel, and ammonium nitrate-based explosives

These types of explosives are much less sensitive to shock and friction than NG explosives. Nevertheless, they are every bit as powerful, and all safety rules must be applied. Any spillage of explosives must be carefully collected and destroyed.

With water-gel explosives, wetness on the outside of a cartridge or separation of the ingredients indicates that gel breakdown has occurred. In such cases, the product will likely fail to shoot. Likewise, an emulsion that has become stiff or crusty, rather than feeling smooth and pliable, has probably become insensitive.

If ANFO is kept too long, fuel oil may leak through the plastic bags and contaminate the magazine. This creates a fire hazard. If the condition is severe, contaminated floor sections may need to be replaced. If ANFO bags are kept for a long time, they should be rotated or turned over. This reduces the oil migration through the material to the bottom of the packaging.

Leakage of explosives through their packaging may contaminate the magazine. Spills must be cleaned up properly. Pay close attention where spilled emulsion or ANFO leaves an oily residue. This residue creates a fire hazard. If all explosives cannot be cleaned up (e.g., spills in cracks or in porous materials), contaminated floor sections may need to be replaced.

Abandoned or buried explosives

Under the Occupational Health and Safety Regulation and the federal *Explosives Act*, explosives must not be buried or abandoned. They must be placed in suitable storage or disposed of in accordance with the manufacturer's recommendations.

Abandoned and buried explosives have caused many accidents. Some explosives may retain their explosive properties for years, even after exposure to cold temperatures and water. For example, nitroglycerine, a component of dynamite, does not degrade with time. In many cases, lives have been lost when nitroglycerine exploded after lying for more than 20 years in the ground, in crevices between rocks, or underwater. Similarly, TNT and some other explosives do not lose their explosive force with time. With the exception of some blasting agents, burying an explosive or soaking it in water will not safely dispose of it.

Damaged or deteriorated explosives can be extremely dangerous and must be disposed of by competent persons. Do not attempt to dispose of a large quantity of explosives or an unfamiliar type of product. Instead, secure the area and get help from the manufacturer's representative.

If abandoned or buried explosives are found, report them to Natural Resources Canada and the local authorities.

Decommissioning and disposing of explosives equipment

"Explosives equipment" refers to items used in the life cycle of explosives. Examples of such equipment include magazines, pumps, hoses, and mobile manufacturing and transport vehicles. Persons responsible for decommissioning and/or disposing of explosives equipment must ensure that the equipment is free of explosives before disposing of it. This helps reduce the risk to workers who handle the equipment and may not be aware of the hazards.

Part 3:
The blasting process

Chapter 10:
Blast design

Learning objectives

- Explain the basics of blast design, including evaluating uncontrollable variables and adjusting controllable variables.
- List the blast performance factors that help control the release of explosive energy.
- Describe the significance of even distribution of energy within the rock.
- Demonstrate how to calculate the stiffness ratio.
- Explain how explosive efficiency affects the blast design.
- Describe confinement of energy and its role in efficient blasting.
- Explain the importance of pattern design and timing in blast design.
- Describe burden and spacing.
- Using burden and spacing calculations, explain how to determine blast patterns.
- Discuss the relationship between stiffness ratio and blast effects (air blast, fly rock, etc.).
- Explain the role of hole diameter and depth in the blast design.
- Describe subdrilling and how to calculate adequate subdrilling distance under different conditions.
- Explain overburden and how to minimize material fallback.
- Determine the correct collar length to prevent fly rock.
- Explain stemming and how it is used to help contain explosive gases.
- Describe the key elements, and importance, of selecting correct blast timing.
- Discuss overbreak and how to control it.
- Calculate the powder factor for a blast hole and for an entire blast.

Overview

Blasting activities must, above all, be conducted safely. However, blasters are also expected to blast as effectively as possible. Blast design is the systematic process of planning and considering the many factors that contribute to the safety and desired outcome of a blast.

This chapter provides an overview of blast design, including the following elements:

- Blast design basics
- Blast performance factors
- Key factors in blast design
- Determining the blast pattern
- Selecting the blast timing
- Calculating the powder factor

Blast design basics

Designing a blast is part science and part art. Although basic general rules apply to the blast design process, adjustments are to be expected in order to best fit specific site conditions and situations.

Each blast presents the blaster with controllable and uncontrollable variables. Variables are factors that can vary or change. Controllable variables are those which the blaster can change or adjust, such as the drill-hole diameter or the stemming length. Uncontrollable variables are those which the blaster has little to no ability to change, such as regulations and the properties of the rock to be blasted.

Designing and planning the blast requires the blaster to evaluate the following:

- The desired results
- Information from previous blasts
- The uncontrollable variables of the project

The blaster then adjusts the controllable variables (such as loading procedures, *blast patterns*, and delay intervals) to meet the various project criteria.

By adjusting these variables, the blaster has the ability to control the amount of explosive energy released during the blast. This is key to achieving optimum blast performance. When the release of explosive energy is not controlled, the blast can result in poor rock breakage and even cause fly rock and high vibration levels.

Blast performance factors

The following blast performance factors help control the release of explosive energy:

- Even distribution of energy
- Explosive efficiency
- Confinement of energy

Even distribution of energy

Even distribution of energy within the rock leads to consistent breakage. The blaster can control factors leading to even distribution of energy. These factors include:

- The *stiffness ratio*
- Appropriate *burden* and *spacing*
- Appropriate blast-hole diameter for the *bench* height
- Accurate drilling of the pattern and hole depth

Why not use the powder factor to determine blast performance?

The powder factor of a blast does not consider the distribution of energy in a blast. This makes the powder factor a poor tool for determining blast performance. The even distribution of energy is significantly more important to blast performance than the powder factor. For more information, see "Calculating the powder factor" on page 147.

The distribution of explosive energy is usually better achieved by using many holes of a smaller diameter rather than by using fewer, larger-diameter holes. A test shot is always the best practice on new sites or unfamiliar rock.

The stiffness ratio, which compares the bench height to the burden distance, can be used to determine factors such as the following:

- The spacing required between blast holes
- The amount of vibration and overbreak that will result
- How the rock will break up and where it will go (i.e., the shape of the *muck* pile)

Note

This chapter uses only imperial measurements in its calculations, with the exception of explosive density.

The stiffness ratio can be calculated as:

$SR = L \div B$

Where: SR = Stiffness ratio (unitless)

L = Bench height (ft. or m)

B = Burden (ft. or m)

A stiffness ratio greater than 3 and less than 4.5 leads to appropriate and even distribution of energy and good blast performance. For more information, see "Stiffness ratio" on page 136.

Explosive efficiency

The explosive efficiency is another performance factor to consider in the blast design. The explosive efficiency is the total amount of work energy from the explosive actually captured in a blast. The major work energy produced by an explosive is in the gas pressure inside of the blast hole. The explosive efficiency should be as close to 100% as possible.

Confinement of energy

Another key factor in efficient blasting is the ability to confine the energy of the explosives.

Insufficient confinement occurs when the energy is not confined long enough to break and displace the rock or when there is insufficient burden. Insufficient confinement can lead to excessive flying material (fly rock) and air blast, as well as poor rock breakage.

However, if the explosive energy generated is too confined (e.g., excessive *toe*, heavy burden, or improper timing), it will be hard to excavate or crush the resulting blast material. In some cases, the blast may freeze (i.e., it does not move or break the rock) and excessive ground vibration can occur.

The blaster can control factors to ensure appropriate confinement of the explosive energy and achieve optimal blast performance. These factors include:

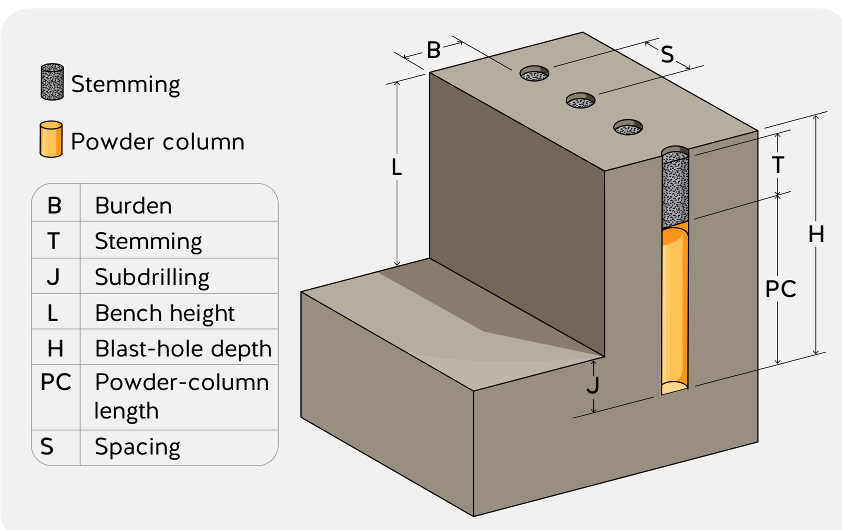
- Appropriate burden and spacing
- Accurate drilling of the pattern and hole depth
- Accurate collar length and appropriate selection of stemming material (e.g., clear, crushed rock)
- Appropriate placement of explosives (e.g., not loading explosives into cracks, voids, or seams in the rock)
- Appropriate delay intervals

Key factors in blast design

As a blaster, you will need to evaluate the site to determine conditions and make the decisions required to create a good blast design. You will also need to adapt to changing environments and make adjustments when conditions change. Designing a blast requires careful consideration of the following key factors:

- Blast pattern design
  - Burden
  - Spacing
  - Stiffness ratio
  - Hole diameter
  - Hole depth
  - Subdrilling (subgrade drilling)
  - Overburden
  - Collar length
  - Stemming
- Blast timing
  - Overbreak (backbreak and *endbreak*)
  - Hole-to-hole delays
  - Row-to-row delays
  - 8 millisecond rule
  - Timing on low benches or short holes
  - Timing effects on ground vibration
- Other considerations
  - Geology
  - Water conditions
  - Equipment
  - Powder factor

Several blast pattern design factors are illustrated in the following diagram.



The top and side view of a bench with an even free face. Some key factors in blast pattern design are labelled.

Determining the blast pattern

The process of blast design begins by determining the blast pattern. To determine this pattern, the burden and spacing must be calculated.

Burden

The burden is the distance from the free face to the first row of blast holes, as well as the distance between rows of blast holes. The burden should always be measured from the toe of the blast (or largest portion of the burden).

Selecting the proper burden is one of the most important decisions made in any blast design. Of all the design dimensions in blasting, it is the most critical and has the least allowable error.

The burden must be sufficient to contain the explosive energy. If burdens are too small, then rock is thrown further from the face, air blast levels are higher, and fragmentation may be too fine.

> **Note**
>
> If burden is too small in sections of the blast hole (for example, if the free face is uneven), smaller-diameter explosives should be loaded in those sections. Alternatively, *decking* should be used to prevent fly rock and air blast. (Decking is a method of loading in which a *spacer* or stemming material is placed between *deck charges* in a blast hole. For more information, see “Decking” on page 182.)

Burdens that are too large may cause the following issues:

- Increased ground vibration (up to five times the normal level)
- Severe backbreak and back shattering on the back wall
- Creation of boulders and high bottom or toe problems

Excessive burden can also cause overconfinement, which can “freeze” a *shot*. Or it may cause blast holes to “rifle,” throwing fly rock for considerable distances. This may result in vertical cratering of the rock and high levels of air blast.

When you have detailed information on the geology of a bench, you can use the following formula to estimate the burden.

$$B = K \times D_e \times \left(\frac{2SG_e}{SG_r} + 1.5\right)$$

Where: B = Burden (ft. or m)

K = Unit constant (1 for imperial, 0.012 for metric)

D_e = Explosive diameter (in. or mm)

SG_e = Specific gravity of explosives (explosive density)

SG_r = Specific gravity of rock

Example

If the explosive diameter is 2 in., the specific gravity of the explosives is 1.10, and the specific gravity of the rock is 2.8, the calculation is as follows.

$B = 1 \times 2 \times (2 \times 1.10/2.8 + 1.5) = 4.57$ ft.

Specific gravity of rock types

Rock type	Specific gravity
Basalt	2.8–3.0
Diabase	2.6–3.0
Diorite	2.8–3.0
Dolomite	2.8–2.9
Gneiss	2.6–2.9
Granite	2.6–2.9
Hematite	4.5–5.3
Limestone	2.4–2.9
Marble	2.1–2.9
Mica schist	2.5–2.9
Quartzite	2.0–2.8
Sandstone	2.0–2.8
Shale	2.4–2.8
Slate	2.5–2.8
Trap rock	2.6–3.0

Specific gravity (explosive density) of explosives

Explosive type	Specific gravity
Poured ANFO/WR	0.80–0.90
Pneumatically loaded ANFO	0.80–1.00
Boosters	1.25–1.30
Dynamite (NG)	1.34–1.51
Packaged emulsion	1.10–1.20

When you don't have detailed information on the geology of a bench, you can use the following as a rule of thumb.

Burden is generally parallel to the free face or the direction of the blast. Burden ranges between 25 and 35 times the diameter of the explosive charge, depending on rock type, as shown in the following table.

Rock type factor

	Rock type		
	Hard	Medium	Soft
Rock type factor	25	30	35

The formula for calculating burden when you don't have detailed information on the geology of the bench is:

$B = (25 \text{ to } 35 \times D_e) \div 12$

Where: B = Burden (ft.)

25 to 35 = Rock type factor, according to rock type

D_e = Explosive diameter, in inches

12 = A constant to provide measurement in feet

Note: Burden is usually rounded off to the nearest foot.

Example

The burden for hard rock drilled with a 3-inch bit is calculated below.

$B = (25 \times 3) \div 12 = 75 \div 12 = 6$ ft. (6.25 ft., rounded off to 6)

Spacing

Spacing is the distance between blast holes in a row. The optimum spacing of blast holes will range from 1.0 to 2.0 times the burden distance depending on the rock, the hole-to-hole delay, and the stiffness ratio of the bench.

The ratio of spacing to burden is known as the *spacing ratio*. Harder rock will require a lower spacing ratio (leading to a smaller pattern). Softer rock will require a higher spacing ratio (leading to a larger pattern).

To help prevent poor blast results, spacing should not be less than burden. If the spacing is too small for the *firing* method and stiffness ratio, a splitting action can occur between blast holes instead of proper breakage to the face. This can result in the following:

- Ejection of stemming material
- Creation of boulders (oversize material)
- Breakage beyond the last row, toe, or high bottoms
- Higher air blast (also known as overpressure)

If spacing is too large, poor fragmentation (oversize material) and uneven grade will occur. Because of the need to use different delays and the existence of geological planes of weakness, the general rule or formula for calculating spacing is as follows:

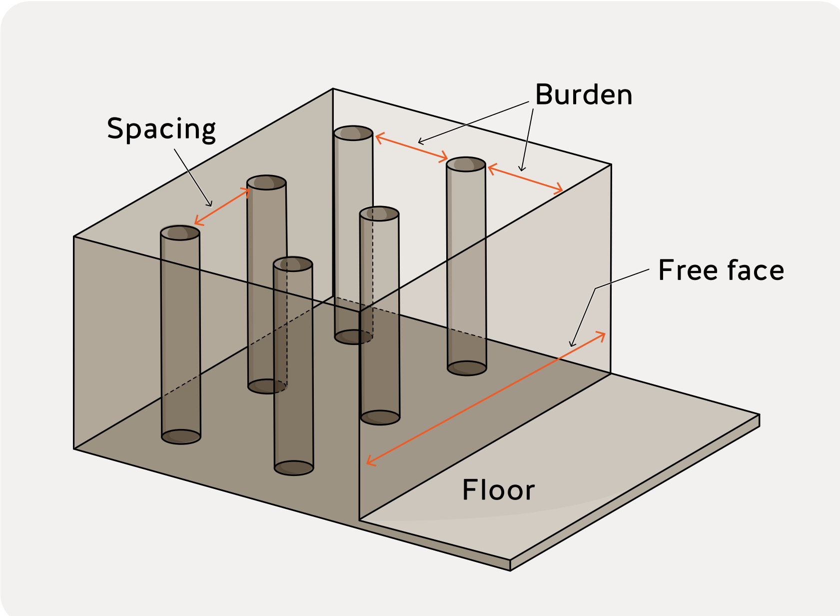
$S = B \times 1.0 \text{ to } 2.0$

Where: S = Spacing (ft. or m)

B = Burden (ft. or m)

The multiplier of 1.0 to 2.0 includes the rock type factor, according to rock type, the timing factor, and the stiffness ratio.

The burden and the spacing give the blaster the initial pattern for blast-hole layout and drilling (see image below). Whether the blaster chooses to go ahead with this pattern depends on any number of factors.



The burden and the spacing give the blaster the initial pattern for blast-hole layout and drilling.

Stiffness ratio

In general, the larger the explosive diameter (i.e., the width of the product), the more problems (such as fragmentation, air blast, fly rock, and ground vibration) are possible. Larger explosive diameters require increased burdens and spacings, even if the powder factor is held constant.

To gain insight into the potential problems that can result, consider the stiffness ratio. This ratio is the bench height (L) divided by the burden (B).

$SR = L \div B$

Where: SR = Stiffness ratio (unitless)

L = Bench height (ft. or m)

B = Burden (ft. or m)

For example, if a blaster is faced with a 30 ft. (10 m) bench, an explosive diameter of 3 in. (75 mm) will require burdens and spacings about half the size of a blast with an explosive diameter of 6 in. (150 mm). The powder factor will be almost the same, with some minor variations. But the performance will be substantially different due to the distribution of the explosive energy in the rock.

The following calculations determine the burdens and stiffness ratios for the two blasts described on the previous page. The burden calculations use a medium rock type factor of 30.

Example 1: Explosive diameter of 3 in.

$B = (30 \times D_e) \div 12 = (30 \times 3 \text{ in.}) \div 12$

$B = 7.5$ ft.

$SR = L \div B$

$SR = 30 \text{ ft.} \div 7.5 \text{ ft.} = 4$

Example 2: Explosive diameter of 6 in.

$B = (30 \times D_e) \div 12 = (30 \times 6 \text{ in.}) \div 12$

$B = 15$ ft.

$SR = L \div B$

$SR = 30 \text{ ft.} \div 15 \text{ ft.} = 2$

The following table summarizes the effects that commonly result from different stiffness ratios. For construction blasting, the general rule of thumb is to aim for a stiffness ratio between 3 and 4.5. In general, a stiffness ratio below 3 is not recommended.

Effects by stiffness ratio

Effects	Stiffness ratio			
	1	2	3	4
Fragmentation	Poor	Fair	Good	Excellent
Air blast	Severe	Fair	Good	Excellent
Fly rock	Severe	Fair	Good	Excellent
Ground vibration	Severe	Fair	Good	Excellent
Comments	Severe overbreak and toe problems. Do not shoot. **Redesign!**	Redesign if possible.	Good control and fragmentation.	No increased benefit from increasing stiffness ratio above 4.5.

The stiffness ratio also influences the spacing of the blast. Higher stiffness ratios require higher spacing ratios (i.e., spacing divided by burden).

Hole diameter and depth

The blaster should choose the proper drill-hole diameter for each job. One size of drill bit does not fit all jobs. The blaster should choose the drill-hole diameter based on the hole depth. The combination of hole diameter and depth plays a key role in achieving a controlled blast.

Another consideration is whether bulk or packaged explosives are being used and how they affect the hole diameter. Blast holes that are much larger in diameter than the cartridge diameter lead to significant decreases in the blast-hole pressure. This can cause reductions in *throw* and fragmentation. Reductions to the burden may be required to compensate for the lower blast-hole pressure. Blast holes closer in diameter to the explosive diameter reduce the need for cartridge compression. These factors make the selection of blast-hole diameter critical, even when using cartridge product.

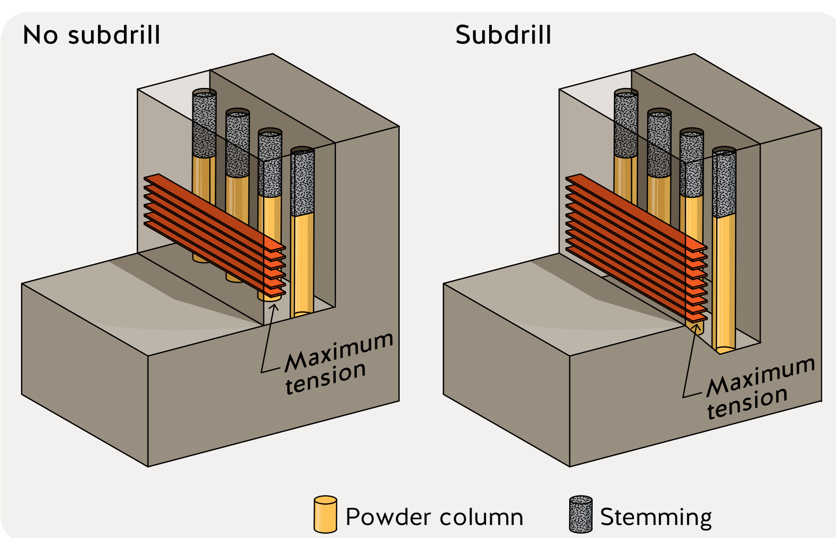
The bench height (hole depth) plays an important role in the choice of a blast-hole diameter. Benches less than 15 ft. (4.5 m) in length should be blasted with an explosive diameter equal to or less than 1.5 in. (3.8 cm) to achieve a stiffness ratio of about 3 and have good blast results. This is nearly impossible to do with bulk explosive products. In many cases, using free-poured products (such as ANFO) in small-diameter holes would exceed the manufacturer's critical hole-diameter recommendations.

Subdrilling

Subdrilling (or subgrade drilling) means drilling a blast hole below the desired elevation. Subdrilling ensures that the blast breaks to grade and achieves proper elevation.

In most cases, an adequate subdrilling distance can be approximated by multiplying the burden by a factor of 0 to 0.5. Harder rock requires more subgrade (e.g., a factor of 0.5). Softer rock requires less subgrade (e.g., a factor of 0.1). Rock with horizontal bedding, such as limestone, requires little to no subgrade drilling (e.g., factor of 0). Research has shown that starting with a subdrill of 0.3 is a good starting point for the first test blast on site.

Proper subdrilling helps ensure that the bench breaks to the desired grade. During a blast, the face of a bench will break. This is caused by the explosive gas pressure. The breaking process puts the bench face into tension, with the maximum tension zone in the middle of the face. Proper subdrilling can extend this maximum tension zone down to include the bottom. This helps to achieve the desired grade.



Proper subdrilling can extend the maximum tension zone down to include the bottom of the face. This helps to achieve the desired grade.

Too much subdrilling increases ground vibration. Too little subdrilling can lead to high bottom and boulders (oversize material) that may require additional blasting. No subgrade drilling is required if there is rock with horizontal bedding at the desired grade.

The formula for calculating subdrilling is:

$J = B \times 0 \text{ to } 0.5$

Where: J = Subdrilling distance (ft. or m)

B = Burden (ft. or m)

0 to 0.5 = The rock type factor, according to rock type and structure

Example

J = 5 ft. burden × 0.5 = 2.5 ft. subdrill in hard rock

The subdrilling should not contain drill cuttings, mud, or any rock materials. If blast-hole walls tend to cave in, they will partially fill the hole. Drillers should account for this by drilling deeper than the subdrilling discussed previously. In addition, blasters can clean out the holes with compressed air in the event of minor debris. As a result, at the time of loading, the calculated amount of subdrilling should be open and should contain only explosives.

Ensure the following:

- Drillers plug holes to prevent fallback (material that falls into the hole after drilling and before loading).
- Blasters measure and record fallback.
- Blast holes are open to proper depth at the time of loading.

Despite random drilling-depth errors and sloughing holes, drilling to a depth below grade ensures that all hole bottoms will be at the proper depth at the time of loading. If some holes are too deep at the time of loading, the blaster can bring them up to the desired height by adding stemming materials.

Overburden

Overburden is any material (soil, gravel, clay, etc.) that is drilled through before hitting bedrock. The driller must note the depth of the overburden and report it to the blaster. This information is critical for adequate loading of blast holes. That's because the depth of the overburden adds to the collar length and increases the amount of stemming required.

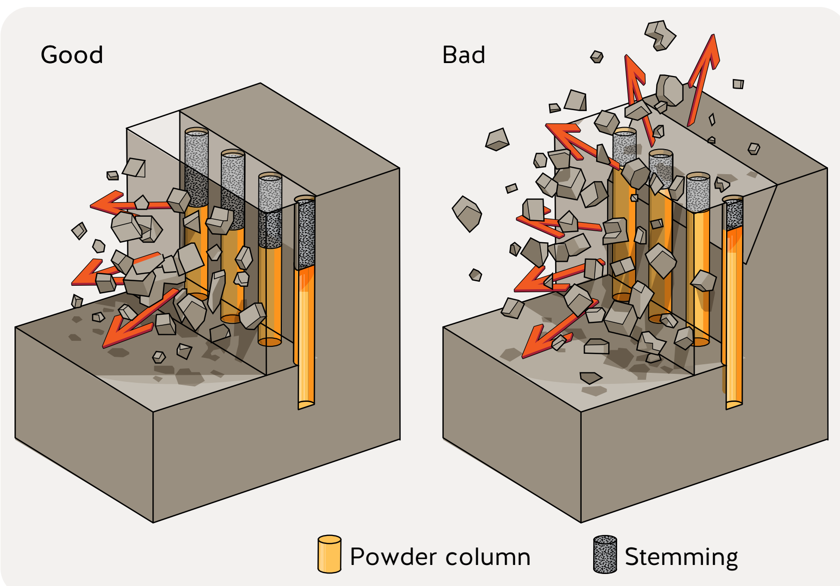
Overburden that falls back into the blast hole after drilling and before loading (fallback) reduces the total depth of the blast hole. Take steps to minimize fallback. The best option is to do one or more of the following:

- Remove overburden before drilling.
- "Mud the collar." This is a drilling technique that uses water, alone or with various other liquids, to create a paste-like material out of the drill cuttings and earth. This material is then used to establish a clean collar and reduce fallback.
- Block the collar with a hole plug after drilling.

If material is slumping from inside the blast hole, one option is to drill below the intended hole depth to allow for slumping. Then the blaster can add back drill cuttings or stemming if the hole is too deep. This technique helps prevent the major problem of fallback. It also helps prevent toes (high bottom) from forming in the excavation due to insufficient hole depth.

Collar length

Collar refers to the top portion of the blast hole above the explosives or powder column. The collar is filled with *stemming* (crushed rock or inert material) to confine the explosive gases. The high-explosive charge must be confined in the blast hole for the charge to work properly and to release the most energy possible. Adequate confinement is also necessary to control air blast and fly rock. If the blast design is not reasonable, no amount of stemming will prevent the release of fly rock.



The results of adequate confinement of explosive gases (left) and inadequate confinement (right). The collar length (i.e., the amount of stemming) and the size of the stemming materials work together to confine the explosive gases and control air blast, fly rock, and backbreak.

To prevent fly rock, the collar length commonly used for construction blasting near structures should be equal to or greater than the burden. The exact collar length depends on the hardness of the rock, the hole depth, and the site conditions. The blaster can determine the ideal length after conducting a test shot.

When quarry blasting with a well-designed blast pattern, a collar length (or stemming distance) of 0.7 times the burden is usually adequate to keep material from ejecting prematurely from the hole. However, such a short collar length is not recommended for construction blasting.

A worker controls the amount of explosives loaded in a hole by monitoring the collar length with a loading pole.

The formula for calculating collar length is:

$T \geq B$

Where: T = Collar length (ft. or m)

$\geq$ = Greater than or equal to

B = Burden (ft. or m)

Example

On a construction blast site using a blast pattern with 5 ft. of burden, the collar length would be:

$T \geq B$

$T \geq 5$ ft. collar

Note

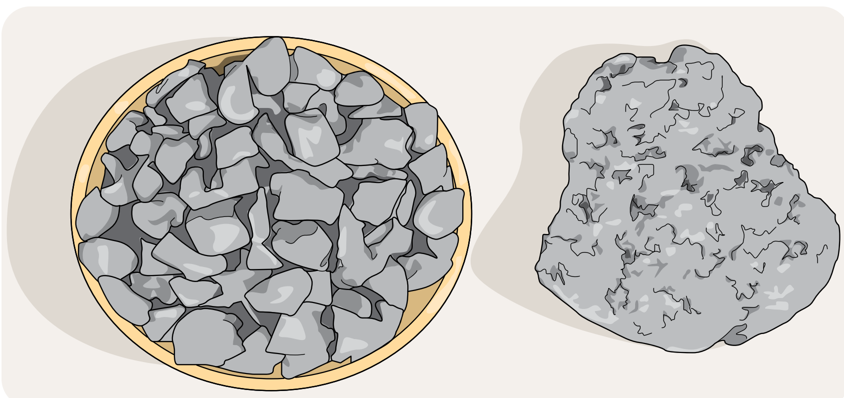
Collar length is usually rounded up to the nearest foot and does not include the depth of any overburden.

Stemming

Stemming is the material used in the collar of the blast hole to help contain the explosive gases. Selecting the proper size of stemming material is important. Very fine drilling dust or cuttings are too light to contain the explosive gases and may be blown out. Very coarse stemming materials have the tendency to bridge (block or get stuck in) the hole when loading, and they may be ejected like golf balls. A blowout of stemming material indicates a loss of explosive energy, which reduces the explosive efficiency.

Stemming material should have an average diameter of about 0.05 times the diameter of the blast hole. It should be angular to work properly. In general, the stemming material should be crushed stone. In some cases, such as in small-diameter holes, bird’s eye gravel (tiny pebbles) should be used.

If the stemming does not hold throughout the blast, the blast performance will suffer. A successful blast compacts the stemming material into a solid “plug,” as shown in the image below.



Stemming material immediately above a charge before a blast (left) and after (right). The blast compacts the stemming material into a solid plug.

As mentioned, drill cuttings make poor stemming material. The lack of confinement of explosive energy causes excessive flying material (fly rock) and air blast, as well as poor rock breakage. Drill cuttings would not be acceptable stemming material in any blasting operation that is not extremely remote. Their use is never recommended.

Selecting the blast timing

Selecting the correct blast timing is crucial for a safe, effective blast. Many blasting problems (e.g., air blast, fly rock, excessive vibration, and poor fragmentation) are directly related to timing. The following sections focus on key elements of blast timing.

Controlling overbreak (backbreak and endbreak)

Overbreak, such as backbreak and endbreak, is common in many types of blasting. In general, backbreak and endbreak can be controlled by selecting the proper timing.

In blasting operations, it's common practice to give the last row, and sometimes the end holes in a row, more time before they fire to allow earlier-firing rows to move out of the way. This reduces the resistance on those holes and reduces the pressure on the back walls. This, in turn, results in cleaner breaks with less endbreak and backbreak.

Defining overbreak, backbreak, and endbreak

Overbreak means breakage beyond the excavation limits (i.e., the rock cut). It includes backbreak and endbreak.

Backbreak is the area of breakage occurring behind the last row of blast holes.

Endbreak is the area of breakage occurring on the sides of the blast (i.e., at the ends of each blast row).

Delay timing

Delay timing includes both delays between blast holes in a row and delays between rows. The delay time between holes in a row will change the fragmentation, throw, ground vibration, and air blast.

Timing is one of the most important parts of blasting, so take care to assess proper delay practices for each blast site. To assess or complete blast designs, some relatively simple rules on delay timing should be followed, as summarized in the following sections.

Hole-to-hole delays

A hole-to-hole delay is the set amount of time between two adjacent holes firing in a row. Most commonly used commercial initiation systems have a predetermined delay time of 25 milliseconds (*ms*). The actual delay time may be affected by methods of tying in (sequencing) the blast.

Depending on the application, the blaster decides whether some or all of the holes will be shot at the same time (instantaneously) or with delays (one at a time). Proper hole-to-hole delayed blasting will lead to finer fragmentation and less throw or heave. For information on how to calculate specific hole-to-hole delay times, see "Blast design calculations" on page 385.

Firing multiple holes in the same row at the same time (instantaneous firing) will result in greater heave or throw, higher air blast, and more ground vibration.

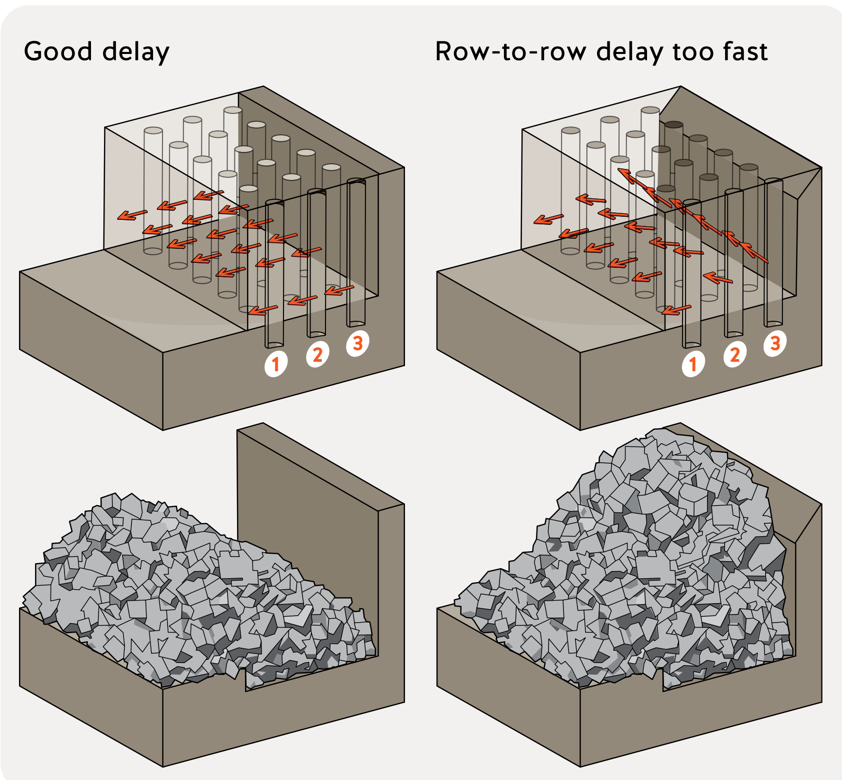
Row-to-row delays

The timing between rows in a blast controls the piling or casting of the broken material (i.e., the shape of the muck pile). The row-to-row delay must be long enough to allow each row a free face (relief) to break toward. The rows can be fired either in straight lines as the rows were drilled, or in a pattern. The decision on how the rows fire also affects the muck pile.

If the row-to-row delays are too short, the following can occur:

- Rock can rifle (be thrown vertically into the air), and flying material may be created.
- Stemming can blow out, even when adequate stemming is used.

If row-to-row delays are longer, the material has the opportunity to peel away row by row, allowing forward motion of the broken rock. These are outcomes the blaster aims to achieve.



Piling and uplift resulting from different delay timings

In summary:

- Short row-to-row delay times can cause the following:
  - Higher rock piles closer to the face
  - More overbreak
  - More violence (excessive air blast, ground vibration, and fly rock)
- Long row-to-row delay times decrease levels of ground vibration and the amount of overbreak

Results of various row-to-row delay times

Time factor (TF, in ms/ft.)	Result
<2	Violence (excessive air blast, fly rock, overbreak, etc.)
2–3	High pile close to face, moderate air blast, and overbreak
>3–4	Average pile height, air blast, and overbreak
>4–8	Low, scattered pile with minimum overbreak

The time factor (noted in the table above) is the row-to-row delay time (in milliseconds per foot of burden). The time factor should not be less than 2 ms/ft. of burden between rows.

When the stiffness ratio is not ideal and wall control is critical in multi-row shots (i.e., six or more rows), row-to-row delays may be expanded to as much as 20 ms/ft. of burden. This helps ensure good blast results.

What is wall control?
Wall control means preserving the integrity and cleanness of the face.

Since the row-to-row and hole-to-hole timings depend on burden and spacing, the timings will also change based on the explosive diameter. That's because larger diameters require more time.

The following equation calculates the delay time between rows:

$TR = TF \times B$

Where: TR = Time delay between rows (ms)

TF = Time factor between rows (ms/ft.)

B = Burden (ft.)

Example

If the desired time factor is 5 ms/ft. and the burden is 5 ft., the calculation would be as follows:

$TR = 5 \times 5 = 25$ ms

Currently, most detonators are preset with 25 ms delays. And row-to-row, out-of-hole *trunkline* (surface) delays are preset at various timings. To reduce vibration effects, longer delays should be used. In any case, selecting accurate delay times is critical to predicting the blasting effects. The delay times should be clearly documented in the blaster's log book.

8 millisecond rule

Charges fired within 8 ms of each other are not considered separate events from the standpoint of ground vibration. Damaging levels of ground vibration can occur when delay times are this short. The 8 millisecond rule states the following:

- The weight of all explosive charges fired within 8 ms must be added together.
- Charges fired at delays of greater than 8 ms act separately.

The 8 millisecond rule is widely accepted in the blasting industry.

Timing on low benches or short holes

It takes time to overcome the inertia of the rock material. On low benches, commonly one-half to one-third of the bench depth contains stemming instead of explosives. There is a greater time lag for bench movement on a low bench than there is on a high bench.

For low benches or short holes, increasing the timing between rows to as much as double the usual amount can do the following:

- Produce forward motion of the rock toward the face
- Reduce overbreak
- Reduce the production of boulders

Calculating the powder factor

The powder factor is the ratio between the total weight of explosives detonated and the total volume of rock blasted above grade level. In construction, this volume is measured in pounds per cubic yard or kilograms per cubic metre.

The powder factor is a useful tool for estimating the cost of blasts but a poor tool for designing blasts. That's because the powder factor varies based on the following:

- The distribution and confinement of explosive energy
- The rock type and structure
- The geometry of the bench (i.e., the length, width, and height of the section of bench to be blasted)
- The required or desired level of rock fragmentation
- The type of explosive
- The blast configuration
- Hole-to-hole timing
- Row-to-row timing
- The bench height
- The stemming materials

The formula for calculating the powder factor per blast hole is:

Powder factor (PF) = Weight of explosives per blast hole ÷ Volume of rock material to be blasted per blast hole

The following steps walk you through the process of calculating the powder factor. Before you can determine the weight of explosives per blast hole, you'll need to calculate the length of the explosive column and the loading density (see steps 2 and 3).

Step 1: Calculate the volume of material to be blasted per blast hole

The formula for calculating the volume of rock material to be blasted per blast hole is:

Volume of material per blast hole (in cubic yards) = $B \times S \times L \div 27$

Where: B = Burden (ft.)

S = Spacing (ft.)

L = Bench height (ft.)

27 = 1 cubic yard (cu. yd.) = 3 ft. × 3 ft. × 3 ft.

Example

For a 5 × 5 pattern of 20-foot holes, the calculation would be as follows:

$5 \times 5 \times 20 \div 27 = 18.51$ cu. yd. per blast hole

How big is a cubic yard?

One cubic yard is the volume of a cube with the length, width, and height of one yard (3 ft.). One cubic yard is equal to 27 cubic feet. Picture a giant Rubik's Cube.

Step 2: Determine the length of the explosive column

The formula for calculating the length of the explosive column is:

$PC = J + L - T$

Where: PC = Length of explosive column (ft.)

J = Subgrade drilling (ft.)

L = Bench height (ft.)

T = Collar length (ft.)

Example

Where the bench height is 20 ft., subgrade drilling is 2.5 ft., and collar length is 5 ft.

$PC = J + L - T = 2.5 + 20 - 5 = 17.5$ loaded feet

Step 3: Calculate the loading density

The formula for calculating loading density is:

Loading density (pounds per foot or lb./ft.) $= 0.34 \times D_e^2 \times ED$

Where: 0.34 = A constant

D_e = Explosive diameter (in.)

ED = Explosive density (*g/cc*)

Example

If the explosive diameter is 2.5 in. and the explosive density is 0.84 g/cc, the calculation would be as follows:

Loading density (lb./ft.) $= 0.34 \times 2.5^2 \times 0.84 = 0.34 \times (2.5 \times 2.5) \times 0.84 = 1.78$ lb./ft.

Note

Loading densities for a range of explosive diameters and types of explosives are found in the tables on pages 150 and 151.

Step 4: Determine the weight of explosives per blast hole

The weight of explosives per blast hole can now be calculated by multiplying the length of the explosive column by the loading density as follows:

Weight of explosives per blast hole (lb./hole) = Length of explosives column × Loading density

Example

As mentioned previously, the length of the explosives loaded in the column is 17.5 feet and the loading density is 1.78 lb./ft. So the weight of explosives per blast hole is as follows:

Weight of explosives per blast hole (lb./hole) = 17.5 × 1.78 = 31.15 lb./hole

Step 5: Calculate the powder factor

Now that the weight of explosives per blast hole and the volume of material to be blasted per blast hole have been calculated, the powder factor can finally be determined.

The formula for calculating the powder factor is as follows:

Powder factor (PF) = Weight of explosives per blast hole ÷ Volume of material to be blasted per blast hole

In Step 4, the weight of explosives per blast hole was calculated at 31.15 pounds. In Step 1, the volume of material to be blasted per blast hole was calculated at 18.51 cubic yards. So the powder factor is as follows:

Powder factor = 31.15 lb. ÷ 18.51 cu. yd. = 1.68 lb./cu. yd.

To calculate the powder factor for the entire blast, multiply the length of the explosive column for a single hole (in this case, 17.5 loaded feet) by the total number of holes (for example, 100 holes). If there are multiple holes of varying depths, the powder factor would be calculated by dividing the total weight of explosives to be used by the total volume of material to be blasted.

Note that on a through cut, or only one open face, the outside row is not included in the volume and will increase the powder factor. A easy way to calculate the volume of a through cut would be to measure length × width × depth.

Loading densities by explosive diameter and type of explosive

The following tables provide examples of common loading densities for a range of explosive diameters and types of explosives. Note that the loading densities listed are rounded and may vary between manufacturers.

Imperial load chart

The formula for determining the loading density (in lb./ft.) in a blast hole is:

Loading density (lb./ft.) = $0.34 \times D_e^2 \times ED$

Where: 0.34 = A constant

D_e = Explosive diameter (in.)

ED = Explosive density (g/cc)

Examples

For dynamite with an approximate explosive density of 1.50 g/cc:

- With a 1-inch product, the calculation would be: $0.34 \times 1^2 \times 1.50 = 0.34 \times (1 \times 1) \times 1.50 = 0.51$ lb./ft.
- With a 2½-inch product, the calculation would be: $0.34 \times 2.5^2 \times 1.50 = 0.34 \times (2.5 \times 2.5) \times 1.50 = 3.19$ lb./ft.

For ANFO with an approximate explosive density of 0.84 g/cc:

- In a 3-inch hole, the calculation would be: $0.34 \times 3^2 \times 0.84 = 0.34 \times (3 \times 3) \times 0.84 = 2.57$ lb./ft.

Explosive diameter (in.)	Loading density (lb./ft.)			
	0.84 g/cc (ANFO/WR)	1.15 g/cc (Emulsion)	1.30 g/cc (Gelatin dynamite)	1.50 g/cc (Dynamite)
1	0.29	0.39	0.44	0.51
1¼	0.44	0.61	0.69	0.80
1½	0.64	0.88	1.00	1.15
1¾	0.87	1.20	1.36	1.56
2	1.14	1.57	1.77	2.04
2¼	1.44	1.98	2.24	2.59
2½	1.78	2.45	2.77	3.19
2¾	2.16	2.96	3.35	3.86
3	2.57	3.52	3.98	4.60
3½	3.49	4.80	5.42	6.26

Metric load chart

The formula for determining the loading density (in kg/m) in a blast hole is:

Loading density (kg/m) = $0.00078 \times D_e^2 \times ED$

Where: 0.00078 = A constant

D_e = Explosive diameter (mm)

ED = Explosive density (g/cc)

Examples

For dynamite with an approximate explosive density of 1.50 g/cc:

- With a 25-mm product, the calculation would be:
  $0.00078 \times 25^2 \times 1.50 = 0.00078 \times (25 \times 25) \times 1.50 = 0.73$ kg/m
- With a 65-mm product, the calculation would be:
  $0.00078 \times 65^2 \times 1.50 = 0.00078 \times (65 \times 65) \times 1.50 = 4.94$ kg/m

For ANFO with an approximate explosive density of 0.84 g/cc:

- With a 75-mm product, the calculation would be:
  $0.00078 \times 75^2 \times 0.84 = 0.00078 \times (75 \times 75) \times 0.84 = 3.69$ kg/m

Explosive diameter (mm)	Loading density (kg/m)			
	0.84 g/cc (ANFO/WR)	1.15 g/cc (Emulsion)	1.30 g/cc (Gelatin dynamite)	1.50 g/cc (Dynamite)
25	0.41	0.56	0.64	0.73
32	0.67	0.92	1.04	1.20
38	0.94	1.30	1.47	1.70
45	1.32	1.83	2.07	2.38
50	1.63	2.26	2.55	2.94
57	2.13	2.93	3.31	3.82
65	2.77	3.81	4.31	4.94
70	3.21	4.42	5.00	5.77
75	3.69	5.07	5.74	6.62
90	5.31	7.31	8.26	9.53

Conversions

Metric to imperial

1 mm = 0.03937 in.

1 m = 3.28 ft.

1 m^3 = 35.32 *cu. ft.*

1 m^3 = 1.308 *cu. yd.*

1 kg = 2.2046 lb.

1 tonne = 1.1023 ton

1 tonne/m^3 = 0.842777 ton/cu. yd.

Imperial to metric

1 in. = 25.4 mm

1 ft. = 0.3048 m

1 cu. ft. = 0.0283168 m^3

1 cu. yd. = 0.764555 m^3

1 lb. = 0.454 kg

1 ton = 0.907185 tonne

1 ton/cu. yd. = 1.1866 tonne/m^3

Chapter 11: Drilling precautions and requirements

Learning objectives

- Explain precautions required for drilling.
- Identify the drill operator's responsibilities related to the inspection and maintenance of drilling equipment.
- Describe what to survey to ensure site stability.
- Explain the drilling requirements that apply once drilling begins.

Overview

A blaster is expected to know and understand the precautions and requirements for drilling where explosives will be used. Unsupervised drilling into rock can result in accidents.

Employers must provide drillers with the information, instruction, training, and supervision they need. This helps ensure the safety of drillers and other workers and the safe operation of equipment.

Pre-drilling requirements

The following requirements apply before drilling begins.

Inspect and maintain drilling equipment

The drill operator's responsibilities include the following:

- Ensure that equipment and accessories are ready for work.
- Visually inspect the drill to detect any abnormalities, such as cracks, missing parts, and leaks.
- Ensure that levelling jacks, measurement devices, and tools for proper drill set-up on stable ground are in working order and are used.
- Ensure that dust-control equipment and devices are in place and in good working order.
- Wear adequate hearing protection when working with or near drills.
- Inspect the drill's safety devices (e.g., the emergency shutdown system) and ensure any accessories needed are present and in good working order.

A worker performs maintenance on a drill.

Here are some examples of things to inspect and what to look for:

- The hoses are in good condition and secured with whipchecks (safety cables).
- The feed chain, tracks, and belts have proper tension.
- The oil, filters, and fluids are in good condition.
- All machine parts are lubricated.
- The centralizer is clean.
- The drill rods are in good shape and threads aren't over-worn.
- The winch and cable blocks are in good condition.
- The hammer is working correctly.

A worker installs a whipcheck (safety cable) on a compressed-air hose.

Ensure the following safety equipment and accessories are present:

- Hose mender
- Fire extinguishers
- Spill kit
- Tools
- Spare parts

Survey the site for stability and previous blasting

The site and the surrounding area must be surveyed. The goals are to determine the following:

- The stability of rock faces and the locations where the drilling rig will operate
- Whether the area has been blasted before

An example of an unstable rock face

The area to be blasted may have to be excavated by machinery to do the following:

- Stabilize the material.
- Create a safe surface on which the drilling rig can move and operate.
- Expose previous blast holes.

If evidence of previous blasting (such as protruding wires or cartridges) is found, the blaster must examine the site for misfires. Old blast holes (also known as *bootlegs* or sockets) or remnants of holes should be examined and clearly marked for identification during upcoming drilling operations.

Deal with misfired holes or unexploded explosives

Misfired holes or holes containing unexploded explosives are dangerous. Drilling into explosives can cause an explosion. Check for misfired holes and unfired explosives before drilling. These explosives must be dealt with before other regular work can be carried out. Disposal procedures are covered in Chapter 9, “Disposing of explosives.”

Locate and mark underground utility services

Drilling into underground gas or electrical utilities can cause an unexpected explosion or electrocution. Before drilling begins, the location of utility services must be determined and clearly marked.

BC 1 Call is the link between the excavating community and the owners of underground utilities (such as pipelines, communication cables, and water utilities) who are registered members of BC 1 Call. People who plan to disturb the ground submit requests (at no charge) to identify underground utilities. BC 1 Call then contacts its members who own utilities in the area and notifies the user about where utilities are buried on the site. For more information, visit BC 1 Call.

Mark where holes are to be drilled

Ensure that the blast pattern design is properly laid out and blast-hole locations are adequately marked for the drill.

Drilling requirements

The following requirements apply once drilling begins.

Measure the depths of overburden

Overburden is material (dirt, gravel, sand, etc.) that lies on top of the material to be drilled and blasted. Special care must be taken to note the depths at which the drill hits bedrock. This is crucial information for blasters, as they will need to adjust the collar length appropriately when loading.

Ensure good communication between blaster and driller

Ensuring good communication between the blaster and the driller is an occupational health and safety requirement in B.C.

The driller must maintain a detailed report of each *anomalous* (unusual or abnormal) *drill hole*. The report must contain the following information:

- The date, location, burden, spacing, depth, diameter, angle, and marking of each drill hole
- Any changes in geology, including the presence of subsurface water, mud seams, or voids, and similar details

The blaster must review the report before loading begins.

The anomalous holes detailed in the report must be clearly marked at the blast site. Marking and identification can be done in many different ways. Examples include using double or triple cones (drill hole plugs), spray paint, sticks, etc.

Marking an anomalous hole with double cones and spray paint

The driller can be of great help in assessing rock variations that are not apparent from the surface. The driller should watch for the following signs and communicate them to the blaster:

- Slow penetration, excessive drill noise and vibration. These are signs of hard rock that may be difficult to break.
- Fast penetration and lower-than-usual drill noise. These indicate soft rock that may be more easily broken.
- Sudden drops of the drill. These indicate the drill has entered a void, a slip, or a soft seam.
- Changes in penetration time. These are signs of different rock layers.

Don’t drill near bootlegs

Drilling must not take place within 15 cm (6 in.) of any part of a bootleg or socket (an old blast hole). This requirement aims to prevent contact with any leftover explosives from previous blasting operations.

A bootleg or socket (an old blast hole) as seen from above

Don’t drill near loaded holes

In most operations, it is unnecessary to drill near loaded holes or to load near drilling operations.

Under the Occupational Health and Safety Regulation, no drilling can take place within 6 m (20 ft.) of any part of a hole containing explosives. The exception to this rule is when prior written permission has been obtained from WorkSafeBC.

Dealing with collapsing drill holes or conducting drilling and loading underwater may require written permission from WorkSafeBC to deviate from the Regulation’s 6 m (20 ft.) restriction. If permission is granted, the blaster must direct the angle and depth of the holes being drilled to ensure no contact is made with explosives in adjacent loaded holes. A *tamping rod* placed in the collar of the loaded hole may help determine the correct angle for the new hole.

Ensure sufficient hole diameter and depth

Each drilled hole must be wide enough to let the explosives travel to the bottom of the hole without ramming, pounding, cutting, or excessive pressure.

Check for proper hole depth before moving the drill to begin the next hole.

Take precautions while changing drill steel or bits

While a drill is rotating under power, the operator must not manually add or remove drill steel or bits without a *helper*. The operator and the helper must stay clear of rotating parts of the drill system. Do not wear loose clothing when working near rotating shafts.

Take precautions when drilling angle holes

Drill angle holes only when measurement equipment and controls are in place. These devices help to ensure correct blast-hole location and end direction.

Chapter 12: Securing the area surrounding a blast

Learning objectives

- Explain what the most critical period in a blasting operation is, and why.
- Describe the authority and responsibilities of the blaster of record for blasting operations.
- List the qualifications, training, supervision, and responsibilities of assistants to a blaster.
- Describe the blast site and the danger area.
- Discuss specific actions the blaster of record must take to clear and control the danger area.
- Describe blaster responsibilities for guarding the danger area.
- Describe guard qualifications and duties for guarding the danger area.
- Describe standard blasting signals, including how and when they are used.
- Explain the safety protocols required to ensure safety of aircraft.

Overview

The most critical period in a blasting operation is the time of the blast. At that time there is the greatest potential for damage and serious injury.

To prevent incidents resulting from the detonation of explosives, the area surrounding a blast must be under the control of the blaster of record. The blaster of record is responsible for the safety of persons who could be affected. In addition, the area must be guarded to prevent entry during the time of the blast.

The blaster of record has the sole authority to limit people, equipment, and materials on the blast site at any given time. People, equipment, and vehicles not required during loading of explosives should be removed from the blast site.

About the blaster of record and the assistants

The blaster of record and their authority

To avoid conflict when more than one certified blaster is involved in a blasting operation, the employer must designate one blaster as the "blaster of record." The blaster of record is responsible for conducting or directing the use of explosives on the blast site. They also must have authority to safely conduct and direct activities on the blast site. The employer and supervisors must support the blaster in exercising this authority.

The employer and supervisors should not interfere with the blaster of record during a blasting operation. However, the employer must ensure that all activities are planned and conducted in a manner consistent with the Occupational Health and Safety Regulation and recognized safe blasting practices. If an employer has evidence that the blaster of record has failed to comply with the Regulation or safe blasting practices, the employer should immediately investigate the incident and may suspend the blaster from performing their duties.

In the Regulation

Section 21.5 of the Regulation sets out the blaster of record's authority to blast and the requirements for assistants.

Verifying the blaster of record's certification

The blaster of record must have a valid blaster's certificate issued by WorkSafeBC. The certificate specifies the type of blasting the blaster of record is qualified to conduct or direct. The employer should verify details of the blaster's certification, including the following:

- Name and address
- Certificate number
- Certification codes
- All conditions and/or restrictions
- The expiry date

Most employers retain a copy of the blaster's certificate. The original must be kept by the blaster of record. Whenever the blaster of record conducts or directs a blasting operation, the certificate must be readily available at the worksite. The blaster must show the certificate to a WorkSafeBC officer upon request.

Qualifications, training, supervision, and responsibilities of assistants

Only competent persons are permitted to assist a blaster, and then only if they have demonstrated a knowledge of safe work procedures.

The blaster is responsible for the assistants and any work they perform. When an assistant is unfamiliar with a task, the blaster is expected to provide training and exercise continuous visual supervision.

An assistant must not conduct tasks in a blasting operation unless the blaster directing the work is physically present on the blast site. Whenever the blaster leaves the blast site, the assistants must guard the explosives and wait until the blaster returns before continuing the operation.

Defining the blast site and the danger area

Under the Occupational Health and Safety Regulation, the *blast site* is the area that extends 15 m (50 ft.) in all directions from:

- Loaded holes
- Explosives stored outside of a magazine
- A known or suspected misfire

However, the blast may create hazards beyond the blast site. This larger zone is called the *danger area*. This is the distance in which people, equipment, or property could suffer injury or damage from the effects of the blast. These effects include the following:

- Air blast (concussion)
- Flying material (e.g., fly rock)
- Ground vibration
- A mud or snow slide
- Fire
- Fumes and dust

The danger area exists at the time of a blast or misfire. Its size is determined by the blaster based on the following:

- The amount of explosives used
- The blasting technique and the type of material blasted
- The potential for geological or environmental instability

Clearing and controlling the area

The blaster of record is responsible for ensuring that all tasks in the blast site are coordinated so that they may be performed safely.

During priming, placing, and connecting charges, only the blaster and the blaster's assistant(s) should remain in the area. No other person is allowed entry unless the blaster gives permission and maintains control over that person's activities.

The blaster must ensure that the danger area is clear of people and is kept clear during the blasting period.

The blaster must ensure that no charge is fired unless the following apply:

- All persons are at a safe distance from the blast or are in a shelter sufficient to protect them from injury.
- All property, including machinery and equipment, is located at a safe distance from the blast. (This does not apply to implosions.)
- Sufficient audible *warning signals* are given to all persons in or near an area where the blast may create a hazard.

Note

If there is any sign of thunder or lightning storm activity, all blasting activity must be suspended. In addition, the danger area must be cleared and guarded if explosives are present at the blast site.

Guarding the danger area

The blaster is responsible for posting *guards* to prevent entry to the danger area. Whistles, signs, or other signals cannot substitute for guards. The guards must be posted in safe locations, usually outside the danger area.

When blasting near a highway or populated area, it may be difficult to control public access. Traffic control personnel may be needed to block off streets or stop traffic.

Blasters should be in constant communication with guards posted at the perimeter of the danger area.

Guard qualifications and duties

Only competent persons should be assigned to guard a danger area. They must be mature individuals capable of performing guard duties.

The blaster is responsible for instructing all guards on their duties and responsibilities, including the following:

- Knowing the location of the guard post
- Understanding how and when to use warning devices and signals
- Preventing persons from entering the danger area
- Watching for flying material
- Preventing re-entry to the danger area until the all-clear signal is given or the guard is personally relieved by the blaster

Guards must be posted in safe locations. Signs cannot substitute for guards.

Guarding charges

Charges must be guarded at all times, at every point of the loading and blasting process. The blaster should ensure that explosives are attended by a competent person, except when they are stored in a locked magazine.

The competent person must:

- Protect the charges from damage or accidental detonation.
- Prevent deliberate tampering with or theft of any part of a charge.

When overnight guarding is required

Typically, a member of the blasting crew will guard charges until they are detonated. If the charges cannot be detonated during normal working hours, a designated person must be posted overnight.

The designated person should be provided with suitable equipment, including lights and signs. If equipped with a radio, the designated person must maintain a safe distance from any electric detonators.

Blasting signals

Once charges are connected to one another or to a means of firing, blasters and employers must ensure that firing takes place as soon as it is safe to do so.

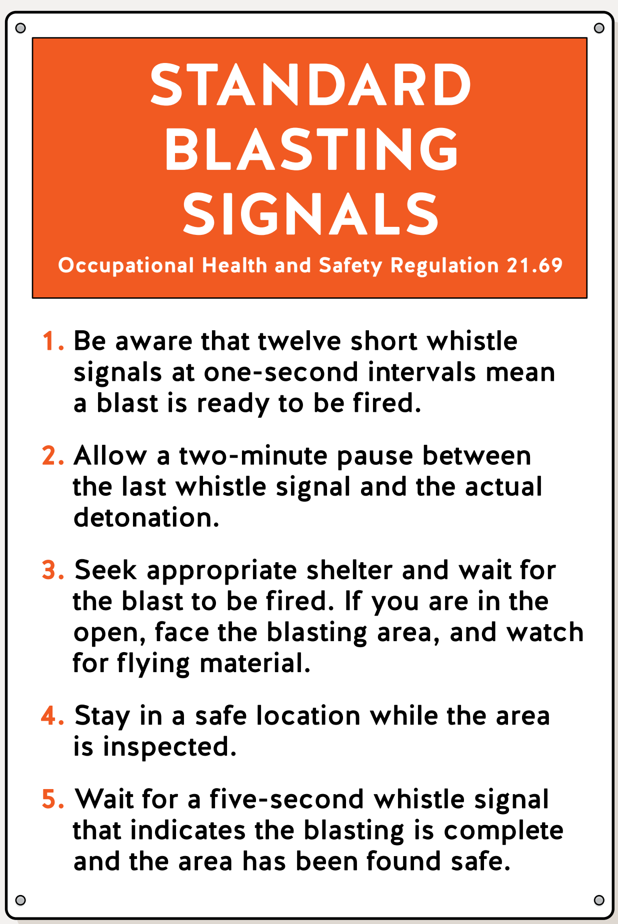
Every person in the area surrounding a blast should understand the blasting signals. These signals warn that a blast is about to be fired.

The blasting signals and steps the blaster must take are as follows:

1. Before the blast, sound 12 short whistle signals at one-second intervals.
2. After the last warning signal, wait two minutes before initiating the blast.
3. Following the blast, examine the area. If the area is found to be safe, sound one whistle for at least five seconds. This whistle indicates permission to return to the blast site.

Before any charge is fired, the blaster must do the following:

- Post blasting-signal signs where they can be easily seen at each blasting operation.
- Ensure that workers have been instructed in what the blasting signals mean and what to do when they hear the signals.



Blasting-signal signs must be posted where they can be easily seen at each blasting operation.

Devices for sounding blasting signals must be both of the following:

- Distinct from other signal devices in the danger area
- Audible throughout the danger area

A compressed-air horn, or a horn device attached to a compressor or air hose, is commonly used. A standard car or truck horn is not distinct. For this reason, it is unacceptable as a blasting-signal device.

Notice to Airmen (NOTAM)

If the blast could pose a hazard to aircraft, special precautions must be taken. A Notice to Airmen (NOTAM) warning of the blasting operation should be issued to pilots.

A NOTAM will be required if the blast site is within 5 nautical miles of a location from which flight operations take place. To request a NOTAM, contact NAV Canada at least 24 hours before the scheduled time of blasting.

Do not assume the NOTAM has been received and understood by all pilots in the area. If blasters detect an aircraft in the immediate vicinity of a blast, they should contact the aircraft by radio on the 123.2 *MHz* frequency and identify the aircraft by type and colour. (For example, “Red and white helicopter, you are over an active blast site. Clear the area immediately.”)

To request a NOTAM for blasting operations, visit NAV Canada’s Data Submission webpage. In the NOTAM Request Forms section, download the Airspace NOTAM request form, and then complete and submit it to NAV Canada. For more information on NOTAM requests and blasting, see section 5.5.5 of the Canadian NOTAM Operating Procedures (CNOP). The CNOP is updated from time to time and is available at the webpage noted above.

Chapter 13: Priming and loading explosives

Learning objectives

- Describe what priming is and how it works.
- Explain best practices for adequate priming to ensure detonation of charges.
- Discuss the principles of priming.
- Describe how to prime a detonator-sensitive explosive cartridge.
- Describe how to prime a cast booster.
- Explain the process and principles of loading.
- Describe the process of decking.
- Identify precautions when working around loaded holes.
- Describe the process of pneumatic loading and the safety precautions required.
- Describe bulk emulsion and ANFO loading and best practices for each method.
- Identify requirements for successful tamping.
- Describe stemming, its purpose, its importance, and how to use it.

Overview

Blasting operations involve preparing and placing explosive charges. Combining a charge with a detonator is known as *priming*. Placing a primed charge into a blast hole before detonation is known as *loading*. A blaster is expected to know the procedures, requirements, and restrictions for priming and loading explosive charges in any situation.

Priming the charge

Priming a charge brings together — for the first time — an explosive and a detonator. Safe procedures for priming a charge are determined by the conditions, the application, the explosives, and the initiation system.

Primers

A *primer* is a detonator-sensitive explosive, such as a stick of dynamite or a cast booster, that has a detonator (known in the past as a blasting cap) inserted. The primer is used in the initiation chain to increase the effects of the detonator and cause the remainder of the explosive column to detonate. The detonator needs to be properly installed in the explosive for the pairing to be considered a primer.

The definition of a primer depends on how the explosive is used, not on the explosive's form, composition, or sensitivity. For example, a cast booster is commonly a mixture of TNT and PETN (sometimes with *RDX* and other compounds). On its own, the cast booster is considered an explosive. When placed without a detonator into a blast hole filled with emulsion, the cast booster is considered a booster (an explosive used to increase the effects of another explosive). When a detonator is inserted, the cast booster becomes a primer.

A worker prepares a primer. The detonator is already inserted in the stick of dynamite.

Priming considerations

To ensure detonation, the explosive charge must be adequately primed. The velocity of detonation (VOD) of the primer must equal or exceed the VOD of the explosives in the main charge. In addition, the primer should have a detonation pressure equal to or greater than that of the explosives in the rest of the column (e.g., a cast booster in a column of ANFO).

Do not under-prime a charge. This may result in a misfire, improper breakage, and excessive fumes.

Under normal conditions, most high explosives are reliably initiated by a high-strength detonator. Modern dynamites have high sensitivity to initiation, even in cold temperatures. Water-gel and emulsion explosives tend to become less sensitive in colder temperatures. And blasting agents have low sensitivity to initiation. For these reasons, the blaster should use a high-strength primer to ensure proper detonation.

Be sure to follow the manufacturer's technical data sheet recommendations when priming an explosive charge, especially in longer blast holes.

What is detonation pressure?

Detonation pressure is a measure of the amount of force exerted by an explosive. It is calculated using the explosive's VOD as well as its density. Some explosives exert more pressure than others. The higher the density and/or VOD, the higher the detonation pressure.

Principles of priming

The following principles apply to preparing all primers:

- Do not prepare primers in a magazine or near large quantities of explosives.
- Do not prepare a primer until immediately before placing the explosives. To ensure the safety of workers and others, the period of time an initiating device is connected to an explosive must be minimized.
- Do not prepare more primers than immediately needed.
- Do not punch a hole in an explosive that is very hard or frozen.
- Protect the detonator from abrasion, impact, and other harm.
- Point the detonator in the direction of the main explosive charge.
- Never force or attempt to force a detonator into an explosive.
- Make sure the detonator is fully inserted in the explosive.
- Secure the detonator to the explosive so that no tension is placed on the leg wires, shock tube, plastic tubing, or detonating cord at the point of entry into the detonator.
- Do not tie a half hitch with shock tube, as it can pinch or damage the tube.
- Do not slit, drop, twist, or tamp a primer.

Priming with an explosive cartridge

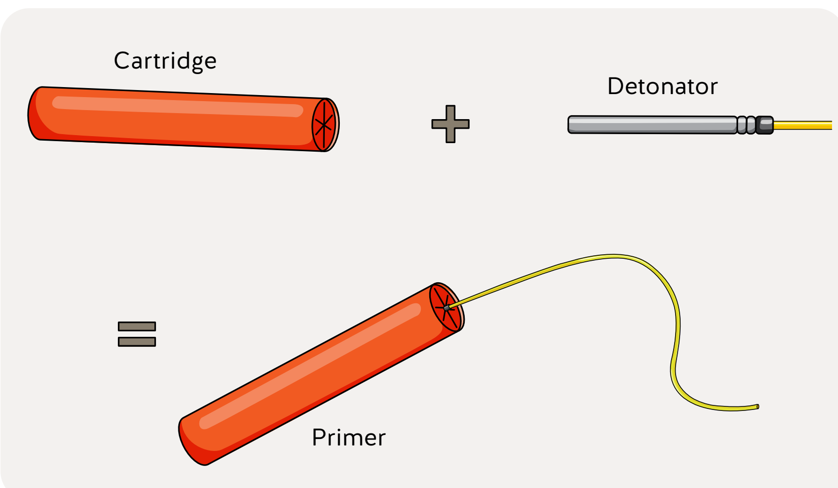
Explosive cartridges are most commonly used in priming. They can contain dynamites, emulsions, or water gels. Cartridges are designed to maintain rigidity while being loaded into drill holes and to compress readily when tamped. Cartridges are made of heavy paper or plastic tubing. These materials allow for water resistance and protection from the elements.

Note

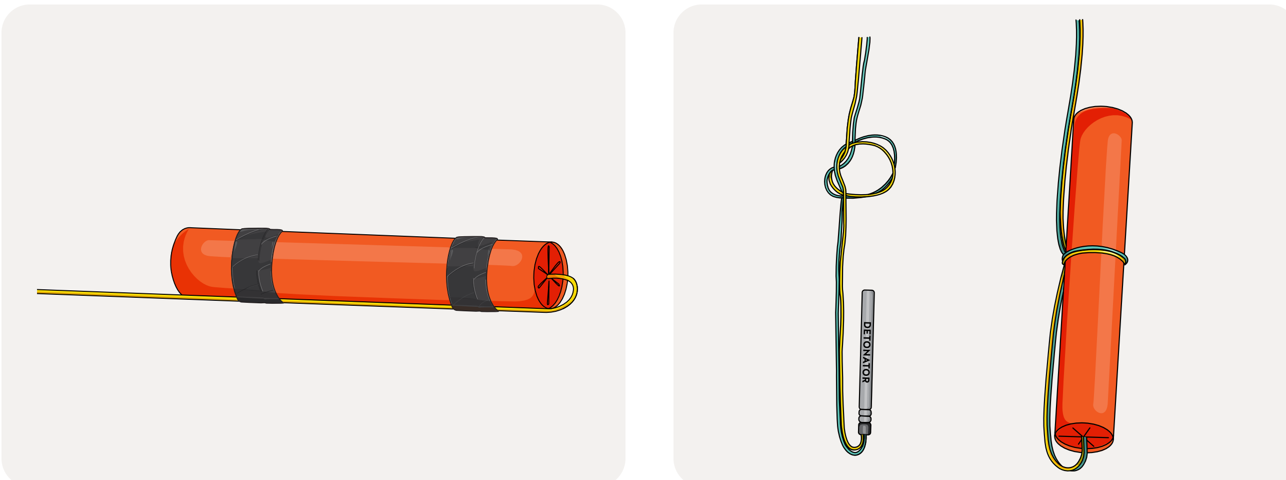
Many blasters refer to a cartridge simply as a "primer." This is accurate only when a high-strength detonator has been inserted into a detonator-sensitive explosive.

How to prime a detonator-sensitive explosive cartridge

1. Use only:
   - A cartridge of good structural integrity, capable of being initiated by the detonator.
   - A "powder punch" made of wood, plastic, or non-sparking metal such as brass or copper.
2. Use the powder punch to form a hole so the detonator can be fully inserted. The hole may be punched in the end of the cartridge, but take care to ensure it does not exit through the side.
3. Insert the detonator so it is completely buried in the centre of the cartridge with the base or "business" (closed) end pointed toward the bulk of the cartridge.



4. If the primer could become caught up in the hole during loading, ensure that the detonator is securely fastened to the cartridge by doing one of the following:
   - Tape any protruding leg wires, detonating cord, or shock tube to the cartridge.
   - If using an *electric detonator*, tie a half hitch in the leg wires around the middle of the cartridge. (For larger cartridges, it may be necessary to tie the leg wires in two places.)



Ensure that the detonator is securely fastened to the cartridge by doing one of the following:
- Taping leg wires, detonating cord, or shock tube to the cartridge (left)
- Tying a half hitch in the leg wires around the middle of the cartridge (right)

Priming with a cast booster

A cast booster is a manufactured unit of high explosive designed to initiate an explosive charge. A cast booster achieves this by boosting or amplifying the shock wave from a detonator.

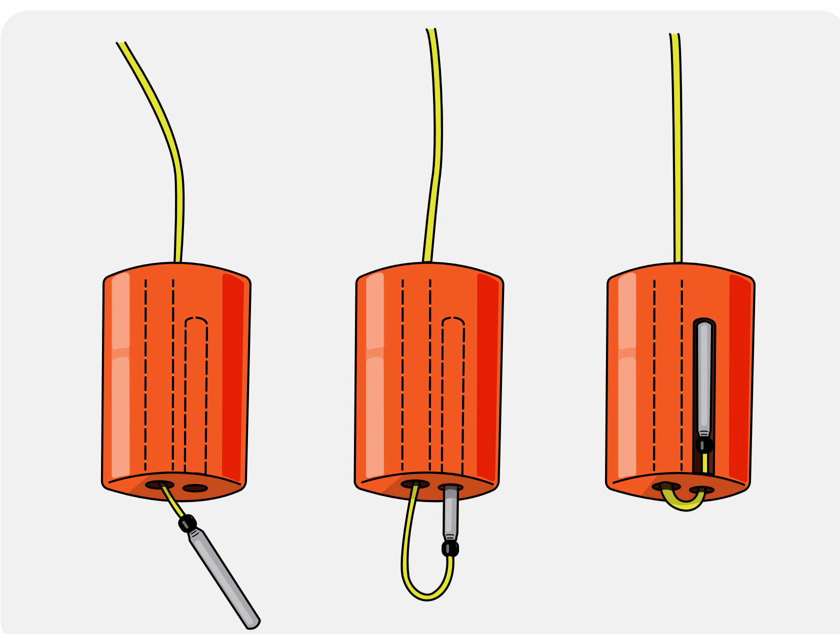
A cast booster is a cylinder of pentolite high explosive (a mixture of TNT and PETN). Some cast boosters also contain other explosives such as RDX. Cast boosters have a high VOD and very high detonation pressures that increase the initiating power of detonators. Some cast boosters have a *detonator well* for easily inserting and holding the detonator. Larger cast boosters may also have a hollow core (or "tunnel") through which a detonator may be passed. This helps to secure the detonator to the cast booster during the priming and loading operation.

How to prime a cast booster

The following procedure applies to priming a cast booster with a detonator.

1. Use only a booster with a detonator well that allows the detonator to be easily and completely inserted.
2. Thread the detonator through the tunnel.
3. Insert the detonator into the bottom of the detonator well.
4. If the primer could become caught up in the hole during loading, securely fasten the detonator to the cast booster by doing one of the following:
   - Tape any protruding cord line, leg wire, or tubing to the booster.
   - Tie a half hitch in the electric detonator leg wires around the middle of the charge.

Never try to enlarge the detonator well in the cast booster.



A detonator is threaded through a tunnel in a cast booster (left) and then inserted into a detonator well (centre and right).

Loading

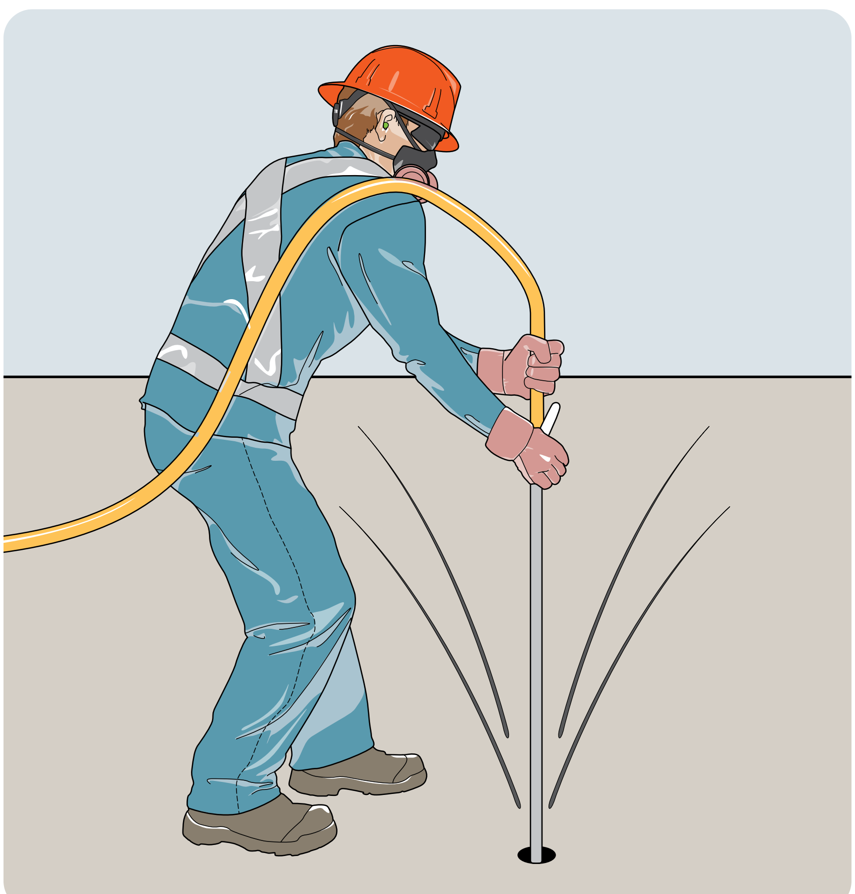
Drilled holes must be examined to ensure they are clear of obstructions that could hinder loading the explosives. Where blast holes may collapse (e.g., due to groundwater or unstable ground), tubular inserts may be used to keep the holes open.

Techniques for removing mud and rocks from a hole include the following:

- Blowing out the mud and rock with a *blow pipe* using compressed air (as shown in the drawing below)
- Removing the obstruction using a "scraper" or spoon (a rod with a dished end)
- Pushing the obstruction to the bottom of the hole with a drill steel (rod) or *loading pole*

In general, primers are best placed in the lower part of the explosive column, normally at or below grade. If charges are separated by inert material, primers should be placed in each charge section to ensure reliable detonation. Follow manufacturers' recommendations for priming locations.

Lower each charge into the hole gradually. Dropping charges into the hole can lead to premature detonation. Follow the progress of each charge with a loading pole to ensure it doesn't become lodged in the wrong location. If an explosive is not in direct contact with a primer, the explosive may fail to detonate.



A worker uses a blow pipe to blow mud and rock out of a hole.

Other loading principles

- Inspect the blast site for overhead hazards and safe working conditions before loading.
- Check each blast hole to ensure it is safe for loading.
- Where two-inch-diameter or smaller cartridges are used, use the first cartridge in the blast hole as the primer cartridge.
- It must be possible to place the primer easily and safely in a blast hole without damage to the detonator, leg wire, or tubing.
- Position the primer so that the base or "business" (closed) end of the detonator is oriented toward the main part of the explosive column.
- Ensure direct contact between the primer and the additional explosives.
- Never force explosives into a blast hole.
- Never load a blast hole containing hot or burning material. Temperatures above 65°C (150°F) could be dangerous.
- Do not stack more explosives than needed near working areas during loading.
- Do not drop large-diameter, rigid cartridges — 102 mm (4 in.) or larger — directly on a primer.

Decking

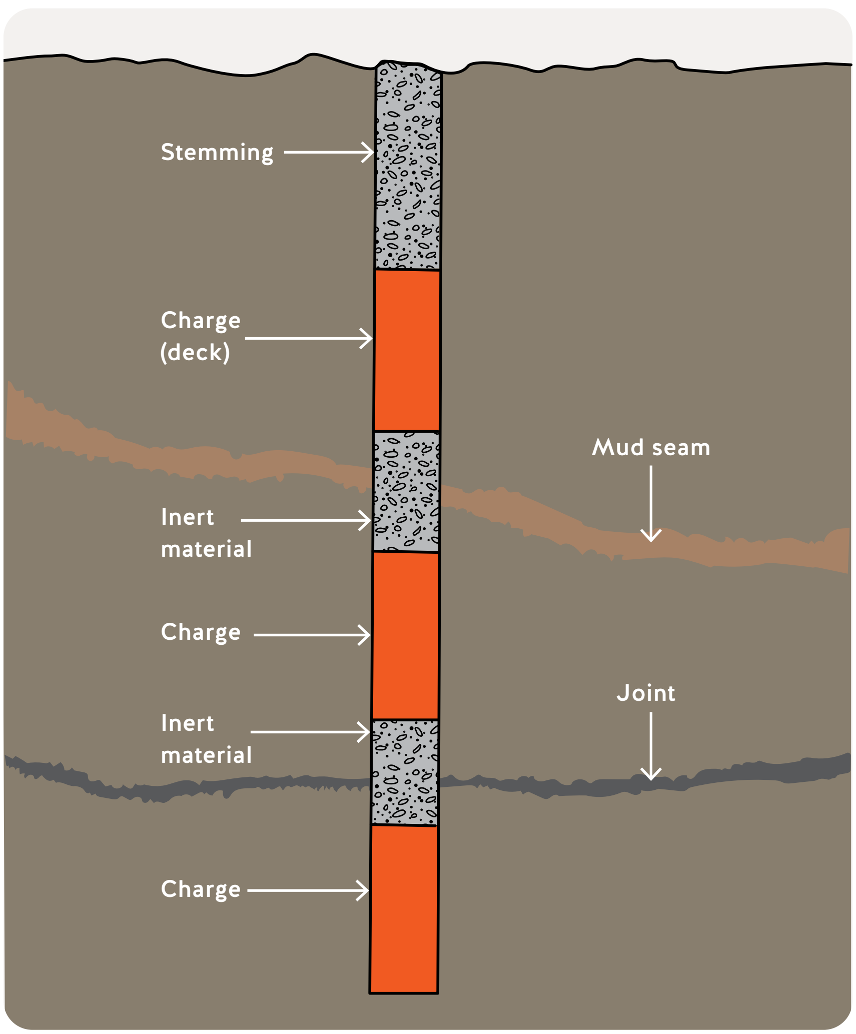
Decking is a method of creating inert (unloaded) zones within blast holes to enhance explosive performance or limit the weight of explosives used per hole. This is usually done with stemming or wooden *spacers* (air decking). The term “deck” (or “deck charge”) refers to an explosive charge separated from other charges by inert zones.

Each deck requires a separate primer that is initiated separately.

In some cases, the blaster can use decking to do one or more of the following:

- Protect a weak zone (e.g., a mud seam or a joint) from explosive energy.
- Create a zone without explosives to cushion the back wall.
- Separate charges to improve energy distribution.
- Reduce unnecessary use of explosives.

When decking is used, the blaster should provide enough distance between charges to prevent them from interfering with each other and causing misfires.



Cutaway view of decked charges in a blast hole

Precautions around loaded holes

The blast site, especially loaded holes, should be clearly identified. This can be done using individual markers such as cones (drill plugs), with warning or caution tape, or with other highly visible indicators.

Blasters must ensure that no vehicle or other equipment is moved over a loaded hole.

Equipment and vehicles not required in the blasting operation should be kept out of the blast site. Mobile equipment is only permitted near explosives when under the direct control of the blaster of record and only to assist the blaster in the following:

- Excavating
- Placing fill or stemming materials
- Placing blasting mats

Pneumatic loading

Pneumatic loading uses compressed air to place explosives into a drilled hole. The process requires a pneumatic loading machine and a special hose. The loading hose can be up to about 30 m (33 yd.) long in some cases.

Pneumatic loading of explosives such as ANFO moves the prill material through the loading hose at relatively high velocity. As a result, the prills exit the hose (in the blast hole) at high velocity and collide with material that has already been loaded. The purpose is to break down or crush the material in the blast hole and increase the overall packing density.

Pneumatically loaded ANFO densities can increase to between 0.95 and 1.00 g/cc depending on a number of factors and the skill of loading personnel. Some material may be crushed very finely and can blow out of the blast hole as fine dust.

When pneumatically loading a blasting agent (such as ANFO), use only a semi-conductive hose designed for this purpose. This type of hose drains away *static electricity*, which can increase the risk of accidental detonation. Static electricity may be produced by the flow of the blasting agent through the hose. Hole liners made of plastic can also contribute to the buildup of static electricity during loading.

During the loading operation, the pneumatic loading machine must be effectively *grounded*. This means connecting the machine to a metal stake driven into the ground or rock surface. The grounding cable must not be attached to rails, pipes, or other *conductors*. These items could introduce stray electric charges from distant sources such as lightning.

Electric or electronic detonators must not be placed in a hole before it is loaded pneumatically. The exception is if written permission has first been obtained from WorkSafeBC.

Bulk loading

Bulk loading refers to filling a drill hole with either bulk emulsion or bulk ANFO (or a similar type of explosive, such as water-resistant ANFO).

Bulk emulsion loading

In bulk emulsion loading, a loading hose is inserted in the hole and emulsion is loaded from the bottom up. The bulk emulsion is under pressure, and this loading method is similar to the way toothpaste is squeezed out of a tube. As loading progresses, the hose is retracted so it doesn't become embedded in the emulsion and can be removed when loading is complete.

Since bulk emulsion can be loaded into wet holes, floating primers (i.e., primers that move out of their intended location) are a concern. Efforts should be taken to prevent this from happening. An experienced hose handler can prevent floating. Putting some weight on the primer can help ensure it stays in place.

Follow the manufacturer's recommendations concerning the position of the hose in the blast hole to avoid trapping water in the hole. Water can cause poor blasting results.

Bulk loading into wet holes should not be done via the top-down method of ANFO loading. The emulsion may bridge where it meets the water and not fully fill the blast hole.

Bulk ANFO loading

Bulk ANFO loading is similar to pneumatic loading. However, the former is done with a larger-diameter hose and, if assisted with air, at a much lower pressure. The ANFO prills are usually moved to the hose by an auger screw from the bin on the vehicle. From there, they go into the hose to be dropped into the hole. This is sometimes referred to as top-down loading.

This type of loading usually does not result in floating primers. That's because the drill hole needs to be dry in order to load any ANFO product. This loading method also does not greatly change the in-hole density of ANFO above its standard (0.82–0.88 g/cc).

Monitor the height of the explosive column

For both types of bulk loading, the blaster and the bulk truck operator must continuously monitor explosive column rise. This is done by dipping a weighted tape measure into the blast hole and measuring the amount of explosives pumped. These steps help avoid losing product in seams and overloading blast holes.

Tamping

To help ensure a successful blast, explosives loaded into a blast hole should fill the hole's diameter as much as possible. This is very important when using cartridge explosives. The diameter of each cartridge should be slightly smaller than the diameter of the hole so that the cartridges can be easily placed. The difference in size between the cartridge diameter and the blast-hole diameter is called the annular space.

For an effective blast, explosives may be compressed into a blast hole with a tamping rod to remove as much annular space as possible. This ensures contact with the other explosives. *Tamping* should be done frequently during the loading process. Ideally, it should happen after each cartridge is loaded into the blast hole. At the very least, tamping should be done after every second cartridge is loaded.

Tamping rods should be made of wood or plastic and have non-sparking metal fittings. Devices made of a ferrous metal, such as iron or steel, must not be used.

Successful tamping requires steady pressure. Excessive force or impact could damage the explosives or cause premature detonation. Undue pressure on a primer can result in an accidental explosion.

In an "up hole" (one that is drilled or angled upward), cartridges can be held in place by means of a plastic drill-hole plug known as a "shuttlecock." The shuttlecock is inserted with the points gripping the walls of the hole to prevent withdrawal.

Other tamping principles

- Do not tamp a primer or explosive product that has been removed from its cartridge.
- Do not kink or damage detonating cord, shock tube, plastic tubing, coupling devices, or wires of detonators when tamping.

A worker compresses explosives into a blast hole with a tamping rod (loading pole).

Stemming the collar

The final stage of loading explosives into a blast hole is stemming the collar (i.e., the unloaded portion) of the hole. The purpose of stemming is to maintain detonation gases and pressures for as long as possible in order to do useful work. Stemming also helps to reduce noise and air blast from detonation. In short, stemming is a crucial part of loading a blast hole.

The type and quantity of stemming, as well as how it is used, play critical roles in any blast operation and should be factored into every blast plan. Stemming that is too small for the hole tends to rifle (blow out at the time of detonation). Stemming that is too large blocks the hole, creating large pockets into which the explosive gases escape.

In general, crushed rock is the best stemming, as it compacts well and acts as a plug to contain the explosive gases. For more in-depth information, see "Collar length" on page 140 and "Stemming" on page 142.

When stemming the collar, do the following:

- Pour slowly enough to avoid clogging the hole with stemming buildup.
- Ensure the leg wires, cord, or tubing is held to one side to avoid damaging it or obstructing the stemming.
- Make sure the stemming materials are the correct size for the diameter of the hole.
- Make sure the stemming has settled before moving on to the next hole.
- In small-diameter holes, gently moving the *downline* from side to side will indicate whether the stemming has settled.
- Make note of how much stemming has been poured and if the amount is consistent with other holes of the same depth.

A worker carefully pours stemming into the collar of a blast hole.

Chapter 14: Controlling the effects of a blast: Flying material, ground vibration, and air blast

Learning objectives

- Describe flying material, its causes, and techniques to control it.
- Explain what a blasting mat is and how to use it properly.
- Explain the purpose of a test shot.
- Discuss the different types of ground vibration, how they are measured, and the damage they can cause.
- List and describe factors affecting ground vibration.
- Describe how ground vibration can be controlled.
- Explain scaled distance and the formula used to measure it.
- Describe the relationship between shock waves and fragmentation.
- Describe air blast and the damage it can cause.
- Explain the factors that affect air blast.
- Describe techniques used to control air blast.
- Describe backbreak and how to control it.

Overview

Explosives used in rock blasting produce both desirable and undesirable effects. The desirable effects include breaking up and moving rock. The undesirable effects include flying material, ground vibration, and air blast. This chapter focuses on how to control the undesirable effects of a blast.

Flying material

Flying material is the undesirable throw of debris from an explosion. High-pressure gases can propel materials a considerable distance with great force. Flying material can cause serious injury and property damage.

All blasting operations are capable of producing flying material. The blaster should know the causes and the techniques necessary for controlling it. The blaster and the employer are responsible for protecting people and property from flying material.

Fly rock thrown from a poorly controlled blast

Types of flying material

Flying material is any material (such as rock, pieces of *blasting mats*, and overburden) disturbed by the blast. The most common type of flying material is rock (or "fly rock").

Causes of flying material

There are many causes of flying material, including the following:

- Geological seams, planes, and cracks that cause the rock to break unevenly
- Geological cavities that collect an excessive amount of explosives
- Poor pattern design with insufficient or excessive burden and spacing
- Improper distribution of explosives in the rock
- Shallow holes or "crater" blasting without sufficient containment
- Blast holes that have been overloaded
- Improper delay timing that does not provide adequate burden relief
- *Collar priming*, which can create greater throw than bottom (toe) priming
- Failure to use covering material, blasting mats, or sand to contain the flying material
- Inadequate or insufficient stemming
- Reduced burden due to improperly placed angle holes or wandering holes at the face

To summarize, flying material can be produced if:

- The rock is abnormal.
- The drill pattern is inaccurate.
- Explosives are overloaded.
- The sequence of initiation is improper.
- Effective containment, such as blasting mats and cushion (ground material placed in front of the open face), is not used.

Techniques to control flying material

To control flying material effectively, the blaster should do the following:

- Select the most appropriate drill pattern. This is usually determined by the type of explosive, the depth of the cut, the type of rock, and other factors such as the proximity of structures.
- Consult with the driller about the nature of the material. Drilling the material should reveal the location of any abnormalities (e.g., slips, cavities, and groundwater). Drillers must log and communicate these abnormalities to the blaster, who may then make adjustments while loading the blast.
- Double-check the burden of face holes to ensure it is adequate, especially when re-blasting a misfire.
- Choose the most suitable explosive for the conditions, with an energy factor that is adequate but not excessive.
- Properly load each hole. Should a cavity, *fault*, or slip exist, load accordingly. Beware of cavities, and do not overload a hole. Monitor column rise in the blast hole.
- Ensure the hole is properly stemmed. The minimum depth of stemming is generally 1.0 to 1.1 times the burden distance. Ideally, the stemming material is clear, crushed rock.
- Choose the most suitable initiation system. Delay-sequence blasting must allow for adequate burden relief. Generally, bottom (toe) priming does not create as much throw as top (collar) initiation, and is not as likely to result in a misfire.
- When blasting near potentially occupied buildings or structures, blasting mats must be used to contain flying material.

In remote areas, if blasting mats are not available, the blaster should cover the blast with a layer of sand or other soft fill material.

Blasting mats

Blasting mats are usually constructed of rubber tires. These mats contain small gaps to retain debris but allow the escape of explosive gases.

Woven-steel blasting mats are also available. These mats provide flexibility and effective cover. These mats are considered more environmentally friendly because they do not release rubber into the environment.

Solid coverings (such as steel plates) should not be used. They can be thrown by the expanding gases.

Matting a blast requires a skilled operator and non-verbal communication between the blaster and the machine operator. Hand signals for rigging and heavy equipment operation are set out in section 15.20 of the OHS Regulation. It is essential that the blaster and the machine operator discuss and confirm these signals prior to matting a blast. In these discussions, do the following:

- Determine blind spots and establish clear hand signals.
- Discuss where the blaster wants the machine to be positioned to swing the mats.
- Discuss where the rigger will be positioned to hook the mat.
- Ensure that the machine operator never lowers a mat onto blast holes without direction from the blaster of record.
- Ensure that mats are never dragged over blast holes.
- Discuss where the blaster would like the mats to be placed after the blast for the next shot.
- Discuss cushion material and placement.
- Inspect rigging and blasting mats for holes, embedded rock, or other defects before placement.

A blaster uses hand signals to communicate with a machine operator during placement of a blasting mat.

For large blasting mats, aim for a 1 m (3 ft.) overlap between mats. Blasters must be aware of potential backbreak and allow for adequate cover, especially on sloped terrain. In some cases, survey paint can be used to show the area around the blast that the mats should cover. On steep slopes, it may be necessary to drill a few holes for pins and to secure mats in place using chains or cables. This prevents the mats from sliding away.

Blasting mats are not failproof, and there have been many cases where blasting mats ended up in power lines and other unwanted places. The first line of defence always involves the following:

- A good drill pattern
- Proper explosive load
- The right type and amount of stemming
- Effective burden relief
- A cushion of muck or earth in front of the open face prior to covering the blast

The aftermath of a blast gone wrong. In this case, the blast sent a blasting mat through the air, where it struck and brought down a power line. The blast also produced a large amount of fly rock.

For small blasts, such as boulders and in places with limited machine access, hand mats may be used. These mats are usually made from conveyor belts cut and woven into squares or rectangles. Hand mats are moved into place by hand. Multiple mats are needed to adequately cover a small blast, and they should overlap.

At times, covering a blast with mats is impractical. To protect property from damage, it may be more effective to place a substantial guard or covering material directly over the object requiring protection. However, this is not acceptable practice in close proximity blasting.

In the Regulation

Requirements for close proximity blasting are detailed in sections 21.86 to 21.93 of the OHS Regulation.

Test shot

A small test blast (or test shot) should always be conducted first. A test shot is especially valuable in the following cases:

- Close proximity blasting
- Whenever there is doubt as to the effect of the explosives on the material

A test shot allows the blaster to assess the material and make any adjustments prior to engaging in larger blast operations.

Ground vibration

When an explosive detonates, rock *fracturing* occurs due to the pressure of the high-density and high-temperature gases in the blast hole. When the gases enter these fractures, bending occurs and causes the fractures to open and expand outward from the hole.

Although the explosives in a blast are designed to break and move rock, some energy is wasted as ground vibration. Excess ground vibration is normally the sign of a poorly designed blast pattern or a lack of adequate delays.

Vibrations move in three different ways or directions:

- Vertical (up and down)
- Lateral (forward and backward)
- Transverse (left and right)

In blasting, ground particles move in response to vibration. To measure ground vibration, a seismograph is used. This device can measure waves in four different ways:

- **Displacement** is the distance the particle moves from its position of rest.
- **Acceleration** is a measure of the maximum change in speed of the particles.
- **Frequency** is the number of times the particles move back and forth in 1 second. Frequency is measured in hertz and is one of the most important factors controlling the response of structures. (Blasters normally want high-frequency readings and aim to avoid low-frequency blasts.)
- **Particle velocity** measures the speed at which the particles in the ground are vibrating during the blast. This is measured in inches per second (in./s) or millimetres per second (mm/s). Particle velocity (along with frequency) is primarily used to determine damage potential for structures.

A worker uses a seismograph to measure ground vibration.

Ground vibration damage

Excessive ground vibration (or ground motion) caused by blasts can lead to damage to structures. The most common type of damage associated with excessive ground motion is the cracking of plaster or drywall walls in residential homes.

Note

When blasting near buildings and other structures, the blasting contractor should have pre-inspections done on those structures before starting the work. Some municipalities require pre-inspections and blasting permits.

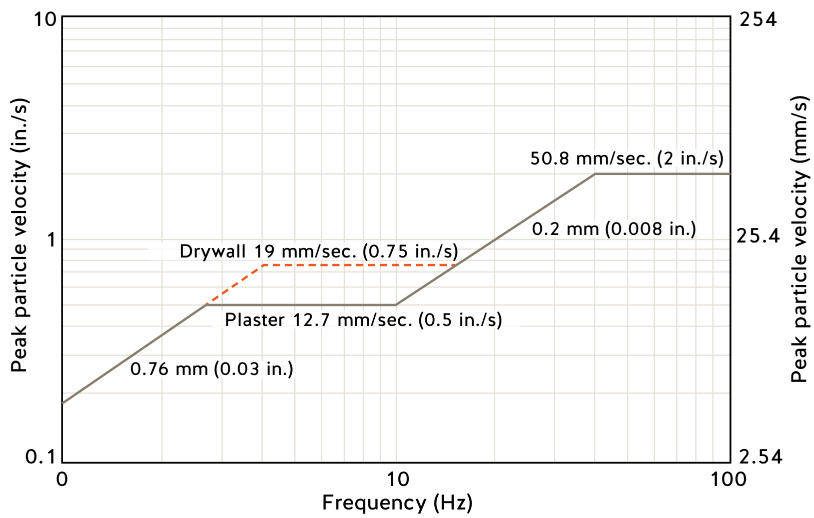
The U.S. Bureau of Mines (USBM) carried out research to determine the effects of various ground vibration levels on nearby residential buildings. The findings are shown in the following table.

Effect on nearby residential buildings by ground vibration level

Ground vibration level (peak particle velocity or PPV)	Effect on nearby residential buildings
2.0 in./s	Safe level
4.0 in./s	Threshold of damage • Opening of old cracks • Formation of new cracks • Dislodging of loose objects
5.4 in./s	Minor damage • Fallen plaster • Broken windows • Fine cracks in masonry • No weakening of structures
7.6 in./s	Major damage • Large cracks in masonry • Shifting of foundation-bearing walls • Serious weakening of structures

Later research by the USBM further examined safe criteria for residential structures. These criteria were based on the impact of ground vibration on plaster and drywall, some of the weakest components of a residential structure. This research developed what is known as the Z-curve, which shows the allowable limits of vibration frequency and intensity for blasting. The Z-curve is today's standard for ground vibration on residential structures. The Z-curve (see next page) established lower ground vibration limits than those shown in the table above.

The Z-curve



In the Z-curve, allowable levels of vibration frequency and intensity fall below the lines shown. Vibration levels that are higher than the limits appear above the lines. (Source: Report of Investigations 8507, USBM)

The Z-curve is solely for residential structures. Industrial structures can withstand much higher levels of ground vibration.

Factors affecting ground vibration

All structures close to a blast site will respond to ground vibration depending on the following:

- Distance
- Charge weight per delay
- Frequency of the vibration
- Shot design
- Confinement of the blast

Differences in geology and building construction can mean some structures are more susceptible to vibration damage than others.

In the following table, various factors are listed and rated as to the amount of influence they have on ground vibration.

Factors that influence ground vibration

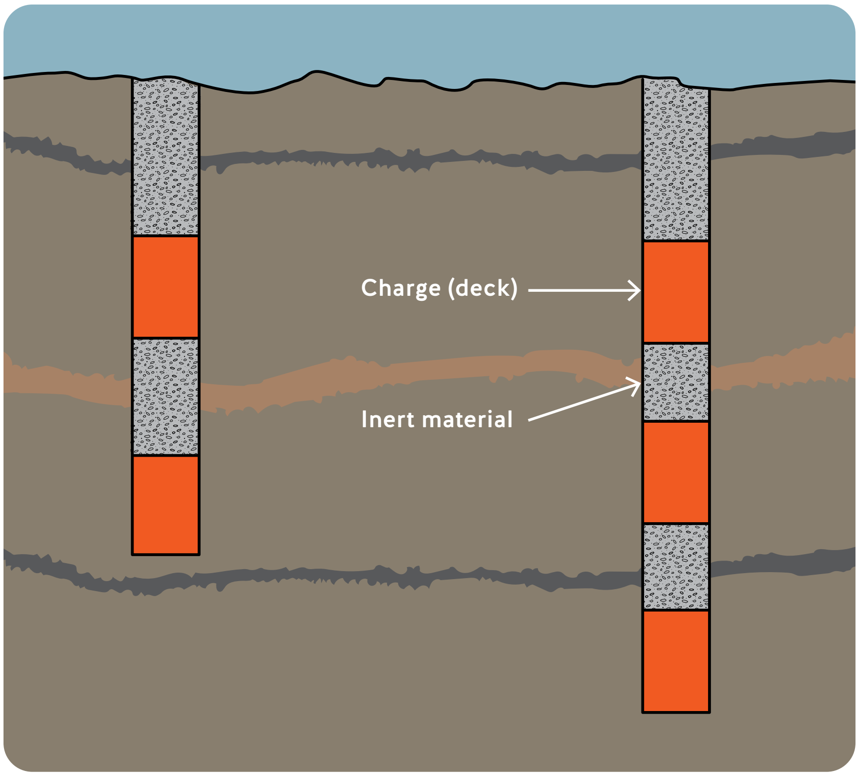
Factor	Amount of influence on ground vibration		
	Significant	Moderately significant	Insignificant
Charge weight per delay	●		
Delay interval	●		
Burden and spacing		●	
Stemming (amount)		●	
Stemming (type)		●	
Charge length and diameter		●	
Angle of blast hole		●	
Direction of initiation		●	
Charge weight per blast			●
Charge depth		●	
Bare vs. covered detonating cord			●
Charge confinement	●		
Wind and weather conditions			●

Controlling ground vibration

To keep ground vibration under control, do the following:

- Reduce the charge weight per delay. This is easily done by reducing the number of holes fired on a given delay. If using only one delay per hole, go to a smaller or shorter hole. An alternative is to deck the holes and use more than one delay per hole, as shown in the figure on the next page.
- Be sure to use the correct amount and size of stemming. Stemming blowout can lead to energy loss. Energy loss leads to overconfinement, which causes ground vibration.
- Do not exceed subdrilling required to break the rock to grade, as this can increase ground vibration.
- Make sure that the toe burden is not excessive. Too much burden results in excessive pressure on the next row of holes, causes severe vibration, and may not break the rock to grade.
- If there is not enough relief time for the first row of holes to efficiently move, consider increasing the time delay between rows.

- The length of delay between holes and rows may also be increased. However, this may result in complaints from nearby residents and businesses because long blasts (1 s or 1000 ms, for example) tend to increase air blast. To reduce the risk of complaints, the blast duration should be as short as possible while allowing enough time for each hole to fire and move the rock before the next hole fires.



Multiple delays per hole (decking)

Measuring scaled distance

Scaled distance gives a blaster an estimate of effects that a blast may have on a structure at a given distance. Scaled distance compares blast effects (e.g., ground vibration) from various sizes of charges of the same explosive at various distances.

Scaled distance provides a good starting point to determine:

- An allowable charge weight of explosives per delay
- What hole diameter to use
- If decking may be required

Check local bylaws to find out if scaled distance is approved for use in blasting operations. In the absence of seismographs, scaled distance can be calculated with the following formula.

The imperial formula for scaled distance is:

$D_s = D \div \sqrt{W}$

Where: D_s = Scaled distance (ft./lb.)

D = Distance (ft.) to nearest structure

W = Maximum weight of explosives (lb.) per delay

$\sqrt{}$ = Square root

The following variations of this formula can be used to calculate the distance to the nearest structure and the maximum weight of explosives per delay:

$D = D_s \times \sqrt{W}$

and

$W = (D \div D_s)^2$

Example: Calculating maximum weight of explosives per delay

A house is 300 ft. away. The local bylaws allow a scaled distance of 50. What is the maximum weight of explosives per delay that could be fired without causing damage?

$W = (D \div D_s)^2$

$W = (300 \div 50)^2$

$W = 6^2 = 36$ lb.

If loading up to 18 lb. of explosives per hole, two holes could be fired on one delay. If a hole contains 34 lb., only one hole could be fired per delay. If a hole contains 72 lb., the blaster would need to deck and use two delays per hole.

Predicting peak particle velocity (ground motion)

The ground vibration from a construction blast can be determined before the blast is fired. The prediction equation for a typical construction blast is as follows:

$PPV = 51 \times D_s^{-1.15}$

Where: PPV = Peak particle velocity (*in./s*)

51 = A constant

D_s = Scaled distance (ft./lb.$^{1/2}$)

This is an industry standard that applies to all rock types encountered in construction blasting. It aims to predict the upper limit of ground vibration. Most blasts should have vibration levels below these predicted limits.

Shock waves and fragmentation

Studies have confirmed that shock waves have no effect on fragmentation. Shock waves decrease very rapidly and do not have enough energy within less than a metre from the blast hole to have any noticeable effects on the rock. In addition, data supports that shock waves have no effect on ground vibration.

For example, when compared on a scaled-distance basis, black powder (a deflagrating low explosive) creates the same level of ground vibration as dynamite and ANFO (high explosives). However, black powder has no shock wave effects.

Air blast

Air blast is an atmospheric pressure wave that transmits from the blast outward to the surrounding area. This pressure wave consists of an audible sound that can be heard and a concussion sound that can be felt but not heard. Weather plays a large part in how far away this air blast is heard or felt.

This pressure wave, which is also known as overpressure, may be able to cause damage. However, air blast is mostly considered a nuisance, as it can rattle windows in nearby buildings. Part of the blaster's responsibility is to reduce air blast levels as much as possible.

Air blast damage

Air blast is measured in decibels (dB) and in pounds per square inch (psi). The following table illustrates some of the typical sound and pressure levels and the damage they can produce.

Sound and damage levels

dB	psi	Damage type or noise comparison
180	3.0	Structural damage
176	2.6	Plaster cracks
164	0.5	Windows break
128	0.007	Maximum accepted by U.S. Bureau of Mines
120	3×10^{-3}	Jackhammer (10 000 impacts a day; complaints likely)
100	3×10^{-4}	Pneumatic hammer
60	3×10^{-6}	Conversational speech
0	3×10^{-9}	Threshold of hearing

Causes of air blast

Common causes of air blast include the following:

- Stemming blowout
- Displacement of the rock face
- Secondary or boulder blasting

Factors affecting air blast

The most important factors that affect air blast are weather and atmospheric conditions.

Temperature inversions and surface winds can affect air blast considerably. Temperature inversions are quite common in the early morning when cool ground air lies below warm air. In an early-morning blast, the pressure wave created by the blast passes up through the cool air and hits the warm air. Due to the change in temperature, refraction causes the pressure wave to bend. This can cause the pressure wave to travel back to the ground and may lead to higher sound levels than predicted.

Wind direction and speed also affect the travel of the pressure wave. The wave will follow the direction the wind is blowing to a degree. Wind speed is usually lower at ground level than higher up.

In addition, cloud cover can amplify noise due to refraction. Humidity differences can also cause refraction to occur. For these reasons, it is preferable to wait for a clear, sunny day to fire a larger blast.

Air blast control techniques

Air blast does not commonly cause structural damage, but it may rattle windows and doors. Windows that are poorly mounted are more likely to rattle and crack (or even break) depending on the level of air blast.

The following methods can help reduce air blast damage and complaints:

- Stay below the maximum air blast levels outlined by the U.S. Bureau of Mines. If levels can be kept under 134 dB, the chance of any damage to a structure is slight. However, complaints may still occur.
- Stem every hole to a proper depth. Two or three poorly stemmed holes in a blast can lead to complaints.
- Use the proper stemming material (¼-in. to ½-in. clear, crushed stone). Ensure that there is no bridging of material, especially in small-diameter blast holes.
- Make sure that burden and spacing are as planned, especially the burden at the face.
- In the case of mud seams or voids, mark these on the drill sheet and avoid loading explosives near them. Decking may be required in these holes.
- When possible, avoid firing the blast in the direction of highly populated areas.
- Use the proper sequence of delays. Make sure to use sufficient delay times between holes and rows.
- When carrying out secondary blasting (i.e., blasting boulders), use smaller-diameter holes and adequate stemming material.
- Ensure that burden is sufficient when blasting angle holes.

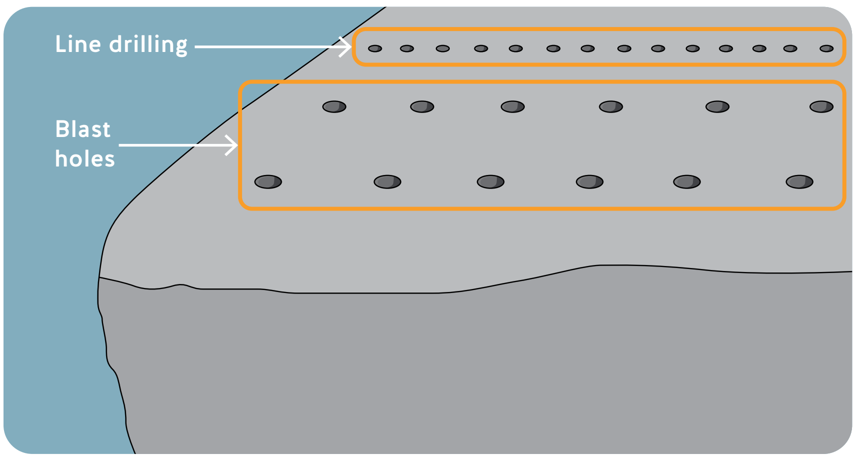
Controlling backbreak (wall control)

In some cases, it may be necessary to ensure a clean wall after the last row of holes is blasted. This is known as wall control. Blasters have a couple of wall-control options to choose from.

Line drilling

Line drilling means drilling a single row of closely spaced, unloaded holes neatly along a desired excavation line. This provides a plane of weakness that fractures will break to, reducing the risk of backbreak. This results in less shattering and stressing of the finished wall.

For many years, line drilling was the only technique used to control backbreak. Today, pre-splitting or pre-shearing is the most common technique.



Pre-splitting or pre-shearing

Pre-splitting or pre-shearing is a method of blasting that involves drilling and loading a single row of holes designed to minimize or eliminate backbreak to produce a smooth rock wall. This row is initiated before the primary blast to produce a planar crack. The crack helps to screen the surroundings from ground vibrations during the firing of the main round.

Detonating cord is often used to trace the loaded blast holes using this method. Detonating cord for this application is usually of much higher explosive *core load* (typically 150 to 400 *grains*/ft.) than detonating cord normally used to tie in a blast.

For blast design calculations for precision pre-splitting, see page 386.

Chapter 15:
Post-blast hazards and requirements

Learning objectives

- List the steps that must be taken after a blast before anyone can enter the blast site.
- Describe how to protect workers from air contaminants.
- Explain how to examine the blast site for undetonated explosives and other hazards.
- Describe requirements for safely excavating blast rock.
- Describe the post-blast hazards that can occur and measures used to control them.
- Explain how hand scaling is carried out.
- Describe how cleanup is conducted at the blast site.
- Describe how to record and maintain pre- and post-blast loading details and results in a blasting log.
- Describe the contents of dangerous incident reports and when they must be submitted to WorkSafeBC.

Overview

After a blast, the blaster of record must ensure that no one enters the blast site until all of the following occur:

1. The blaster has examined the blast site for misfires and other hazards.
2. The “all clear” has been sounded.
3. The blaster has given permission for work to proceed.

The blaster must identify and control any hazards. The all-clear signal is not sounded until the site has been examined and found safe.

The following precautions are required after a blast.

Protect workers from air contaminants

Air contaminants (e.g., silica dust, fumes, and toxic gases) must be reduced to a safe level. As a general rule, no one should return to a blast site if air contaminants are visible.

In surface blasting, air contaminants rapidly disperse into the atmosphere. In confined areas, such as underground, dust and fumes are a more serious problem. Atmospheric tests must be done following a blast. And the space should be ventilated before workers are permitted to enter.

For information on identifying confined spaces in the workplace and preparing and implementing a confined space entry program, see Part 9 (Confined Spaces) and Part 22 (Underground Workings) of the Occupational Health and Safety Regulation.

Examine the blast site

The blaster must carefully examine the blast site for undetonated explosives and other hazards.

The blaster must not leave the blast site before attending to any undetonated explosives or other hazards caused by the blast. Otherwise, serious injuries or damage may occur. The blaster should inspect for the following:

- *Loose material* that could be released from above or from the face
- Unstable trees
- Hanging branches

Excavating the blast rock (muck pile)

Equipment operators who excavate blast rock must be trained and competent to recognize misfires. Whenever possible, blasters should supervise the initial excavation of the blast rock to ensure all the holes were initiated and the rock has broken to grade. Having eyes on the ground from outside the machine is always better than not.

Operators must use caution when excavating blast rock. They should understand that a misfire may be handled only by, or under the direction of, a blaster. If a suspected misfire has occurred or explosives are seen in the muck pile, the operator should stop work immediately and notify the blaster of record to re-examine the area.

An equipment operator excavates blast rock.

Control post-blast hazards

All hazards must be identified and controlled before other work resumes on the blast site. The location of a misfire should be identified by a hole plug, flagging (coloured tape), spray paint, or other effective means.

Control measures can include the following:

- Roping off the area surrounding the hazard
- Keeping metal tools and equipment away from misfires
- Bracing or supporting loose material that may fall or move

Remove or manage loose material

Any unstable material that could cause injury or property damage is commonly referred to as "loose material." Examples include the following:

- Broken tree limbs
- Overhanging rocks
- Unstable boulders

Loose material has caused fatalities, serious injuries, and incidents involving property damage.

Loose material on a slope or face must be scaled (removed), trimmed, or otherwise stabilized. To remove loose material safely and effectively, use machinery such as front-end loaders or hydraulic excavators. This equipment reduces the risk of injury to workers.

Carry out hand scaling where appropriate

In some cases, hand scaling may be appropriate. Hand scaling is done using a metal scaling bar.

Determine the nature of the material by striking the surface with the end of the bar. A sharp (hard) sound indicates solid rock. A hollow (thud) sound indicates unstable or loose material.

When hand scaling, do the following:

- Wear a safety belt or harness attached to a securely anchored lifeline.
- Wear protective footwear and a hard hat.
- Use a scaling bar in good condition and of suitable length.
- Begin scaling from a safe location and from the top down.
- Stand on a solid surface and maintain your balance.
- Watch for holes containing explosives.
- Do not scale above any misfired holes or undetonated explosives.
- Do not scale where anyone may be endangered by falling rock.

After the blaster has examined the site and deemed it clear of all hazards, sound the five-second all-clear signal.

In the Regulation

For more information on scaling operations, see sections 20.96 to 20.101 of the Occupational Health and Safety Regulation.

Clean up

The blaster should ensure that empty explosives containers are removed from the blast site. They must be handled with care to prevent undue impact or exposure to excessive heat or flame.

Boxes, cartons, and liners that have contained explosives must be collected and destroyed safely or as recommended by the manufacturer. Never allow any explosives packaging materials to be burned in a confined space or a non-ventilated area.

Check that detonators, explosives, and other hazardous substances are separated from other waste material. These items must be destroyed in the manner recommended by the manufacturers. Never abandon any explosives.

Unused explosives and detonators that were on the blast site must be returned to a day box or magazine. The employer should ensure that a blaster inspects unused explosives and detonators. The goal is to determine if they can be stored safely before they are returned to a magazine.

Maintain a blasting log

Under the Regulation, the blaster of record must record and maintain pre- and post-blast loading details and results in a *blasting log*. Blasting logs must be maintained at the worksite. They must be available for inspection by WorkSafeBC officers, workers, and worker representatives.

The employer must ensure blasting logs are kept for at least five years after the blasting operation ends. And they should be kept indefinitely.

The blaster must include the following **pre-blast loading details** in the blasting log:

- Time, date, and location of the blast
- Names of the blaster of record and all other persons handling explosives
- Type and weight of explosives used
- Number of detonators used
- Type of initiating device used

The blaster must also include a **post-blast remarks section**. This section is used to record detailed results of the blast and the results of the post-blast examination.

The blaster should also include the following information in the blasting log:

- Distance from the nearest potentially occupied building or significant structure
- Number of holes
- Hole diameter
- Hole depth
- Burden
- Spacing
- Overburden

- Total quantity of explosives
- Type and length of stemming
- Material blasted
- Number of delays used
- The period numbers of the detonators used in the blast
- Electrical resistance (in ohms) in an electric *blasting circuit*
- Seismograph reading (for close proximity blasting)
- Number of blasting mats and precautions taken to contain flying material

The second part of a blasting log should include a sketch of the blast site that shows the following:

- Details of the loading pattern and *tie-in* for the blast
- The direction to north
- Timing and delays
- Point of initiation
- Nearest structures

Resources

Blasting log templates are available on worksafebc.com. They cover the following types of blasting:

- Urban and construction
- Forestry
- Avalanche control

Look for the "Blasting log templates" section on the Blaster certification webpage.

Submit dangerous incident reports when required

The Regulation requires employers to report to WorkSafeBC in the following cases:

- A blasting accident occurs that causes personal injury.
- Any other dangerous incident occurs involving explosives, whether or not there is personal injury.

In such cases, the employer must do both of the following:

- Report the incident immediately to WorkSafeBC.
- Forward a written report of the incident to WorkSafeBC without undue delay.

The written report of the incident must contain the following:

- The date, time, and location of the incident
- The names and certificate numbers of all blasters involved
- The names and occupations of any persons injured
- The types of explosives, including detonators, and initiating device used
- The instrument used to test the electric blasting circuit
- A factual account of events including the blaster's log records
- The names of all employers responsible for workers present at the worksite when the incident occurred
- The actions taken by each employer

Definitions of reporting terms

Dangerous incidents include the following:

- Incidents involving explosives, whether or not they cause personal injury
- Problems with particular products (for example, repeated or suspicious misfires or premature detonations)

"Immediately" means the reporting should occur as part of the employer's response at the time of the incident. To report a dangerous incident, call WorkSafeBC's Prevention Information Line at 604.276.3100 (Lower Mainland) or 1.888.621.7233 (toll-free). For more information, see the Reporting serious injuries and fatalities webpage on worksafebc.com.

"Without undue delay" means that the written report must be submitted within 48 hours of the incident unless the particular circumstances of the operation prevent this. The report should be submitted to the nearest WorkSafeBC office, which will forward a copy to Certification Services.

For more information, see "Reporting incidents and injuries to WorkSafeBC" on page 35.

Chapter 16:
Misfires

Learning objectives

- Describe misfires and the hazards they can create.
- Discuss the common causes of misfires in charges, cartridge explosives, and initiation systems.
- Discuss misfire wait times by type of initiation system or event.
- Describe how misfires can present differently depending on the type of initiation system.
- Describe the signs of partial misfires, and identify one reason for them.
- Describe procedures for handling misfires safely.
- Explain how to troubleshoot misfires by type of initiation system.

Overview

A misfire occurs when explosives fail to explode, in whole or part, as planned. Misfires are dangerous and increase the potential for an accident. They can cause personal injury, equipment damage, and lost production.

Misfires must be handled with care by certified, experienced blasters. They must be dealt with as soon as possible, yet at a safe and suitable time. If in doubt, contact the explosives manufacturer's representative for expert assistance.

Regardless of precautions taken, misfires can still occur. For this reason, blasters are expected to know the causes of misfires, recognize their indicators, and understand the safe work procedures for handling them.

Causes of misfires

If blasting procedures are carried out properly, the chances of a misfire are greatly reduced. However, for a variety of reasons, misfires do occur. Some of the more common reasons are listed in the sections that follow.

Issues with explosives

Misfires in **charges** can result from the following:

- Detonator becomes detached from a charge.
- Charges in the blast hole become separated by gravel, other materials, or ground movement.
- There is too much space between individual charges.
- Detonators are not hooked into the blasting circuit.
- Cartridges are primed incorrectly.

Misfires in **cartridge explosives** can result from the following:

- Product has deteriorated or reached expiration date.
- Product is frozen or below manufacturer's recommended temperature.
- Cartridges become separated due to water in the hole.

Issues with initiation systems

Misfires in **all types of systems** can result from the following:

- Incorrect use of initiation system
- Damage to initiation system
- Improper use of delay detonators or detonating connectors

Misfires in **safety fuse assemblies** can result from the following:

- Detonator has deteriorated.
- Detonator is damaged.
- Powder core is moist or contaminated.
- Fuse is cut or kinked.
- Fuse or assembly is low quality.
- Safety fuse is damaged.

Misfires in **electric initiation systems** can result from the following:

- Unbalanced circuits (multiple series)
- Improper electrical connections
- Insufficient electric current
- Damage to electric detonator leg wires
- Damage to shot line

- Blasting wire shorted out or connected improperly
- *Current leakage* in blasting circuit
- Blasting machine damaged or defective
- Blasting machine used improperly

Misfires in **shock tube assemblies** can result from the following:

- Tubing is damaged.
- A hole or a row is not connected.
- Moisture has compromised the explosive powder core of the tubing.

Misfires in **electronic initiation systems** can result from the following:

- Current leakage
- Communications interference
- Loss of connection during programming
- Loss of connection after successful programming and in the holding window prior to sending or receiving blast commands
- Dynamic pressure (a high-pressure pulse that results from detonation of adjacent blast holes)
- Incorrect procedures or operations

Other reasons for misfires include the following:

- Explosives have been exposed to extreme temperatures.
- The charge is primed inadequately.
- The blasting circuit or tie-in has not been examined.
- A charge or part of a charge has been "dead pressed" by the detonation of an adjacent charge.
- A charge or part of a charge has been "cut off" due to excessive ground movement (such as a fracture, fault, or joint).
- Loading was improper.
- Coarse stemming has cut the detonator wires or tube.

Misfire wait times

In the case of a known or suspected misfire, no one can enter or move around the blast site until the blaster has examined it. The blaster must also wait until the applicable waiting period has passed before examining the blast site. The duration of the waiting period depends on the method of initiation or type of event, as shown in the following table.

Misfire wait times by type of initiation system or event

Initiation system or event	Required waiting period
Safety fuse	30 minutes from the time the last charge was due to explode, or longer if recommended by the manufacturer
Electric	15 minutes
Shock tube	15 minutes
Electronic	30 minutes
Burning charge (known or suspected)	60 minutes after smoke no longer visible

Burning charge

Burning explosives are highly sensitive and can detonate on their own at any moment. Keep everyone away from a burning charge for the minimum waiting time (one hour after the last visible smoke or as stated in the manufacturer's instructions, whichever is longer). Make no attempt to extinguish burning explosives.

Misfire indicators by type of initiation system

Misfires can present differently depending on the type of initiation system. The following sections describe misfire indicators in several common initiation systems.

Safety fuse

Safety fuse has the greatest delay potential. It may burn more slowly for a number of reasons, such as lower atmospheric pressure at higher altitudes. Temperature and humidity also affect the atmospheric pressure and can cause moist powder or damaged fuse.

With safety fuse, a misfire has occurred if the explosives fail to explode after the determined appropriate time based on the length of the fuse. Under the Occupational Health and Safety Regulation, blasters must wait 30 minutes (or longer if stated in the manufacturer's recommendations) after the estimated time of detonation to return to the blast site. Manufacturers that provide safety fuse in Canada recommend a minimum wait time of **60 minutes**.

Electric

When firing electrically, a misfire has occurred if the explosives fail to explode after attempting to fire the shot. After the attempt, the blaster must do the following:

- Disconnect the *firing cable* (shot line) or lead wires from the power source.
- Shunt the wires.
- Wait 15 minutes (or longer if stated in the manufacturer's recommendations).

After the wait, the blaster should inspect the cable and connections and repair any obvious break in the cable.

In some cases, a break in the cable or a poor connection can be repaired quickly, and a successful detonation can occur on the second attempt. This situation does not count as a misfire.

Hangfires

A *hangfire* is an unplanned delay in the electric detonation of a charge. This delay can occur in any part of the system that is contaminated, damaged, or otherwise defective.

A hangfire may occur when an explosive in a hole begins to burn rather than explode. The fire may eventually cause detonation if it reaches the detonator's *base charge*. Detonation can take a few minutes or seconds after firing the *blasting machine*. Due to the potential for a hangfire, no one should ever approach a misfired electric blast for at least 15 minutes.

Electronic

When firing electronically, a misfire has occurred if the explosives fail to explode after attempting to fire the shot. The blaster must wait 30 minutes (or longer if stated in the manufacturer's recommendations) before returning to the blast site.

Shock tube

When firing with shock tube, a misfire has occurred if explosives fail to detonate after initiating the blast. After the attempt and waiting 15 minutes (or longer if stated in the manufacturer's recommendations), the blaster should first determine whether the powder in the *lead-in line* has burned.

It's easy to tell when a shock tube misfire has occurred because the surface connectors on both the assembly and the delays will remain intact if the shock tube has not fired. In most cases, hooking up missed holes with fresh surface connectors and lead-in line will fire the shot.

Partial misfires and cutoffs

In addition to charges failing to fire at all, misfires can also involve only part of a charge going off.

Partial misfires are the most dangerous kind, as there may be little, if any, evidence to suggest that a misfire has occurred. However, the following signs should arouse suspicion:

- A change in the sound (noise) of a blast
- A change in fragmentation (e.g., oversize boulders in the muck pile)
- Finding detonating cord or undetonated surface connector blocks (tattletales)
- Finding explosives in the muck pile
- Less displacement than expected
- Too much displacement on one side
- High bottom or humps and valleys
- Smoke rising from the pile (could indicate burning explosives)
- Orange- or yellow-tinted fumes (could indicate oxides of nitrogen, which are products of improper detonation)

One reason for a partial misfire is a *cutoff* in the hole. A cutoff is a type of misfire that involves a break in the initiation system. Cutoffs are usually caused by interference such as shifting ground or flying material.

Procedures for handling misfires safely

After the required wait time has passed, blasters can take the following steps to deal with misfires.

Keep the danger area clear of people and assess the hazard

Once the waiting time is over, the blaster of record may approach the misfires or suspected misfires to assess the hazard. As the “all clear” has not yet been sounded, guards must continue to stop traffic and keep people out of the danger area.

Based on the blaster of record’s assessment, the boundaries of the danger area may need to be adjusted. Everyone except the blaster and the equipment operator must be removed from the danger area. Any misfired holes that cannot be dealt with immediately must be clearly marked, and the danger area cordoned off and guarded.

Identify the locations of misfires

Any hole containing a misfired charge should be identified by one of the following:

- Spray painting the collar of the hole
- Placing a wooden marker
- Stuffing a coloured rag in the open end of the hole
- Placing a plastic cone in or near the collar of the hole
- Tying coloured “survey” flagging to a stake near the collar of the hole
- Other effective means

Remove broken material by hand before excavating

The blaster must direct the hand removal of as much broken material as possible before metallic tools or equipment is used. Sparks from metallic tools or equipment can cause accidental detonation.

Do not use metallic equipment to remove broken material unless the following apply:

- A blaster directs the use of the equipment.
- Lighting in the area is adequate.
- Precautions are taken to prevent injury in the event of accidental detonation.

When using an excavator, everyone except for the blaster and the operator must be removed from the danger area. Operators must follow the direction of a blaster and use caution when excavating blast rock. They should understand that a misfire may be handled only by, or under the direction of, a blaster. Adequate safeguards must be provided to protect the blaster and the operator in the event of an accidental detonation.

Specific misfire procedures should be developed for the explosives being used. These procedures must be contained in the blast plan. For advice on developing these procedures, contact the manufacturer or its representative.

Follow restrictions on removing explosives from holes

Until a misfire has been successfully detonated with a fresh primer, the unexploded charge that contains a primer must not be removed. No attempt to remove it may be made, and no other work may take place within the danger area.

Extracting or attempting to extract a primer or explosive of the nitroglycerine type from a loaded hole is prohibited.

A blaster or a person authorized by the blaster may remove ammonium nitrate, water-gel, or emulsion explosives from a blast hole only if all of the following apply:

- The blast hole does not contain a detonator.
- The removal procedure is carried out with caution using:
  - Moderate air and/or water pressure.
  - A blow pipe made of non-metallic materials.
- Stemming material is removed carefully.

Destroy misfired charges

Once a misfired charge has been located and identified, it must be destroyed before other work begins. Misfired charges are usually destroyed by detonation using a fresh primer.

Destruction of misfires should be treated like any other blast. Warning signals should be sounded and the danger area guarded.

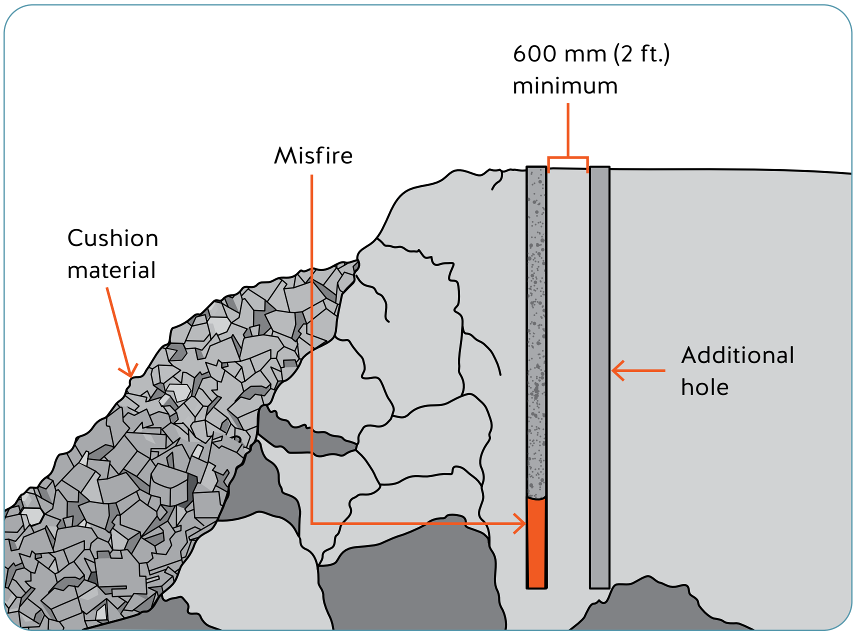
Drill to re-fire a misfire

One way of destroying a misfire is to drill, load, and fire a hole parallel and close to the misfired hole. The purpose of the additional hole and charge is to expose the misfire so it can be destroyed with a fresh primer.

Drilling an additional hole to re-fire the charge is permitted, but only if the following apply:

- The angle of the misfired hole is accurately determined.
- The blaster of record who placed the misfired charge directs the angle and depth of the hole being drilled.
- The hole being drilled is at least 600 mm (2 ft.) from any part of the misfired charge.

These precautions help prevent the possibility of drilling into any undetonated explosives.



Drilling to re-fire a misfire

Ensure sufficient burden before re-firing

If the method for treating the misfire is re-firing, the blaster must ensure that there is sufficient burden before proceeding.

Whenever re-firing is attempted, the blaster must establish that it is safe, or even possible, to do so. If only some holes have misfired, this could mean that there is a greatly reduced burden for the hole(s) to be re-fired. With reduced burden, the rock could fly many times the normal distance, and the air blast would be greatly increased. In some cases, it may be possible to increase the burden and cushion the blast by using methods such as dumping additional material in front of the face.

How to troubleshoot misfires by type of initiation system

The following sections describe how to troubleshoot misfires depending on the type of initiation system.

Electric

If several blast holes (or the complete round) have misfired, and a visual inspection has not revealed the fault, it will be necessary to test the circuit.

Take the following steps before looking for the problem:

- Disconnect the firing line from the power source and shunt it.
- Put the power source under positive control.

Next, disconnect the firing line from the rest of the circuit and re-test it. Then check the leg wires for detonator *continuity* using an approved testing device (e.g., a *blasting galvanometer* or *blasting multimeter*). If there is continuity, it may be possible to fire the missed charge by hooking up the wires again.

If continuity is not present, then use another technique. (See “Locating a break in the circuit” on page 288.) Never pull on the wires leading to an electric detonator.

If a fault is not found, divide the circuit in half and test each half. Continue to divide the defective circuit in half until the defective detonator is found. (Note that there may be more than one.)

Testing must be done from a place of safety. Blasting meters are designed so that the *current* is insufficient to set off a detonator. However, one can never be too careful with a misfire.

Shock tube

If a misfire happens with shock tube, the problem could be with the surface delays or a particular hole. With surface delays, the blaster should be able to replace surface connector blocks or reconnect them to re-fire. If a hole has not fired, a surface connector block will still be intact. These shock tubes can be reconnected and fired. The blaster must ensure that the shock tubes have not been damaged by flying material.

Another test can be performed to verify that a tube has fired. Cut a short piece (15 cm or 6 in.) of the tube. Blow through the tube as if it were a straw, while pointing the other end of the tube toward the palm of your hand. If a small amount of white or greyish powder appears on your hand, the tube or detonator is live. The tube can then be reconnected and blasted.

Safety fuse

Never attempt to re-light any safety fuse. Re-fire with a fresh primer and safety fuse assembly.

Mislight

A *mislight* is a failure or perceived failure of a pull-wire lighter to *ignite* a safety fuse assembly, particularly in an avalanche control setting. A mislight is not considered a misfire.

Part 4:
Initiation systems

Chapter 17:
Safety fuse assemblies

Learning objectives

- Describe the components of a safety fuse assembly.
- Discuss burning speed and the factors that affect it.
- Explain storage and handling requirements for safety fuse.
- Describe procedures for safely igniting a safety fuse assembly.
- Describe acceptable lighting devices.
- Explain how to check that a fuse is actually burning.
- Discuss the hazards of safety fuse assemblies and the precautions to take when using them.

Overview

A safety fuse assembly is made up of a length of safety fuse with:

- A detonator attached to one end
- A removable plastic cover on the other end

A safety fuse assembly

Components

Safety fuse

Safety fuse consists of a special black powder core in a spirally wrapped cover of textiles and waterproof materials. The cover protects against contamination and abrasive damage. It also allows the *fuse* to carry flame to the detonator at a uniform speed.

The shortest safety fuse assembly allowed is 1 m (3.3 ft.) long. In some cases (e.g., with longer fuse assemblies), it may be necessary to *trim* the end of the fuse.

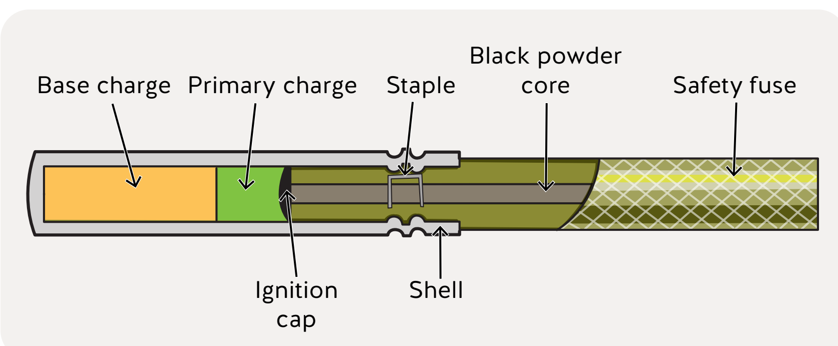
Damaged or deteriorated safety fuse must not be used, as it can result in a misfire.

Detonator

The detonator is an initiating device capable of detonating most explosives. It has an aluminum shell about 6 mm (¼ in.) in diameter and 48 mm (1⅞ in.) long, with a composite charge pressed into the base end.

The composite charge is made up of a primary charge and a high-explosive base charge. The primary charge is heat- and flame-sensitive and composed of *lead azide* and *lead styphnate*. The high explosive is PETN (pentaerythritol tetranitrate).

The *ignition spit* from the safety fuse ignites the primary charge. The primary charge then detonates the base charge.



Cutaway view of a safety fuse detonator

Static shunt (staple)

All detonators used in safety fuse assemblies contain a static shunt. A metal staple is embedded in the detonator. The staple touches the shell and penetrates through the fuse to the powder core. The staple drains off static electricity to help prevent premature detonation.

The static shunt does not provide complete protection from static and other electrical hazards. For this reason, a safety fuse assembly should not be used if excessive amounts of static or other *extraneous electricity* are known or suspected to be present.

Burning speed

The typical burning speed of safety fuse is 131 seconds per metre (40 seconds per foot) at sea level. The actual speed may vary by plus or minus 10 percent.

The burning speed may be affected by the following:

- High altitude, which exerts less external pressure on the powder granules and causes the fuse to burn slower.
- Altitudes below sea level, which cause the fuse to burn faster due to greater external pressure.
- Confinement, which causes the fuse to burn slightly faster. Confinement can result from fuse that is underwater or buried under mud.
- Moisture, which is absorbed by the powder and causes the fuse to burn slower. Moisture absorption usually occurs over a long period of storage. For this reason, it's important to use the oldest product first. In some cases, moisture absorption means the full length of the fuse does not burn, and the result is a misfire.
- Chemicals, oil, and solvents, which can destroy the outer cover and contaminate the powder. This causes the fuse to burn slower or fail to burn (misfire).
- Kinks and bends, which can cause the fuse to burn faster, but are more likely to make it burn slower or fail to burn (misfire).

If a safety fuse assembly comes in contact with itself or another assembly, cross initiation (lighting) may occur.

Storage and handling

To maintain the specified burning speed, the safety fuse must be stored in a cool, dry, well-ventilated magazine. Rotate stock by using old fuse first.

When handling safety fuse, avoid bending, pinching, or twisting it. These actions can damage the covering. In cold weather, warm the fuse slightly before using it to avoid cracking the waterproofing.

Safety fuse assemblies should **not** be used to prime except in an avalanche control operation.

Igniting the safety fuse assembly

Igniting a safety fuse assembly is a critical operation. Difficulties in lighting one assembly while others are burning have resulted in accidents and serious injuries. For this reason, the safety fuse and the lighting device must be in good condition.

Safety fuse is easy to ignite if the lighting device has an intense (hot) flame and the fuse end is clean and dry.

If a fuse end is moist or contaminated, about 25 mm (1 in.) should be cut from the end of the fuse before attempting to ignite it. This is known as trimming the fuse.

The minimum length of safety fuse assembly that can be sold is 1 m (3.3 ft.). The safety fuse must not be trimmed to a length shorter than 90 cm (3 ft.).

A blaster should use two safety fuse assemblies when initiating a blast. This greatly reduces the chance of misfires.

Acceptable lighting devices

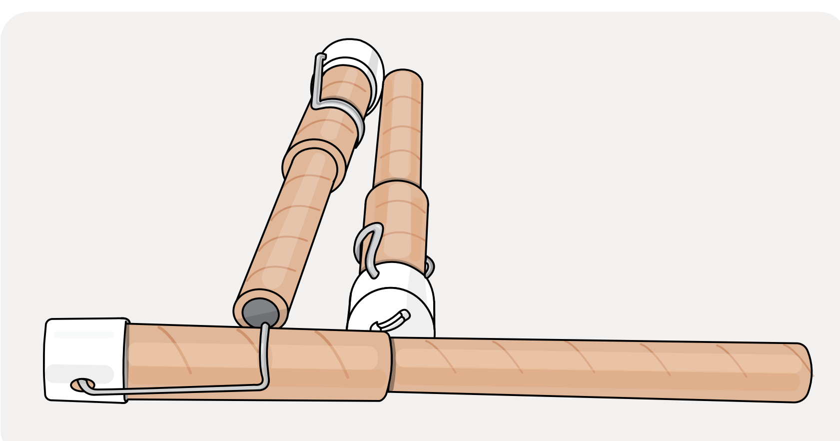
A safety fuse assembly must only be ignited using an acceptable device. Smouldering or open-flame devices such as cigarettes, cigarette lighters, and propane torches are not acceptable for lighting a fuse assembly. Such devices are unreliable and could endanger people in the danger area. In addition, smouldering materials and open flames are prohibited on the blast site.

The following types of devices are acceptable for lighting safety fuse assemblies.

Pull-wire lighters

A pull-wire lighter is a flame-producing device used with a single fuse assembly. It is effective where high winds could hamper other methods of ignition. A pull-wire lighter is the preferred device for lighting a safety fuse assembly.

To prepare the assembly, remove the plastic cap from the end of the fuse. Make sure the inside of the pull-wire lighter and the exposed end of the fuse are clean and dry.



Pull-wire lighters

To attach the pull-wire lighter, gently insert the fuse about 50 mm (2 in.) into the open end of the tube. Internal teeth will hold it in place. Do not apply excessive force or twist the fuse. Serious damage or premature ignition could result.

To activate the pull-wire lighter, hold the tube securely and pull the handle firmly. This will produce an internal flame jet and ignite the fuse.

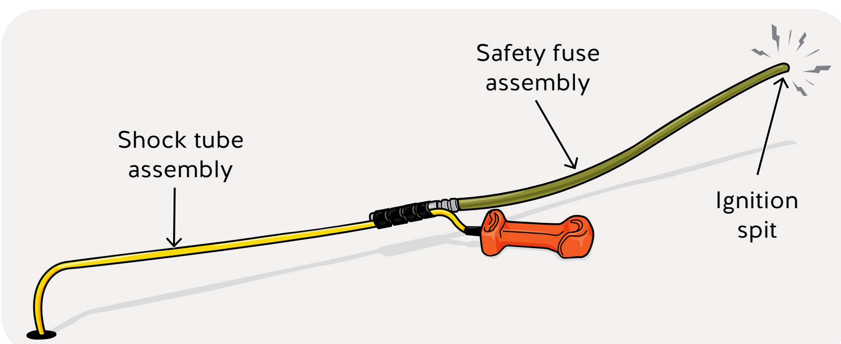
Safety matches

Safety matches only ignite when struck against a specially prepared surface. They are permitted if only one fuse assembly is to be ignited in one operation. Safety matches produce a flame of medium intensity and short duration.

Determining ignition

A blaster must be able to determine that a fuse is actually burning. After lighting the fuse, take about five seconds to check for the following:

- Visible grey smoke
- The acrid smell of smoke
- Discoloured fuse
- Fuse droop (i.e., the fuse becomes very flexible and limp)
- Ignition spit (sparks that shoot out the end of a fuse)



An example of a safety fuse assembly initiating a shock tube assembly and showing ignition spit. (This application would only be acceptable in a remote operation.)

As the fuse burns, the outer covering darkens. But the powder core in the fuse burns ahead of the discoloration.

Everyone but the blaster of record should leave the area before the safety fuse is lit. As soon as a blaster knows or suspects that a fuse is burning, they must leave the area and go to a safe place before the first charge detonates.

Hazards and precautions

The main causes of premature detonation are mishandling and exposure to heat. Impact or shock can compress the explosive charge in the detonator to the extent that it will detonate. Temperatures in excess of 66°C (150°F) can ignite the sensitive detonator. Accidental detonation may also result from improper ignition techniques.

Do not handle detonators roughly, tamper with them, or expose them to heat sources. The human body can generate temperatures that will affect the sensitive composition of a detonator. For this reason, do not carry them in clothing, and avoid holding them in a closed hand.

Note

With the exception of avalanche control, safety fuse assemblies should be used as a last resort. There are much safer options available (e.g., shock tube assemblies used with remote firing systems).

Take care when handling fuse-lighting devices. Mishandling could cause them to ignite prematurely or make them less efficient. When lighting fuses, keep the device away from detonators and heat-sensitive explosives.

In some cases, blasters did not realize a fuse was burning, or they waited too long to leave the blast site after lighting the first fuse. Some of these incidents have resulted in serious or fatal injuries. When more than one safety fuse assembly is ignited, the blast site must be evacuated well in advance of the expected detonation of the first charge (i.e., at least two minutes before).

Returning to the blast site too soon has also resulted in many incidents. If a misfire is known or suspected to have occurred, wait the full 30 minutes (or the manufacturer's recommended wait time) after the last charge was expected to detonate.

Mislight

When a blaster cannot confirm that a safety fuse assembly has been lit, or if an assembly is in an unknown state, the blaster should assume that it is lit. Re-lighting a safety fuse assembly is prohibited. The blaster and all workers should exit the danger area. If the detonator does not initiate the explosives, the blaster can then assume there is a misfire.

Chapter 18: Detonating cord

Learning objectives

- Discuss typical uses of detonating cord and why shock tube assemblies are more commonly used.
- Describe the components of detonating cord.
- Describe how to safely handle and store detonating cord.
- Explain what can cause accidental detonation.
- Describe the process for cutting detonating cord.
- Explain loading procedures, layout patterns, and hookup procedures.
- Describe procedures and materials used to splice or connect detonating cords.
- Describe initiation procedures for detonating cord.
- List the safety procedures for working with detonating cord.

Overview

Detonating cord is an explosive product used to initiate other explosives directly or with a booster or primer. In applications such as pre-splitting or perimeter blasting, detonating cord is used as the main explosive charge. It can also be used with shock tube assemblies and surface delays to increase timing options.

Detonating cord was widely used in the past. However, shock tube assemblies are now more commonly used due to their timing options and lower noise potential. Today, detonating cord is typically used in certain types of pre-splitting or in remote mining operations where noise is not an issue.

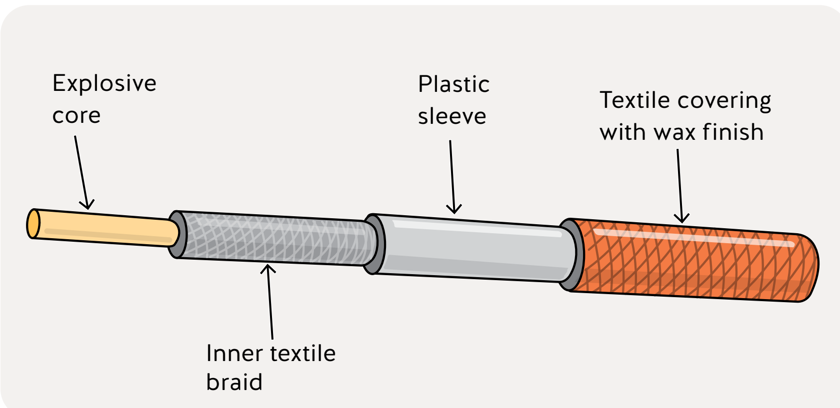
Components

Detonating cord has a core of high-velocity explosive contained in a plastic sleeve wrapped in other materials.

The explosive core is usually made of PETN (pentaerythritol tetranitrate). When initiated by a high-strength detonator, detonating cord explodes with a velocity of about 7000 m (23,000 ft.) per second.

Detonating cord has several layers of covering materials. These typically include an inner braid of textile, a plastic sleeve, an exterior textile covering, and a wax finish. These materials protect the core from abrasion, moisture, and damaging substances.

These layers of covering materials are not necessarily destroyed during detonation. Instead, they may be ejected violently outwards. This can often cause cutoffs.



Cutaway view of detonating cord

There are several types of detonating cord. The strength of the explosive core load can vary between types, as can the quality of the outer covering and its flexibility. Thinner, more flexible detonating cords can be tied together and used in a wide variety of applications.

Explosive strength is usually expressed in terms of grams of PETN per metre (g/m) of cord, or grains of PETN per foot (gr./ft.).

Handling and storing detonating cord

Detonating cord is relatively safe to handle and has good storage properties. However, it can detonate accidentally if it is struck by machinery, falling rock, or lightning. For this reason, detonating cord must be treated with respect.

Protect detonating cords and connectors from damage and abuse. Damaged cord could result in a misfire. Damage to a surface delay connector could result in accidental detonation or a misfire.

Detonating cord can be damaged by:

- Scraping action on metal and rock surfaces
- Contact with bulk loading hoses
- Vehicles driving over it
- Shovels used to place stemming
- Coarse or jagged stemming material
- Frozen chunks of stemming

A reel of detonating cord should not be thrown or allowed to come in contact with tools, rocks, or other sharp objects.

Detonating cords are kept or stored with other explosives. Surface delay connectors that contain sensitive "primary" explosives must be kept or stored with detonators, and not with detonating cord or other explosives.

Detonating cord reels must be kept in boxes when stored in magazines. Once the boxes are opened, reels must be marked and identified with the magazine number and the approximate amount of cord left.

Cutting detonating cord

Cut detonating cord with a knife or a cord cutter. Ensure the cutting edge is sharp and clean. A cord cutter must have a single cutting blade acting against a brass plate or a non-metallic surface. Do not cut detonating cord with scissors, plier-type cutters, or similar instruments.

After cutting detonating cord, the cord ends should be sealed with tape or a plastic sleeve. This keeps the explosive clean and dry. It also prevents the PETN (white powder) from spilling out of the cord.

All cutting tools should be cleaned to remove any PETN from the metal surfaces or moving parts. Contact between PETN and grit or metal may result in accidental detonation.

Loading, layout, and hookup

Loading procedures

Detonating cord is commonly used on the surface to initiate multiple downhole detonators (e.g., shock tube assemblies) attached directly to the detonating cord. Using detonating cord to initiate primers in the blast hole is no longer a common practice.

If planning to use ANFO or emulsion in a hole containing detonating cord, consult the manufacturer's technical data sheets, as this may not be recommended. Detonating cord detonates significantly faster than most commercial explosives. This can cause problems such as misfires, dead pressing, and desensitized and unburnt explosives in the blast hole. Blasting agents must always be adequately primed as recommended by the manufacturer.

Layout patterns

In the past, detonating cord was often used to initiate a blast pattern containing one or more rows of loaded holes. These patterns were initiated instantaneously or with delays.

Today, detonating cord is used primarily for the following:

- Initiating downhole detonators
- Initiating stem charges (small charges placed into stemming to help break *cap rock*, the harder top layer of rock)
- Wall control using a single row (precision pre-splitting)

Depending on how it is used or its location in a blasting circuit, detonating cord is often referred to as the following:

- *Downline* — a length of detonating cord that extends into a blast hole
- *Trunklines* — the lengths of cord on the surface to which the downlines or downhole detonators connect

Hookup procedure

- Do not interconnect blast holes with detonating cord until:
  - All holes are loaded.
  - Immediately before the intended time of detonation.

  That's because an accidental detonation will affect all interconnected charges. However, connecting charges within the hole at the time of loading is permitted.
- Begin connections from the farthest part of the circuit and work toward the point of initiation.
- Keep connections tight and secure, and avoid in-hole connections. If this is not possible, make a tight knot and secure the ends with electrician's tape.
- Remove excess cord from the downlines after tying in, and destroy cut-off ends in a safe manner. This helps prevent cutting off the trunkline.

- Keep all connections at right angles (90 degrees) to the path of detonation. An acute angle can cause a cutoff.
- Ensure there are no loops, sharp angles, or kinks that direct the cord back toward the oncoming detonation path.
- Ensure the circuit has no excessive slack and the cord is undamaged.
- Keep the blast site clean so the detonating cord layout is readily visible.
- Detonators used to initiate the main trunkline should not be connected until:
  - All connections have been visually inspected.
  - Everything is ready for the blast.

Connections

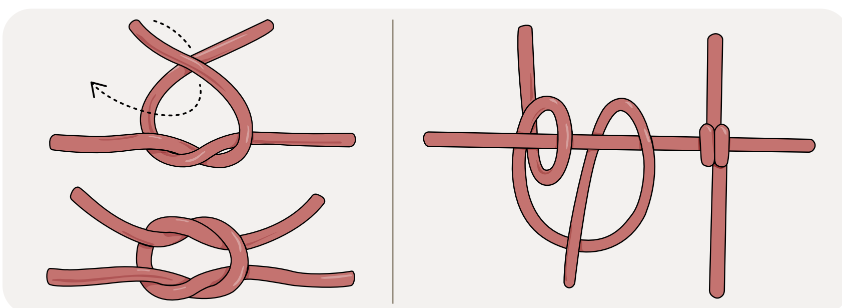
Detonating cords are spliced or connected together using knots, tape, or plastic connectors. A reel of detonating cord may contain a factory splice (an overlap connection secured by a string tie). This splice must not be used in a blasting circuit. When a splice is encountered, the string should be removed and a connection made using a standard knot.

Knots

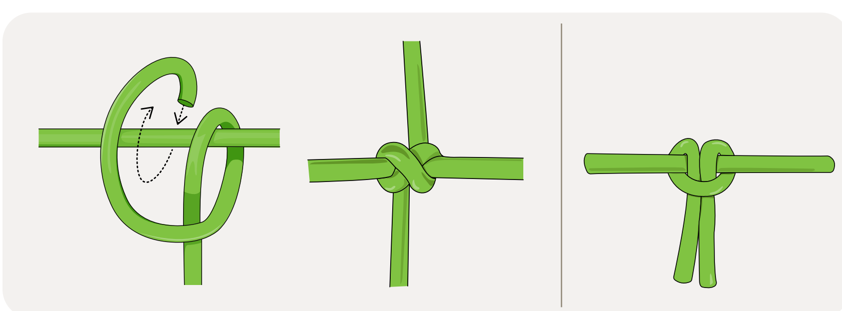
Knotted connections are popular. The flexibility and wax surface of most detonating cords make knot-tying easy and reliable under most conditions and temperatures.

Common knots include:

- The square or reef knot, recommended for joining lengths of trunkline. Ends should be secured (with electrician's tape) or trimmed. This ensures that the ends do not lie across trunklines or downlines and cause cutoffs.
- The double half hitch, a popular connection between downlines and trunklines. Pull the knot tight so the lines are in positive contact.
- The clove hitch and double wrap half hitch, used for connecting trunklines to downlines.



At left, a square or reef knot.
At right, a double half hitch.



At left, a clove hitch.
At right, a double wrap half hitch.

Taping

Two lengths of detonating cord may be connected by overlapping the ends by at least 10 cm (4 in.) and taping them together with electrician's tape.

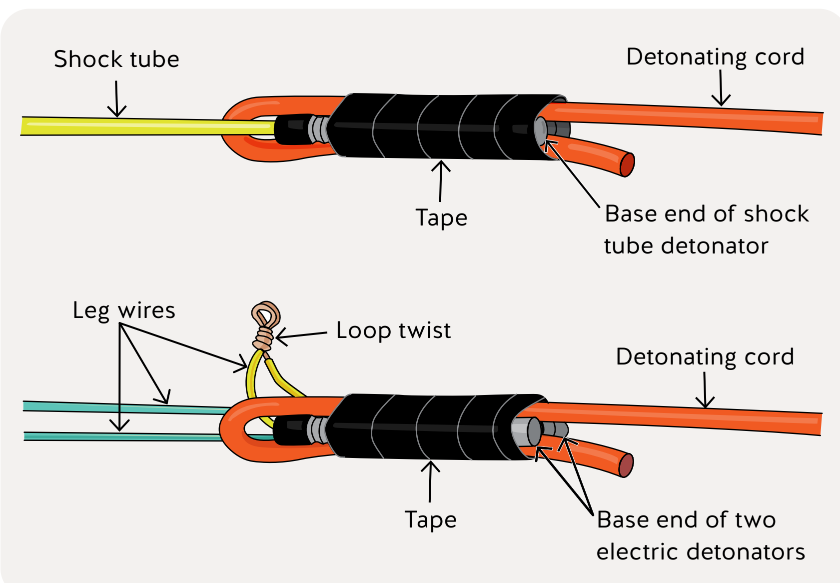
Initiation procedures

Detonating cord is designed to be initiated by a high-strength detonator. Follow the cord manufacturer's recommended initiation procedure.

Dual initiation is the use of two detonators at each initiation point. At least one manufacturer recommends this technique, and many blasters use it. The second detonator helps ensure a successful blast. Dual initiation should be used whenever the blast is critical and the charge is not easily recovered.

In a dual-initiation set-up, detonators to initiate detonating cord should be attached as follows:

1. Bend about 20 cm (8 in.) of the initiating end of the detonating cord into a loop. (Be sure to bend the cord in the opposite direction to its natural curve from being on the spool.) Place the detonators in the loop with the base end (business end) pointing in the direction the shock wave will travel.
2. With the detonators held tightly in position, secure them in place with electrician's tape. Keep the base end of each detonator in contact with the detonating cord.
3. Leave about 6 mm (¼ in.) of the base end exposed. This allows checking for misfires without disturbing the connection.
4. If electric detonators are used, connect them in a *single series circuit* and thoroughly tape all connections.



Methods for attaching detonators to detonating cord. The top image shows detonating cord taped to a shock tube detonator. The bottom image shows detonating cord taped to two electric detonators.

Safety procedures

Select the appropriate detonating cord for the job. The type of cord should match the blasting method and the types of explosives being used. If in doubt, consult the manufacturer or supplier. Do not use damaged detonating cord.

When using detonating cord, do the following:

- Keep and store:
  - Detonating cord with other explosives.
  - Surface delay connectors with detonators.
- Keep cord supply spools in the shipping case before and after use.
- Handle detonating cord as carefully as other explosives.
- Use a hand-held rod or a stand when removing cord from a reel.
- Use a sharp, single-bladed device designed or approved for cutting detonating cord.
- Cut the detonating cord downlines from the spool before loading the rest of the explosives into each hole. An accidental detonation within a hole could detonate the spool on the surface.
- Cut the detonating cord trunklines from the spool before attaching downhole detonators.
- After loading and cutting a downline from the spool, either stem the hole or secure the end of the downline to a wooden dowel or other anchor. This is an important step if there is any possibility of the downline slipping into the hole.
- Avoid abrasion to the cord from hole collars or other sharp edges.
- Connections between detonating cords should not occur within blast holes. These connections could be damaged when explosives or stemming is added.
- Collect all scrap pieces of cord and destroy them as recommended by the manufacturer.
- Do not attach detonators for initiating the blast to detonating cord until the blast area has been cleared and secured for the blast.
- Attach the cord-initiating detonator at least 15 cm (6 in.) from the cut end of the detonating cord.
- Use surface delay connectors designed for use with detonating cord.
- Do not damage detonating cord prior to firing.

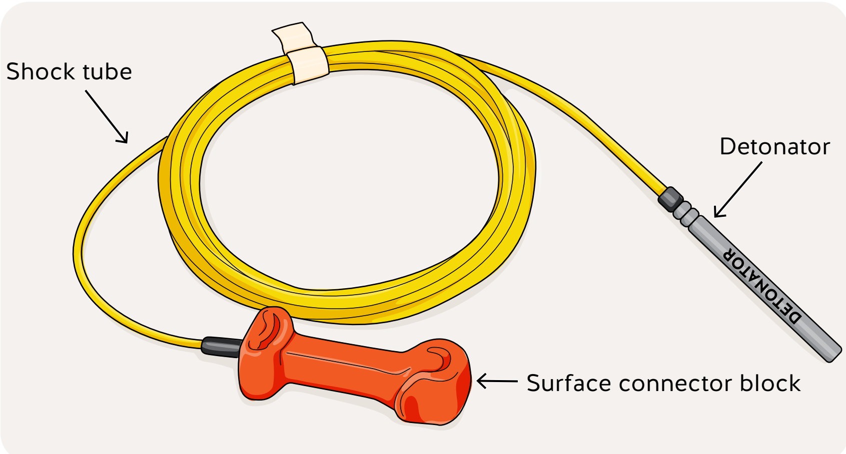
Chapter 19:
Shock tube assemblies

Learning objectives

- Identify the components of a shock tube assembly.
- Describe the safety features that contribute to the electrical safety of a shock tube assembly.
- Discuss the range of delay-timing options for shock tube assemblies.
- Distinguish between surface delay timing and downhole delay timing.
- Describe the requirements for storing and handling shock tube assemblies.
- Explain the procedures for splicing and when it is permitted.
- Describe the procedures for priming and loading with shock tube assemblies.
- List the recommendations for connecting shock tube assemblies.
- Discuss the initiation options and procedures for shock tube assemblies.
- Describe safety procedures for using shock tube assemblies.

Overview

A shock tube assembly is a length of shock tube with a high-explosive detonator on one end and a surface connector block or a connecting clip on the other end. The assemblies are available in a range of lengths and delay-timing options.



A shock tube assembly

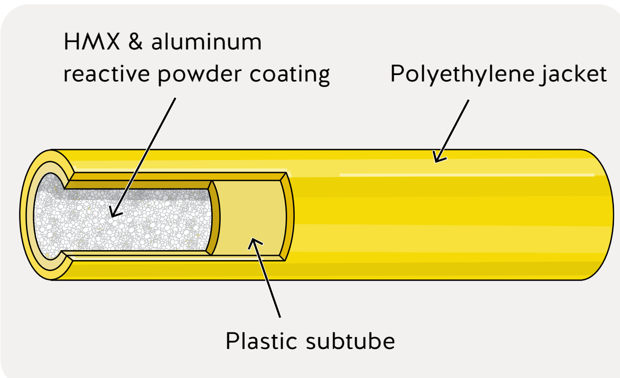
A shock tube assembly is a non-electric type of initiation system. Shock tube assemblies are widely used and are highly preferred in industry over electric initiation. That's because of their electrical insensitivity, durability, flexibility, and ease of *hookup*. The main advantage of a shock tube assembly is its lower sensitivity to stray current. The main shortcoming is the inability to test the circuit prior to initiation.

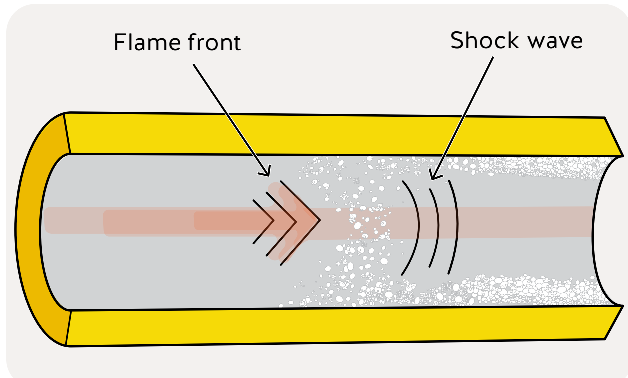
Components

Shock tube

Shock tube is a plastic tube coated with a thin layer of reactive powder on the inside. This reactive powder is usually a composition of HMX (a high explosive) and aluminum. A static charge holds the powder on the inside wall of the tubing.

When sufficient external shock is delivered to the tubing, the reactive components shake loose from the wall and the ignition occurs. This reaction continues and generates a shock wave. The shock wave travels internally through the tube at about 2000 m (6,560 ft.) per second.



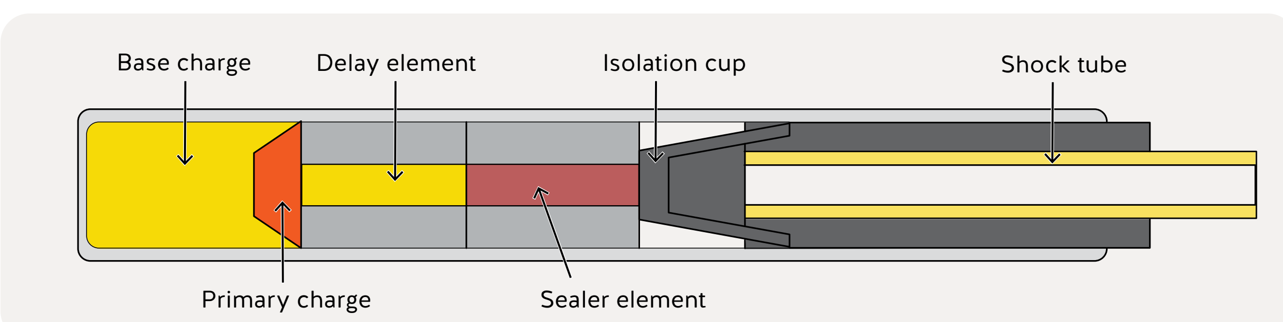


At left, a cutaway view of shock tube. At right, a cutaway view of the reactive powder igniting and generating a shock wave inside a shock tube.

The shock wave's energy stays contained in the tube, which remains intact due to the strength of the plastic. This feature allows a shock tube assembly to be used with any explosive, regardless of its sensitivity. The shock wave will not initiate explosives within contact until it reaches the detonator.

Detonator

The detonator has an aluminum shell about 7.5 mm (⅓ in.) in diameter and between 58 and 84 mm (2¼ and 3¼ in.) long, depending on the delay period. The primary charge is lead azide, a heat-sensitive explosive. The base charge is PETN, a high explosive. The shell also contains a millisecond (ms) *delay element*.



Cutaway view of a shock tube detonator

The shock wave from the shock tube enters the shell, bursts through the isolation cup, and reacts through the sealer element and delay element. This ignites the primary charge, which in turn detonates the base charge.

Surface connector block or clip

A surface connector block or clip connects the shock tube assembly to one of the following:

- Another shock tube assembly in a nearby hole
- An initiation source at the top of the hole

A surface connector block is also used to initiate an entire blast. This is usually done by removing the block from a shock tube assembly or surface delay and splicing it to the lead-in line. Always follow the manufacturer's recommendations for these procedures.

Safety features

There are three main features that contribute to the electrical safety of a shock tube assembly:

- Isolation cup
- Plastic tubing
- Electrostatic bleeder

Isolation cup

The most important safety feature is the detonator's isolation cup (or anti-static cup). The cup is made of a conductive plastic. It provides a path for any electric current travelling down the tube to be dispelled from the detonator shell.

Plastic tubing

Shock tube may conduct static electricity or stray current. However, the plastic tubing is highly resistant, and the conductivity is much lower than with electrical leg wires.

Electrostatic bleeder

The detonator's sealer element contains an electrostatic bleeder. The electrostatic bleeder's purpose is to disperse any electric current or static electricity that has travelled down the tube.

Note

Despite these safety features, blasting operations involving shock tube assemblies must be suspended in the presence of lightning or approaching storms. A lightning strike has the potential to set off the assemblies.

Delay options

Shock tube assemblies offer a range of delay-timing options. These options allow blasters to set up a variety of efficient blast patterns. This section explores several common delay options.

Dual-delay assemblies

Dual-delay shock tube assemblies are made up of the following:

- A high-strength detonator on one end
- A length of shock tube
- A low-strength initiator on the other end, contained within a plastic housing called a surface connector block

The term “dual-delay” means there is a delay in the detonator and a delay in the surface connector block.

The surface connector block allows for quick, easy connection to other shock tube assemblies or to tubing. This allows the blast to be expanded to any size.

Dual-delay shock tube assemblies are more commonly used today than single-delay assemblies.

A worker holds several standard 25/500 ms dual-delay shock tube assemblies.

The surface connector block contains a low-strength initiator that is suitable only for initiating other shock tubes. This reduces the risk of cutoffs due to shrapnel. The surface connector block should clip to the next shock tube assembly to fire. Then the connector should be slid toward the collar of the blast hole. This removes slack and allows for good pre-blast visual inspections.

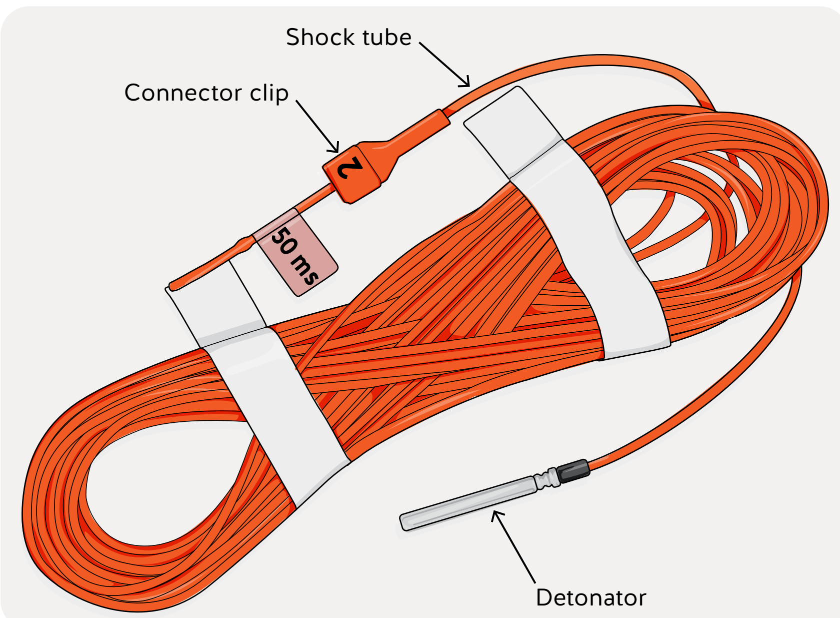
The most common dual-delay combination is a 25/500 assembly (25 ms surface and 500 ms downhole). The downhole detonator initiates after the surface initiator. This prevents cutoffs to downlines and trunklines during ground movement within a blast. A number of timing combinations are available to help blasters accomplish complex delay patterns.

Single-delay assemblies

Single-delay shock tube assemblies come with a predetermined length of shock tube. One end has a heat seal with a plastic connector clip. The other end has a high-strength detonator.

Single-delay assemblies are designed to be used as downhole detonators for initiation. Single delays come equipped with a connector clip that works with the following initiators:

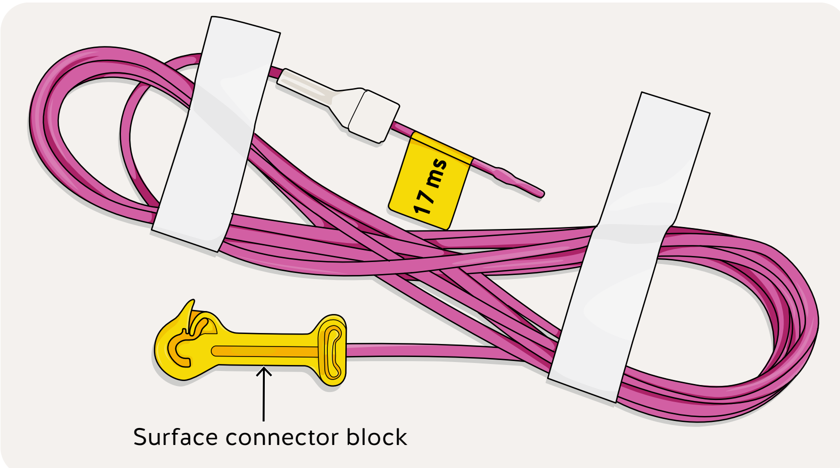
- Detonating cord
- Electric or non-electric detonators
- Shock tube starter devices



A single-delay assembly with a connector clip

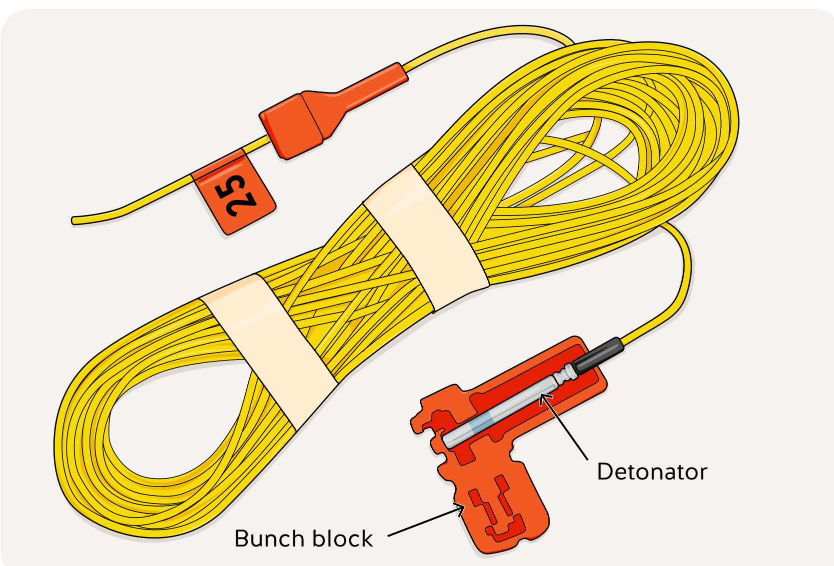
Surface-delay assemblies (trunkline delays)

Surface-delay shock tube assemblies provide out-of-hole delays in non-electric blast patterns. Most surface-delay assemblies use the same surface connector block found on dual delays. This type of connector is only suitable for initiating other shock tubes.



A surface-delay assembly (trunkline delay)

Other kinds of surface delays may have the detonator end contained within a removable "bunch block" (or other plastic fitting capable of holding multiple shock tubes in close contact with the detonator). These are used with detonating cord downlines or other shock tube detonators. Always consult the manufacturer's recommendations for proper use.



A surface-delay assembly with the detonator end contained in a removable bunch block

Product delay times

Shock tube detonators are either short- or long-delay types. Manufacturers produce shock tube assemblies with various colour codes. The connector block colour represents the delay time. The delay time is also displayed on a tag or on the connector block. The shock tube colours represent either the tube length or its tensile (breaking strength). While these colours are usually universal (i.e., used across products and manufacturers), always consult your manufacturer's technical data sheets.

Surface delay times by connector block colour

Surface delay time (in ms)	Connector block colour
17	Yellow
25	Red/orange
33	Green
42	White

At left, dual-delay shock tube assemblies. At right, surface-delay assemblies.

Timing with shock tube

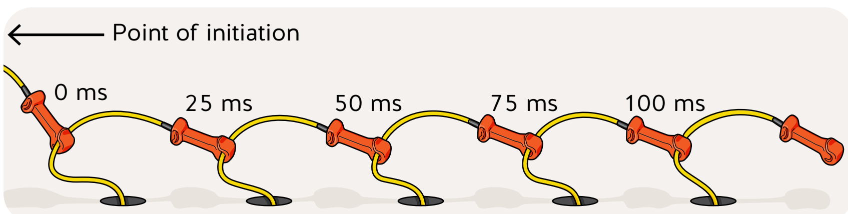
Not only can the delays be timed between holes in a row, but the individual rows can also be delayed.

Surface delay timing

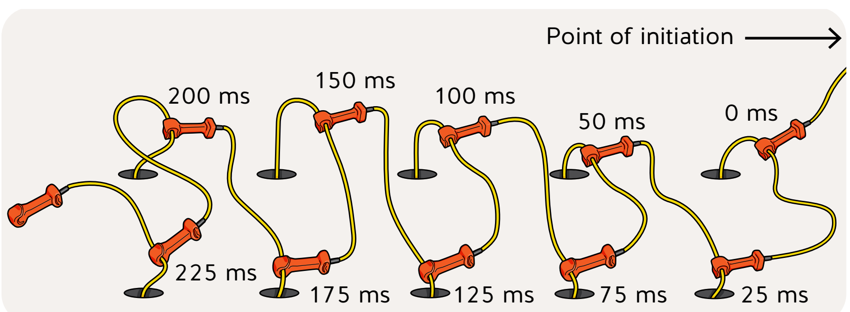
Surface delays can be used to create the timing needed between blast holes and rows in various patterns of all sizes. The goal is to produce an efficient blast with enough time between each hole to achieve good fragmentation and less throw or heave.

In a single-row pattern, the shock tube assemblies are usually connected from one hole to the next hole to fire (i.e., daisy chained). See the "single-row pattern" drawing below.

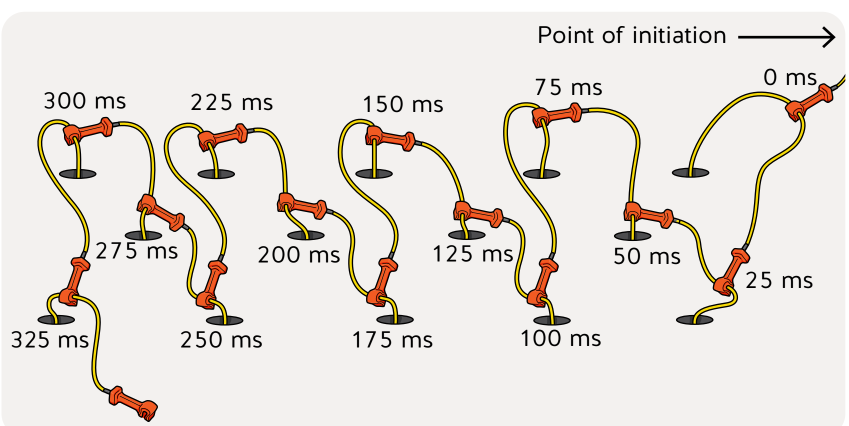
The following drawings show examples of using dual-delay shock tube assemblies to achieve one hole per delay of timing.



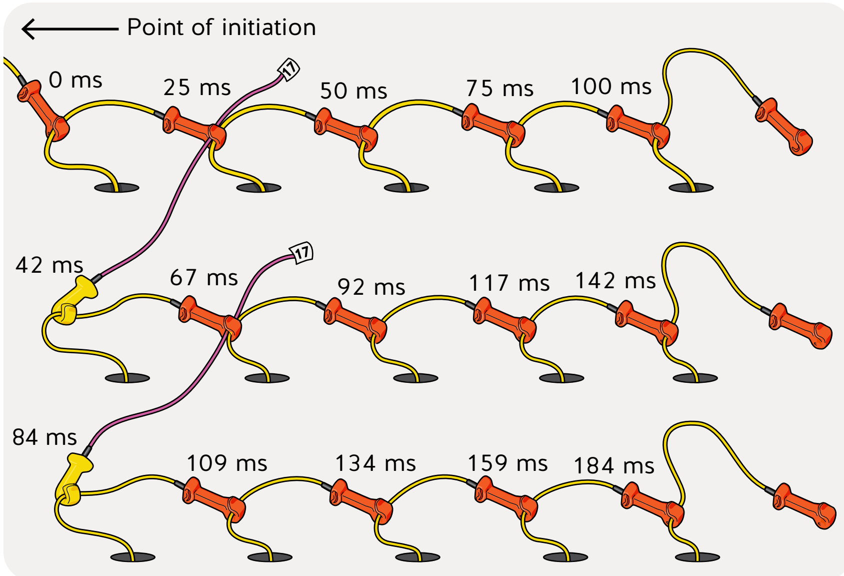
This is a single-row pattern of dual-delay shock tube assemblies with the surface delay times marked.



This is a simple example of a trench pattern with surface delay times marked.



This is a five-of-dice trench pattern with surface delay times marked.



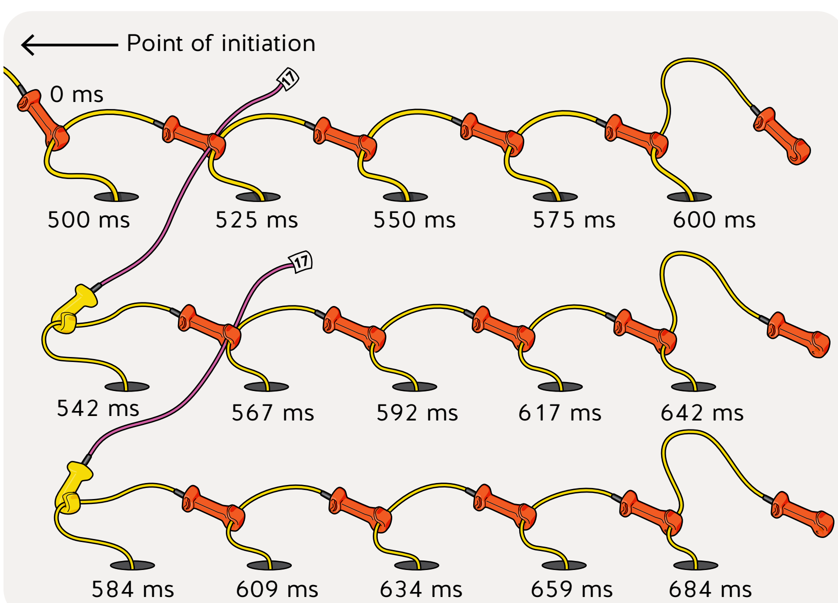
This is an example of using surface delays to fire additional rows of dual-delay assemblies. The surface delay times are marked.

When calculating the timing of surface delays for dual-delay shock tube assemblies, the first hole to fire is considered to be zero milliseconds. The time for additional surface delays is added from there.

In other applications, a single surface connector block can be used to connect to more than one hole at a time. However, this requires accounting for holes firing at the same time.

Downhole delay timing

Calculating the complete timing of a blast includes factoring in the downhole delay time on the first hole. At the end of the downhole delay time, the first hole initiates. The holes that follow will then initiate based on their surface delay timing, as shown in the diagram below.



This is an example of calculating timing, including downhole delays and surface delays. The delay times are marked.

Storage and handling

Shock tube assemblies must be properly stored and treated with care. Since the detonators contain sensitive explosives, all shock tube assemblies must be stored with detonators, not with detonating cord or other explosives.

Shock tubes must remain undamaged. Do not throw them or allow them to contact tools, rocks, or other sharp or jagged objects. If cut, nicked, or otherwise punctured, shock tube may not function properly. The location of the damage may become a point where the shock wave that travels within the tube can vent out, stopping the reaction from progressing.

No one should hold shock tube when it is initiated. A manufacturing flaw or damage to the tubing could cause serious injury.

Shock tube must be kept sealed, dry, and uncontaminated. Unspliced tubing and detonators are impervious to moisture, but fuel oil can penetrate the plastic tubing. Prolonged exposure to ANFO mixtures can result in failure to initiate or propagate. Shock tube must not be exposed to ANFO mixtures or other oil-containing explosives in a loaded hole for more than a few days.

Assemblies must be protected from high temperatures and damaging substances. Temperatures in excess of 75°C (167°F) can cause the tubing to soften. At lower temperatures, the tubing stiffens but will not shatter or crack unless it has surface nicks or abrasions. With careful handling and loading, shock tube assemblies have been used in temperatures as low as -40°C (-40°F).

Damage to shock tube can occur as a result of the following:

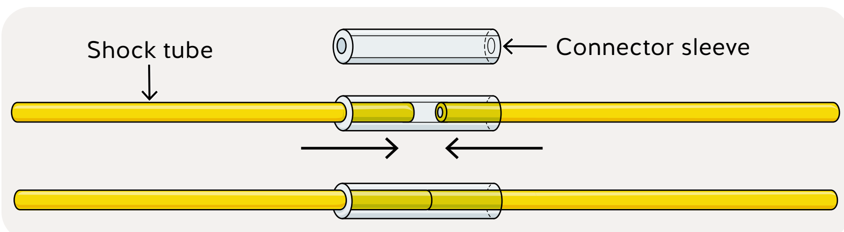
- Scraping action on metal and rock surfaces
- Contact with equipment
- Workers tripping over connected tubing
- Vehicles driving over the tubing
- Contact with shovels used to place stemming
- Contact with coarse or jagged stemming material
- Contact with frozen chunks of stemming material
- Dragging action when placing blasting mats with an excavator
- Explosive ejection of the coverings from detonating cord as it detonates

Splicing

To provide a safe distance from the blast to the blaster upon initiation, the blaster will run a *lead-in line* of shock tube. (A lead-in line is a long line of shock tube between the point of initiation and the blast.) This requires a factory-installed or spliced connector block on one end of the lead-in line used to connect and initiate a loaded blast.

The act of splicing is precise and may only be done when taking every reasonable care. Manufacturers do not permit spliced connections anywhere in a blast other than to initiate the first hole. The reason for this is that the amount of movement a blast creates will cause cutoffs. Using the last connector of a blast row (the tattletale) to initiate a blast is also not recommended. This is because the tattletale provides visual evidence that all holes have successfully fired or not.

Splicing procedures for an assembly are specific to the manufacturer's recommendations. The manufacturer's accessories and techniques for splicing must be used. Otherwise, moisture can enter the explosive lining and render it insensitive. Also, a blowout may occur through the open end and prevent the shock wave from reaching the detonator.



Splicing shock tube with a connector sleeve. At bottom, the shock tubes are coupled tightly together and ready for taping.

While preparing a lead-in line connection for initiation, best practices for splicing shock tube are as follows:

- Always use a clear, clean *connector sleeve*.
- Keep the sleeve and the connections completely dry. Wet connections may fail to propagate.
- Cut the tube at clean, straight angles. Take care not to crush or collapse the ends.
- Push the two ends together tightly in a connector sleeve.
- Using electrician's tape, tape one side of the tube and the connector. Then give the other side a firm push inward. This helps ensure the ends are still connected tightly. Then tape the other side of the connector and the tube. Double wrap the tape to ensure the two ends don't come apart.
- Do not place spliced shock tube under pressure.
- Ensure that the cut end of the tubing (i.e., from the spool or the tail of an assembly with the connector block removed) is tied in multiple knots, taped, or capped with the manufacturer's supplies. This helps prevent moisture from entering the tubing or loss of the explosive powder core.
- When cutting lead-in line from a spool, always cut off at least 30 cm (1 ft.) of tubing before attaching a connector block. This helps ensure a fresh, dry powder core.

Priming and loading

A shock tube assembly contains a high-strength detonator capable of initiating many types of explosives. To reliably initiate insensitive explosives, a primer or a high-strength booster is required.

Under normal conditions, plain tubing may be appropriate. Under adverse conditions, reinforced tubing may be required.

When loading a hole with a shock tube assembly, do the following:

- For a dual-delay assembly, use sufficient tubing to allow enough tail to be present outside of the hole to reach the next hole.
- Lower the primer into the hole. Do not drop ("airmail") it.
- Do not use the shock tube as a lowering line on a heavy primer. The weight of a primer can damage or stretch the tubing and cause a failure. Use a special lowering rope with a self-releasing hook.
- Ensure the primer is in the desired position in the hole, preferably at the bottom (toe).
- Hold the shock tube taut to one side of the hole during loading and stemming. This helps prevent damage to the shock tube and displacement of the detonator.
- When loading bulk explosives, ensure the shock tube does not tangle around the bulk loading hose. Also, check that the primer does not "float" up as the hole is being loaded.
- Never pull on shock tube to the point of breakage. If it breaks, there is a slight chance that it may initiate ("snap, slap, and shoot") and fire the hole.

Prior to adding stemming, secure the tubing to prevent it from being kicked into the hole or pulled in by explosives slumping in the hole. Leave sufficient slack to allow for some slumping.

Use care in stemming the hole. Avoid using frozen chunks and jagged material as stemming. Also avoid contacting the tubing with shovels or other tools.

Connecting shock tube assemblies

Follow the manufacturer's directions for using shock tube assemblies and trunkline delays.

Some recommendations for connecting shock tube assemblies are as follows:

- Do not connect shock tube until all holes are loaded and stemmed.
- Do not connect shock tube until the last practicable moment before the intended time of detonation. Accidental detonation will initiate all connected charges.
- Keep connections tight and clean. Loose, dirty connections can result in cutoffs.
- Use assemblies with the appropriate length of tubing.
- Do not cut (trim) or lengthen shock tube assemblies.
- Ensure there is no damage to the tubing and no excessive slack.

What does practicable mean?

Under the Occupational Health and Safety Regulation, practicable "means that which is reasonably capable of being done."

Initiation options and procedures

No person should hold shock tube when it is initiated. A manufacturing flaw or damage to the tubing could cause a blowout and result in serious injury.

Follow the manufacturer's instructions concerning the correct trunkline and connection configuration for each type of assembly.

Shock tube and shock tube lead-in line were originally designed to be initiated by a high-strength detonator. Examples of high-strength detonators include electric detonators and safety fuse assemblies. Other types of explosives are considered unreliable for initiation.

Today, the most commonly used initiation sources for shock tube are mechanical devices that use a shot shell primer activated by a firing pin. Examples of shock tube initiators include thumper or mushroom starters and hand starters (shot shell starters).

Thumper or mushroom starters

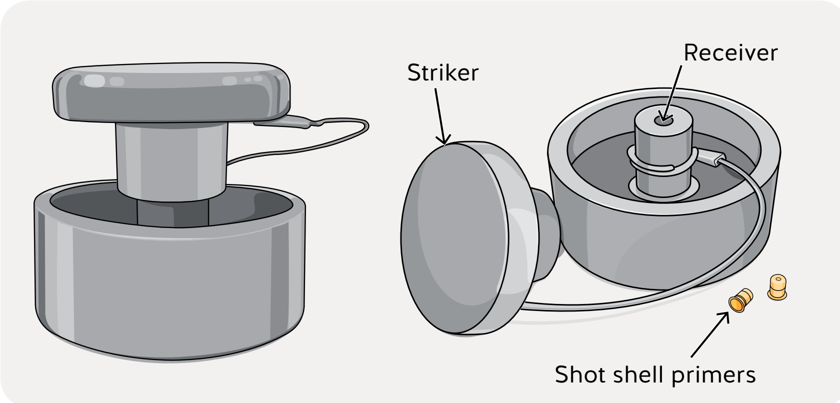
Follow the manufacturer's directions for using the starter. Use the starter only to initiate shock tube lead-in line.

When preparing to use a thumper or mushroom starter, do the following:

1. Insert shock tube from the outside through the upper hole in the safety ring on the starter base.
2. Pull through 15–20 cm (6–8 in.) of shock tube.
3. Pass the shock tube back over the rim of the safety ring.
4. Pass the shock tube through the lower hole into the port in the barrel as far as possible.
5. Pull the loop formed as tight as possible.

To fire:

1. Remove the striker from the receiver.
2. Place a shot shell primer in the receiver.
3. Place the striker back in position gently, allowing the spring to hold the striker up in the ready position.
4. Set the starter on the ground or a solid object.
5. Strike the starter firmly with a foot or a fist.

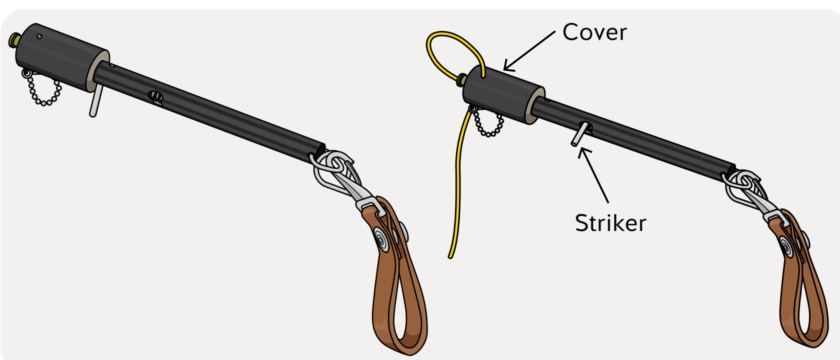


At left, a thumper or mushroom starter. At right, preparing a thumper or mushroom starter for firing.

Hand starters (shot shell starters)

To initiate shock tube with a hand starter, do the following:

1. Pull the striker back so it locks in place.
2. Slide down the cover.
3. Load the shot shell primer in the receiver.
4. Slide the cover back up.
5. Gently place the striker back in its starting position (to avoid accidental initiation).
6. Thread the shock tube through the cover and then into the receiver hole.
7. Pull the striker back. When ready, release it to fire the shooter.



At left, a hand starter. At right, an armed hand starter, shown just before releasing the striker.

High-strength electric detonators

To initiate with a high-strength electric detonator, do the following:

1. Attach the detonator to the shock tube by securely taping them together with electrical tape. Ensure that the detonator's business end points in the direction of initiation.
2. Ensure the lead-in line is long enough to prevent detonator shrapnel from cutting off the blast.
3. Place the detonator on the ground and carefully cover it with dirt or sand to contain shrapnel and prevent cutoffs. High-strength detonators (electric or non-electric) produce large amounts of metallic shrapnel when they detonate.
4. Check the resistance of the shot line (firing cable) and the detonator prior to blasting.
5. Fire the blast with a blasting machine.

Note

An electric single-series endorsement (an add-on to the blaster's certificate) is required to initiate shock tube assemblies with this method.

Safety procedures

When using shock tube assemblies, do the following:

- Select the proper assembly and trunkline for the job.
- Avoid abrasion to the shock tube from sharp or jagged objects.
- Do not use damaged tubing, as it may not initiate or propagate.
- Follow the manufacturer's recommendations for cutting and splicing shock tube for lead-in lines and trunklines.
- Do not connect the assemblies until the last practicable moment.
- Ensure the trunkline is not damaged or located near a sensitive explosive.
- Make proper connections. Ensure they are tight and clean, and are at right angles to, or in the general direction of, the detonation path.
- Where necessary, use two detonators at each initiation point.
- Collect all scrap tubing and destroy it. (You may attach unused connector blocks to the last row of holes to fire them.)
- Return all unused shock tube assemblies and other explosives to a safe location.
- Avoid situations where initiation system components can become entangled in machines, equipment, vehicles, or their moving parts.
- Unhook surface delay connectors before dealing with a misfire.
- Protect surface delay connectors from unintended energy sources such as the following:
  - Impact from falling rock.
  - Impact from tracked vehicles, other mobile equipment, or drilling equipment.
  - Flame.
  - Friction.
  - Electrical discharge from power lines.
  - Static electricity.
  - Lightning.
- Do not drive vehicles over shock tube.
- Do not pull, stretch, kink, or put tension on a shock tube such that the tube could break or otherwise malfunction.
- Do not hook up a surface delay connector to its own shock tube.
- Do not leave an unhooked surface delay connector near the shock tube of a loaded hole.

Chapter 20:
Electric initiation systems

Learning objectives

- Describe the principles of electrical theory.
- Explain the water tank analogy as it relates to current, resistance, and voltage.
- Describe Ohm's law and the Ohm's law triangle.
- Discuss the basics of electrical initiation.
- List and describe the components of electric initiation systems.
- Describe electric detonators, their purpose, and their components.
- Explain how detonator delays work.
- Describe leg wires and what they are made of.
- Discuss the safety features of modern commercial electric detonators.
- Describe generator and capacitor discharge blasting machines and how they work.
- Explain the requirements for marking and maintenance of blasting machines.
- Describe the different types of blasting wire used in blasting.
- Explain how to secure connections between lengths of wire in a circuit.
- Describe the types of equipment required for testing electric detonators and blasting circuits.
- Describe how to test a circuit.
- Explain blasting circuit configurations.
- Demonstrate how to calculate blasting wire resistance for single and multiple series circuits.
- Describe how to calculate the voltage required to successfully initiate a blast.
- Discuss causes of extraneous electricity and their potential for causing premature detonation of electric detonators.
- Describe general safety precautions to take when working with electric initiation systems.

Overview

Electric initiation systems use detonators designed to be initiated by the basic principle of electric current flow. When voltage is applied from a source, the current travels through a circuit and returns to the voltage source.

The main benefit of using electric detonators is the ability to test the circuit. The goals are to verify resistance and continuity (meaning there is no break or fault in the circuit) before initiating a blast. The main limitation of using electric detonators is the risk of initiation by stray current.

This chapter deals with the principles of electrical theory and the components and methods of electrical blasting.

Principles of electrical theory

Before using electric initiation systems, a blaster must understand basic electrical theory and Ohm's law.

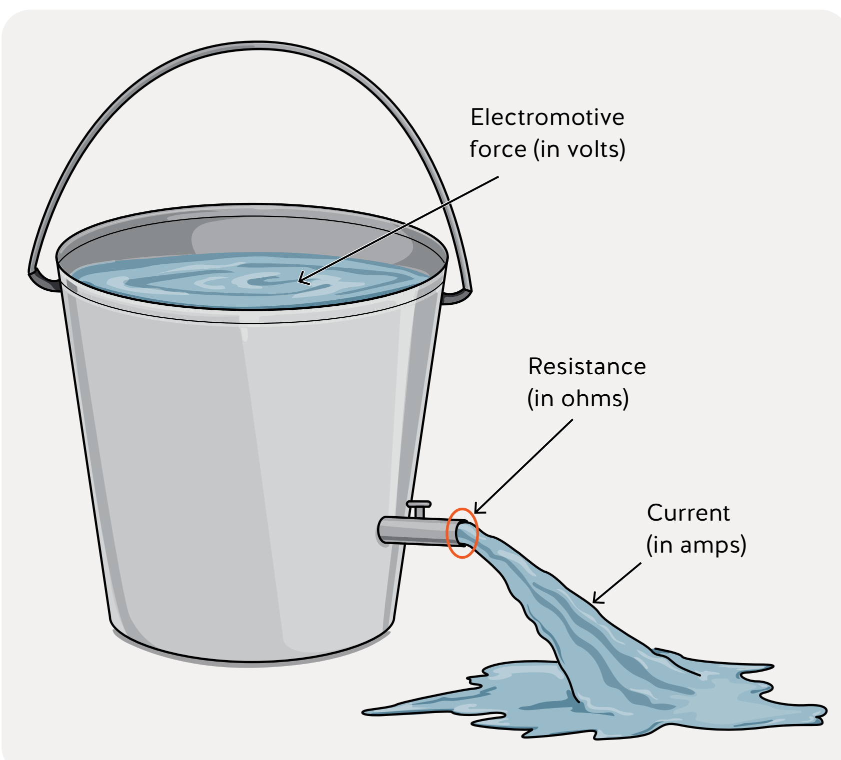
Electricity is a type of energy that occurs in two forms: dynamic (current) and static (charge). Dynamic electricity involves the flow of electrons along a conductor. This flow is known as *current*, which is measured in *amperes* (amps).

Current flows more easily along a good conductor (e.g., copper wire) than a poor conductor (e.g., dry wood). The difficulty encountered by the flow of current is known as *resistance*, which is measured in ohms.

Current moves because of a difference of potential within the circuit. This is known as electromotive force, which is measured in *volts*. One volt is the amount of electromotive force necessary to move 1 ampere of current across 1 ohm of resistance. The following analogy can be used to demonstrate this relationship.

Water tank analogy

A tank contains water. Water flows from a 25 mm (1 in.) diameter pipe at the bottom of the tank. The force of gravity causes the water to flow from the pipe, but the flow rate is restricted by the size of the pipe.



The water tank analogy

The analogy works as follows:

- The flow of water represents current (in amps).
- The size (diameter) of the pipe represents resistance (in ohms).
- The gravitational pressure represents electromotive force (in volts).

An increase in current means more water flows through the pipe. A larger pipe will allow this to happen because it offers less resistance. Conversely, a smaller pipe offers more resistance. The greater the height of water in the tank, the greater the gravitational pressure, which is the force behind the water.

Just as water flows inside a pipe, electric current flows within the solid portion of a conductor. A conductor is any material capable of carrying this flow.

Electricity travels at the speed of light, 300 000 kilometres (186,000 miles) per second. As a result, it passes through an electric blasting circuit in a fraction of a second. And initiation of detonator bridgewires is virtually instantaneous.

Depending on the power source, the current is one of the following types:

- Alternating (*AC*, such as that found in household lighting or outlets)
- Direct (*DC*, such as batteries in a flashlight or in automobiles)

Most blasting machines produce direct current.

The composition of a conductor determines its resistance to the flow of electric current. Copper is a good conductor, so it offers little resistance.

The diameter (thickness) of a conductor also affects its resistance. As diameter is increased, resistance is decreased. Wire thickness is expressed in gauge or *AWG* (American Wire Gauge). Thicker wire has a low AWG number, and thin wire a high AWG number. Wires used for blasting range from 8 to 22 AWG. Leg wires on electric detonators are usually 22 gauge. Firing cables may be as thick as 8 gauge.

Length also affects conductor resistance. As the length increases, the current has a greater distance to travel. For this reason, the resistance increases. Resistance increases with each unit of length. The resistance of wire is usually stated in units of 305 metres (1000 feet).

The condition of a conductor can affect its resistance. Contamination, deterioration, oxidation of the bare metal exposed ends, or damage will usually increase resistance.

Ohm's law

Ohm's law describes the mathematical relationship between voltage, current, and resistance. The blaster of record usually knows two of these variables and needs to calculate the third.

Resistance (in ohms)

Ohms are the standard measure of resistance to the flow of current.

Current (in amperes)

An ampere is a unit of electric current produced by 1 volt acting through a resistance of 1 ohm. A minimum of 1.5 amps DC is required to detonate each series of electric detonators.

Voltage (in volts)

The power source must have the necessary voltage to reliably initiate all detonators in a circuit. To calculate this voltage, apply Ohm's law. Ohm's law states that voltage equals current (amps) multiplied by resistance (ohms). This formula is expressed as:

$V = I \times R$

Where: V = Voltage (in volts)

I = Current (in amperes)

R = Resistance (in ohms)

Once the total resistance and total required current have been determined, multiply them to calculate the voltage. Then verify that the power source provides enough voltage to reliably initiate the blasting circuit.

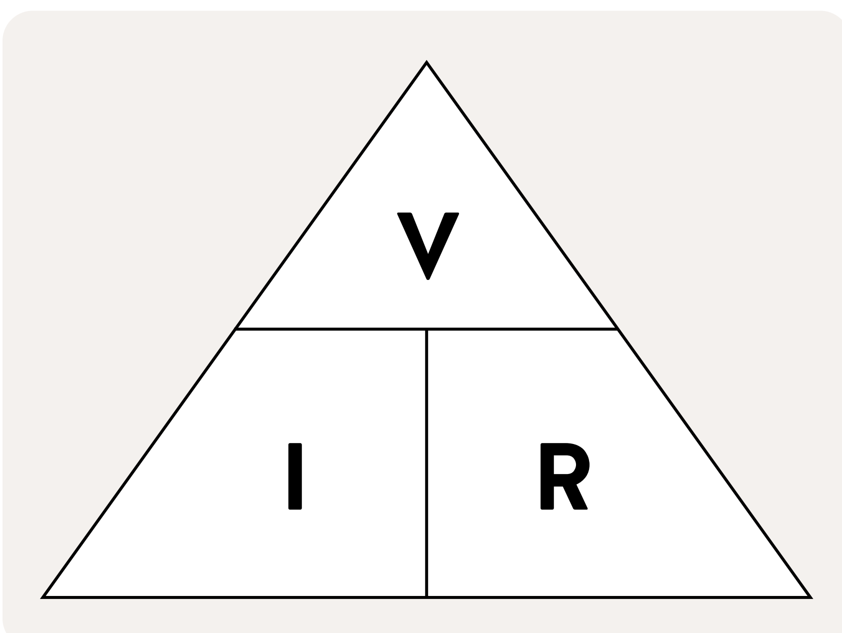
Ohm's law triangle

The Ohm's law triangle is a memory aid for Ohm's law.

To use the triangle, place a finger over one symbol. Then, multiply or divide the remaining symbols according to their relative position in the triangle.

For example, cover V and it equals I multiplied by R. Cover I and it equals V divided by R.

So, $V = I \times R$ and $I = V \div R$.



The Ohm's law triangle

Basics of electrical initiation

All electric initiation systems use similar components, rely on electricity for initiation, and can be affected by electrical hazards.

These systems offer the following advantages over other initiation methods:

- They are easy to prepare and connect.
- The circuit can be tested.
- Initiation happens instantly.
- Delay elements allow sequential blasting.
- The blast can be initiated from a safe location.

They have one disadvantage. Unwanted electricity can enter the circuit and damage the detonator or cause accidental detonation.

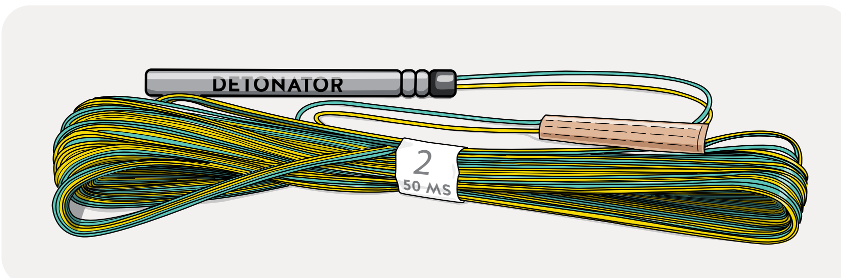
All electric detonators have protection from extraneous electricity (e.g., stray current), some more than others. If electrical hazards are identified and appropriate precautions taken, there is little danger in using an electric initiation system.

Components

The components of all electric initiation systems are similar in design and construction. Each consists of an electric detonator, a power source, and *blasting wire*. A testing instrument is used to verify the continuity of each system.

Electric detonator

An electric detonator is an initiating device capable of detonating most high explosives. A detonator comes with pre-installed leg wires and a metal-foil shunt.



An electric detonator with the wires shunted

Power source

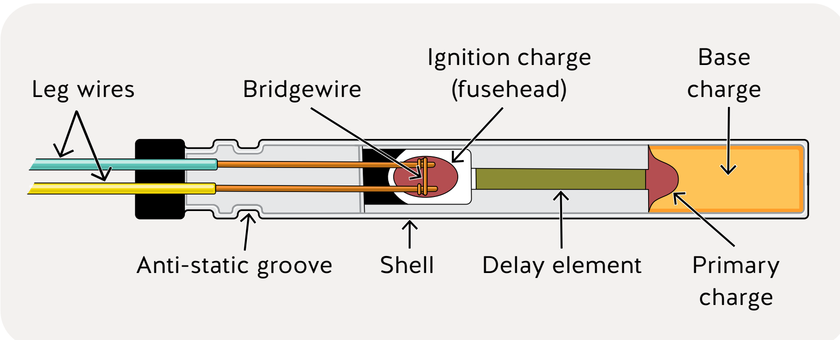
A blasting machine is designed to produce an electric current. For more information, see “Blasting machines” on page 279.

Blasting wire

Blasting wire refers to the conductors that transmit electric current within a blasting circuit. For more information, see “Blasting wire” on page 281.

Electric detonators

An electric detonator is an initiating device capable of detonating most high explosives. It has an aluminum shell about 6 mm (¼ in.) in diameter. The shell's length can range from 33 mm (1¼ in.) for an instantaneous detonator to 100 mm (4 in.) for a detonator with a long delay period.



Cutaway view of an electric detonator

Pressed into the base end of the shell is a composite charge of heat-sensitive lead azide (the primary charge) and high-explosive PETN (the base charge).

Two insulated leg wires enter the shell through a rubber plug. The plug holds the leg wires in position and forms a water-resistant seal.

The leg wires terminate in a *bridgewire* embedded in an *ignition charge*. When a minimum amount of current is passed through this filament, it becomes very hot and ignites the ignition charge. The ignition charge ignites the delay element, which sets off the primary charge and the base charge.

Electric detonators have a *static short* built in for protection against static charges. Each leg wire has a triangular compression slightly ahead of the second *crimp* known as the *anti-static groove*.

The static short is designed to drain off static charges from the leg wires to the anti-static groove before they enter the bridgewire and cause detonation.

Detonator delays

Most electric detonators available today have short-period delays. The delay elements are preset to increase at 25-millisecond (ms) intervals. Numbers on the detonators' labelling represent the intervals, as shown in the table below.

Delay time by detonator number

Detonator number	Delay time
0	0 ms (instantaneous; no delay element)
1	25 ms
2	50 ms
3	75 ms
4	100 ms
5	125 ms
Etc.	Increases by 25 ms

When delays are used properly, they can do the following:

- Minimize cutoff holes
- Reduce vibration and concussion
- Improve fragmentation
- Produce predictable amounts and throw of muck
- Reduce overbreak

For more detailed information on delays, see Chapter 10, "Blast design."

Leg wires

Leg wires are solid metal conductors usually made of copper — a good conductor of electricity. Iron wire is used in operations where foreign materials are removed from blasted rock by magnetic separation.

Leg wires are two separate wires built into a detonator in the factory. These wires are covered with flexible plastic insulation that resists abrasion.

Electric detonators are available with 22-gauge leg wires in a number of common lengths.

Safety features

Bypass or path to ground

All modern commercial electric detonators include an internal feature to prevent electrostatic energy from accidentally initiating the detonator. There are several designs for this feature. Some provide a bypass path around the bridgewire using a semi-conductive material. Others use a printed circuit that provides a controlled path to ground.

Shunts

All electric detonators produced in North America have shunts on the free end of the leg wires. A shunt is an intentional short-circuit that helps protect the detonator from stray current. A shunt usually consists of aluminum foil with an insulated layer on the outside. At the site of the shunt, the foil holds the bare leg wires together and they are shorted out.

Once removed, a shunt may be difficult to replace. The detonator can also be shunted (short-circuited) by twisting the bare ends of the leg wires together.

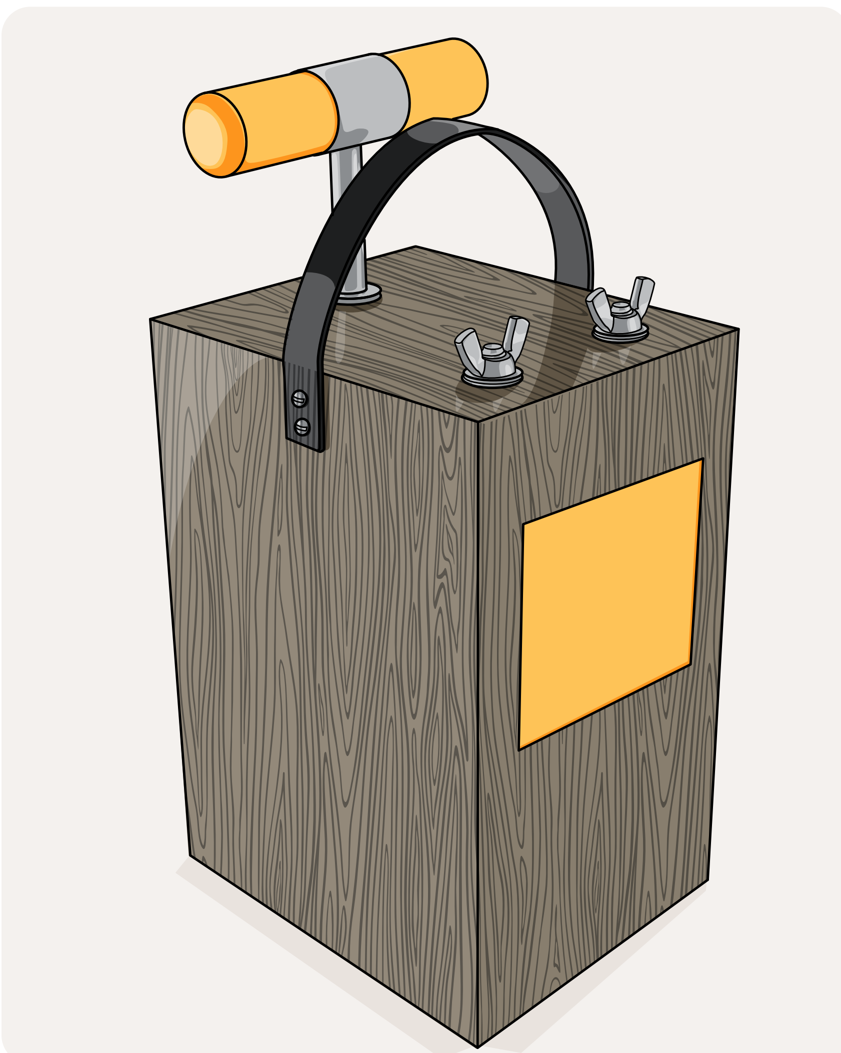
Blasting machines

A blasting machine is a current-producing device used to initiate an electrical blast. Most blasting machines are small and portable. There are two types of blasting machines: *generator* and *capacitor discharge*. Both types produce electrical energy with enough current and voltage to “fire” the number and types of detonators for which they are rated.

Generator

In this type of device, a rackbar or twist spindle rotates the armature of a small generator inside the machine. Upon reaching full capacity, the generator automatically releases the current.

When connecting the circuit to a “push-down” machine, the rackbar must be in the down position. A deliberate up-and-down movement is required to fire the blast.

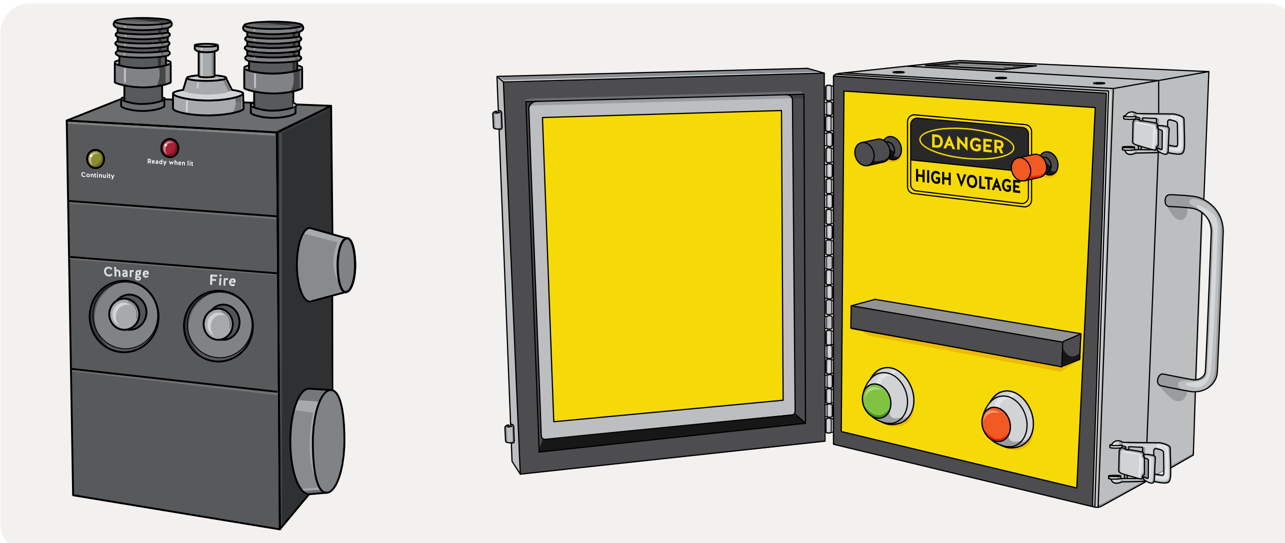


A 50-shot push-down blasting machine

Capacitor discharge

By pressing a button or a switch on this type of device, a high-voltage charge from a dry cell battery builds up on a bank of capacitors. A glowing light indicates a full charge. When the firing button is pressed, the capacitors discharge the current.

Capacitor discharge machines are also available in multi-circuit models. In these models, each series can be wired separately and fired with precise electronic delays between circuits. These are known as sequential blasting machines.



At left, a 50-shot blasting machine — an example of a capacitor discharge machine used to fire a single series circuit. At right, a 200-shot condenser — an example of a capacitor discharge machine used to fire a multiple series circuit.

> **Warning**
>
> A dry (flashlight) or wet (car) battery should not be used. The power output from such batteries is unreliable, and a misfire could result. In addition, these batteries have exposed terminals. If the firing cables inadvertently touch the terminals, an accidental (premature) detonation will occur.

Requirements for marking and maintenance

A blasting machine must have its firing capacity clearly marked on it. The label must indicate the maximum number of electric detonators that can be initiated in a *single series* or in *multiple series* (series in parallel). This is known as the *rated capacity* of the blasting machine. In all cases, the manufacturer's specifications must be adhered to.

Blasting machines must be maintained in good condition. Do not make repairs or adjust them at the worksite. They should be serviced only by competent technicians. The battery of a capacitor discharge blasting machine must be replaced with a type recommended by the manufacturer.

Take precautions to prevent a premature blast. Keep the machine in a safe, secure location, and do not connect it to the circuit until immediately before use.

Blasting wire

Blasting wire refers to the conductors that transmit electric current within a blasting circuit. The following types of blasting wire are commonly used in blasting.

Connecting wire

Connecting wire is a light (18- to 22-gauge) copper wire available in *simplex* (a single wire) or *duplex* (two wires separately insulated in a common plastic covering). Both types have an insulating layer of plastic that is usually red or yellow. Connecting wire can be added to leg wires to reach the next hole. It is also used to connect the circuit to the lead wire or firing cable.

When used to connect detonators or multiple series of detonators in parallel, connecting wire is referred to as the *bus line* or bus wire.

Lead wire

Lead wire is a medium (12- to 16-gauge) copper wire. It has an insulating layer of plastic that is usually yellow. Lead wire may be simplex or duplex. It is used to connect a detonator or a series of detonators to a firing cable or a blasting machine.

Firing cable (shot line)

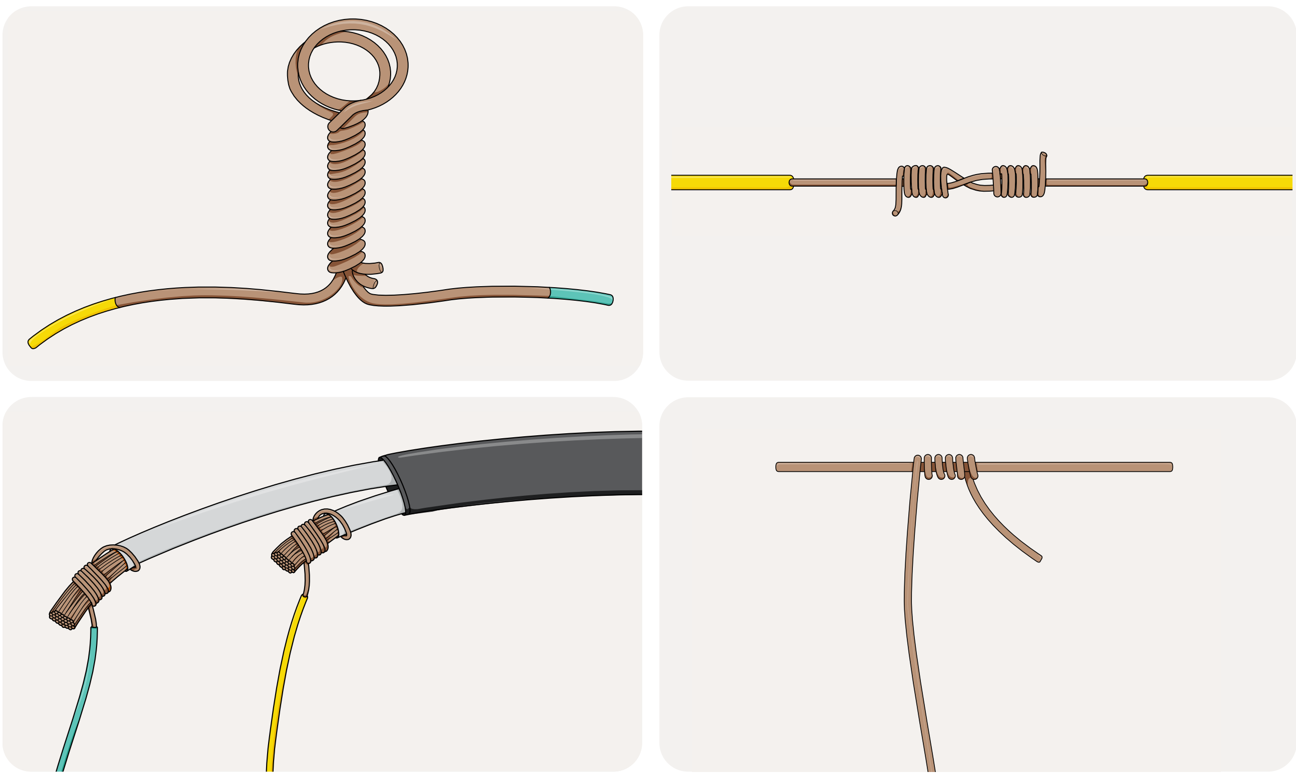
Firing cable is a heavy (8- to 12-gauge) copper wire, usually consisting of insulated duplex wires in a strong black or white cover. Firing cable may extend from the power source to the blasting area, and it is connected to the blasting circuit. If a firing cable isn't long enough, duplex lead wire may be used to extend it.

Bare sections of blasting wire, particularly connections, must be prevented from contacting the ground or conductive material. This is done by elevating them or insulating them with electrician's tape. Contact with the ground or other conductive materials can lead to current leakage and can adversely affect the blasting circuit.

Connections

Connections between lengths of wire in a circuit should be secure and offer little resistance to the current flow. Sections of wire to be joined should be clean and bare.

Similar gauge wires can be joined with the loop-twist or western union connection. The loop-twist is very effective for light (18- to 22-gauge) wire. The western union is used with heavier (8- to 14-gauge) wire. When joining wires of different gauges, the straight wrap connection is most effective.



Clockwise from top left: loop-twist connection, western union connection, straight wrap connection, and blasting circuit connected to firing cable

Testing equipment

Instruments specifically designed and manufactured for testing electric detonators and blasting circuits are required.

Testing equipment, such as blasting galvanometers and multimeters, will have the word “blasting” on their labels. These devices have special batteries and/or internal resistors to limit current output to a maximum of 25 milliamperes (0.025 amperes). That is less than one-tenth of the minimum current required to initiate an electric detonator.

Testing equipment must be maintained in good condition. Avoid exposure to cold temperatures. Exposure to cold can cause the battery to become weak and produce unreliable readings.

Readings will be inaccurate if the needle does not deflect to zero when the instrument’s terminals are shorted. In some such cases, the instrument may be damaged or not properly calibrated (adjusted). In other cases, the battery may be weak and needs to be replaced. The battery must be replaced with a type recommended by the manufacturer.

All testing instruments are designed to verify the continuity of a blasting circuit. Continuity (meaning there is no break in the circuit) is determined by measuring the resistance.

In addition to continuity, blasting multimeters are designed to test for current leakage and stray current. Current leakage occurs when a bare wire contacts the ground or another conductor. Stray current is the presence of extraneous electricity in the blasting circuit.

The testing capability of common types of test equipment is outlined in the table below.

Testing capability by type of test equipment

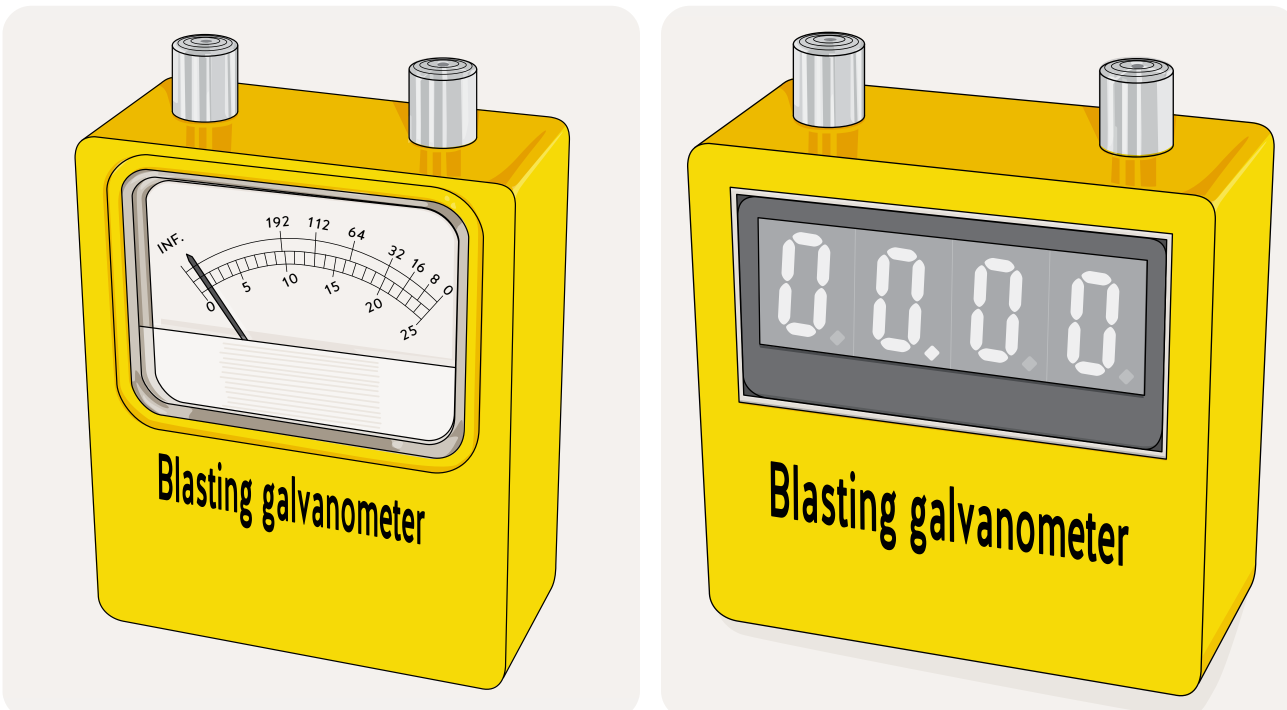
	Testing capability		
Type of test equipment	Continuity	Current leakage	Stray current
Blasting galvanometer	Yes	No	No
Blasting multimeter	Yes	Yes	Yes

Blasting galvanometer

The blasting galvanometer, a special type of ohmmeter, is designed for testing continuity. It is commonly known as a "galvo" or "tester."

Analog galvanometers indicate resistance with a needle that points to a number on a scale. Digital galvanometers produce a numeric display of the resistance.

Some manufacturers call their instrument a blasting ohmmeter. All blasting galvanometers and ohmmeters have special batteries and/or internal resistors and two bare terminals.



Examples of blasting galvanometers, in analog (left) and digital (right) models

Blasting multimeter

Blasting multimeters are precision instruments designed to measure ohms, volts, and amperes (stray current). They have special batteries and/or internal resistors. They also have a switch to select the appropriate scale of measurement.

Blasting multimeters can be used in the following ways:

- As a galvanometer (to measure resistance and test blasting circuits)
- As a voltmeter (to measure voltage, current leakage, and stray current)
- To measure the voltage output from a blasting machine

Most of these instruments are capable of measuring alternating current (AC) and direct current (DC).

Testing a circuit

To test a circuit, press the bare ends of the blasting wire to the terminals of the testing instrument. Then compare the reading with the calculated value. This determines the continuity of the circuit.

What the test readings indicate

Measurement	Indication
Within 10% of expected value	Circuit okay
No measurement	Open circuit or faulty tester
High resistance	Poor or loose connection
Low resistance	Short, current leakage, or detonators missing from the circuit

Blasting circuit configurations

An electric initiation system uses one or more electric detonators wired into a *single series circuit* or a *multiple series circuit* (also known as series in parallel).

The configuration of an electric blasting circuit is based on whether there is one or multiple paths for the current to flow.

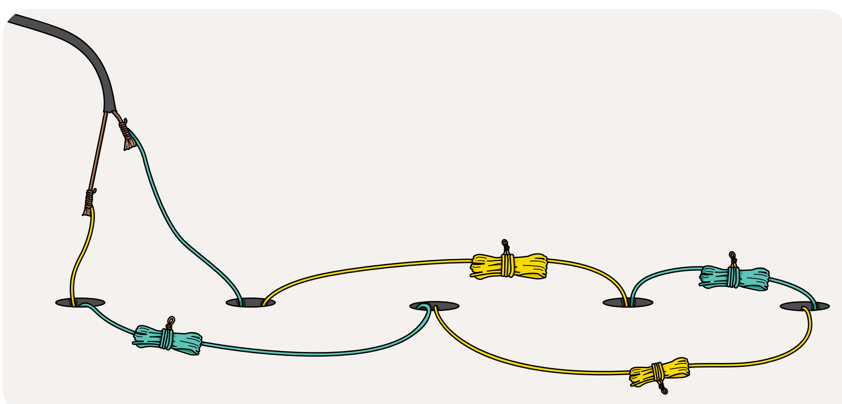
Blasters most commonly use a single-path circuit to initiate a blast. This is known as a single series circuit.

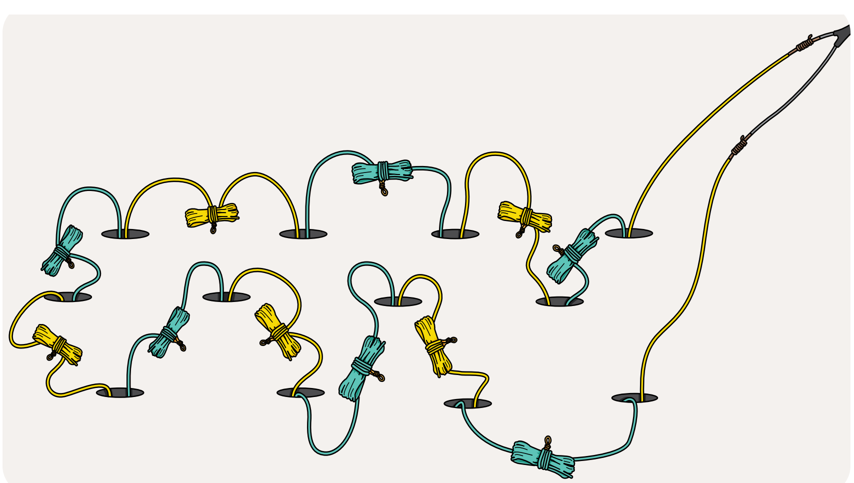
A multiple series circuit is made up of two or more single series circuits that run parallel and are tied into the same bus line to be initiated simultaneously. This method requires more amperage because the flow of current is divided among multiple paths.

Single series circuit

A single series circuit has one or more electric detonators connected into one series. The total number of detonators in a single series circuit must not exceed the rated capacity of the blasting machine. Most electric blasting machines are limited to 50 detonators.

The following diagrams show how to tie in a single series electrical circuit.





At top, a single series circuit set up in a single row. Loop-twist knots are used to connect one detonator's leg wire to the next detonator's leg wire.

At bottom, a single series circuit set up in multiple rows.

A single series circuit may be connected (wired up) in patterns other than those shown on the previous page. However, it must include every detonator and should be laid out in a tidy way.

Single series calculations

The resistance for each series, and the complete circuit, must be calculated to ensure there are no breaks in the circuit. To do so, blasters must know:

- The number and type of detonators
- The length and type of blasting wire

All calculations should follow a simple format. To calculate the resistance for a single series circuit, refer to the proper resistance table (see "Electrical calculations" on page 292) for:

- The type of detonator
- The length of leg wire

The steps of the calculation are as follows:

1. Determine the resistance of each detonator connected into the single series.
2. Add the resistance of all the detonators in the series. If all detonators have the same type and length of leg wires, multiply the resistance of one detonator by the total number of detonators in the circuit.
3. Determine the resistance of all blasting wire used in the circuit. Duplex wire has two separate wires in a protective covering. Double the given length of duplex wire to obtain the total length of lead wire in the blasting circuit. (For example, 500 feet of duplex wire is equal to 1000 feet of lead wire.)
4. Total resistance equals the resistance of all detonators plus the resistance of all blasting wire.

Testing the circuit

Each series and the complete circuit must be tested with a blasting galvanometer or multimeter. Once all the detonators are connected into a series, test the series before connecting it to the blasting wire or firing cable. Some blasters prefer to test the blasting wire separately before connecting it to the circuit.

The testing device should be tested prior to use. Touch a short length of wire to both terminals, and the galvanometer should read a resistance between 0 and 1 ohm. A high reading, or no movement of the needle from infinity (∞), indicates the galvanometer is damaged or out of adjustment, or the battery must be replaced.

The next steps are as follows:

- Re-check the testing device (as described above).
- Re-check the calculations.
- Re-check the blasting circuit.

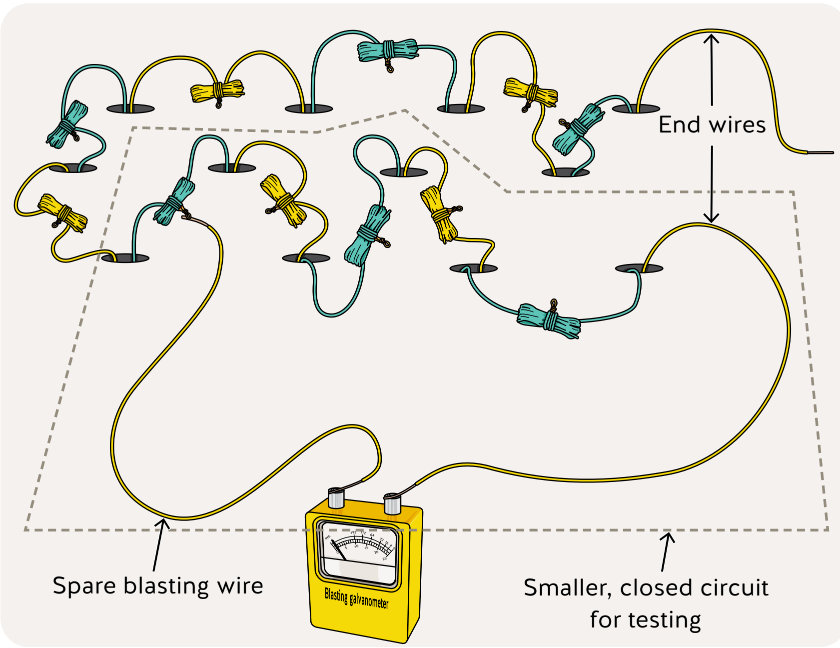
If the test reading does not equal the calculated value, do not attempt to fire the circuit until the problem has been corrected.

Locating a break in the circuit

A testing instrument connected to a blasting circuit will indicate the possible source of the problem.

Test a detonator or section of blasting wire by touching the bare wire ends to the terminals of the testing instrument. Each detonator or section of blasting wire may be tested individually.

It is unnecessary to disconnect individual detonators from a circuit. That's because the instrument only measures the resistance in the portion of the circuit between its terminals.



An example of the process for locating a break in a circuit

When a circuit contains numerous detonators, it may be easier to locate a break using the following procedure (as shown in the image above):

1. Open the blasting circuit and hold one of the end wires to one terminal of the galvanometer.
2. Use a piece of spare blasting wire and touch one end to the other terminal of the galvanometer.
3. Use the other end of the piece of spare blasting wire to touch bare connections within the blast circuit. This creates smaller, closed circuits within the blast circuit for the purpose of finding a reading on the galvanometer. Start in the middle of the circuit to determine in which half the break is located.
4. Continue to touch the end to bare connections until the break is found.
5. After correcting a break, test the series and circuit again. There could be more breaks.

Multiple series circuit (series in parallel)

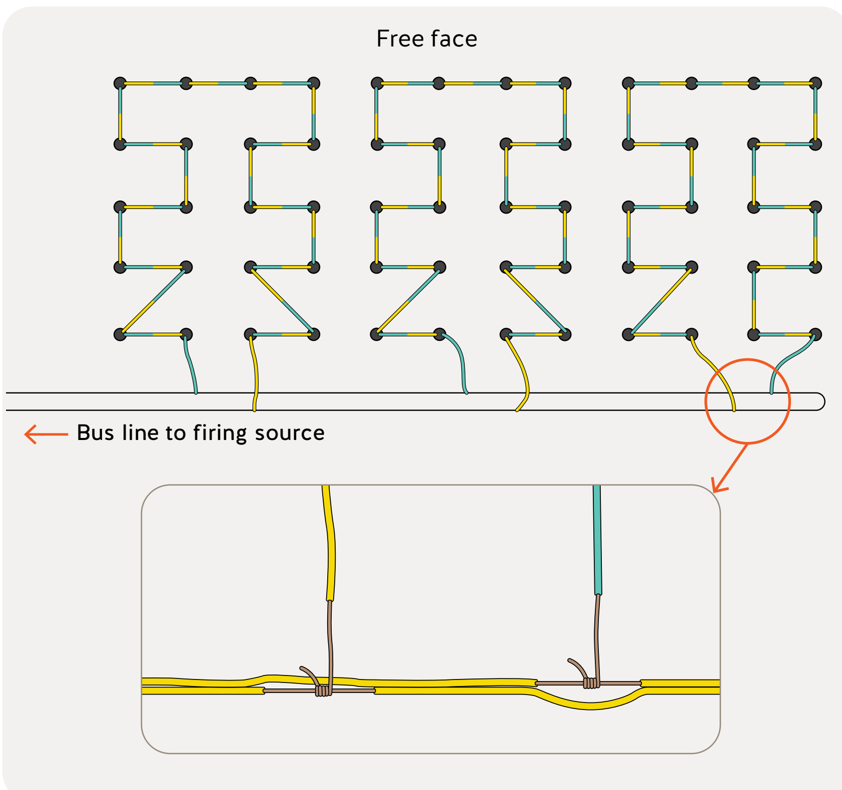
In British Columbia, a series-in-parallel circuit is commonly known as multiple series. A multiple series circuit may be thought of as two or more single series circuits joined together into one circuit.

It is very important that the resistance (in ohms) of each series in the circuit is the same or nearly the same. This is called series balancing. Balancing the circuit ensures that the total current travelling from the power source will be divided equally into each series.

Many blasters balance their series by placing the same number of detonators in each one. Sometimes extra detonators are added to balance one series with the others. However, the detonators themselves do not have ohms. The length of the leg wires determines the resistance. So in a series with varying hole depths and leg wire lengths, the resistance of the wires needs to be balanced, not necessarily the number of detonators.

Each series should be limited to a maximum of 40 detonators or 100 ohms. The number of series in a multiple series circuit is only limited by the rated capacity of the power source. Two series in parallel, or a "double series," would be the most common.

Best practice would have each series tied in side by side and shooting toward an open face. This way, if one series fails to shoot, it is not directly in front of a series that does shoot. The following diagram shows three series with 20 holes per series.



The main drawing shows a multiple series circuit made up of three series with 20 holes per series. The inset shows how one series is tied into the bus line using duplex wire.

Multiple series calculations

To calculate the resistance of a multiple series circuit, first follow the procedures for a single series circuit for each series in the circuit.

Calculations must include the following:

- The number (amount) of detonators in each series
- The number of series
- The lengths and types of blasting wire

The purpose of circuit calculations is to ensure each series will receive enough current to fire all of the detonators. Each series provides a separate path for the electric current. This means the resistance of the circuit decreases as more series are connected to it. When the series are balanced, the total resistance of a multiple series circuit equals the resistance of one series divided by the number of series in the circuit.

For example, assume there are a number of series of electric detonators, with each series having a resistance of 12 ohms. As more series are connected into the multiple series circuit, the total resistance of the circuit is reduced as shown in the table below.

Total resistance by number of series

Number of series in the circuit	Total resistance of the circuit
1 series	12.0 ohms
2 series	6.0 ohms
3 series	4.0 ohms
4 series	3.0 ohms
5 series	2.4 ohms
6 series	2.0 ohms

It is important to keep the resistance of each series balanced. If not, more electric current will flow through the series with the least resistance. Unbalanced series make it difficult to calculate and test the resistance of the complete circuit with conventional techniques and equipment.

The steps for calculating the resistance of a multiple series circuit are as follows:

1. Determine the resistance (ohms) of each detonator.
2. Calculate the resistance of all detonators connected into one series.
3. Calculate the resistance of all detonators that are connected into the multiple series circuit. (To do this, divide the resistance of one series by the total number of series in the circuit.)
4. Determine the resistance of all blasting wire used in the circuit.
5. Total resistance of the complete circuit equals the sum of steps 3 and 4.

Testing the circuit

With a blasting galvanometer or multimeter, test each series individually before connecting it into a multiple series circuit. Unless each series is tested, the final circuit test may fail to reveal breaks in a series.

Record the test reading for each series. Because many instruments are not completely accurate, it may be impossible to obtain identical readings. However, the readings should be within 10 percent of each other. The greater the difference in resistance between series in a circuit, the greater the likelihood of a hangfire or misfire.

If the test reading does not agree with the calculated value, locate and correct the problem before connecting the entire circuit.

After all series are connected, a test reading of the complete circuit is unlikely to reveal a problem within a particular series. A faulty connection or a break in one series may not be detected by a test of the complete circuit.

Electrical calculations

This section provides completed examples of single series and multiple series calculations. The examples are designed to help blasters make their calculations.

As a blaster, you will need to know how to determine the resistance (in ohms) of the length of the blasting wire (in feet) to be used in a blast. You will also need to know the quantity and resistance of the detonators to be used. Then you can go on to determine the resistance of the entire single or multiple series circuit.

Blasting wire resistance calculations

Follow the steps below using the "Resistance of copper blasting wire by gauge" table (see below).

Simplex (single wire) resistance calculation

Step 1: In the table, look up the gauge of the wire to determine the resistance per 1000 ft.

Step 2: Multiply the resistance per 1000 ft. by the length of wire used.

Step 3: Divide the result by 1000. This provides the total resistance of the simplex wire.

Duplex (dual wire) resistance calculation

Complete steps 1 to 3 above.

Step 4: Multiply the answer for step 3 by 2. This provides the total resistance of the duplex wire.

Resistance of electric detonators

Length of leg wire		Resistance of copper wire (in ohms)
Metres	Feet	
2	6.6	1.40
3	9.8	1.55
4	13.1	1.70
5	16.4	1.85
6	19.7	1.95
7	23.0	2.15
9	29.5	2.20
12	39.4	2.25
15	49.2	2.35
20	65.6	2.80
25	82.0	3.20
30	98.4	3.35

Resistance of copper blasting wire by gauge

Gauge of copper blasting wire	Resistance (in ohms per 305 m or 1000 ft.)
4	0.248
6	0.395
8	0.628
10	0.999
12	1.588
14	2.525
16	4.016
18	6.385
20	10.150
22	16.140
23	20.360

Single series resistance calculations

Follow the steps below, and refer to the “Resistance of electric detonators” and “Resistance of copper blasting wire by gauge” tables on the previous page.

Example calculation 1

Situation: A blaster is required to blast a single series circuit. The circuit contains two electric detonators with 6 m (19.7 ft.) copper leg wires and 305 m (1000 ft.) of duplex, 16-gauge blasting wire.

Question: What is the total resistance of this circuit?

The resistance of one electric detonator = 1.95 ohms.

The resistance of two detonators = 2 × 1.95 = 3.90 ohms.

The resistance of the blasting wire = [(4.016 × 1000) ÷ 1000] × 2 = 8.032 ohms.

Answer: The total resistance of the circuit = 3.90 + 8.032 = 11.932 ohms.

Note: It is permissible to round off the numbers to one decimal place. So the total calculated resistance of this circuit may be expressed as 11.9 ohms.

Example calculation 2

Situation: A blaster is required to blast a single series circuit. The circuit contains 30 electric detonators with 4 m (13.1 ft.) copper leg wires and 229 m (750 ft.) of duplex, 12-gauge blasting wire.

Question: What is the total resistance of this circuit?

The resistance of one electric detonator = 1.70 ohms.

The resistance of 30 detonators = 30 × 1.70 = 51.00 ohms.

The resistance of the blasting wire = [(1.588 × 750) ÷ 1000] × 2 = 2.38 ohms.

Answer: The total resistance of the circuit = 51 + 2.38 = 53.38 ohms.

Note: By rounding off the numbers to one decimal place, the calculated value of this circuit may be stated as 53.4 ohms.

Multiple series resistance calculations (series in parallel)

Example calculation 1

Situation: A blaster is required to blast a multiple series circuit. The circuit contains two series with a total of 20 electric detonators. Each detonator has 3 m (9.8 ft.) copper leg wires. There are 76 m (250 ft.) of duplex, 14-gauge blasting wire.

Question: What is the total resistance of this circuit?

The resistance of one electric detonator = 1.55 ohms.

The resistance of one series of 10 detonators = 10 × 1.55 = 15.50 ohms.

Balance the circuit by placing 10 detonators in each series. Divide the resistance of one series by the number of series in the circuit.

The resistance of two series = 15.50 ÷ 2 = 7.75 ohms.

The resistance of the blasting wire = [(2.525 × 250) ÷ 1000] × 2 = 1.26 ohms.

Answer: The total resistance of the circuit = 7.75 + 1.26 = 9.01 ohms.

Example calculation 2

Situation: A blaster is required to blast a multiple series circuit. The circuit contains three series with a total of 75 electric detonators. The detonators have 2 m (6.6 ft.) copper leg wires. There are 457 m (1500 ft.) of duplex, 12-gauge copper blasting wire.

Question: What is the total resistance of this circuit?

The resistance of one electric detonator = 1.40 ohms.

The resistance of one series of 25 detonators = $25 \times 1.40 = 35.00$ ohms.

The resistance of three series = $35.00 \div 3 = 11.66$ ohms.

The resistance of the blasting wire = $[(1.588 \times 1500) \div 1000] \times 2 = 4.76$ ohms.

Answer: The total resistance of the circuit = $11.66 + 4.76 = 16.42$ ohms.

Example calculation 3

Situation: A blaster is required to blast a multiple series circuit. The circuit contains four series and a total of 200 detonators. The detonators have 4 m (13.1 ft.) copper leg wires. There are two types of blasting wire in the circuit:

- 76 m (250 ft.) of simplex, 14-gauge copper connecting wire
- 305 m (1000 ft.) of 8-gauge, duplex copper firing cable

Question: What is the total resistance of this circuit?

The resistance of one electric detonator = 1.70 ohms.

The resistance of one series of 50 detonators = $50 \times 1.70 = 85.00$ ohms.

The resistance of four series = $85.00 \div 4 = 21.25$ ohms.

The resistance of the connecting wire = $(2.525 \times 250) \div 1000 = 0.63$ ohms.

The resistance of the firing cable = $[(0.628 \times 1000) \div 1000)] \times 2 = 1.256$ ohms.

Answer: The total resistance of the circuit = $21.25 + 0.63 + 1.256 = 23.14$ ohms.

Voltage calculations

A blaster should calculate whether the blasting machine provides enough voltage to successfully initiate a blast.

Example calculation 1: single series blast

Both amperage and voltage calculations are required.

Situation: A blaster is required to blast, in a single series, 50 electric detonators. The detonators have 6 m (19.7 ft.) copper leg wires. There is 153 m (500 ft.) of duplex, 14-gauge copper blasting wire.

Questions:

1. What is the total resistance of this circuit?
2. How much current (amperage) is required?
3. How much voltage is required?

The resistance of one electric detonator = 1.95 ohms.

The resistance of 50 detonators = 50 × 1.95 = 97.50 ohms.

The resistance of the blasting wire = [(2.525 × 500) ÷ 1000] × 2 = 2.525 ohms.

Answers:

The total resistance of the circuit = 97.50 + 2.525 = 100.025 ohms.

The total current required for one series = 1 × 1.5 = 1.5 amps.

The total voltage required for the circuit is calculated as:

$V = I \times R$

$= 1.5 \times 100.025 = 150.0375$ volts.

Note: A power source producing in excess of 150 volts and 1.5 amps is required to fire this circuit.

Example calculation 2: series-in-parallel blast

Situation: A blaster is required to blast, in four series, 160 electric detonators. The detonators have 2 m (6.6 ft.) copper leg wires. There are two types of blasting wire in the circuit:

- 153 m (500 ft.) of simplex, 16-gauge copper lead wire
- 305 m (1000 ft.) of duplex, 12-gauge copper firing cable

Questions:

1. What is the total resistance of this circuit?
2. How much current (amperage) is required?
3. How much voltage is required?

The resistance of one electric detonator = 1.40 ohms.

The resistance of each series of 40 detonators = 40 × 1.40 = 56.00 ohms.

The resistance of four series = 56.0 ÷ 4 = 14.00 ohms.

The resistance of the lead wire = (4.016 × 500) ÷ 1000 = 2.01 ohms.

The resistance of the firing cable = [(1.588 × 1000) ÷ 1000] × 2 = 3.18 ohms.

Answers:

The total resistance of the circuit = 14.00 + 2.01 + 3.18 = 19.19 ohms.

The total amperage required for four series = 4 × 1.5 = 6.0 amps.

The total voltage required for the circuit is calculated as:

$V = I \times R$

$= 6.0 \times 19.19 = 115.14$ volts.

Note: A power source producing more than 115.14 volts and 6 amps is required to fire this circuit.

Electrical blasting hazards

The minimum firing current necessary to initiate an electric detonator is 0.25 amperes (250 milliamperes). The Institute of Makers of Explosives (*IME*) has established the maximum safe current permitted to flow through an electric detonator without hazard of initiation to be one-fifth of the minimum firing current. This means the maximum safe current is 0.05 amperes or 50 milliamperes. For this reason, blasting operations using electric detonators must not be conducted in areas where extraneous electricity exceeds 0.05 amps (50 milliamps).

Extraneous electricity is undesirable electrical energy that can enter a blasting circuit and cause premature detonation of a detonator.

A blaster conducting or directing an electrical blasting operation must be able to recognize the following causes of extraneous electricity:

- Electrical storms
- Static electricity
- Stray current
- Induced current
- Power lines
- Galvanic current
- Radio frequency energy

Electrical storms

Electrical storms can generate two hazardous conditions: lightning and static electricity.

A lightning strike can have voltage exceeding a million volts and discharge currents of over 100,000 amperes. The electrical energy is capable of travelling great distances through the ground or a conductor. It can also cause premature initiation of an electric detonator. The danger from lightning increases greatly if it strikes near conductors that can carry the current between the storm and the blast site. Examples of conductors include power lines, water lines, compressed air lines, fences, and streams.

If thunder and lightning are present or expected, do the following:

- Suspend the blasting operation.
- Evacuate everyone from the site, and ensure they stay away until the storm has passed.

Static electricity

Static electricity generated by an electrical storm can build up on people, vehicles, or other insulated conductors. It can discharge to ground through the leg wires of an electric detonator and cause it to explode.

Static electricity is also generated by atmospheric conditions, mechanical friction, and pneumatic loading operations. It can be created by dust storms, snowstorms, and low humidity.

When handling electric detonators in cold, dry conditions, do not wear synthetic clothing.

A Canadian Forces study found that under cold, dry conditions, the following occurred:

- The outer surface of a nylon arctic suit held 200 volts.
- The removal of gloves produced 500 volts.
- The removal of a jacket created 5000 volts.

Keep the detonator leg wires shunted. For additional protection, the ends of the leg wires should be in direct contact with the shell of the detonator until it is ready to be used.

Do not drag detonator leg wires along the ground, and do not unravel them by throwing them into the air.

Static electricity can build up on an insulated conductor. Once connecting of detonators has begun, equipment should not be operated on the blast site.

Pneumatic loading produces static charges that, if permitted to collect, can initiate an electric detonator. For this reason, electric and electronic detonators are not permitted when pneumatic loading is performed. In such cases, use non-electric initiation systems (e.g., shock tube assemblies) instead.

Stray current

Stray current usually refers to electrical discharge from an energized power line. Electric current that flows from a battery, generator, or transformer through power lines to electrical equipment will always return to the source by the three available paths:

- Additional conductors insulated from the ground, such as electrical cables
- Conductors not insulated from the ground, such as rails
- The earth

Electricity flows to ground via the easiest possible route. If stray current enters a blasting circuit, it could cause accidental detonation. Machinery with faulty grounding or worn wires may be another source of stray current.

Stray current is measured using a blasting multimeter connected to both of the following:

- A metal stake driven into the ground
- Any metal conductor in the blasting area

The multimeter will indicate if stray current is present.

Best practice is to use a non-electric initiation system when blasting near power lines or other sources of electricity (such as generators). If an electric initiation system is the only option, do the following:

- De-energize the power line.
- Check for stray current.

Induced current

Induced current is electricity produced by alternating electromagnetic fields around energized power lines, transformers, and switches. A multimeter can detect induced current.

Induced current can cause detonators to misfire. For this reason, take steps to minimize the risk of induced current when carrying out blasts with electric detonators. These steps include understanding sources of induced current (such as radio towers and high-voltage power lines) and using other forms of initiation. If electric detonators must be used, keep them in the form received from the manufacturer until loading is complete. Electric detonators are packaged in a way that helps reduce the risk of induced current.

Best practice is to use a non-electric initiation system when induced current is present.

Power lines

High-voltage power lines can cause induced current in electric detonators. Best practice is to use shock tube assemblies or electronic detonators when high-voltage power lines are present. If using electric detonators near high-voltage power lines, keep the wires on a reel or held in a figure-eight set-up. Extending the leg wires or lead wires into a straight length of wire increases the risk of induced current.

In addition to generating induced and stray currents, power lines hold a greater danger. Blasting wire that can be thrown from the blast could come into contact with an energized power line. If such contact were to occur, it would pose a danger of electrocution to anyone in the area.

Take precautions to prevent wire from being blown across an energized line. Minimize the length of wire in a circuit. Keep blasting wire away from — not parallel to — the power lines. And stake or otherwise secure the wire.

Galvanic current

Galvanic current is produced when two dissimilar metals (i.e., metals that are not alike, such as copper and steel) are immersed together in an *electrolyte* (e.g., salt water). This current could initiate an electric detonator. Similarly, alkaline mud in a blast hole may react with metallic objects. The resulting current could cause premature initiation.

This is one reason for keeping metal tools and equipment out of the area when an electric initiation system is being used.

Galvanic currents flow when dissimilar metals are in electrical contact. This is the case when dissimilar metals touch each other. It is also the case when a conductive material or liquid separates dissimilar metals. When the earth is damp, the liquid forms an electrolyte to make an in-ground battery.

Best practice is to use a non-electric initiation system if galvanic current could be produced.

Radio frequency energy

Radio frequency (RF) energy results from electromagnetic fields produced by RF transmitters. Examples of these transmitters include the following:

- UHF and VHF radio or television
- AM and FM radio
- Citizens' band (CB) and mobile radio
- Microwave towers
- Radar

The intensity of RF energy potentially induced in an electric blasting circuit depends on the following factors:

- Radiated power
- Distance away
- Frequency
- Wiring layout

In recent times, RF sources have increased as more and more portable RF devices enter the workplace. Although the output of such devices is very low, the threat to safe blasting operations is still present.

Examples of RF devices include:

- Smartphones and other wireless devices
- Warehousing and inventory management systems
- Wireless computer LAN systems
- Remote equipment control systems
- Keyless vehicle-entry systems
- Handheld two-way radios
- Portable radios in vehicles or equipment

Electric blasting circuits are not permitted within the minimum distances specified in Safety Library Publication (SLP) 20 from the IME. The standard's full title is Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps).

Electrical blasting is not permitted unless the following apply:

- The exact type, frequency, and output power of the RF energy transmitter has been identified from manufacturer specifications.
- The distance from the blasting circuit to the transmitter is outside the minimum distance specified in SLP 20.

If minimum distances have not been determined, electric blasting circuits are not permitted within the following:

- 100 m (330 ft.) of a CB radio or other mobile or portable RF transmitter
- 1000 m (3300 ft.) of an AM or FM radio, TV, or other fixed RF transmitter

RF safety precautions

RF energy can cause accidental initiation of an electric detonator. In a strong RF field, the leg wires may act as an antenna and absorb sufficient RF energy to cause initiation. Shunting or short-circuiting a blasting circuit offers little protection if the configuration and orientation of the leg wires are aligned with the RF energy source.

When considering using electric detonators, do the following:

- Inspect the area for RF energy transmitters before starting a blasting operation.
- Ensure RF energy transmissions are outside the minimum distances specified in SLP 20.
- Keep mobile transmitters away from the blasting area. Post warning signs and, if necessary, have a traffic control person instruct operators to keep radio transmitters switched off.
- Avoid large loops in the blasting wire by running wires parallel to each other and close together.
- If a loop is unavoidable, keep it small and oriented at right angles to the transmitting antenna.
- Keep blasting wire on or near the ground, with bare connections insulated or sufficiently elevated to prevent current leakage.
- Keep blasting wire out of the beam from directional devices such as radar and microwave relay stations.

General safety precautions

- Do not mix electric detonators made by different manufacturers in the same circuit.
- Ensure wire used in a blasting circuit is capable of transmitting the required current.
- Do not use aluminum wire in a blasting circuit.
- Keep detonator leg wires or lead wires disconnected from the power source and shunted until ready to test or fire.
- Hold the detonator leg wires to the side of the hole during loading, tamping, or stemming.
- Do not fire any electrical blast unless the test reading corresponds to the calculated resistance for each series and the complete circuit.
- Do not exceed the firing capacity (rated capacity) of the blasting machine.
- Test the blasting machine:
  - Using methods specified by the manufacturer.
  - Regularly.
  - Before any blast requiring the maximum output of the machine.
- Do not use any instruments, such as electrician's meters, that are not specifically designed for testing blasting circuits or detonators. Such meters produce sufficient electrical energy to prematurely initiate electric detonators, which can result in injury or death.
- Do not use electric detonators near RF sources unless in accordance with SLP 20. Consult the manufacturer of the detonator for additional assistance.

Chapter 21: Electronic initiation systems

Learning objectives

- Describe the features, components, and benefits of electronic blast initiation systems (EBISs).
- Distinguish between electronic detonators and other types of detonators.
- Describe the safety features of electronic detonators.
- Discuss how delay timing is provided in electronic detonators, the range of delays available, and best practices for using those delays.
- Describe the types of accessories and tools used with electronic detonators.
- Explain the role of electronic blasting machines after testing is complete.
- Distinguish between software and firmware and what they do in electronic initiation systems.
- Describe requirements related to EBIS user training and certification.
- Identify general safety precautions for working with electronic initiation systems.

Overview

Electronic initiation systems, also known as electronic blast initiation systems or EBISs, are the most recent development in blast initiation technology.

Unlike electric initiation systems, EBISs contain detonators with programmable delay modules and capacitors. These features offer a higher level of protection from extraneous electricity (e.g., stray current). They also allow precise timing abilities. These abilities allow for improved blast results, such as better fragmentation, less vibration, and more control over air blast.

However, communications within wired systems are critical and specific. Disruptions due to stray current, current leakage, or static electricity could result in garbled communications and commands.

Every electronic initiation system has a different design. Blasters need to complete an education and training program for each system they use.

Components

While the designs of electronic initiation systems vary widely, they have some components in common.

Electronic detonators

An *electronic detonator* is an initiating device capable of detonating most high explosives. Most electronic detonators are wired, some use shock tube, and others are wireless. For more information, see "Electronic detonators" on page 306.

Communication system

Most electronic initiation systems include a way for their parts to communicate, whether the systems are wired or wireless.

A worker uses a bench tester to communicate with a wired electronic detonator.

On-bench field testing and programming equipment

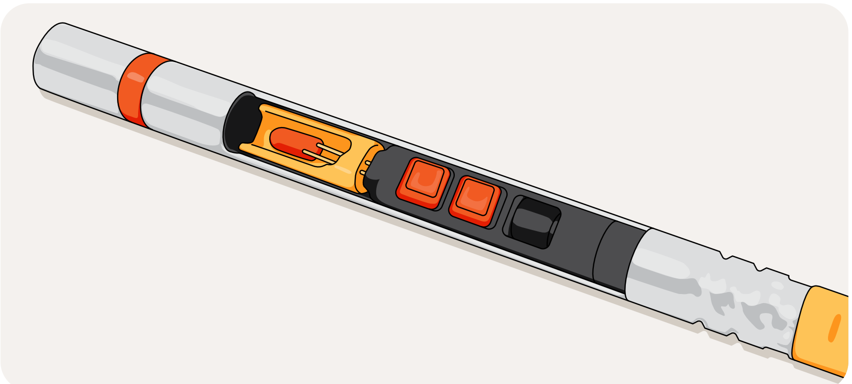
The electronic bench testing unit (*bench tester*) can communicate with an individual detonator or a series of detonators. For more information, see "On-bench field testing and programming equipment" on page 309.

Electronic blasting machine

An *electronic blasting machine* is required to fire the blast. For more information, see "Electronic blasting machines" on page 310.

Electronic detonators

Electronic detonators have an aluminum or copper alloy shell. Viewed from the outside, an electronic detonator may appear similar to an electric, safety fuse, or shock tube detonator. The main difference is in the internal design and construction.

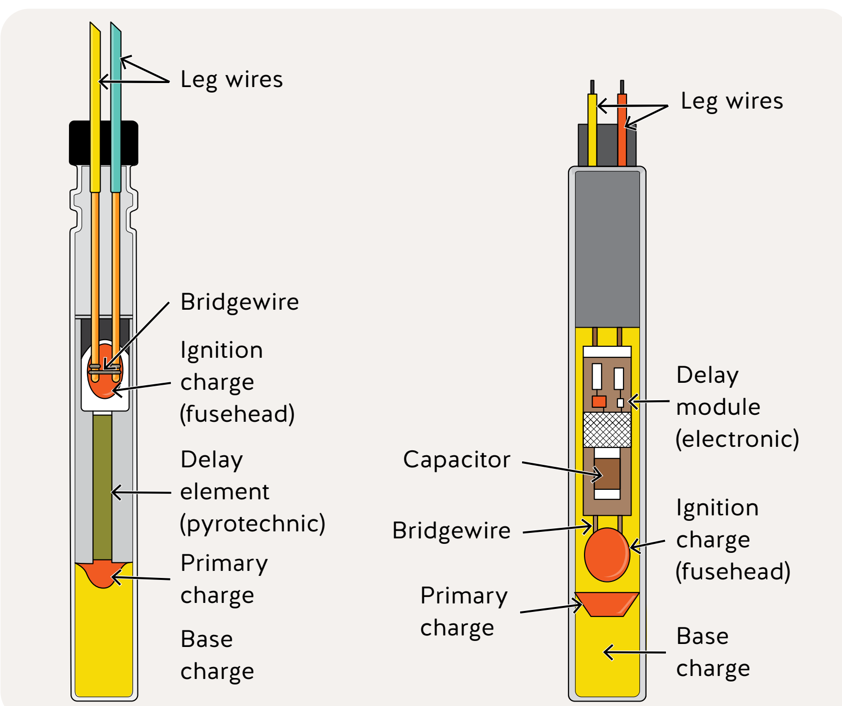


An electronic detonator with part of the shell removed to reveal the internal design

In an electronic detonator, a *circuit board* and a microchip (or *ASIC*, an application-specific integrated circuit) provide delay timing. In conventional detonators, a pyrotechnic composition (a delay element that burns) provides delay timing.

In an electric detonator, the leg wires are directly connected to the ignition charge or bridgewire. This puts the detonator at risk of initiation from static, stray current, and/or radio frequency (RF) energy in the field.

The following drawing compares an electric detonator to a wired electronic detonator.



At left, an electric detonator. At right, a wired electronic detonator.

In a wired electronic detonator, the wires are connected to a circuit board. This provides a level of separation where safety features are incorporated.

Safety features

Electronic systems are at lower risk of premature detonation caused by static electricity and stray current. The lower risk is due to the communication, voltage, and frequency protocols used in these systems. Very specific commands at certain voltages and frequencies are needed to begin and sustain any communication with the detonator.

One of the main safety features is that the ignition charge is physically separated from the leg wires by the delay module and its safety structures. There are also several other design components that further increase the level of protection from extraneous electricity and the risk of premature initiation.

These safety features may include the following:

- Spark gaps (to discharge static charges)
- Input resistors (to handle high current inputs)
- Voltage-specific capacitors (for charging)
- Other electrical components necessary to provide safety during use

Despite these safety features, electronic detonators are not immune to premature detonation caused by high levels of electrical energy (e.g., a lightning strike).

Electronic detonators also provide a level of timing control and security from unauthorized use. The built-in logic circuits allow operators to control who can use the system though passcode protection.

Delays

Electronic detonators can provide delays of 1 to 30 000 milliseconds (30 seconds) in 1 ms intervals.

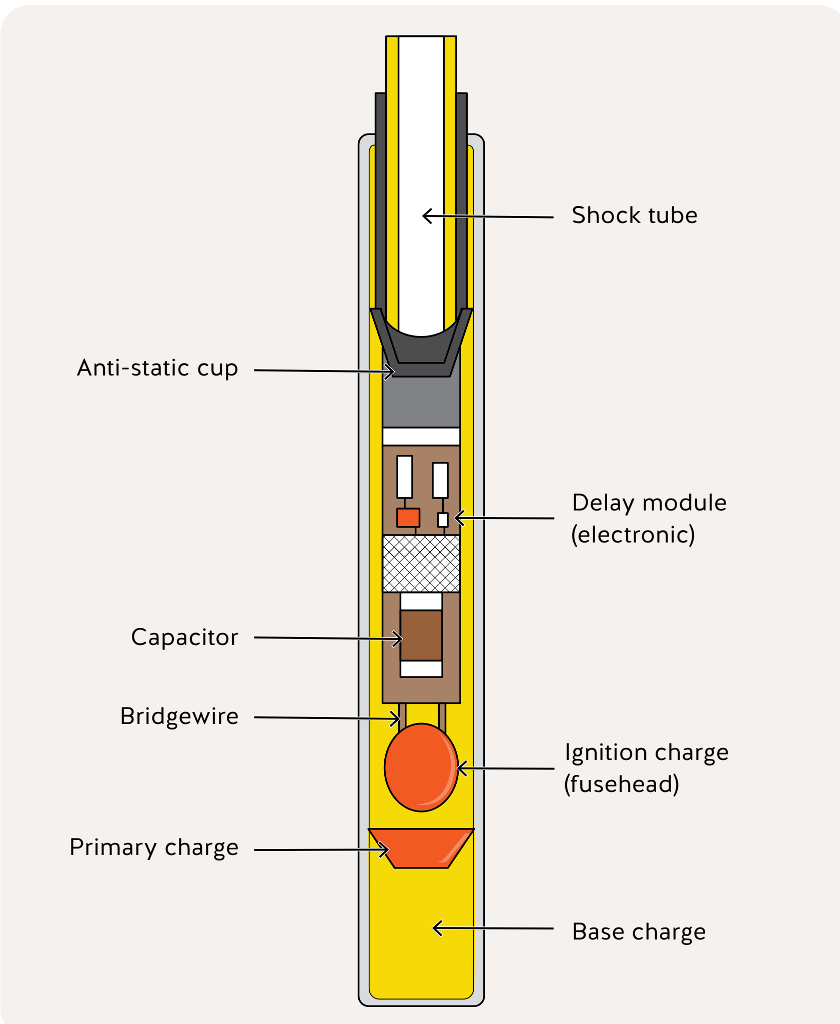
This allows precise blast-timing options that can be tailored to the rock characteristics of the blast location. This precision allows a lot of flexibility, but blasters need to adhere to the blast design. All blast-timing improvements are of no benefit unless an accurate drilling and blast layout is taken into account.

Shock tube-based electronic blast initiation system delays

The one exception to increased blast-timing flexibility is the use of a shock tube-based electronic blast initiation system. This type of system has predetermined delay timing built into it.

The advantages of shock tube-based EBISs are the similarity and wide understanding of how they work, as well as minimal training requirements.

One disadvantage is that these systems cannot be tested before firing. Another disadvantage is that the user is relying on the robustness of a familiar product type. In addition, timing accuracy can be compromised during use. That's because shock tube has inherent time incorporated into it as the reaction in the tube progresses along its length.



A shock tube-based electronic detonator

Accessories and tools

Electronic detonators have various pieces of communication and control equipment. This hardware allows for the testing, addressing, programming, arming, and firing of the electronic circuit.

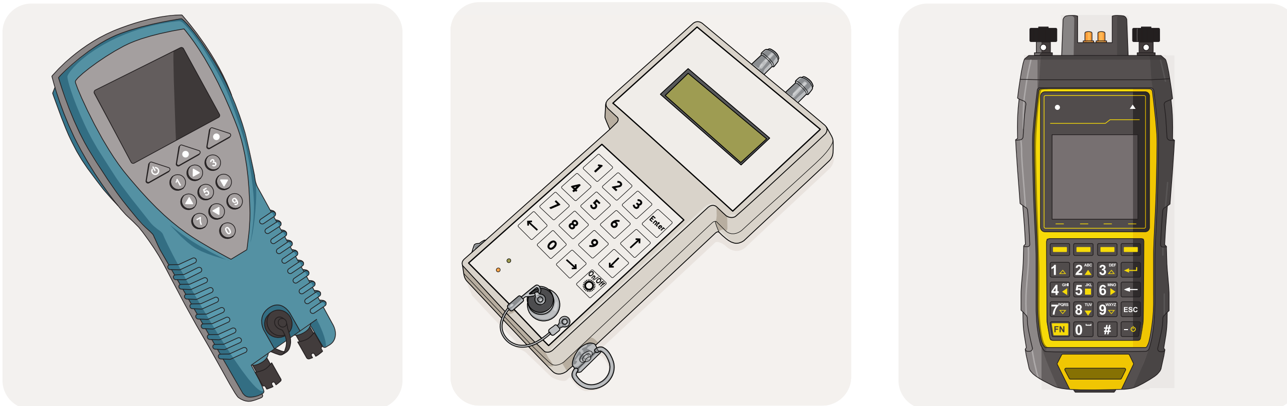
On-bench field testing and programming equipment

The electronic bench testing unit (bench tester) can communicate with an individual detonator or a series of detonators. This communication provides the blaster with a large amount of information as well as the ability to set times for the detonators.

A worker programs an electronic detonator with a bench tester.

The bench tester may be called a scanner, logger, tagger, or programmer unit by different manufacturers. These units provide the blaster with circuit tests to ensure communication with the detonator. These tests detect the following:

- Broken wires
- Current leakage ranges
- Circuit board test protocols
- Fusehead existence



Examples of testing units, including a scanner (left), a logger (centre), and a tagger (right)

These units also allow programming of delay times and sequences of individual detonators. The methods, sequences, and types of communication vary between manufacturers.

Typically, these units can be used to test one or more detonators before, during, and after the blast-hole loading process. They can also provide blasters with the ability to do the following:

- Test the entire blast.
- Review individual detonator information.
- Check the number of detonators in a circuit.
- Check the full system integrity of a blast.

Bench testers are designed to be “inherently safe” devices. Inherently safe designs require that all electronic testing and communication are always done at voltage and current levels that are below the levels needed to charge and fire a detonator. By design, the tester does not have the capability to produce or deliver enough energy to fire a blast or a single detonator. This design feature makes electronic detonators nearly impossible to fire accidentally.

Today’s testing and programming equipment is also designed with methods of securing the communication. Passcodes and protocols ensure that only qualified and properly trained personnel use the equipment.

Some EBISs have the ability to import a blast design created by a computer. This includes predetermined timing as well as the order of hookup. Importing a design relieves blasters of managing the input of timing but requires them to adhere to a predetermined plan to completion. When necessary, the blaster does have the option to make adjustments.

Electronic blasting machines

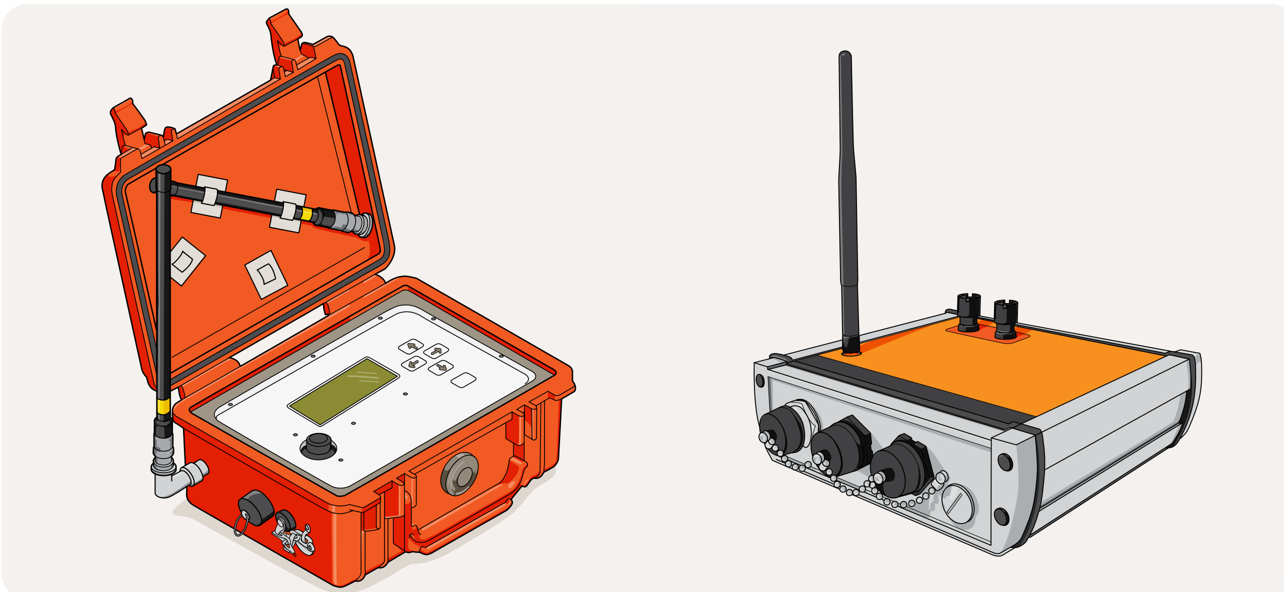
After successful testing of all electronic detonators, a blasting machine is required to fire the blast.

Most electronic blasting machines offer the ability to successfully program and fire several thousand electronic detonators in a single operation. In addition, electronic blasting machines can synchronize and fire remotes and repeaters. This allows the blaster to be up to several kilometres away from a blast site.

A specific blasting machine must be used with each manufacturer's system. Blasting machines have unique design features and communication protocols. These features and protocols help ensure safe and reliable system-level tests, programming, charging, and firing of the shot. Only fully qualified and trained personnel should use these systems.

Electronic blasting machines provide the following:

- Password protection and/or a physical key or other device to prevent accidental firing
- Programming capability
- The energy levels needed to charge the detonators in a circuit and send a fire command



Examples of electronic blasting machines

How they differ from other field equipment

The charging capability of electronic blasting machines sets these units apart from all other field equipment for electronic detonators. These blasting machines are not considered inherently safe devices. For this reason, blasters are required to clear the blast area of personnel, vehicles, and equipment before hooking up the circuit to the firing device or blast controller.

In general, electronic blasting machines have the same ability as bench testers to test electronic detonators. They also have the ability to test and program the entire system or all units within a blast. However, a blasting machine accomplishes this at a higher voltage than any bench tester. For this reason, a blasting machine should only be connected to an electronic detonator blast with the intention of programming and firing that blast.

Full-scale testing is made possible by the blasting machine's ability to communicate at a higher energy level. The extra energy helps ensure reliable communication as well as charging of all firing circuits. In general, two-way communication is needed for full system testing as well as full charging of each detonator's communication and/or firing capacitors. This allows for reliable performance of the manufacturer's system-wide tests before the final charge and fire commands are sent.

Software and firmware

Blasters can use laptop computers to create and analyze blast designs for electronic initiation systems.

The blast design software typically allows the blaster to do the following:

- Visualize the blast.
- Ensure efficient blast performance.
- Download the design directly into the EBIS control equipment.

Bench testers and blasting machines use firmware that acts as the operating system for the detonators and other parts of the EBIS. The firmware helps ensure communication, reliability, and safety.

User training and certification

Each manufacturer's EBIS is unique, and none of the parts or technologies can be interchanged between systems. For example, each EBIS requires a specific blasting machine designed by the manufacturer of that system. Users need to be fully trained and certified by the manufacturer in order to operate these systems.

Each system can vary considerably in design, function, complexity, and capability. To ensure safety and reliability on the worksite, every user needs to understand all of the features of the system they will use.

General safety precautions

- Follow the manufacturer's instructions, especially hookup procedures and safety precautions.
- Do not use electronic initiation systems outside the manufacturer's specified operational temperatures.
- Do not use equipment or electronic detonators that appear to be damaged or poorly maintained.
- Do not mix electronic detonators of different types in the same blast, even if they are made by the same manufacturer.
- Use the wires, connectors, and coupling devices specified by the manufacturer.
- Keep exposed wires from contacting the ground or other conductors.
- Keep wire ends, connectors, and fittings clean and free from dirt or contamination prior to connection.
- Protect electronic detonator wires, connectors, coupling devices, shock tube, and other components from mechanical abuse and damage.
- Do not load blast holes near power lines unless the firing lines and detonator wires are anchored or are too short to reach the power lines.
- Use extreme care when programming delay times in the field to ensure correct blast designs. Incorrect programming can result in misfires, flying material, excessive air blast, and vibration.
- Keep detonator leads, coupling devices, and connectors protected until ready to test or fire the blast.
- Follow the manufacturer's recommended practices to protect electronic detonators from electromagnetic, RF, or other electrical interference sources.
- Do not use test equipment and blasting machines designed for electric detonators with electronic detonators.
- Do not use blasting machines, testers, or instruments with electronic detonators that are not specifically designed for the system.
- Verify the electronic initiation system's integrity before firing the blast.
- Do not hold an electronic detonator while it is being programmed.
- Ensure the blaster has control over the blast site throughout the programming, system charging, firing, and detonation of the blast.
- Clear the blast site of personnel, vehicles, and equipment before hooking up the circuit to the firing device or blast controller.
- Fire electronic detonators using the equipment and procedures recommended by the manufacturer.
- Follow the manufacturer's instructions when aborting a blast. Then follow the manufacturer's recommended wait time before returning to the blast site.

- If the manufacturer's specific instructions for aborting the blast were not followed, wait a minimum of 30 minutes before returning to the blast site after aborting the blast.
- Do not allow the battery terminals of an electronic device to be exposed to the electrical wire leads of an electric detonator.
- Do not handle or use electronic detonators during an electrical storm. Evacuate workers from the blast site to a safe location.

Chapter 22:
Remote firing systems

Learning objectives

- Explain remote firing systems and their purpose.
- Describe the components and basics of a remote firing system.
- Describe how to use a remote firing system.
- List the general safety precautions for working with remote firing systems.

Overview

Remote firing systems allow blasters to initiate shock tube or electric detonators from a remote location. The remote-control technology in these systems allows blasters to increase their distance from blasts to help ensure safety. As a result, blasters are free to move around to achieve both the safest firing position and the preferred viewing position.

A remote firing system is a set of electronic initiating devices for a shock tube assembly set-up or an electric initiation system. The blaster of record must have an endorsement for remote firing systems on their blasting certificate, as well as an endorsement for the initiation system being used.

Components and basics

A remote firing system is made up of electronic initiating devices that contain no explosives. One or more remote units are placed at the blast site. A shock tube or firing cable (shot line) runs from each remote unit to the detonators. The controller is placed at a distant, safe position.

The devices communicate with two-way, digitally encoded radio signals. When it's time to initiate the blast, the blaster uses the controller to send a firing signal to the remote units.

These systems are designed to have highly reliable communications. This helps ensure successful full-scale testing, programming, and firing of blasts.

Users need to be fully trained and understand the capabilities and limitations of these systems. Distance limitations, weather conditions, line-of-sight requirements, RF interference, and other factors all play roles in communication reliability.

The blast site should be cleared of all workers before connecting a remote unit.

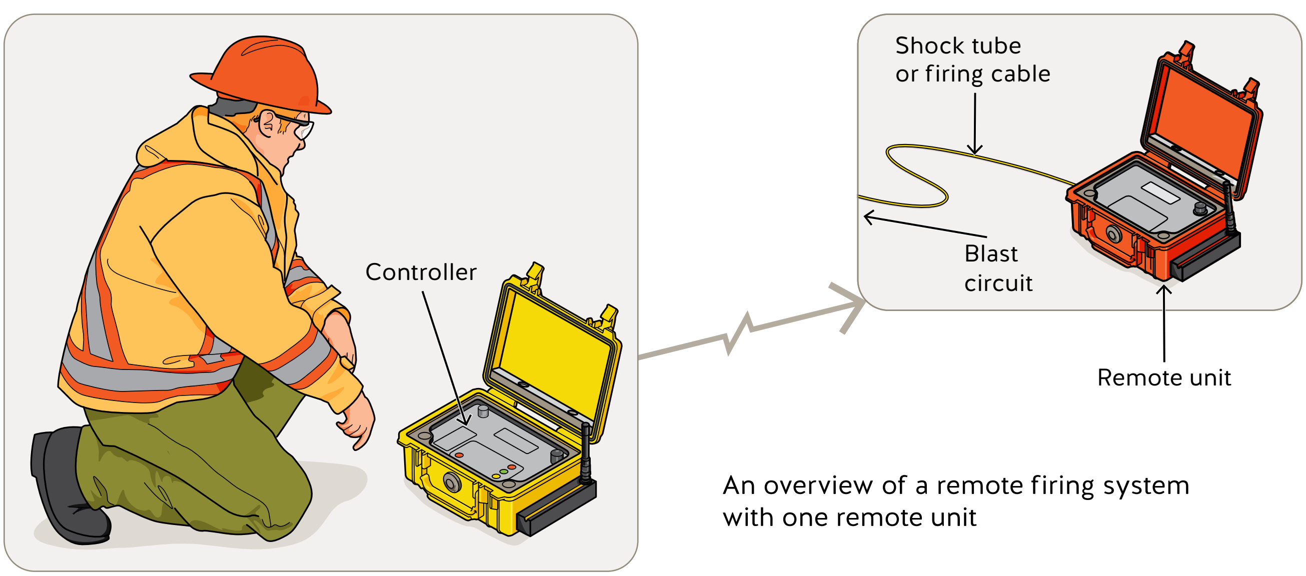
Controller

The controller is responsible for initiating all communications with the remote units. The controller fires the remote units and reports that blast movement was detected.

Remote units

When firing, the remote unit's shock tube circuit develops a high-voltage spark to initiate shock tube lead-in line. Each remote unit includes shock tube igniter tips and an antenna. The igniter tips are designed to be rugged and to perform a rated number of shots before they need to be replaced. Some remote units may also fire electric detonators.

The remote units are normally positioned at protected locations relatively close to the blast site.



An overview of a remote firing system with one remote unit

Using a remote firing system

Setting up the controller

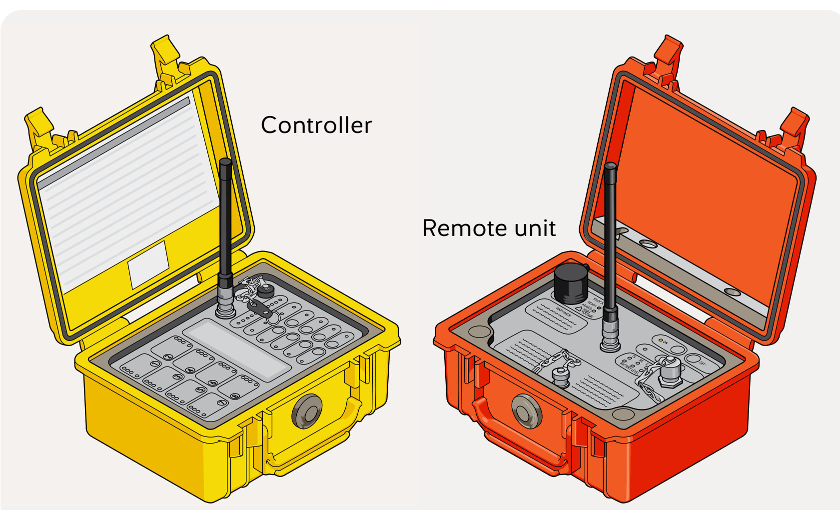
When setting up the controller, do the following:

- Ensure the controller is sufficiently charged and tested according to the operation manual.
- Make sure the controller's antenna is installed correctly.
- Ensure the controller key is removed (if applicable).
- Do not turn on the controller near electric detonators.

Setting up a remote unit

When setting up a remote unit, do the following:

- Ensure the remote unit is sufficiently charged and tested according to the operation manual.
- Position the remote unit at a safe location but close to the blast site.
- Make sure the remote unit's antenna is installed correctly.
- Turn the remote unit to the "power on" position. Then confirm that the battery light is steady and not flashing.
- Ensure the battery reads the minimum required voltage.
- Make sure that:
  - The shock tube is firmly connected into the jack on the remote unit, or
  - The electric detonator wires are connected properly to the binding posts.
- When inserting the key into the remote unit, ensure the indicator light shows the key is active.
- Select the electric detonator or shock tube firing circuit.
- Close and fasten the lid on the unit.
- Repeat these procedures for each additional remote unit to be fired.



Firing the system

To fire the system, do the following:

- Check the system's status light on the controller. Does it show that the system is ready?
- Insert the controller key (if applicable).
- Arm selected remote units.
- Wait for lights to indicate the remote units are armed.
- Fire the system when ready.
- When the status light shows that the action has been completed, turn off the power.
- Remove the controller key (if applicable).

The system can be used repeatedly throughout an operation. The blaster can use the controller to check the status of any or all of the remote units. Most remote units can usually be held in the standby (disarmed) mode for 12 or more hours and still maintain the energy to initiate the shot. In most systems, if the remote units do not receive a properly addressed firing signal within two minutes of being armed, the system will automatically return to the disarmed state.

Controllers and remote units are typically housed in rugged, watertight cases with vents to equalize pressure. The electronics are specially mounted to help prevent damage from shock and vibration from blasting, transportation, and mishandling.

General safety precautions

- Remote firing systems can pose additional challenges when clearing an area. For example, visibility may be an issue in some situations, such as underground blasting.
- Remote firing systems should be tested and verified before connecting them to any blast circuit.
- **Do not** touch the shock tube tip or output jacks when arming or firing, as contact may result in serious injury or death. For tip-handling procedures, always refer to the manufacturer's operation manuals.
- Prevent debris and moisture from entering the shock tube tip or tube.

Part 5:
Avalanche control

Chapter 23:
Avalanche control

Learning objectives

- Explain the concept of avalanche control.
- Define the common terms related to avalanche control.
- Describe the qualifications, roles, and responsibilities of personnel who work in avalanche control blasting operations.
- Explain how closures and sweeps are carried out in the danger area.
- Describe the general requirements for handling explosives in avalanche control operations.
- Discuss actions required to examine the blast site after a blast.
- Describe the requirements and procedures for disposing of misfires.
- Identify the blasting experience required to obtain a WorkSafeBC avalanche control blasting certificate.
- Describe Avalaunchers, their composition, and how to work with them in avalanche control.
- Describe how cornice-control operations work and why they are used.
- Explain how hand-charging operations work and why they are used.
- Explain how case-charging operations work and why they are used.
- Describe how helicopter deployment works and why it is used.

Overview

"Avalanche control" refers to using explosives to reduce the risk that avalanches pose to people, property, and activities. It can involve intentionally triggering avalanches during times when people are not present at a facility or on a road. It can also involve frequently triggering smaller avalanches to help prevent larger, more destructive avalanches.

Avalanche control can be done only by blasters with an avalanche control blasting certificate and one or more avalanche control endorsements. For more information, see page 334.

Common terms

Avalauncher	A nitrogen-powered launcher designed for the safe and efficient delivery of avalanche explosive rounds to the intended target. Mission type abbreviation: Xl
Case charging (a subclass of hand charging)	The detonation of explosives — often multiple bags of ANFO — that have been placed (as opposed to thrown or dropped) at the bottom of the targeted avalanche path. Mission type abbreviation: Xb
Cornice control	An avalanche control technique in which workers on the ground use mountain rope access techniques to safely place charges and/or detonate several charges at once with detonating cord. This technique is used to reduce the risk of cornice hazards. Mission type abbreviation: Xc
Hand charging	A technique in which workers on the ground throw or place explosives into the avalanche path start zone. This technique is often performed while wearing skis. The hand charging endorsement also includes case charging, tram charging, and hanging charges by rope for cornice control. Mission type abbreviation: Xe
Helicopter deployment	A technique in which a blaster drops explosives from a helicopter to perform avalanche control. Mission type abbreviation: Xh
Lanyard	A flexible line of webbing or synthetic or wire rope that is used to secure a safety belt or full body harness to a lifeline or anchor.
Misfire	A dangerous condition in which a charge or part of a charge fails to completely detonate or function on initiation. Also called a mishole.
Mislight	A failure or perceived failure of a pull-wire lighter to ignite a safety fuse assembly.
Remote avalanche control system	A technique in which preplaced explosives are dropped or suspended from a tower or mast by remote control to perform avalanche control. Mission type abbreviation: Xp
Tram charging	A technique in which workers use a gravity-fed tram or ropeway system to deliver explosives across avalanche start zones. Mission type abbreviation: Xt

Personnel

Every avalanche control blasting operation in B.C. must have an individual with both of the following:

- A WorkSafeBC certificate valid for avalanche control blasting with the appropriate endorsements for the control methods used
- An Explosives Regulatory Division letter or equivalent

When more than one certified blaster is present in a team, a blaster of record must be designated to oversee all aspects of the blasting operation.

Blasting operations must have a minimum of two workers: the blaster and an assistant. Exceptions may apply in helicopter operations as specified in the respective written procedures. Some operations may have more than one assistant.

If assistants do not hold valid blasting certificates (with required endorsements), the blaster must do the following:

- Exercise visual supervision over them.
- Be responsible for their work during loading, priming, fixing, or firing of explosives.

An Avalauncher team at work (CIL photo)

Responsibilities

Every person who has knowledge and control of any particular activity in a blasting operation must ensure that the activity is planned and conducted in a manner consistent with the Occupational Health and Safety Regulation and recognized safe blasting practices.

Explosives and blasting accessories must be stored, transported, handled, and used:

- In the manner recommended by the manufacturer
- In accordance with the OHS Regulation

Other responsibilities are listed below by team member.

Blaster of record

The blaster of record is responsible for:

- Determining whether avalanche control measures are required, and if so, what type of mission is performed
- Conducting a safe and efficient avalanche control mission from the time it is announced to the time the facility or road is reopened
- Ensuring that all members of the team understand the blasting plan and their roles and responsibilities
- Carrying out all phases of the mission, including:
  - Charge preparation
  - Communication
  - Safe travel
  - Target selection
  - Deployment of shots
  - Dealing with any misfires that occur
- Recording all blasting activity and results in a personal blasting log (see "Record keeping" on page 330)

Blasters must be familiar with the following:

- The manufacturer's handling recommendations
- Current laws and regulations related to acquiring, transporting, storing, using, and disposing of explosives

Blasters are also responsible for immediately reporting any theft or attempted theft of explosives to the Chief Inspector of Explosives at the Explosives Regulatory Division of Natural Resources Canada.

Any dangerous incident involving explosives, whether or not there is personal injury, must be reported to WorkSafeBC.

Assistant

The assistant is responsible for assisting the blaster of record as necessary. This can involve tasks such as:

- Assisting with loading, priming, fixing, or firing of explosives
- Alerting the blaster about unsafe conditions
- Recording observations in the log book kept at the worksite

Record keeping

Every blaster must maintain a personal blasting log. Blasting logs must be kept for at least five years.

In the log, keep records for each explosive placed and its results. For more information on what to record in the log, see “Maintain a blasting log” on page 212.

The blaster should also maintain avalanche occurrence forms that include the following information:

- Avalanche characteristics
- Any resulting damage
- Closure and sweep start and end times

A copy of the approved avalanche control procedures must be kept on site. The procedures should be available for all workers and for inspection by WorkSafeBC upon request.

Reviewing and revising procedures for the use of explosives

Avalanche control work procedures must be submitted to and accepted by WorkSafeBC before any work is performed.

Employers must ensure the following:

- All procedures for the use of explosives in avalanche control are reviewed annually.
- Proposed changes to the procedures are submitted to WorkSafeBC for approval before implementing them.

Avalanche program workers should review the procedures regularly to ensure they reflect current industry best practices.

Carrying out closures and sweeps

The danger area includes:

- The blast site
- All areas affected by the air blast
- All terrain where avalanches could result from the use of the explosives

The danger area must be:

- Cleared of people before each avalanche control operation begins
- Confirmed clear by radio communication

Designated workers must carry out road or facility closures and perform a “sweep” (i.e., clear people out of an area) before every avalanche control operation. Where backcountry users may be present, perform a visual sweep of the danger area. A visual sweep is done by helicopter.

Blasting signals for avalanche control are not necessary as long as the above measures are taken to ensure safety within the danger area.

Closure control workers with warning signs and physical barriers should be located at each end of a closure area. Sweep workers are responsible for travelling between the identified closure points to ensure the following:

- No one remains within the danger area.
- It is safe to proceed with avalanche control operations.

The sweep workers notify the blaster of record by radio once they have left the danger area.

Once avalanche control is complete, the blaster of record notifies the closure control workers on site. Provided no further avalanche activity is expected, the maintenance contractor or facility operator is responsible for:

- Clearing the road or facility of avalanche deposits
- Ensuring the road or facility is safe before reopening it to the public

Handling explosives and returning to the blast site

Handling explosives

Specific procedures for preparing explosives are contained in each avalanche control operation procedure. Explosives must be stored, transported, handled, and used in a manner recommended by the manufacturer.

The blaster of record determines the most appropriate primer-assembly location closest to the blast site. The blaster of record also ensures that explosives and detonators are only brought together at the last practicable moment.

Returning to the blast site

After a blast, the blaster of record carefully examines the blast site for undetonated explosives and other dangers where possible. Where this is not possible (for example, where a blast site is inaccessible), the blaster of record will observe and listen to the detonations and verify the charges have fired. If the blaster of record thinks that a charge did not fire, they will record the suspected misfire in their blasting log. Then the blaster follows the misfire-disposal procedures described on the next page.

Disposing of misfires

Misfires anywhere in the avalanche path create hazardous debris that can affect a road or facility. Because these misfired explosives can move due to natural or planned avalanches, the blaster of record must be on site before cleanup starts.

All workers must be educated in the following:

- How to identify explosives
- The potential hazards of a misfire
- Who to contact if an explosive is found

When a safety fuse assembly fails or appears to have failed to ignite, the control team must treat this situation as a misfire. This means waiting for at least 30 minutes, or for the length of time recommended by the manufacturer (whichever is longer), before approaching the misfire location.

The location of found misfires must be communicated immediately to the blaster of record. All work is suspended until the blaster of record has disposed of the misfires.

All misfires and suspected misfires are to be recorded in the blasting log. Suspected misfires are explosions that may have detonated properly but may not have been heard or seen by the control team due to a deep snowpack, strong winds, or poor visibility.

Misfires should be disposed of as soon as safely possible. Ensure that a misfire is not disturbed. It should be detonated using a new primer of equal or greater VOD that is placed as close as possible to the unexploded material without making contact. Use non-sparking shovels when digging for misfires in the snowpack.

If snow or avalanche conditions prevent access to misfires, they should be left until spring when conditions are safer. Mark the locations of these misfires and record their GPS coordinates as soon as possible to identify the areas to be searched later. At least two patrols should be conducted during the spring and summer to find and dispose of misfires. These recovery missions are usually performed as soon as the snow melts and before vegetation grows significantly.

Access points where recreationists could enter areas affected by avalanche control operations must have physical barriers with signs warning of the dangers of misfires. In some cases, blocking access to an area may not be feasible. In these situations, prominent warning signs with a phone number to call for current information must be clearly visible at all access points.

Disposing of explosive products

In some cases, it may be necessary to dispose of explosives without detonating them. In these situations, follow the procedures set out by the manufacturer. For more information, see Chapter 9, "Disposing of explosives."

Avalanche control blasting certificate

To obtain a WorkSafeBC avalanche control blasting certificate, a candidate must have a minimum of six months of blasting experience (one full snow season). This experience must be gained while working under the direction of a blaster of record who holds a valid certificate.

The candidate must have a minimum of six missions and 25 shots in each endorsement being sought. (For descriptions of the endorsements, see the next section.) This experience must be recorded in the candidate's blasting log. It must also be verified in a letter of competency from the blaster of record or employer prior to the examination.

A maximum of two missions in a day will be counted toward certification. Candidates must take part in the complete mission. Preparing charges does not count as a mission.

Avalanche control blasting endorsements

WorkSafeBC offers four endorsements for an avalanche control blasting certificate:

- Avalauncher
- Cornice control
- Hand charging
- Helicopter deployment

Avalauncher

An Avalauncher is a type of gun used for delivering explosives to inaccessible or remote targets from a safe distance. An Avalauncher operates by releasing a measured amount of compressed nitrogen gas through the barrel. The gas propels an explosive projectile toward a target.

The gun is composed of the following:

- Two chambers
- A floating piston in one chamber
- A series of interconnected hoses and valves
- The barrel

Bottles of compressed nitrogen provide the required gas pressure.

An Avalauncher (CIL photo)

The explosive projectile detonates on impact due to a mechanism within the tail fin assembly. The mechanism does not become armed until the projectile has left the barrel of the gun and a series of safety devices has been removed.

Avalauncher round

An Avalauncher round is made up of the following:

- An explosive (cast pentolite or Composition B booster, 1 kg or 2 kg)
- A high-strength detonator (minimum no. 8)
- Accessories (tail fin assembly)

Transportation and assembly of explosives

Avalauncher boosters and detonators must be transported separately to the gun platform and assembled on site.

Before assembling the projectile, inspect the tail fin assembly. Ensure there are no irregularities in the moulding or working action of the safety pin, the bore rider pin, or the base plate arming wire.

Inspect the detonator well (cap well) of the booster. Ensure there are no obstructions. Make sure there is sufficient detonator well depth by inserting a wooden dowel.

> **Note**
>
> Do not dismantle primed Avalauncher projectiles or return them to the magazine.

Avalauncher team roles

The blaster of record must have an Avalauncher endorsement and assumes the role of gunner. The second team member assumes the role of assistant.

Blaster of record

The blaster of record is responsible for the following:

- Ensuring safety of the entire operation
- Operating the gun
- Supervising the blast site
- Confirming detonation of charges
- Preparing the rounds
- Loading and remotely firing the rounds
- Completing the blasting log

Assistant

The assistant is responsible for the following:

- Recording the shots in the log book
- Double-checking the system assembly
- Observing the projectile in flight
- Confirming base plate separation in flight
- Confirming the targets and detonation of charges

Note

For an Avalauncher mission, a log book is used to record information such as pressure, elevation, azimuth, target, and comments about wind conditions. This is extra information that doesn't go into blasting logs or occurrence sheets. Log books are also used in other types of avalanche control operations.

Pre-use inspection

Before using an Avalauncher, do the following:

- Ensure the nitrogen tank valve is closed. Inspect all hoses, and make sure connections are tight.
- Check all safety and pressure-release valves for normal functioning.
- Inspect pressure gauges. Check ball valves and emergency pressure-release valves for damage and normal functioning.
- Check exterior surfaces of the Avalauncher and all fittings. Look for signs of wear, dents, or other damage. If there is any visible damage (including dents) to the pressure vessel, do not use the Avalauncher until it has been inspected by a competent authority (i.e., the manufacturer, a professional engineer, or Technical Safety BC).
- Ensure elevation and direction locks work properly.
- Perform a visual inspection of the barrel. Ensure there are no obstructions, debris, dents, or other flaws that could interfere with the launch of the projectile.
- Slide an inert projectile (tail fin assembly and base plate) through the barrel. Ensure there are no obstructions and that clearances are adequate.
- Test the system (dry fire the gun).

Any damaged or faulty parts found during the pre-use inspection must be repaired or replaced before using the Avalauncher.

Generic Avalauncher procedures and commands

Follow the manufacturer's firing procedures. These procedures include a series of verbal commands that the gunner (blaster) calls out as actions are completed. The assistant verbally repeats the commands. Examples of the procedures, commands, and their meanings for a breech-loading Avalauncher are as follows:

- "All valves closed." Line, fill, fire safety, and fire valves have all been closed.
- "Aim." The gun has been placed at the desired elevation and pointed at the target.
- "Breech open." The breech has been opened.
- "Barrel and breech clear." The barrel and breech have been visually inspected and are clear of any obstructions.
- At this stage, the gunner carries out a final check to ensure that both the base plate arming wire and the safety cotter pin are in position through the two holes in the bore rider pin.
- "Shot in breech." The projectile has been placed into the breech.
- "Safety pin out." The safety cotter pin has been removed from the bore rider pin.

- “Breech locked.” The breech has been closed and locked.
- At this stage, the gunner does the following:
  - Opens the pressurized-line valve.
  - Opens the fill valve to increase pressure within the vessel to the desired psi.
  - Closes the fill and line valves.
- “Clear the deck.” The gunner and the assistant move to the remote firing location behind the blast shield.
- “Ready to fire.” A visual sweep of the entire zone of effect has been carried out.
- “Safety off.” The remote safety valve has been opened.
- “Fire.” The gunner is about to open the remote-fire valve to fire the gun.
- “Safety on.” Safety and fire valves have been closed.

After firing, do the following:

- Ensure the nitrogen cylinder valve is closed.
- Observe the target to visually confirm detonation, and note the results.
- Repressurize the gun to a minimum standard (seat the gun).

Repeat this procedure for each target until testing (firing) is complete. Record the details of each firing in the log book kept at the gun site.

Cornice control

A cornice is a body of hardened snow that hangs over the edge of a mountain ridge. Depending on its size and structure, a cornice can trigger an avalanche if it breaks off and falls on the slope directly below it.

A cornice can be removed by placing charges in a line within or on top of the snowpack and detonating them to effectively “cut off” the cornice. These cornice-control explosions often initiate avalanches that help stabilize the slopes below.

A line of charges detonates along a cornice. (CIL photos)

Equipment

The following equipment is typically used in cornice-control operations:

- Explosives (ANFO, cast boosters, safety fuse assemblies, shock tube assemblies, detonating cord, etc.)
- Pull-wire lighters or shock tube initiators
- Timing device
- Portable radios
- Blasting tools and accessories
- Hearing protection
- Appropriate mountaineering equipment

Personnel

The blasting team consists of a blaster of record and one or more assistants. The blaster of record must hold a valid avalanche control blasting certificate with an endorsement for cornice control.

Blaster of record

The blaster of record is responsible for the following:

- Ensuring safety of the entire operation
- Ensuring that all members of the team understand the blasting plan and their roles and responsibilities
- Assessing the extent of the cornice
- Indicating the locations of safe areas and anchor points or belay positions
- Determining an appropriate primer assembly location as close as possible to the blast site
- Supervising the construction of the explosives network
- Ensuring that the area closure is complete
- Designating the cornice charge placement locations
- Ensuring that all team members are aware of the routes and safe alternatives
- Priming and detonation of the network
- Destroying misfires
- Completing the blasting log

Any member of the blasting team has the responsibility and authority to call a halt to the avalanche control mission if they believe that worker safety is, or is likely to be, compromised.

Preparation of explosives

Prepare explosives for cornice-control operations as follows:

- Put together the required number of charges and detonating cord sections into assemblies of sufficient length.
- Place the safety fuse assemblies in the packs in which they will be carried. Do not carry flammable or sparking materials in these packs.

- Place the pull-wire lighters in waterproof bags to be carried well apart from the explosives. Whenever possible, the explosives and the lighters should be carried by different people.
- Carry safety fuse or shock tube assemblies separately from the explosives.

Procedures

Once the explosives are prepared, do the following:

- Initiate the area closure.
- Proceed to the target area.
- Ensure that the closure is effective and the area is clear, both by radio and visually.
- Identify the work area and proper belay locations and techniques.
- Initiate the belay.
- Unless surface charges are to be used, dig or punch holes in the snow at the required spacing and depth.
- Remove a detonating cord assembly from the pack after each hole is dug or punched and bury it in the hole.
- Lay out a section of detonating cord within the safe zone. Include enough extra cord to have the end of the detonating cord well off the cornice area.
- Cut the detonating cord from the roll.
- Extend the detonating cord branchline back to a safe area.
- Properly connect the detonating cord branchlines from the charges to the main trunkline once all charges are placed.
- Move everyone out of the blast site.
- Properly attach two safety fuse or shock tube assemblies to one end of the detonating cord. Notify the blaster of record.
- Freshly trim the fuses just before attaching the pull-wire lighters. Say “Pull-wires on” to the other crewmembers, and have them acknowledge it.
- Light the fuses. To confirm the fuses are burning, take about five seconds to look for the following:
  - Visible grey smoke.
  - Acrid smell of smoke.
  - Discoloured fuse.
  - Fuse droop.

Note

If a fuse fails to light, treat it as a misfire. Clear the danger area and wait out the misfire wait time. Relighting safety fuse is prohibited.

- After ensuring that the fuses are lit, notify crewmembers by saying “Fuses lit.”
- Move to a predetermined safe location to await detonation by safety fuse or to shoot with shock tube.
- Check for misfires.
- Record the results.
- Notify closure control workers that blasting has been completed.
- Remove detonating cord sections from any unused cast explosives. Return the unused explosives to their magazine (only if recommended by the manufacturer). To prevent contamination of the magazine, tape the ends of detonating cord sections before storing them.
- Return unused safety fuse assemblies to their magazine.

Safety precautions

- The cornice blasting team members must be within voice and visual contact at all times.
- Safety fuse assemblies must be carried separately from detonating cord and other explosive products. These assemblies should be attached to the trunkline just before initiating the blast.
- The blaster and all crewmembers must leave the danger area immediately after fuse ignition.
- During detonation of charges, all crewmembers should be well outside of the danger area.
- Use hearing protection during detonation.
- If the travel time to safety precludes any of the above, use a longer safety fuse to initiate the explosives.
- Do not carry flammable or sparking materials in the same packs or containers as the explosives or safety fuse assemblies.
- Before allowing a person to perform rope access, the employer must ensure and document that the person has received training in the safe use of rope access systems.
- All personnel working on the cornice must be “on belay” at all times. Belayers must have good communication with blasters, and they must be prepared at all times for a cornice failure. They must use suitable equipment that is in good condition.

Hand charging

Hand charging involves deploying charges by hand into target areas of an avalanche start zone. Workers on skis transport explosives (which may or may not be primed) in backpacks to a location near the start zone. On arrival, the blaster deploys the charges into target areas. Once the shots have been deployed, the workers retreat to a safe area to await detonation.

For hand-charging operations to be successful, the workers on skis need to have reasonable access to start zones.

Hand charging usually occurs in unfavourable weather and snowpack conditions. For this reason, charges are usually assembled in advance at a safe, sheltered location close to the blast site. The blaster of record determines the assembly location.

Hand charging lets blasters place shots accurately into target areas. It also allows blasters to control many areas in a short period of time at minimal expense.

A blaster deploys a charge by hand. (CIL photo)

Equipment

The following equipment is typically used in hand-charging operations:

- Explosives
- Safety fuse assemblies
- Pull-wire lighters
- Timing device
- Portable radios
- Blasting tools and accessories
- Avalanche-specific PPE (e.g., transceiver, probe, and shovel)
- Hearing protection
- Appropriate means of transportation (skis, snowmobiles, snowcats, etc.)

Personnel

The blasting team consists of a blaster of record and one or more assistants. The blaster of record must hold a valid avalanche control blasting certificate with an endorsement for hand charging.

Blaster of record

The blaster of record is responsible for the following:

- Ensuring safety of the entire operation
- Ensuring that all members of the team understand the blasting plan and their roles and responsibilities
- Determining an appropriate safe primer assembly location close to the blast site
- Supervising construction of the primers
- Ensuring that the blast site and danger area closures are secure
- Ensuring that all team members are aware of the routes and safe alternatives
- Designating the hand charge placement locations
- Destroying misfires
- Completing the blasting log

Assistant

The assistant is responsible for the following:

- Assisting with construction of the primers
- Recording observations in the log book

Blaster of record and assistant(s)

The blaster of record and the assistant(s) are responsible for:

- Constructing the hand charges
- Visually checking that the blast site and danger area are clear
- Placing pull-wire lighters on the safety fuse assemblies
- Ensuring that the fuses burn properly
- Deploying the hand charges

Any member of the blasting team has the responsibility and authority to call a halt to the avalanche control mission if they believe that worker safety is, or is likely to be, compromised.

Preparation of explosives

Prepare explosives for hand-charging operations as follows:

- Assemble explosives according to the manufacturers' recommendations.
- Assemble the primers at the most appropriate safe location close to the blast site.
- Place the pull-wire lighters in a waterproof container. Carry the container separately from the blasting agent and the primers.
- Whenever possible, the explosives and the pull-wire lighters should be carried by different people.

Procedures

Once the explosives are prepared, do the following:

- Initiate the area closure.
- Proceed to the target area.
- Ensure that the closure is effective and the area is clear, both by radio and visually.
- Identify the target locations.
- Remove primers from the pack. Replace pack on back.
- Freshly trim the fuses just before attaching the pull-wire lighters. Say "Pull-wires on" to the other crewmembers, and have them acknowledge it.
- Light the fuses. To confirm the fuses are burning, take about five seconds to look for the following:
  - Visible grey smoke.
  - Acrid smell of smoke.
  - Discoloured fuse.
  - Fuse droop.

> **Note**
>
> If a fuse fails to light, deploy it and treat it as a misfire. Clear the danger area and wait out the misfire wait time. Relighting safety fuse is prohibited.

- After ensuring that the fuses are lit, notify crewmembers by saying "Fuses lit."
- Use an underhand throw to toss the hand charges into the desired locations. Toss only one hand charge at a time.
- Move to a predetermined safe location and wait for detonation of the hand charges.
- Check for misfires.
- Record the results.
- Move to the next target area and repeat the above procedures as necessary.
- Notify closure control workers that blasting has been completed.
- Dismantle any unused cast primers as soon as possible. Return explosives and safety fuse assemblies to their respective magazines. Disassembly of primers must be in accordance with the manufacturer's recommendations. If disassembly is not recommended by the manufacturer, detonate all charges in a safe manner at a secure location.

Safety precautions

- The blaster of record and assistant(s) must be in voice and/or eye contact at all times.
- Do not attach pull-wire lighters to primers until:
  - The backpack is closed and on the blaster's back, and
  - All crewmembers are prepared to move to safe locations outside the danger area.
- The blaster and all crewmembers must immediately leave the danger area after fuse ignition.
- During detonation of charges, all crewmembers should be well outside of the danger area.
- Use hearing protection during detonation.
- If the travel time to safety precludes any of the above, use a longer safety fuse to initiate the explosives.
- When hand charges cannot be tossed into the desired locations, tie a piece of rope or cord to the primer to allow it to be properly positioned. Then attach the pull-wire lighter to the hand charge and ignite the lighter just before placing the hand charge.
- Do not carry flammable or sparking materials in the same packs or containers as the primers.

Case charging (a subclass of hand charging)

Case charging involves detonating a relatively large explosive charge — 25 kg (55 lb.) or more — directly in front of the targeted avalanche paths. The resulting shock waves disturb the snowpack and cause the release of unstable snow. This type of mission is used for the protection of highways as well as ski areas.

Case charging is ideal for unconfined slopes with start zone elevations within 150 m (164 yd.) of shot placements. This type of explosive control is ideal for cleaning out short-slope avalanche paths that tend to continually sluff onto the edges of routes, runs, or roads if left uncontrolled. The shock waves from case charging result in a near total clean-out of unstable snow from the affected avalanche paths.

Case charge locations that require multiple shots must be studied in detail to ensure the safety of the blasting team and the effectiveness of the procedures.

Equipment

The following equipment is typically used in case-charging operations:

- Mode of transportation (e.g., a truck, snowmobile, or snowcat)
- Timing device(s)
- Portable radios
- Explosives
- Safety fuse assemblies
- Pull-wire lighters
- Blasting tools and accessories
- Hearing protection

Personnel

The blasting team consists of a blaster of record and at least one assistant.

Only workers directly involved in the control work will be in the danger area.

The blaster must hold a valid avalanche control blasting certificate with an endorsement for hand charging.

Blaster of record

The blaster of record is responsible for the following:

- Ensuring safety of the entire operation
- Placing guards
- Ensuring that all members of the team understand the blasting plan and their roles and responsibilities
- Ensuring that the area closure and sweep are complete
- Determining the appropriate safe primer assembly location close to the blast site
- Preparing explosives
- Placing and locating case charges
- Detonating explosives
- Completing the blasting log

Assistant

The assistant is responsible for the following:

- Driving the motor vehicle
- Recording observations in the log book
- Warning the blaster of any natural avalanche activity that may threaten crew safety

Guards

Guards are responsible for warning the blaster and/or assistant of any natural avalanche activity that may threaten crew safety.

Any member of the blasting team has the responsibility and authority to call a halt to the avalanche control mission if they believe that worker safety is, or is likely to be, compromised.

Preparation of explosives

Prepare explosives for case-charging operations as follows:

- Assemble explosives according to the manufacturers' recommendations.
- Prepare primers at the most appropriate safe location close to the blast site.
- Use double fuses on primers to ensure ignition.
- Place the pull-wire lighters in a waterproof container. Carry the container separately from the blasting agent and the primers.

Procedures

Once the explosives are prepared, do the following:

- Initiate the area closure.
- Proceed to the avalanche control area.
- Ensure that the sweep and closure have been performed and that the danger area around the blast site is clear.
- Position a guard with an adequate signal device and radio outside the danger area but within sight of the blasting crew and avalanche paths.
- Prepare the explosives in an avalanche-safe location.
- Drive to the blast site.
- Park the truck in the direction of the exit so it can be driven quickly from the blast site and explosives can be set up behind it. **Do not turn the engine off.** Keep the blaster's door and window open for improved communication and easy entry to the truck.
- Place the explosives in the desired location so that all charges are in contact. The explosives should be placed on the outside snowbank facing the slope to be controlled.
- Freshly trim the fuses just before attaching the pull-wire lighters.
- Light the fuses. To confirm the fuses are burning, take about five seconds to look for the following:
  - Visible grey smoke.
  - Acrid smell of smoke.
  - Discoloured fuse.
  - Fuse droop.

Note

If a fuse fails to light, treat it as a misfire. Relighting safety fuse is prohibited.

- After ensuring that the fuses are lit, drive immediately out of the danger area (to a predetermined safe location) to await detonation. Walk quickly from the area if the vehicle fails to operate properly.
- Check for misfires.
- Record the results.
- Notify closure control workers that blasting has been completed.
- Return the unused explosives and safety fuse assemblies (if any) to their respective magazines, or detonate as necessary.

Safety precautions

- Do not attempt case charging if significant (large and frequent) natural avalanche activity is expected to affect case-charging locations.
- Do not work directly beneath the avalanche path to be controlled.
- The guards must be equipped with adequate warning devices and avalanche search and rescue equipment. The guards must be trained in current search and rescue techniques.
- Case charging should only be applied to short slopes — i.e., a start zone within 150 m (164 yd.) above the route, run, or road.
- Park the avalanche control vehicle between the avalanche path and the blaster to provide protection from natural avalanche activity.
- Where possible, the case charge site should be in a safe location (on the outside edge of the avalanche path). This helps ensure the blaster's safety when setting the charge outside of the vehicle.
- Consider using longer safety fuse assemblies if there is any uncertainty about the length of time required to move to a safe location.
- When an assistant is working with the blaster, the assistant will remain in the vehicle throughout the procedures.
- All blasting workers must leave the danger area immediately after fuse ignition.
- Use hearing protection during detonation.
- Keep primed charges separate from all other explosives when transporting the charges to a target area.

Helicopter deployment

Helicopter deployment can be used to easily and safely apply explosives to the snowpack in a relatively short period of time. This control method can be used to easily and safely access terrain that is difficult or impossible to reach by other methods.

In areas with many avalanche paths that need control periodically, helicopter deployment can be the preferred method of control. That's because it allows the facility or highway to resume operations without lengthy preventive closures. Depending on how often it is needed, helicopter deployment can be cost effective, as the cost of closure is often far greater than the cost of control.

A blaster prepares a charge for deployment from a helicopter. (CIL photo)

A helicopter is seen on an avalanche control mission. (CIL photo)

As in any explosive avalanche control mission, safety is a priority. The blaster of record must ensure security within the danger area (i.e., the terrain that may be affected by avalanches caused by explosives).

Helicopter deployment is not an option during the following times:

- Periods of poor visibility
- At night, when conditions would otherwise be ideal for gaining the best results from explosives

Under federal regulations, helicopter operators must obtain approval to do the following:

- Drop explosives from rotorcraft
- Transport dangerous goods

Equipment

The following equipment and supplies are typically used in helicopter deployment:

- A helicopter with a radio set on a closed frequency.
- Intercom headsets or flight helmets.
- Fall-restraint systems, including approved harnesses or belts, anchors, and lanyards. Seat belts cannot be used as anchor points.
- Timing devices.
- Explosives (ANFO, cast boosters, emulsion cartridges, safety fuse assemblies, etc.).
- Pull-wire lighters.
- Blasting tools and accessories (burlap sacks, tape, zip ties, etc.).
- Terrain photos.

Personnel

The blasting team usually consists of a helicopter pilot, a blaster of record, and an assistant. An assistant is optional and at the discretion of the blaster of record and the pilot.

Occasionally a fourth person may be in the helicopter for training or related purposes. This requires the approval of the pilot and the blaster of record.

The blaster of record must be certified for transportation of dangerous goods (TDG) by air. The blaster of record must also maintain direct supervision over all team members who are not TDG-certified.

The blaster of record must hold a valid avalanche control blasting certificate with an endorsement for helicopter deployment.

Federal requirements for TDG during aerial work

For information on federal requirements for transporting dangerous goods during aerial work, see section 12.12 of the TDG Regulations.

Pilot

The pilot is responsible for ensuring the following:

- The safe operation of the aircraft.
- The safety of the passengers.
- Passengers are familiar with procedures and equipment.

Blaster of record

The blaster of record is responsible for the following:

- Ensuring the safe use of explosives
- Being familiar with the area
- Directing the pilot to avalanche sites
- Ensuring that the area closure is complete

- Preparing, igniting, and deploying the explosives
- Recording the time at which each fuse was lit and the time until detonation
- Recording the placement of charges
- Recording the observations (detonations and results)
- Completing the blasting log

Assistant

The assistant is responsible for the following:

- Being familiar with the area
- Recording times, placements, observations, etc. in the log book

For training purposes, an assistant may assume all responsibilities of the blaster of record. However, the assistant remains under the direction and supervision of the blaster of record.

Any member of the blasting team has the responsibility and authority to call a halt to the avalanche control mission if they believe that worker safety is, or is likely to be, compromised.

> **Note**
>
> When additional blasters or assistants are involved in an operation, the blaster of record is responsible for ensuring that these team members understand which parts of the operation they are to perform. Blasters without a helicopter endorsement may prepare and deploy charges. However, they must be under the direct visual supervision of a qualified blaster.

Preparation of explosives

Assemble primers as follows:

- Before entering the aircraft
- At the last most practicable moment
- As close to the helicopter as safety permits

Do not allow the public and workers who are not involved in the blasting mission to enter the area where primers are being assembled. Transport pull-wire lighters separately from charges.

All explosives carried by the helicopter should be used during each mission. If primed explosives have not been used and the mission is complete, the fuse and explosive of the primed charge may only be separated if the explosive has a manufactured detonator well (cap well). Refer to the manufacturer's recommendations and the avalanche control blasting procedures for instructions on dismantling.

Transport primers within the helicopter in a container that:

- Is made of an anti-static material (e.g., wood)
- Can be easily jettisoned (thrown or dropped from the helicopter)

Load primers in the aircraft at the direction of the pilot and in accordance with Transport Canada regulations.

For all charges deployed from a helicopter, use fuses that are at least 1 m (3.3 ft.) long.

Primed ANFO may be carried in the helicopter if the following apply:

- A minimum amount of fuse is exposed outside of the bag — about 10 to 25 cm (4 to 10 in.).
- ANFO bags are securely placed upright in the footwell of the helicopter or, if necessary, on the seat beside the blaster of record. Any bags placed on the seat must be used before those in the footwell. This reduces the risk of bags dropping off the seat.
- ANFO bags do not interfere with the efficiency of the mission or the safe operation of the aircraft. For example, to avoid crimping fuses or ripping bags, place bags so that workers do not step on them.
- Only the amount of ANFO required for the mission is brought on the helicopter. The blaster should be able to jettison the ANFO while in flight if needed.
- The helicopter staging area is close to the target locations. If a considerable distance must be flown, prime the ANFO bags in flight on approach to the targets.

If requested by the pilot, the sleeve of the ANFO bag where the primer is inserted may be securely closed or sealed with zip ties or tape to contain the prills.

Note

To reduce the risk of a misfire, the blaster may wish to use two safety fuse assemblies when priming ANFO.

Procedures

Helicopter deployment procedures are as follows:

- The blaster initiates the area closure.
- The pilot arranges the helicopter in such a way that explosives can be safely dropped. (Examples include removing the rear door and/or ski basket or racks if needed.)
- The pilot ensures that the intercom and the radio (on a closed frequency) are working correctly.
- The blaster rehearses the charge-deployment procedures, including voice commands, with the pilot and crew. This ensures everyone is familiar with the procedures and understands their responsibilities. Rehearsing with live microphones ensures that communications systems are working correctly.
- The blaster loads primers (or unprimed explosives, if priming will occur in flight) aboard the helicopter in a suitable container so that they can be jettisoned easily if necessary.
- The blaster attaches a lanyard to two related anchor points (not the seat belts) in the helicopter and checks the lanyard for correct length. The pilot approves which anchor points to use.
- The blaster puts on an approved harness or belt with a non-instantaneous release system. The blaster then attaches the harness or belt to the helicopter via the lanyard. The assistant wears a standard safety belt.
- The blasting team proceeds in the helicopter to the avalanche path target areas as directed by the blaster of record.

- The blaster of record ensures that any facility closures and sweeps have been performed and completed.
- When unprimed ANFO is used, primers must be kept in a separate container. The primers must be placed into the ANFO in the approved manner just before the shot is placed.
- The blaster of record readies the primer and pull-wire lighter as the helicopter approaches the target area.
- The blaster of record trims the fuse immediately below the end cap (or removes the end cap) and attaches the pull-wire lighter to the fuse.
- After the pull-wire lighter is attached, the dialogue should be as follows:
  - Blaster of record: “Lighter on.”
  - Everyone else: “Lighter on.”
- The blaster of record directs the pilot into the final position for shot placement.
- The blaster of record ignites the fuse and directs the lighter toward the open door to avoid releasing any sparks inside the helicopter.
- To confirm the fuse is burning, the blaster of record takes about five seconds to look for the following:
  - Visible grey smoke.
  - Acrid smell of smoke.
  - Discoloured fuse.
  - Fuse droop.
- After ensuring the fuse is lit, the dialogue should be as follows:
  - Blaster of record: “Fuse lit.”
  - Everyone else: “Fuse lit.”
- The blaster of record drops the charge down and away from the helicopter toward the slope. The charge is dropped only when the aircraft is hovering or in a slow forward flight.
- After dropping the charge, the dialogue should be as follows:
  - Blaster of record: “Shot is away.”
  - Everyone else: “Shot is away.”
- The blaster of record records the time and location of the drop and prepares for any further shots. Meanwhile, the pilot moves the helicopter to the next shot placement or away from the blast site to observe the results.
- When multiple charges are being deployed, the blaster of record stops placing charges 90 seconds after lighting the first fuse. The assistant notes the time and reports to the blaster of record as needed. The pilot then moves the helicopter to a safe location to observe the detonations and results.
- The blaster of record records the results (including any misfires).
- The pilot moves the helicopter to the next target area, and the blasting team repeats the steps above as needed.
- The blaster of record notifies the pilot when all explosive charges have been deployed.

- When the blasting mission has been completed, the blaster of record notifies closure control workers. Any avalanche debris that affects a facility or highway must be cleared off prior to reopening.
- Misfires can move due to natural or planned avalanches. Sometimes, misfires can end up near facilities or highways. The blaster of record must be on site before those areas are cleaned up.
- The locations of found misfires must be communicated in a timely fashion to the blaster of record.
- The blaster of record dismantles any unused cast primers after landing. The blaster then returns the unused explosives and safety fuse assemblies to their respective magazines. Disassembly of primers must be in accordance with the avalanche control blasting procedures and the manufacturers' recommendations. The blaster detonates any unused cartridge (nitroglycerine or emulsion) primers in a safe, approved manner.
- If any explosives were jettisoned from the helicopter due to a safety issue, the blaster of record must deal with those explosives later.

Dealing with non-functioning safety fuse assemblies

If a safety fuse assembly fails to light, the blaster deploys the charge as a dud (i.e., disposes of it as a misfire) when it is safe to do so. This should be done within 45 seconds from the time the pull-wire lighter was activated. The pilot positions the helicopter over the target location (or another location where the charge can be disposed of easily) for this procedure. The pilot then moves the helicopter to a safe zone. The blaster of record stops any further deployment of charges and observes the waiting period for misfires. **Relighting safety fuse is prohibited.**

Glossary

AC
Alternating current, an electric current that periodically changes direction. Found in household lighting or outlets.

air blast
The airborne shock wave from a blast. Also called overpressure.

ampere
A unit of electric current. One ampere is produced by 1 volt flowing through a resistance of 1 ohm. Short form is amp or amps.

ammonium nitrate
An ammonium salt of nitric acid. Abbreviated to AN. AN is the oxidizer in a nitrate mixture explosive such as ANFO.

ANFO
A blasting agent mixture of prilled ammonium nitrate (AN) and fuel oil (FO). For oxygen balance, a mixture of about 94% AN and 6% FO by weight is required.

anomalous drill hole
An unusual or abnormal drill hole. The driller must maintain a detailed report of each anomalous drill hole.

ANSI
American National Standards Institute.

anti-static groove
The indentation (groove) in the shell of a detonator at the open end. The anti-static groove drains static electricity from the static short.

ASIC
An application-specific integrated circuit (ASIC) is an integrated circuit (IC) customized for a particular use, rather than intended for general-purpose use. ASICs and circuit boards are used in electronic detonators to provide delay timing.

assistant
A common term for a helper on a blast site who has had some formal training but cannot perform blasting activities except under the direct supervision of a certified blaster. Also called a swamper.

attended by
The physical presence of a qualified person in visual contact with and with control over explosives.

AWG
American Wire Gauge, a standard for measuring the diameter (gauge) of wire.

backbreak
The area of breakage occurring behind the last row of blast holes. Backbreak is a type of overbreak.

base charge
The main explosive charge in the base of a detonator. Usually consists of PETN.

bench
A horizontal ledge from which holes are drilled vertically down into the material to be blasted.

bench tester
An electronic bench testing unit that can communicate with and set delay times for an individual detonator or a series of detonators. Also called a scanner, logger, tagger, or programmer unit by different manufacturers.

black powder
A deflagrating or low-explosive compound mixture of sulfur, charcoal, and an alkali nitrate (usually potassium or sodium nitrate).

blast
A method of bonding, loosening, moving, or shattering materials using explosives through detonation of a charge, creating a shock wave (detonation wave) and gas pressure.

blast hole
A hole loaded with an explosive charge. Also called a loaded hole.

blast pattern
A dimensional plan of drill holes (bore holes). A description of the location of holes in relation to each other and a free face. Usually includes burden and spacing distances.

blast site
A site where a blast has occurred or is about to occur. Section 21.1 of the OHS Regulation defines "blast site" as an area extending at least 15 m (50 ft.) in every direction from a place where:

- Explosives are stored outside of a magazine or are placed or primed, or
- A misfire is known or believed to exist.

blaster
A person who is the holder of a valid blaster's certificate issued by WorkSafeBC or acceptable to WorkSafeBC.

blaster of record
The blaster who is designated to be in charge of a blasting operation.

blasting accessories
Non-explosive devices and materials used in a blasting operation. Some examples include blasting machines, crimpers, powder punches, blasting galvanometers, and loading poles.

blasting activity
Includes the following:

- Storing, handling, transporting, preparing, and firing a charge
- Drilling at a blast site or in combination with the use of explosives
- Handling a misfire
- Destroying or disposing of explosives

blasting agent
An explosive that is insensitive to initiation without a primer. Includes many ammonium nitrate mixture explosives.

blasting cap
See *detonator.*

blasting circuit
The electric circuit, consisting of blasting wire, used to fire one or more electric detonators.

blasting galvanometer
An instrument used to measure the resistance of blasting wire, electric detonators, and the blasting circuit. Blasting galvanometers and multimeters must have the word “blasting” on their labels.

blasting log
The written record of loading details and examination of the site after a blast. Every blaster must maintain a personal blasting log. Blasting logs must be kept for at least five years.

blasting machine
An electrical or electromechanical device that produces current from a generator or capacitor discharge device. Used to initiate electric detonators.

blasting mat
A device used to cover a blast and control flying material. Usually made of woven tires and wire cable.

blasting multimeter
A testing instrument containing a special power cell and resistors to control current output. Measures ohms, volts, and amperes.

blasting operation
Includes preparing, placing, and firing a charge, handling a misfire, and destroying or disposing of explosives.

blasting wire
Lengths of wire that conduct electric current through a blasting circuit. The term includes connecting wire (simplex or duplex), firing cable (shot line), and lead wire.

blow pipe
A hollow pipe used to direct compressed air into a drill hole to clean it out prior to placing a charge. A non-sparking blow pipe may also be used (with water) to remove stemming after a misfire, for the purpose of refiring. Not to be used to remove detonators or NG explosives.

booster
A cast explosive used to increase the effects of another explosive. Used to initiate explosives that are insensitive to normal initiation.

bootleg
The remnant of a blast hole that did not properly break when the blast was initiated. Also called a socket.

bore hole
See *drill hole*.

bottom prime
The act of placing the primer at or near the bottom of a blast hole.

bridgewire
A resistance wire connecting the ends of the leg wires inside an electric detonator. The bridgewire is embedded in the ignition charge of the detonator.

bulk loading
The act of loading ANFO, slurry, or emulsion by means of a mix or pump truck.

burden
The distance from the free face to the first row of blast holes, as well as the distance between rows of blast holes.

bus line
Blasting wire used to connect electric detonators into single or multiple series circuits. Usually consists of copper. Also called bus wire.

cap
See *detonator.*

cap rock
The harder top layer of rock, usually separated from a weaker layer by a geological seam.

capacitor discharge blasting machine
A blasting machine that uses batteries or a generator to energize one or more capacitors. The stored energy from the capacitors can be released into a blasting circuit.

cartridge
A rigid or semi-rigid unit of high explosive manufactured and wrapped to a predetermined length and diameter. Also called a stick.

cast booster
A cast, extruded, or pressed solid high explosive that contains tunnels or wells. Usually made of pentolite, TNT, Composition B, or similar explosives. Used to initiate non-detonator-sensitive explosives.

charge
An explosive, whether or not the explosive has been primed, that is placed for the purpose of detonation or deflagration.

circuit board
A circuit in which the interconnecting conductors and some of the circuit components have been printed, etched, etc., onto a sheet or board of insulating material. The circuit board supports and connects electronic components. Used along with a microchip or ASIC to provide delay timing in an electronic detonator. Provides a level of separation where safety features are incorporated. Also called a printed circuit board (PCB).

collar
The open end of a drill hole. Also refers to the unloaded portion of a blast hole.

collar distance
The distance from the top of the explosive column to the top of the blast hole. Usually filled with stemming material.

collar priming
The act of placing the primer at or near the opening of a blast hole.

conductor
Any material that allows a continuous current to flow through it when a voltage is applied. A wire, cable, or other form of metal installed for the purpose of conveying electric current.

connecting wire
Blasting wire used to connect electric detonators into a blasting circuit. Usually consists of insulated copper wire.

connector sleeve
A plastic coupling device used to splice two pieces of shock tube together.

continuity
The integrity of an electric blasting circuit. A measure of whether a circuit is complete (unbroken) or not.

core load
The explosive core of detonating cord. The strength of the core load is measured in grams per metre (or grains per foot) of PETN in the cord.

crimp
The circular depression at the open end of a detonator that secures the safety fuse or leg wires in place.

crimper
A special, non-sparking tool used for cutting and stripping electrical wire. Features a powder punch on the handle. Used in the past for crimping.

cu. ft.
Cubic foot (or feet).

cu. in.
Cubic inch(es).

cu. yd.
Cubic yard(s).

current
The flow of electricity in a blasting circuit, measured in amperes (amps).

current leakage
Occurs when some of the firing current bypasses part of the blasting circuit through unintended paths.

cutoff
A break in a path of detonation or initiation caused by flying material, shifting ground, or other interference. A cutoff is a type of misfire.

danger
See *hazard*.

danger area
An area in which there may be danger to people or property from flying material or other hazardous conditions resulting from a blasting operation.

dangerous incidents
Include the following:

- Incidents involving explosives, whether or not they cause personal injury
- Problems with particular products (for example, repeated or suspicious misfires or premature detonations)

day box
A container used at a worksite to store and transport explosives. May be fixed to a vehicle. A day box is:

- Weatherproof
- Constructed with:
  - An outer surface made of non-combustible materials
  - An inner surface made of non-sparking materials
- Equipped with a lock or mechanism to enable locking
- Not used for overnight storage

DC
Direct current, the flow of electrical energy in one direction only. Found in batteries.

dead pressing
The desensitization of an explosive caused by pressurization. Can occur with less-sensitive explosives such as ANFO and emulsions. The shock wave produced by a nearby detonation can compress a blasting agent in a blast hole, such that tiny air bubbles (required for sensitivity) are literally squeezed from the mixture.

decibel
A unit of sound-pressure level commonly used to measure air blast.

deck charges
Separately primed charges in a blast hole, usually separated by a spacer or stemming material.

decking
A method of loading in which a spacer or stemming material is placed between deck charges in a blast hole.

deflagration
An explosive reaction such as rapid combustion that moves through an explosive at a velocity less than the speed of sound.

delay element
In a delay detonator, a composition that produces the predetermined time delay before initiation.

delay timing
The practice of using a detonator with a delay element or using a surface delay (e.g., shock tube) to delay the detonation of a charge or a group of charges. Includes both delays between blast holes in a row and delays between rows.

density
A measurement of the weight/volume ratio of an explosive to an equal volume of water. Usually expressed in grams per cubic centimetre. Also called specific gravity.

deterioration
The chemical breakdown of an explosive.

detonating cord
An explosive core of PETN contained in a flexible waterproof covering. Initiated by a detonator. Explodes at about 7000 m (23,000 ft.) per second. Initiates most explosives in contact with it.

detonation
An explosive reaction that moves through an explosive at a velocity greater than the speed of sound.

detonation wave
See *shock wave.*

detonator
A small metal tube containing a sensitive primary charge and a PETN base charge. Used to initiate detonation in an explosive. Types include electric, safety fuse, electronic, and shock tube detonators.

detonator box
A crush-resistant container used for protecting detonators at a loading site. Also called a cap box.

detonator-sensitive
An explosive that will detonate when it is unconfined and armed with a detonator. Also called cap-sensitive.

detonator well
A pre-formed cavity in a cartridge or booster designed to accept a detonator. Also called a cap well.

double prime
The procedure of using two primers in the blast hole, as recommended by manufacturers' specifications, depending on the length of the explosive column. Used if a blaster suspects a break or gap in the column to protect against a misfire.

downline
A length of detonating cord or shock tube, in a blast hole, that transmits energy from the surface to the charge.

drill hole
A hole, drilled in the material to be blasted, that does not yet contain explosives. Also called a bore hole.

dual initiation
The use of two detonators at each initiation point. The second detonator helps ensure a successful blast. Dual initiation should be used whenever the blast is critical and the charge is not easily recovered.

duplex wire
Two separately insulated lengths of copper blasting wire contained in a common protective covering. Distinct from simplex wire, which involves a single wire. Both duplex and simplex wire are types of connecting wire.

dynamite
A type of high explosive containing liquid nitrate esters. The most common nitrate ester used is NG, which is a mixture of nitroglycerine and nitroglycol.

electric detonator
A detonator designed to be initiated by an electric current. Can detonate most high explosives. Comes with pre-installed leg wires and a metal-foil shunt.

electrical storm
An atmospheric disturbance of intense electrical activity that increases danger during blasting activities. Includes thunder and lightning strikes.

electrolyte
A non-metallic electrical conductor (e.g., salt water or alkaline mud) through which a current is carried by the movement of ions.

electronic blasting machine
A blasting machine designed specifically to communicate with up to several thousand electronic detonators in a blast. Can program, charge, and fire the detonators. Can also synchronize and fire remotes and repeaters.

electronic detonator
A detonator that uses stored electrical energy as a means of powering a programmable electronic timing delay element, whether or not the detonator is wireless.

emulsion
An explosive produced through the interaction of a dissolved oxidizer and fuel in the presence of a chemical emulsifier. Emulsions are water resistant.

endbreak
The area of breakage occurring on the sides of the blast (i.e., at the ends of each blast row). Endbreak is a type of overbreak.

explosion
A rapid chemical reaction that produces high temperatures, a large volume of gases, and (usually) a shock wave.

explosive
A type of chemical that detonates or deflagrates when shock, heat, or impact is applied.

extraneous electricity
Any unwanted electrical energy that may enter a blasting circuit or detonator. Can result in premature detonation. Sources include galvanic action, induced and stray current, lightning, radio frequency, and static electricity.

fault

1. An abnormality in the material to be blasted. Includes cavities, joints, planes, seams, and slips. Usually requires a modified loading technique for a blast to have the desired effect.
2. A bad connection or break in an electric blasting circuit.

fines
Drill cuttings from a drill hole. Undersize material of little value produced by a blasting or crushing operation.

firing
The act of detonating a charge.

firing cable
A heavy-gauge, coated, insulated, duplex blasting wire that extends from a blasting machine to a circuit of electric detonators. Also called shot line or firing line.

flammable material
Includes any fuel, paper, rag, or other similar material that is readily combustible and may cause or spread fire or explosion.

fly rock
A type of flying material.

flying material
Material that is thrown (projected) by the force of a blast. Includes dirt, ice, metal, rock, water, and wood. May be dangerous and is generally undesirable.

fracturing
Breaking or cracking of material (rock).

fragmentation
The extent to which blast rock (muck) is broken or reduced in size. An estimation of average diameter.

free face
A rock surface exposed to air or water. Provides room for expansion upon fragmentation. Also called open face.

fuel oil
The fuel used in ANFO. Usually No. 2 diesel fuel.

fumes
Very fine particulates. See also *toxic gases*.

fuse
A common term for safety fuse.

galvanic current
A battery-like reaction produced when two dissimilar metals (i.e., metals that are not alike, such as copper and steel) are immersed together in an electrolyte (e.g., salt water or alkaline mud). This current could initiate an electric detonator.

gauge
A measurement of the diameter (thickness) of a wire.

g/cc
Gram(s) per cubic centimetre.

generator blasting machine
A blasting machine operated by vigorously pushing down a rackbar or twisting a handle (50-shot push-down, 10-shot twist, etc.).

grain
A measurement of weight. There are 15 400 grains in a kilogram and 7000 grains in a pound.

ground
An electrical connection to earth.

ground vibration
Shaking of the ground caused by the shock wave from a blast.

guard
A person posted for the purpose of guarding a blast.

guarding
The act of preventing entry to a danger area. Also refers to protecting explosives from tampering or theft.

gunpowder
A low explosive consisting of sulfur, carbon, and potassium or sodium nitrate. Used in safety fuse. Also called black powder.

GVW
Gross vehicle weight, the rated capacity of a vehicle.

hangfire
An unplanned delay caused by a defect in an electric blasting circuit. May occur when an explosive in a hole begins to burn rather than explode. The fire may eventually cause detonation if it reaches the detonator's base charge. A very dangerous type of misfire, as the explosive could detonate at any moment.

hazard
A thing or condition that may expose a person to a risk of injury or occupational disease. Also called danger.

helper
See *assistant*. May also refer to a type of relief hole in a cut.

high explosive
An explosive characterized by a very high rate of reaction, high pressure development, and a significant shock wave upon detonation.

hookup
The procedure of connecting shock tube assemblies, detonating cord, or electric or electronic detonators in preparation for firing a blast.

ignite
The act of setting fire to safety fuse or any flammable material.

ignition charge
In an electric or electronic detonator, the component used to ignite or fire the primary charge and base charge. Also called fusehead or match head.

ignition spit
The flame jet produced by a safety fuse at the moment of ignition.

IME
Institute of Makers of Explosives, an industry organization dedicated to safety in manufacturing, transporting, storing, handling, and using commercial explosives in Canada and the U.S.

initiate
The act of detonating an explosive.

in./s
Inch(es) per second.

lb./cu. yd.
Pound(s) per cubic yard.

lb./ft.
Pound(s) per foot.

lead azide
A type of primary charge in a detonator.

lead-in line
A long line of shock tube between the point of initiation and the blast.

lead styphnate
A type of primary charge in a detonator.

lead wire
Blasting wire that extends from the power source to the electric detonators. Usually 12- to 16-gauge insulated copper wire.

leg wires
Insulated wires attached to the bridgewire of an electric detonator. Usually 22-gauge copper. The leg wires exit the detonator shell through a rubber plug. The bare ends are shorted out by means of a shunt.

liner
A plastic “sock” used in a blast hole to protect the explosive (usually a blasting agent) from moisture and other contamination.

loading
The act of placing explosives into a blast hole.

loading pole
A pole, made of non-sparking material, used to place explosives in a blast hole. May also be used to check the depth of the hole, clean the hole before loading, and tamp explosives in the hole. Also called a tamping rod.

logger
See *bench tester.*

loose material
Unstable material (overhanging rocks, broken tree limbs, etc.) that could collapse or fall and cause injury or property damage. Can result from the vibration of a blast.

low explosive
An explosive capable of deflagration and low gas pressure. Includes gunpowder (black powder).

magazine
A building or structure used to store either detonators or explosives. A licensed magazine within the meaning of the *Explosives Act* (Canada).

MHz
Megahertz, a unit of frequency equal to 1 000 000 cycles per second.

misfire
A charge, or part of a charge, that failed to completely detonate. Includes cutoffs and unexploded explosives in the muck pile or debris. Does not include a mislight.

mislight
A failure or perceived failure of a pull-wire lighter to ignite a safety fuse assembly, particularly in an avalanche control setting. A mislight is not considered a misfire.

mm/s
Millimetre(s) per second.

ms
Millisecond, a thousandth of a second.

muck
Broken material (rock) resulting from a blast.

mud capping
A mud-covered or unconfined charge fired in contact with a rock surface without the use of a drill hole. A secondary method of blasting.

multiple series circuit
Two or more (balanced) series of electric detonators connected into a blasting circuit. Also called a series-in-parallel circuit.

NG
A mixture of nitroglycerine and nitroglycol. A clear, oily explosive used as a sensitizer in dynamite. Very sensitive in its liquid form.

non-sparking
A device or material that will not readily produce a spark when struck against a hard surface.

ohm
A unit of electrical resistance.

Ohm's law
$V = I \times R$; voltage equals current (amps) multiplied by resistance (ohms). Used to calculate the voltage required to fire an electric blasting circuit.

overbreak
Breakage of rock beyond the excavation limits (i.e., the rock cut). Includes backbreak and endbreak.

overburden
Any material (soil, gravel, clay, etc.) that is drilled through before hitting bedrock.

overpressure
See *air blast.*

oxidizer
An ingredient in an explosive that supplies oxygen, which combines with the fuel to form gaseous or solid products of detonation. Increases the burning rate of combustible materials. AN is a common oxidizer.

particle velocity
A measurement of the intensity of ground vibration. Specifically, the velocity of motion of the ground particles as they are excited by the wave energy.

pentolite
An explosive consisting of PETN and TNT. Commonly found in cast boosters.

PETN
Pentaerythritol tetranitrate, a white, crystalline powder of high explosive. Used as the core load in detonating cord and the base charge of a detonator.

pneumatic loading
Placing an explosive, usually a blasting agent, into a drill hole using compressed air.

powder
Common term for any commercial explosive.

powder box
Commonly used industry term for a fully enclosed, locked, secure receptacle designed and used for temporarily keeping or transporting explosives. Usually fixed to a vehicle. Can be used as a day box.

powder factor
The ratio between the total weight of explosives detonated and the total volume of rock blasted above grade level. In construction, this volume is measured in pounds per cubic yard or kilograms per cubic metre. Also called loading factor.

powder headache
A type of headache induced by exposure to NG. Blood vessels dilate (expand) and allow an excess of blood to press on nerves in the head.

powder punch
A non-sparking instrument used to punch a hole in a cartridge. Usually made from a 6 mm (¼ in.) diameter brass or copper rod, pointed and fitted with a handle.

premature detonation
The detonation of a detonator or other explosive before the intended time — an unintentional and dangerous condition.

pre-splitting
A smooth-face blasting method in which cracks for the final wall are created by firing a single row of holes before initiating the rest of the holes in the blast pattern. Also called pre-shearing.

prill
A spherical particle of ANFO. Formed by spraying a concentrated ANFO solution against a stream of air.

primary charge
An explosive or explosive mixture that is sensitive to flame, friction, impact, and sparks. Used in a detonator to initiate the base charge.

primer
A detonator-sensitive explosive, such as a stick of dynamite or a cast booster, that has a detonator inserted. Used in the initiation chain to increase the effects of the detonator and cause the remainder of the explosive column to detonate.

priming
The act of combining a charge with a detonator.

programmer
See *bench tester.*

psi
Pounds per square inch.

pull-wire lighter
A flame-producing device used with a single safety fuse assembly. Effective where high winds could hamper other methods of ignition. The preferred device for lighting a safety fuse assembly.

quantity-distance table
A table, published by the Bureau de normalisation du Québec (BNQ), used to determine the proper separation distances between a magazine and its surroundings.

radio frequency (RF) energy
A form of electromagnetic energy that consists of waves of electric and magnetic energy moving together (radiating) through space. Results from electromagnetic fields produced by RF transmitters (e.g., for radio and television signals). RF energy can cause accidental initiation of an electric detonator. Also known as radio waves.

rated capacity
1. The maximum quantity of electric detonators that may be initiated by a blasting machine, as specified by the manufacturer.
2. The GVW of a vehicle.

RCMP
Royal Canadian Mounted Police.

RDX
Abbreviation of Research Development Explosive (cyclotrimethylene-trinitramine), an explosive with a very high velocity of detonation. Used in some cast boosters.

resistance
The difficulty encountered by the flow of current through an electrical circuit. Measured in ohms.

safety fuse
Consists of a special black powder core in a spirally wrapped cover of textiles and waterproof materials. The cover protects against contamination and abrasive damage. It also allows the fuse to carry flame to the detonator at a uniform speed. A component of a safety fuse assembly.

safety fuse assembly
Composed of a length of safety fuse with a detonator attached to one end and a removable plastic cover on the other end. The minimum length of safety fuse assembly that can be sold is 1 m (3.3 ft.).

safety match
A match that only ignites when struck against a specially prepared surface. May be used to ignite a single safety fuse assembly.

scaled distance
A factor that compares blast effects (e.g., ground vibration) from various sizes of charges of the same explosive at various distances. Gives a blaster an estimate of effects that a blast may have on a structure at a given distance. Obtained by dividing the distance of concern by a fractional power of the weight of the explosives.

scaling
The act of removing loose material. Usually accomplished with machinery or a scaling bar.

scaling bar
A device used for scaling. A metal (steel or aluminum) bar with pointed and chisel ends.

scanner
See *bench tester.*

secondary blasting
The use of explosives to break up oversize material. Includes mud capping and blasting boulders.

seismograph
An instrument, useful in blasting operations, that records ground vibration. This device can measure waves in four different ways: particle velocity, displacement, acceleration, or frequency.

sequential blasting
A method of firing holes in rotation (sequence) to reduce burden and provide many separate blasts. Usually the holes with least resistance are blasted progressively. Also called rotational firing.

series-in-parallel circuit
See *multiple series circuit*.

shock tube
A plastic tube coated with a thin layer of reactive powder on the inside. This reactive powder is usually a composition of HMX (a high explosive) and aluminum. When ignition occurs, the powder reacts and generates a shock wave.

shock tube assembly
A length of shock tube with a high-explosive detonator on one end and a surface connector block or a connecting clip on the other end. The assemblies are available in a range of lengths and delay timing options.

shock wave
The initial pressure wave that results from the detonation of an explosive. This wave travels at supersonic speeds. Also called a detonation wave.

shot
See *blast.*

shunt
A metal (aluminum or brass) clip or foil used to short out an electric detonator by interconnecting the leg wires. Also refers to the act of shorting out leg wires by twisting them together. Helps protect the detonator from extraneous electricity (e.g., stray current).

simplex wire
A single blasting wire usually contained in a protective plastic covering. Distinct from duplex wire, which involves two wires. Both simplex and duplex wire are types of connecting wire.

single series circuit
A series of electric detonators with the leg wires connected so that the electric current follows a single path through the entire blasting circuit.

slurry
See *water gel.*

socket
See *bootleg.*

spacer
A piece of material, usually wood, placed between cartridges or charges in a decked blast hole. Used to "space out" the explosives. This can reduce adverse effects (such as overbreak and flying material) or help achieve a clean wall.

spacing
The distance between holes in a row. To help prevent poor blast results, spacing should not be less than burden.

spacing ratio
The ratio of spacing to burden. Harder rock requires a lower spacing ratio (leading to a smaller blast pattern). Softer rock requires a higher spacing ratio (leading to a larger blast pattern).

springing
A blasting technique for opening up a pocket at the bottom of a blast hole. Successive charges are loaded and blasted. Used to remove stumps. Also called stumping.

sq. ft.
Square foot (feet).

sq. yd.
Square yard(s).

static electricity
Electrical energy stored on a person or object. May discharge to a detonator and cause accidental detonation.

static short
The triangular compression in the leg wires of an electric detonator. Located near the anti-static groove. Serves to drain off static electricity and reduce the risk of accidental detonation.

stemming
Crushed stone placed between the top of the explosive column and the collar of a blast hole. Used to confine the explosive gases for an effective blast.

stiffness ratio
The bench height divided by the burden distance. A stiffness ratio greater than 3 and less than 4.5 leads to appropriate and even distribution of energy and good blast performance.

strength
A measurement of the energy produced by a volume or unit weight of an explosive. Used to express the capacity of an explosive to perform work.

subdrilling
Drilling a hole below the desired elevation to ensure adequate breakage. Also called subgrade drilling.

Surface Blaster First Class
This blasting qualification allows the certificate holder to blast within the limits of a regional district, city, town, or village, or within 300 m (328 yd.) of a potentially occupied structure. The blaster must be able to demonstrate knowledge and use of the following:

- Blasting mats
- Seismographs
- Pre-blast surveys
- Appropriate blast design for close proximity blasting

Surface Blaster Second Class
This blasting qualification allows the certificate holder to blast near transport corridors, utilities, or services, and within regional districts where occupied buildings or structures are greater than 300 m (328 yd.) away.

Surface Blaster Third Class
This blasting qualification allows the certificate holder to blast for resource roads, quarries, utilities, or construction in remote areas where occupied buildings and significant structures are greater than 750 m (820 yd.) away.

swamper
See *assistant*.

sympathetic propagation
Detonation of explosives by the shock wave from a nearby charge. Also called sympathetic detonation.

tagger
See *bench tester.*

tamping
Compressing cartridge explosives in a blast hole. Usually done with a wooden or plastic tamping rod. Helps ensure an effective blast.

tamping rod
A non-sparking device for compressing cartridge explosives in a blast hole. Usually made of wood or semi-conductive plastic. Also called a loading pole or loading stick.

throw
The movement of muck during a blast. Specifically, the direction of movement. Airborne muck is known as flying material.

tie-in
A common term for hooking up a blast.

TNT
Trinitrotoluene, a powerful, highly water-resistant explosive. Used with PETN to make cast boosters or on its own.

toe
The unbroken lower part of a face that has been blasted but did not break off or shear loose. Also called high bottom.

toxic gases
The noxious or poisonous gases from detonation of an explosive. Includes carbon monoxide and oxides of nitrogen. Also called fumes in industry.

trim
To remove (cut off) a section of detonating cord, safety fuse, or shock tube.

trunkline
A length of detonating cord or shock tube used in a circuit to connect downlines.

velocity of detonation
The speed at which the shock wave (also known as a detonation wave) travels through a column of explosives. Abbreviated to VOD.

volt
The unit of electromotive force. One volt is the amount of electromotive force needed to make 1 ampere of current flow through 1 ohm of resistance.

warning signals
A series of short whistle signals sounded before a blast. Used to warn workers a blast is about to occur. After a safe blast, a long whistle signal indicates workers can return to the blast site. Also called blasting signals.

water gel
An explosive that contains ammonium nitrate (AN) mixed with fuels, metal particles, and sensitizers. The resulting explosive can be initiated by a high-strength detonator or a booster. Has a jelly-like consistency and can be loaded into wet holes. Also called a slurry.

Appendixes

Blast design patterns

Blast planning considers both the drill pattern and the delay design patterns.

Drill pattern examples

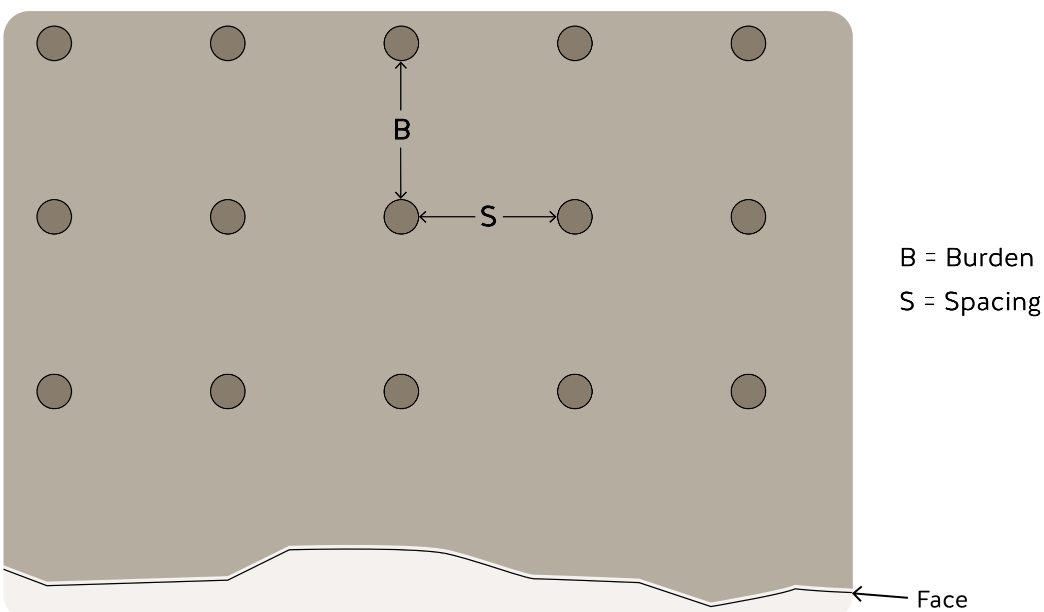
There are three different drill patterns:

- Square
- Rectangular
- Staggered

Square and rectangular drill patterns are used for blasts in which the rock will move at an angle to the original face. Staggered drill patterns are used for blasts in which one row is fired before the row immediately behind it.

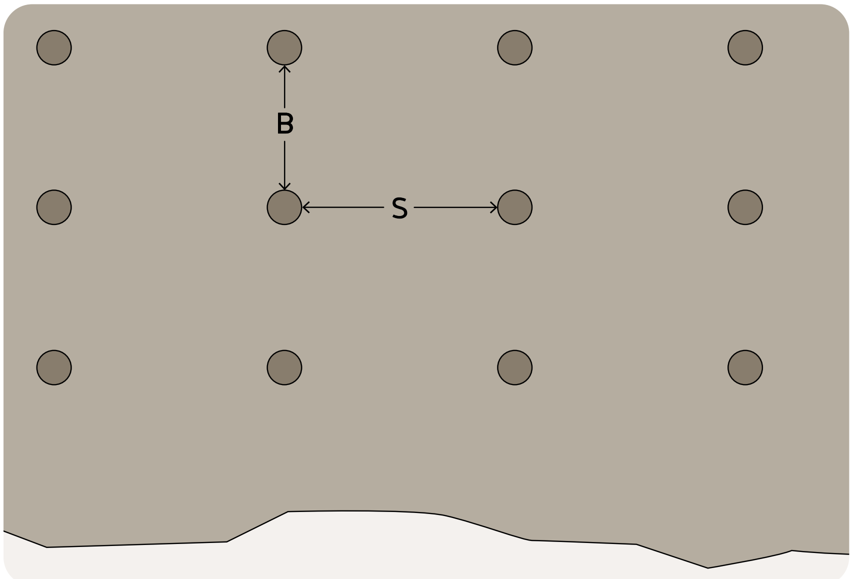
Square pattern

A square pattern has an equal burden-to-spacing ratio. The holes of each row are lined up directly behind the holes of the row in front.



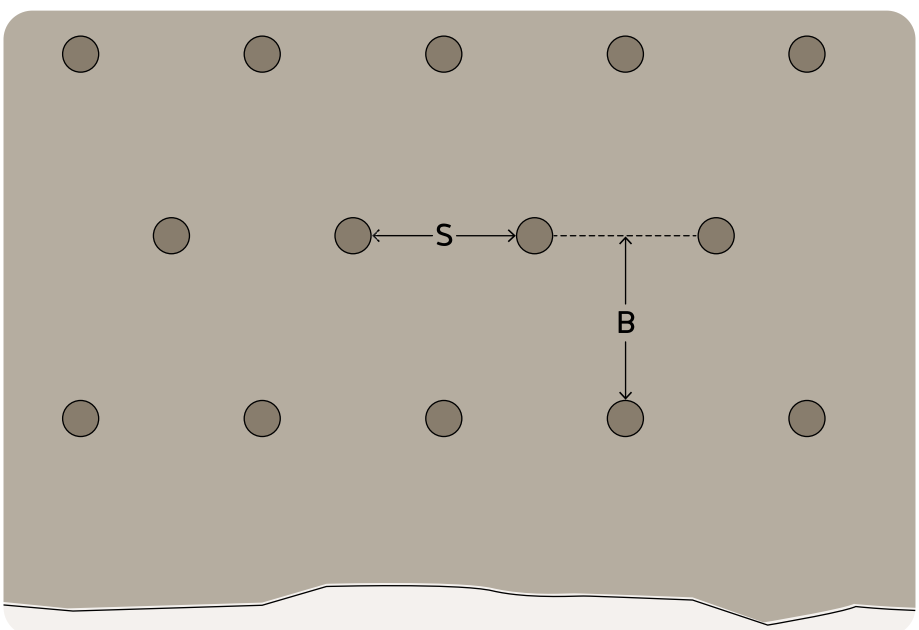
Rectangular pattern

In a rectangular pattern, the spacing is larger than the burden. The holes of each row are lined up directly behind the holes of the row in front.



Staggered pattern

In a staggered pattern, the spacing can be equal to or larger than the burden. The holes of each row are generally positioned at the middle of the spacings of the holes of the next row.



Common tie-in (delay) patterns

For a single-row blast, the use of millisecond delays between holes can improve fragmentation and reduce undesirable effects (ground vibration, air blast, and flying material).

For multiple-row blasts, the use of millisecond delays between rows is also important.

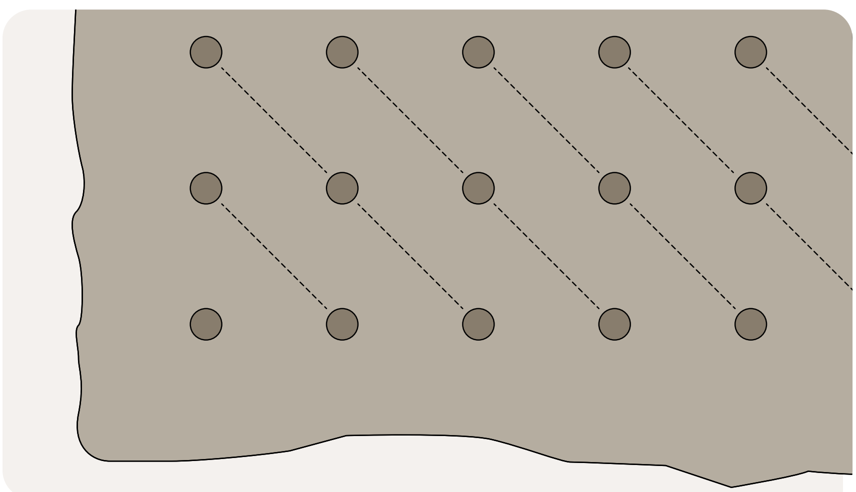
Delays are used between charges for four main reasons:

- To improve fragmentation
- To reduce ground vibration
- To provide relief for blast holes that follow
- To help control the direction of throw

The following diagrams show examples of common delay patterns. In some of the diagrams, numbers indicate the order in which the holes or rows are fired.

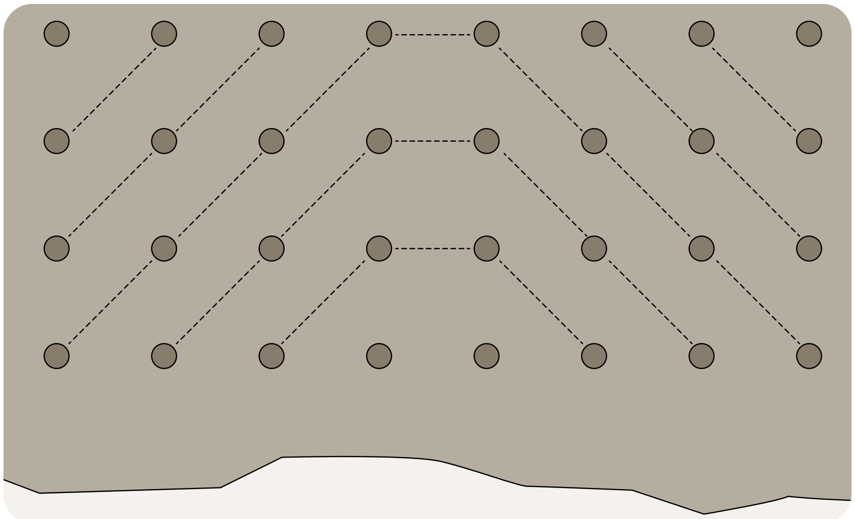
Echelon pattern with two open faces

This is an example of an echelon delay pattern with two open faces tied in on a square drill pattern. This generally produces a low muck pile.



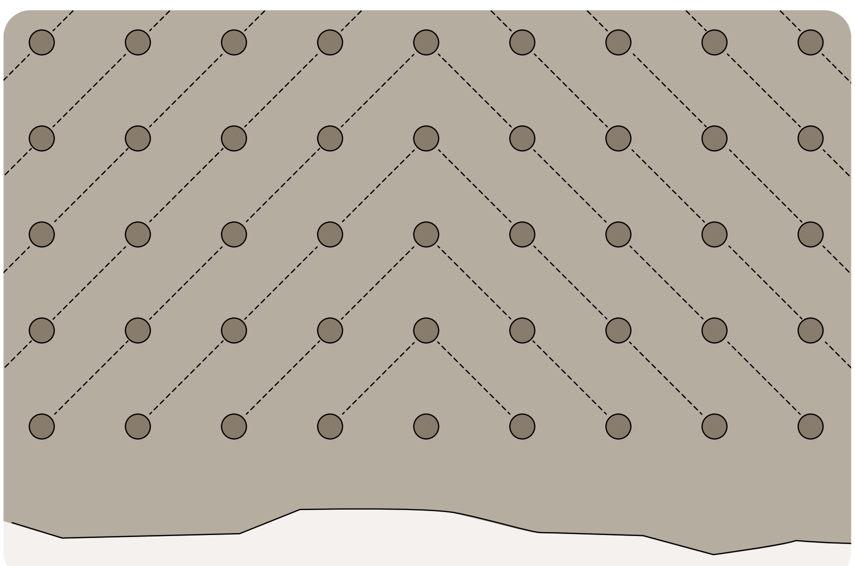
Flat V pattern

This is an example of a V-shaped delay pattern with a flat centre tied in on a square drill pattern. This tends to produce a higher muck pile.



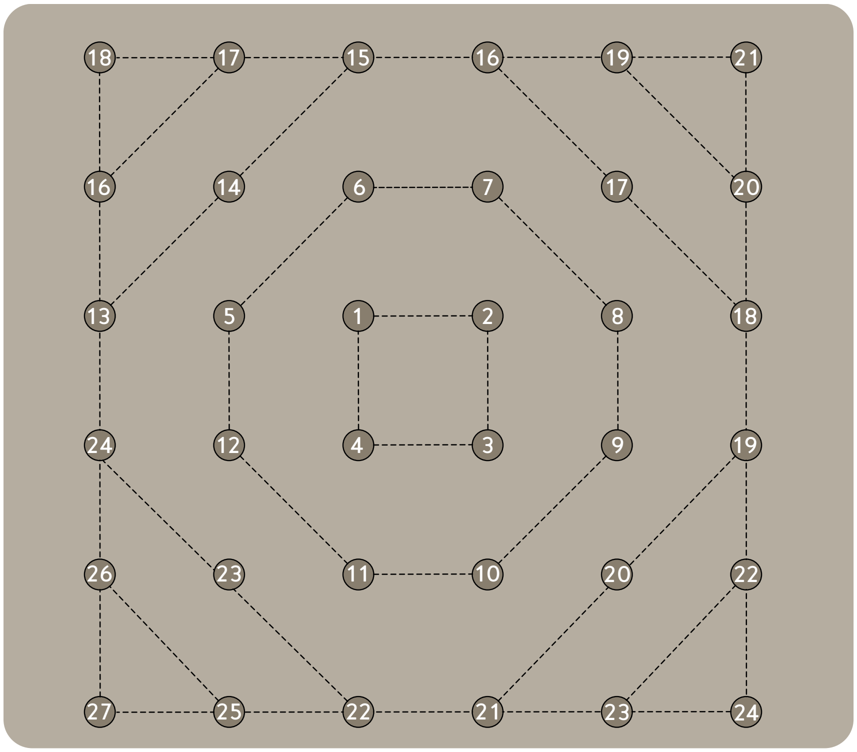
V pattern

This is an example of a V-shaped delay pattern tied in on a square drill pattern. This tends to produce a higher muck pile.



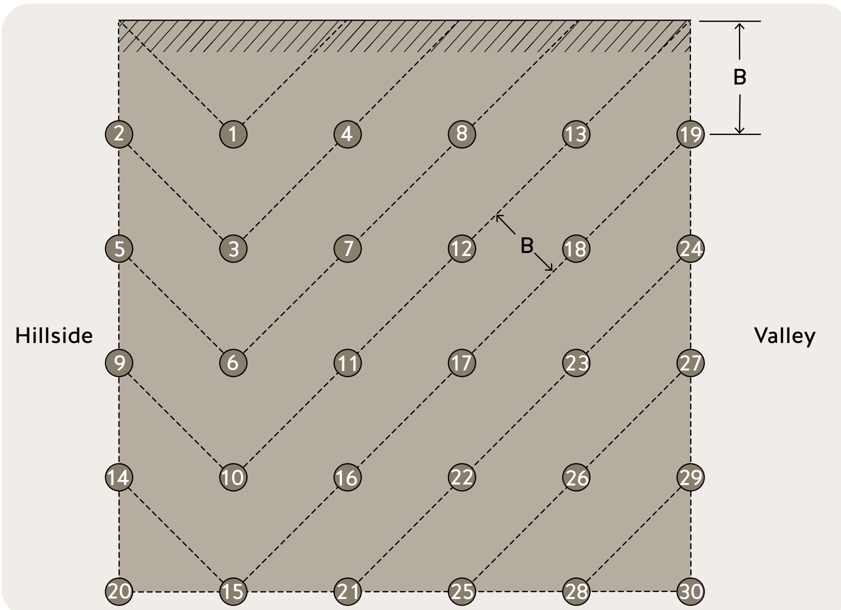
Sinking cut

Sinking cuts differ from the production shots shown on the previous pages in that there is only one open (free) face. This face is the horizontal top surface of the rock at the time the blast is initiated. The first holes that fire create a second *free face* toward which the rock can move. Allowing enough timing between holes is critical, as these shots have more potential for excessive fly rock and high vibration levels.



Hillside or sliver cuts

Hillside or sliver cuts can be difficult to control. To avoid scattering rock down a hillside, use procedures similar to those of a sinking cut or modified V-cut. This method of timing the blast holes helps ensure the rock moves toward the bank rather than the slope.



On steep hillsides, the outer row of holes has very little depth. The depth-to-burden ratio (stiffness ratio) should never be less than 1. Large-diameter holes can be used where more depth is available (i.e., higher up the slope). However, the blast hole diameter, spacings, and burdens should be reduced on the lower edges of the slope. This involves changing the drill steel and bit to a smaller size.

Trench patterns

Trenches tend to be some of the most challenging kinds of blasting projects. This is because of their dimensions and their locations close to structures. Trenches are generally long and narrow, and multiple short rows of explosives are needed to achieve length. In addition, the nature of rock and of trench geometry can vary, so there is not one set of standards for trench blasting. Blasters often need to make adjustments to design the best blast for any situation.

When trench blasting, some of the key goals are as follows:

- Control flying material.
- Minimize ground vibration.
- Minimize overbreak at the crest.
- Achieve proper grade.
- Produce loose, well-fragmented rock.

Achieving these results involves sound engineering skills and proper selection of the following:

- Drill- or bore-hole diameter
- Drill pattern and blast design
- Explosives
- Initiation system
- Seismograph
- Blasting mats

In some cases, a pre-blast survey of homes in the area surrounding the blast site is needed.

Drilling considerations

The character of the rock mass plays a key role in the design and the results of a trench blast. When deciding on the blast design and the delay pattern, the blaster should take first-hand knowledge of the rock mass into account. For this reason, it is imperative that the driller and blaster communicate and work as a team. One short hole in a trench cut can create a severe toe condition.

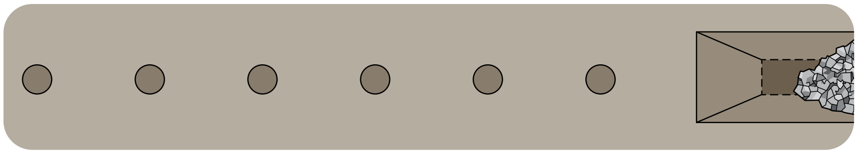
Drill patterns

The following five basic drilling patterns can be used for trenches:

- Single row
- Two-row square
- Staggered or zipper
- Five of dice
- Three-row square

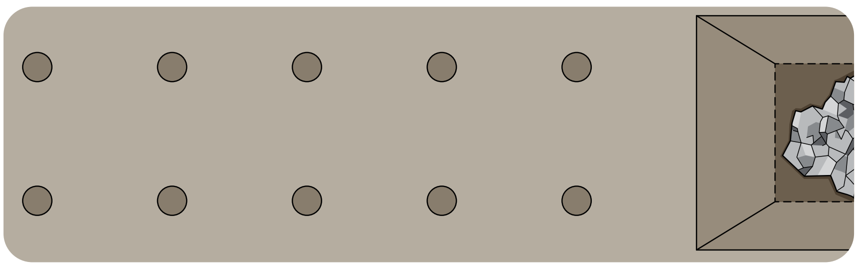
Single-row pattern

A single-row pattern involves a series of short holes. This type of pattern is used for a single line or pipe. This pattern works well in soft rock but is not recommended for hard rock.



Two-row square pattern

A two-row square pattern is used for medium rock types and for normal trench depths of 8 to 12 ft. (2.4 to 3.6 m). This pattern is square-drilled in a 4 × 4 ft. (1.2 × 1.2 m) or 5 × 5 ft. (1.5 × 1.5 m) design.

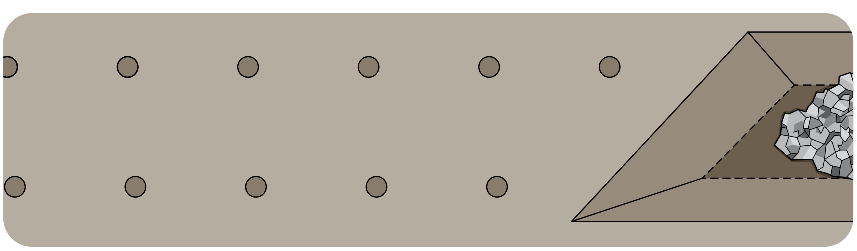


Note

The blasting industry in B.C. tends to favour the use of imperial measurements in calculations. For this reason, imperial measurements are listed first in the appendixes. A conversion table is provided on page 392.

Staggered or zipper pattern

A staggered or zipper pattern is used in soft or medium rock with cuts of 8 to 10 feet (2.4 to 3.0 m). This pattern allows burden to exceed spacing. A 6 x 4 ft. (1.8 × 1.5 m) design is common.

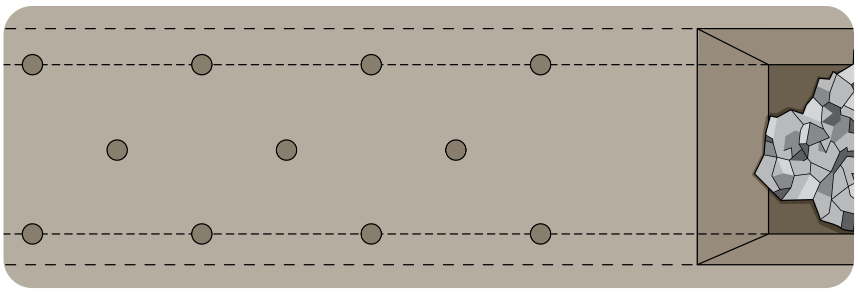


Five-of-dice pattern

A five-of-dice pattern is most commonly used in hard rock and/or medium rock with deep cuts greater than 12 feet (3.6 m). This pattern typically uses a 5 × 5 ft. (1.5 × 1.5 m) design with a centre hole.

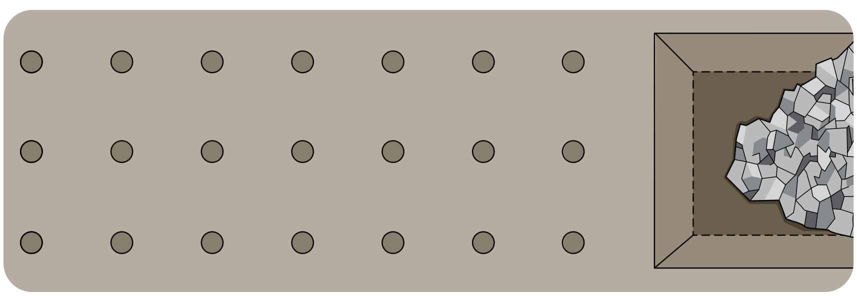
Loading considerations

The centre holes of a five-of-dice pattern provide burden relief for the side holes that follow. These centre (reliever) holes are usually loaded more heavily than side holes. This helps move surface rock out of the way so that deep rock can move. This also helps with toe-shearing action and burden displacement. Depending on the shape of the face, the blaster may shoot a reliever hole first.



Three-row square pattern

A three-row square pattern is used mainly for wider trenches (i.e., for more than one pipe and/or very large-diameter pipe). It is used for medium or hard rock with an average hole depth of 12 ft. or 3.6 m. This pattern is typically drilled in a 4 × 4 ft. (1.2 × 1.2 m) or 5 × 5 ft. (1.5 × 1.5 m) design.



Blast design calculations

The following sections are provided to help blasters with their calculations when planning specific hole-to-hole time delays and precision pre-splitting.

Hole-to-hole time delays

Hole-to-hole delayed blasting involves selecting the proper timing between holes.

In general, the rule of thumb for hole-to-hole timing is to allow 1 to 2 ms per foot of spacing between blast holes. If the timing is faster, the fragmentation will be extremely coarse (about three times as coarse as with proper hole-to-hole timing). If the timing is slower, the fragmentation will be coarse as well (about twice as coarse as with proper hole-to-hole timing). To determine appropriate hole-to-hole delay times, it is typically better to start with longer timing and work toward shorter timing.

While this rule of thumb applies in some situations, it dramatically misses the mark in others. This is because hole-to-hole timing also depends on the rock type due to differences in the crack-propagation speed of rock. Harder rock generally has higher crack velocity and needs less time between holes than weaker rock. By the same logic, rock with significant structure (i.e., many fractures, bedding planes, and joints), which slows crack propagation, needs more time between holes.

The following table sets out hole-to-hole time constants based on the rock type.

Rock type	Hole-to-hole time constant (T_h)	
	T_h in ms/ft.	T_h in ms/m
Sands, loams, marls, coals	1.8–2.1	5.9–6.9
Rock salt, some limestone, some shales	1.5–1.8	4.9–5.9
Compact limestone and marble, quartzite rocks, some granites and basalts, some gneiss and gabbro	1.2–1.5	3.9–4.9
Diabase, diabase porphyrites, compact gneiss and micashists, magnetites	0.9–1.2	3.0–3.9

After selecting a time constant, the blaster can use the following equation to calculate hole-to-hole time delays.

$t_h = T_h \times S$

Where: t_h = Hole-to-hole delay time (ms)

T_h = Hole-to-hole time constant (ms/ft. or ms/m)

S = Spacing (ft. or m)

Precision pre-splitting

Precision pre-splitting is a method of pre-splitting that considers the rock properties and the geological structure as well as site-specific conditions. This method uses closely spaced blast holes and detonating cord as the main charge. The charge weight is calculated based on the rock type, the rock structure, and the spacing between blast holes.

The pre-split forms as a result of gas pressure in the blast holes. This pressure generates a combination of stresses around each hole and between holes. These stresses cause fractures to form in the rock. The blast-hole pressure is determined by the type and quantity of explosives, the hole diameter, and other factors.

The first consideration for the pre-split design is the spacing of the blast holes. The design of the spacing should consider the rock type, the rock structure, and the purpose of the final wall. In order to achieve good walls, limit the number of joints between two blast holes to less than six. The more joints between blast holes, the worse the wall conditions. A typical spacing for a precision pre-split starts at 24 in. (61 cm), but spacing can range from 12 to 60 in. (30 to 152 cm).

Once the spacing has been determined, the next step is to calculate the Konya pre-split factor, as shown in the equation below.

$$K = \left(\frac{40579}{E}\right)^{0.625}$$

Where: K = Konya pre-split factor

E = Young's modulus of rock (GPa)

40579 = A constant

Note

Young's modulus of rock is a rock property similar to tensile (breaking strength). It can be found for most rocks through one of the following:

- Doing a web search
- Using a reference textbook
- Checking the geotechnical packet that is part of the contract documents for many jobsites

After calculating the pre-split factor and determining the spacing, the blaster can use the following equation to calculate the explosive load.

$$EL = 7000 \times \left(\frac{S}{K}\right)^2$$

Where: EL = Explosive load (gr./ft.)

S = Spacing (in.)

K = Konya pre-split factor

7000 = A constant

Other, more advanced methods of calculation are available today with further refinements. However, the approach set out here gives blasters a way to quickly get to an appropriate starting point for a test blast.

Laws and regulations pertaining to industry

Workers Compensation Act and Occupational Health and Safety Regulation

The Occupational Health and Safety Regulation and the OHS provisions of the *Workers Compensation Act* contain legal requirements for workplace health and safety that must be met by all workplaces under the inspectional jurisdiction of WorkSafeBC.

The purpose of the Regulation is to promote occupational health and safety and to protect workers and other persons present at workplaces from work-related risks to their health, safety, and well-being. Compliance with the requirements provides the basis on which workers and employers, in cooperation, can solve workplace health and safety problems. The requirements are not an end in themselves, but are a foundation upon which to build an effective health and safety program.

WorkSafeBC is committed to the regular review of the requirements of the Regulation based on regulatory experience and changes in knowledge, technology, and work practices.

Some examples of parts of the Act and Regulation that are relevant to blasting operations are listed below. Blasters must always be aware of the latest requirements.

Act

Part 2, Division 4, General Duties of Employers, Workers and Others

Regulation

- Part 21, Blasting Operations
- Part 20, Construction, Excavation and Demolition: Scaling Operations
- Part 22, Underground Workings
- Part 23, Oil and Gas
- Part 26, Forestry Operations and Similar Activities
- Part 8, Personal Protective Clothing and Equipment
- Part 6, Substance Specific Requirements: Respirable Crystalline Silica and Rock Dust
- Part 6, Substance Specific Requirements: Asbestos (demolition)

Federal acts and regulations

Explosives Act and Regulations

The *Explosives Act* and Regulations are subject to revision, and blasters must always be aware of the latest requirements.

Transportation of Dangerous Goods Act and Regulations

The *Transportation of Dangerous Goods Act* and Regulations are subject to revision, and blasters must always be aware of the latest requirements.

Workplace Hazardous Materials Information System (WHMIS)

The Workplace Hazardous Materials Information System (WHMIS) is Canada's national hazard communication standard. The key elements of the system are hazard classification, cautionary labelling of containers, the provision of safety data sheets (SDSs), and worker education and training programs.

Industry organizations, vendors, manufacturers, and safety associations

A number of industry organizations, vendors, manufacturers, and safety associations provide information to employers and workers about safe work practices. A few examples of these groups include the following.

Industry organizations

The International Society of Explosives Engineers (ISEE) is a membership-based society that offers training in blasting, vibration, and drilling. The ISEE's courses, publications, and conferences are based on safety and explosives regulations. The ISEE also promotes best practices for the blasting industry.

The Institute of Makers of Explosives (IME) promotes safety and security for the commercial explosives industry and provides safety information on explosives.

Vendors and manufacturers

Vendors are the best sources of up-to-date information on explosives. Many manufacturers maintain websites that have current and detailed product information. Examples of vendors and manufacturers operating in B.C. include the following:

- Orica
- Dyno Nobel
- Austin Powder

Safety associations

- The Canadian Centre for Occupational Health and Safety (CCOHS) is a federal department corporation that promotes the well-being of Canadian workers and provides a wide range of OHS information.
- The CSA Group (previously known as the Canadian Standards Association) is a standards-development, product testing, and certification organization. The CSA Group has developed standards for machinery and equipment, as well as for measurement of airborne sound and ground-borne vibration from blasting.
- The BC Construction Safety Alliance (BCCSA) provides B.C.-specific safety information, training courses, and certification resources to the construction industry.
- The BC Road Builders and Heavy Construction Association is a non-profit organization that represents contractors involved in highway maintenance, construction, underground/utility, and paving work, as well as various service and supply companies in the industry.

- The BC Municipal Safety Association (BCMSA) is an independent, non-profit organization committed to improving worker health and safety in all industries throughout the province.
- The Canadian Avalanche Association (CAA) is a non-profit organization that supports avalanche practitioners in Canada. The CAA organizes professional training courses, provides a system for information exchange, and works to ensure that its members meet the highest standards in their avalanche safety programs.

Conversion table for units of measurement

The units of measurement, abbreviations, and conversion factors used in this handbook appear in the following table. To use the table, do the following:

- To convert a unit in the left column, multiply it by the factor in the middle column to find its equivalent in the right column.
- To convert a unit in the right column, divide it by the factor in the middle column to find its equivalent in the left column.

This unit →	Multiplied by this factor →	Equals this unit
Length		
Metres (m)	39.37	Inches (in.)
Metres (m)	3.281	Feet (ft.)
Millimetres (mm)	0.001	Metres (m)
Centimetres (cm)	0.3937	Inches (in.)
Inches (in.)	25.34	Millimetres (mm)
Volume		
Cubic centimetres (cm^3 or cc)	0.061	Cubic inches (cu. in.)
Cubic inches (cu. in.)	16.39	Cubic centimetres (cm^3 or cc)
Cubic metres (m^3)	1.31	Cubic yards (cu. yd.)
Cubic feet (cu. ft.)	0.028	Cubic metres (m^3)
Cubic yards (cu. yd.)	0.7646	Cubic metres (m^3)
Weight		
Kilograms (kg)	2.2	Pounds (lb.)
Pounds (lb.)	0.4536	Kilograms (kg)
Powder factor		
Pounds per cubic yard (lb./cu. yd.)	0.593	Kilograms per cubic metre (kg/m^3)
Kilograms per cubic metre (kg/m^3)	1.686	Pounds per cubic yard (lb./cu. yd.)
Loading density		
Pounds per foot (lb./ft.)	1.4882	Kilograms per metre (kg/m)
Speed or velocity		
Metres per second (m/s)	3.281	Feet per second (ft./s)
Feet per second (ft./s)	0.3048	Metres per second (m/s)
Inches per second (in./s)	2.54	Centimetres per second (cm/s)
Kilometres per hour (km/h)	0.62	Miles per hour (mph)
Equals this unit ←	Divided by this factor ←	This unit

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