RSHQ
Best Practice Guide

Prevention of explosives misfires in blasting applications

Version 2

NOVEMBER 2025

Resources Safety & Health Queensland

Acknowledgement

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1.1 Background

Blasting is performed to liberate and fragment a rock mass, enabling the downstream processes such as excavation, to occur efficiently and safely. The safe execution of effective blasting practices, within acceptable standards, is necessary for the understanding and prevention of misfires.

Explosives incidents are defined in Schedule 2 of the Queensland Explosives Act 1999. Following an analysis of reported explosives incidents, the most common type of explosives incident reported is consistently misfires (64% between July 2020 - July 2025, Figure 1).

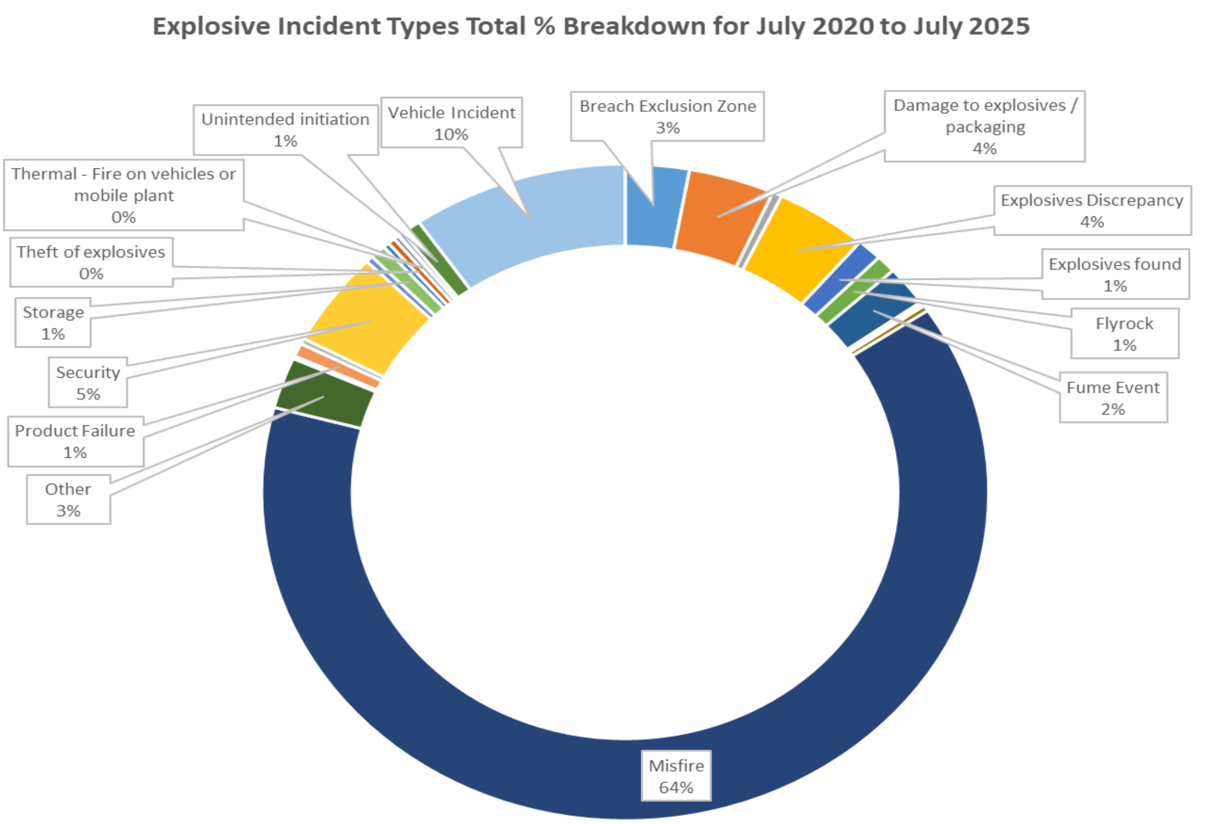

Figure 1: Explosive incidents, July 2020 – July 2025

Misfires are a source of risk for unplanned detonations, as well as for inappropriate persons to have uncontrolled access to explosives. The process of remediating misfires exposes persons to hazards, such as unstable or unsupported ground and handling misfired explosives that have changed in quality or character.

The risk increases with time, and it depends where in process the misfire has been identified, as shown in Figure 2. Hence it is a statutory obligation of all prescribed shotfirers in Queensland to *prevent misfires*[1]. (1)

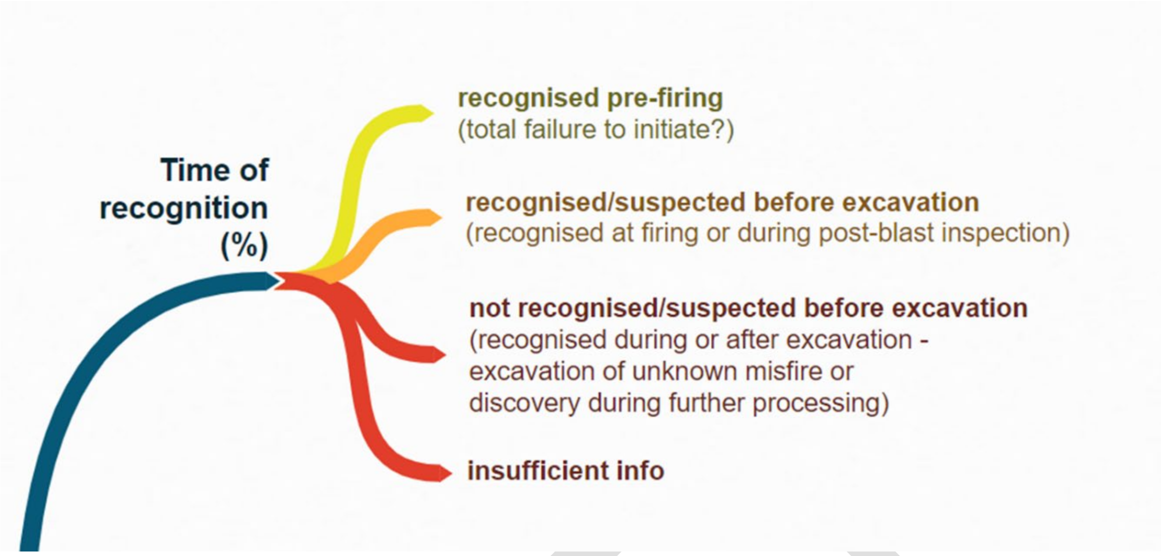

Figure 2: Time of misfire identification – Risk profile

1.2 Introduction

Resources Safety and Health Queensland (RSHQ) Explosives Inspectorate engaged with industry representatives to develop the Best Practice Guideline (BPG) for the prevention of explosives related misfires. As per Figure 1, the continual high percentage of reported misfires has led to a heightened sense of chronic unease throughout industry.

The aim of this BPG is to provide practical means of guidance to prevent the generation of misfires associated with all blasting activities in Queensland.

To ensure this BPG adequately identified and addressed the relevant preventative controls, the misfire working group:

- collated and analysed data and information from RSHQ
- identified the factors that contribute to the occurrence of misfires
- compiled methods and strategies to prevent future misfires.

[1] Queensland Explosives Regulation 2017 , Section 152(b)(i)

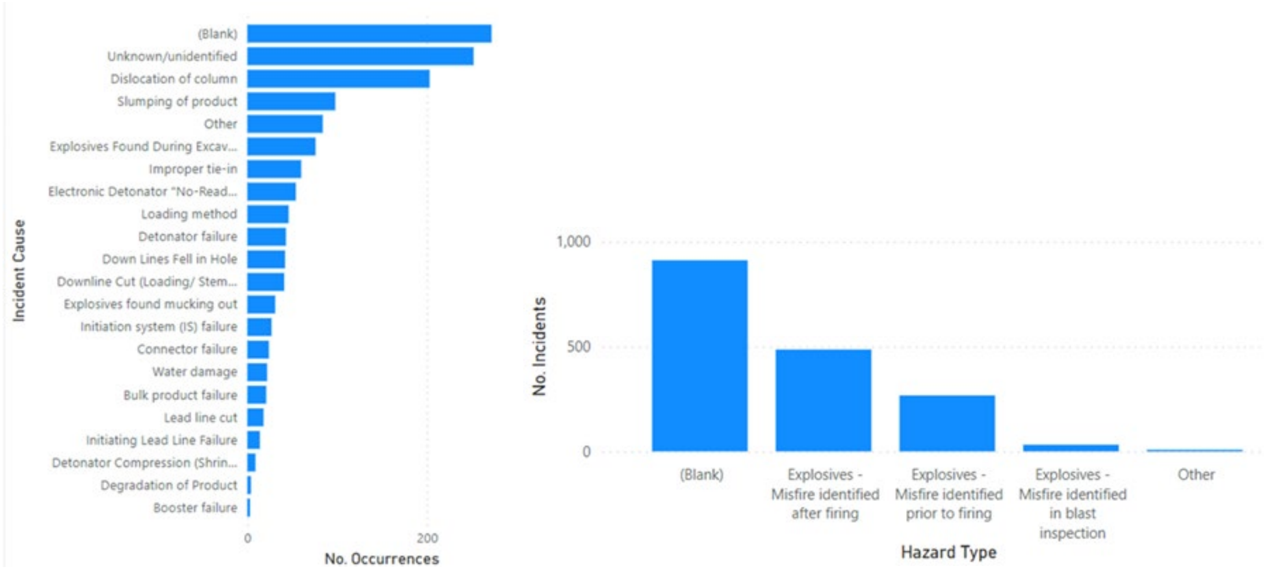

Figure 3: Cause of misfires (in coal) reported to RSHQ at the time of the misfire 2017-2021

For the initial version of this BPG, Brady Heywood Pty Ltd was engaged to conduct detailed analysis into incidents reported to RSHQ between 2017 and 2021. As shown in Figure 3, the analysis identified the majority of these incidents had an ‘unknown’ cause, highlighting the need for improved reporting practices.

1.3 Purpose

The purpose of this BPG is to:

- understand the known causes of misfires by identifying the contributing factors
- provide practical guidance to prevent misfires by controlling the risks.

This BPG is not a ‘Guideline’ as defined in the *Queensland Mining and Quarrying Safety and Health Act 1999*, or a ‘Recognised Standard’ as defined in the *Queensland Coal Mining Safety and Health Act 1999*. This BPG is not called up in the *Queensland Explosives Act 1999* (“the Act”) (2).

In some circumstances, compliance with this BPG may not be sufficient to ensure compliance with the requirements in the legislation. This document is intended for all stakeholders involved throughout the entire blasting process. This includes all stakeholders from explosives procurement, through blast/drill design, supervision and blasting personnel.

1.4 Scope

This BPG is applicable to blasting activities in surface, underground and civil applications involved in the handling and use of explosives. This guide does not include systems and processes associated with full wireless detonator initiation systems. It does not address methods to identify misfires, and misfire remediation process.

This BPG assumes that manufactured explosives (bulk, detonators, boosters, detonating cord, packaged and similar) and raw constituents are fit for purpose to function as intended from the manufacturer. Manufacturing quality management is not covered by this BPG.

This best practice guide will follow the blasting process, which is classified as the following sequence:

- explosives procurement
- blast design
- drill blast holes
- load blast holes
- tie in and fire.

1.5 Definitions

1.5.1 Misfire

The definition of a misfire is prescribed in Schedule 7 of the Explosives Regulation 2017("the Regulation") (1), being:

- misfire means the failure of a charge, or part of a charge, to explode or ignite.

1.5.2 Ammonium Nitrate Emulsions (ANE)

Ammonium Nitrate Emulsions, suspensions and gels, conforming to UN3375, are collectively referred to in this guide as ANEs (As per AEISG Code of Practice Storage and Handling of UN3375). (3)

2.0 Safety and security management system

The storage, transport and handling of explosives must be carried out in accordance with the Act (2) [2] and the Regulation[3] (1), which prescribes the development, implementation and maintenance of a 'safety and security management system'.

In accordance with Section 46B of the Regulation, the safety and security management system may be a part of a safety and health management system required under another Act, such as the Coal Mining Safety and Health Act 1999 (4), or the Mineral Mines and Quarries Safety and Health Act 1999 (5).

Furthermore, as required by mining legislation, safety and health management systems must also give regard to the prevention of and control of risks such as misfires.

In Queensland, the use of explosives should be in accordance with Australian Standard AS 2187.2 (6). For blasting activities that are not undertaken on a mine site, alternative safety measures can be applied instead of AS 2187.2, with provision of underpinning, documented risk management practices, which demonstrate the residual level of risk either equal to, or lower than what is achieved when following AS 2187.2.

Guidance on the establishment and use of a blast management plan can be found in Appendix A of AS 2187.2, which exists to address hazards associated with the blast, including a misfire management system.

To further understand the blast management process and what elements must be addressed to prevent misfires, refer to the tree diagram in Figure 4.

In addition to procedures prescribed in applicable legislation, other operational procedures may need to be developed and implemented to incorporate the best practices covered in this guideline.

2.1 Management of change

Change regularly occurs during blast related activities, which introduces the potential for misfires. Examples of this include changes to blasting processes and/or explosive's products.

Prior to the change occurring, ensure management of change process is undertaken, to identify any misfire hazards and implement effective controls.

This management of change process should 'look at the change proposed, identify any possible effects and side effects, document the likely consequences and hazards, assess the severity of any hazardous outcomes, incorporate the required safety measures and then provide the appropriate risk assessments showing the change achieves an acceptable level of risk. This should all occur, prior to the change being made' (7).

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[2] *Explosives Act* 1999

[3] Explosives Regulation 2017

To prevent misfires, change management should be undertaken for changes in:

- procurement (explosives supplier, explosive products, initiation system types, stemming types)
- design process changes
- drilling
- explosives loading (from new suppliers, new raw materials, delivery rates, blend ratios, densities, gassing rates, including vehicles and delivery systems)
- introduction of new hardware/software/firmware updates within initiation systems
- change to personnel or resourcing.

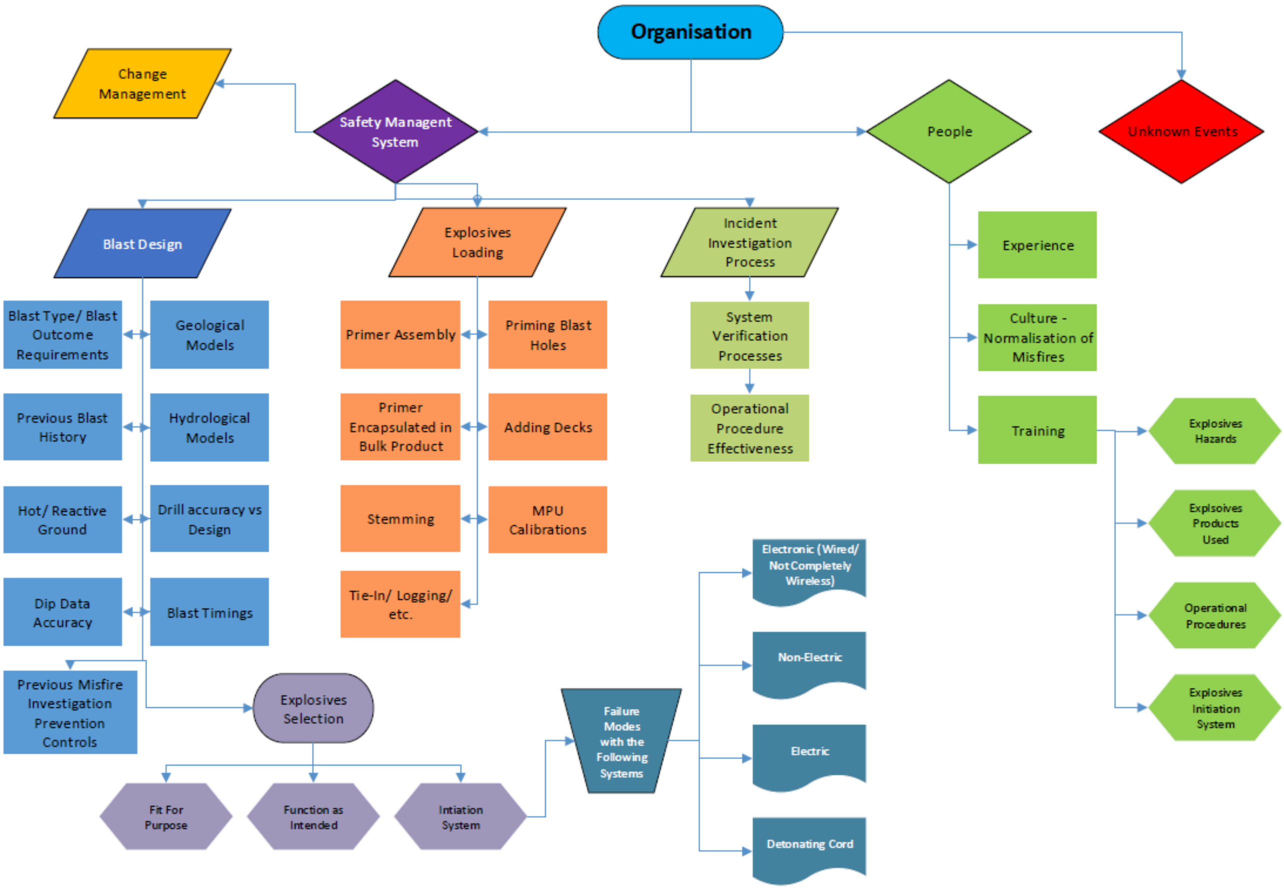

Figure 4: Causal factor tree diagram (a non-exhaustive example)

3.0 Resourcing, training and competency

This BPG assumes that the personnel who perform blasting activities in Queensland are trained and assessed as competent in line with legislative and industry training standards.

Guidance and recommendations on competencies for core positions such as shotfirers, support crew and others involved in the blast process, are available at:

https://www.rshq.qld.gov.au/resources/documents/explosives-and-fireworks/competency-requirements-shotfirer-licences.pdf

Competencies required for Coal Mines are listed in Recognised Standard 22: Management Structure for the development and implementation of the Safety and Health Management System which is available at:

https://www.business.qld.gov.au/industries/mining-energy-water/resources/safety-health/mining/legislation-standards/recognised-standards

Additional guidance can be found within the RII Resources and Infrastructure Industry Training Package available at:

https://training.gov.au/training/details/rii

This BPG assumes that sufficient resources are provided to achieve the recommendations provided, this includes but is not limited to:

- time
- equipment
- personnel and labour
- software or systems
- hardware and tooling
- consideration of peak workload demands.

4.0 Explosives procurement

Explosives procurement should not limit explosive selection for the desired outcomes of the project or activity. Once procurement is finalised the procured explosives specifications listed in technical data sheets are locked in. Therefore, careful consideration should be given to product selection with full involvement of technical personnel, responsible for blasting.

Procurement process of raw materials, technology and explosives should involve technical and end user input. Technical input must include suitability of products offered and risks involved, especially during change of suppliers.

5.0 Storage, transport and handling of explosives

An established system must identify degraded, deteriorated or out of date product. There should be a suitable process for the cleaning and maintenance of equipment, including logging and initiating equipment.

Avoid rough and reckless handling of explosives products, i.e. no throwing, dropping, stretching (this includes harness wire, control equipment and other components that form part of the initiation system). Minimise handling of explosives products were possible, especially for packaged emulsions (when used in pre-split process or when used as a booster to initiate the explosive column), as excessive handling may desensitise the product.

Principles for safe storage and handling of explosives include:

- minimise damage to stored explosives. return unused explosives to original packaging
- manage stock rotation and reconciliation. the new stock is the last to be used
- protect explosives from adverse weather effects
- prevent tampering, damage or substitution from external sources
- store explosives in approved magazines, tanks or containers
- minimise temperature cycling
- follow the explosives' manufacturer's handling requirements.

5.1 Storage of Class 1

To prevent damage and degradation, Class 1 explosives must be stored in accordance with legislative and manufacturer requirements.

5.2 Storage of ammonium nitrate prill

To manage the changes in characteristics of AN due to heat/ temperature cycling, moisture absorption and caking and contamination the following should be considered:

- minimise the amount stored and duration of storage
- stock rotation
- set out and maintain segregation from other chemicals and combustibles
- protect prill from adverse weather effects
- minimise handling.

Ammonium nitrate prill must be stored in accordance with the Queensland Explosives Inspectorate's Information Bulletin 53 and transported in accordance with the Australian Dangerous Goods Code.

5.3 Storage and Transport of ANE and Gels (UN3375)

ANEs must be stored in accordance with relevant legislative and manufacturer requirements.

To minimise changes in characteristics to ANE, the following should be considered:

- Avoid excessive pumping/ transfer, to minimise crystallisation.
- Stock rotation.
- Minimise the potential for accidental mixing of incompatible chemicals.
- Compatibility of ANEs. When storing different ANEs from various suppliers, consider the compatibility of products and intended application; seek product manufacturer advice.
- Tanks must be thoroughly cleaned and decontaminated, prior to storing the non-compatible types of ANE.

ANE and Gels of UN3375 must be transported in accordance with the Australian Dangerous Goods Code. When planning transport routes consider the adverse effects of poor road conditions, temperature, humidity and weather on the product.

5.4 Transport of Class 1 explosives

To prevent misfires resulting from damage to the explosives during transport, the following should be considered:

- Prevent rough/reckless handling during loading or unloading activities.
- Transport explosives in approved packaging and approved carry boxes/containers.
- Ensure explosives are stowed and secured to prevent movement during transport.

For the transport of Class 1 explosives in Queensland, explosives must be transported in accordance with the requirements of the Australian Code for the Transport of Explosives by Road and Rail (8), otherwise known as the AEC3.

6.0 Blast Design

6.1 Blast objectives

Desired blast outcomes including any constraints should be formalised as specific objectives that are captured in the design process. One of the objectives during the design process should be misfire prevention.

The assessment of blast objectives and constraints which form blast design parameters should consider:

- previous blast history (such as geological and geotechnical domains, misfire prevention controls, etc.)
- historical mining activity
- drill and blast schedule
- blast concept design
- drill pattern design – burden, spacing, depth, row orientation, standoffs, hole diameter, intersection with probe and exploration holes and/or redrill holes etc
- charge design – deck layouts, priming requirements, product selection, environment considerations
- initiation design – direction of movement and relief.

Where available, use appropriate software and simulation tools for the design of blasts.

6.2 Scheduling of blasting activities and excessive exposure time

6.2.1 Scheduling – exposure and sleep time

To mitigate potential sleep time risks during scheduling of blasts, the following should be considered in the design development phase:

- Engagement with suppliers or providers for product advice regarding maximum sleep time of intended explosives products, prior to design and scheduling.
- Adequate resources to achieve planned outcomes.
- Changes in the mine's/project operations planning that put the drill and blast schedule at risk.
- Where the ground conditions provide a high (misfire) risk profile – reduce the sleep time to as low as possible.
- Adverse effects of weather events.

6.2.2 Scheduling – blast interaction

Interaction between adjacent blasts can be a source of misfires, particularly with ground movement and/or material and fly rock.

During the design development phase, the following should be considered:

- A buffer of solid material should be maintained between blast patterns in case of ground movement during firing.
- Manage the risk of fly rock and potential damage to downlines/initiating systems.
- Adequate relief in tightly confined blasts where blast patterns have been drilled out could be managed through blasting sequence.

6.3 Ground Conditions

Ground conditions have an effect on blast results and the possibility of misfires. Some of the important considerations point of view are as follows.

6.3.1 Hot and reactive ground

The risks from gas, hot/elevated temperature or reactive ground can pose significant potential for damage or desensitisation of explosives which can result in unintended initiation and/or misfires.

Spontaneous combustion or oxidation of carbonaceous materials such as coal, may also create an elevated temperature situation which can result in unintended initiation and/or misfires.

To mitigate the potential risks due to gas, hot and/or reactive ground, the following should be considered in the design development phase:

- reactive ground identification, testing and management
- elevated temperature ground identification, testing, and management.

Regularly review and consider:

- Geological models that identify:
  - potential hot and reactive ground
  - propensity for spontaneous combustion
- Use of appropriate explosive products, specifically inhibited explosives and ensure the drill pattern configuration supports the product.
- The blasting schedule should consider any impacts associated with maximum sleep times in elevated temperature and/or reactive ground conditions.

Information can be found in Standards and Codes (e.g. AS2187.2 (6); Guidance Note QGN10 (9) and Guidance Note QGN11 (10); Elevated Temperature and Reactive Ground AEISG Codes of Practice (9) (10), Explosives: Definitions, Classification & Hazards (13) etc)

6.3.2 Inadequate blast hole stability

Misfire risks associated with blast hole stability should be considered as early as the conceptual design stage. Unstable holes may collapse leading to misfires through loss, damage or severance of initiating systems and downlines, or discontinuities in charge columns.

To mitigate the potential misfires due to unfavourable ground or geological conditions and inadequate blast hole stability, the following should be considered in the design development phase:

- geological mining blocks or domains that may be prone to unstable or poor ground conditions
- identification and demarcation of previously mined areas (especially underground voids e.g. highwall mining)
- abandoned holes or old exploration holes
- collapsed/redrilled holes, as well as history of hole stability in the area
- vertical blast holes versus angles holes
- necessary standoff from preconditioned ground
- visual inspection of the area prior to commencing design
- consider test hole drilling to verify existing ground conditions and confirm the presence of water.

To prevent material movement or dislocation prior to column detonation, the following should be considered:

- modification of the angle of initiation to maximise stability
- compress timing (reduction in relief) to reduce potential for movement of unfired ground
- suitable relief to avoid any increase in the potential for gas injection leading to dislocations. this may be mitigated by:
  - ensuring adequate powder factor for material to break
  - defining maximum burden limits and apply to design
  - ensuring adequate timing for relief. relief should be applied in the required direction of movement and, where possible, make use of the existing and developed voids.

6.3.3 Inadequate blast hole collar stability

Instability at the hole collar can lead to collapse and subsequent misfires through loss, damage or severance of initiating systems and downlines.

To mitigate the potential misfires due to inadequate blast hole collar stability, the following should be considered in the design development phase:

- The amount of subgrade or subdrill that is suitable for the ground conditions without causing excessive overbreak.
- The use of collar stability systems that improve the stability of a blast hole collar in broken conditions.
- The drill collar offset position.
- A stable surface for drilling operations, which could be achieved by:
  - using suitable quality fill material
  - using pit shell design to limit design excavation surfaces to within drilling capability
  - using terraces to limit the depth of fill
  - allowing sufficient time for fill to settle and by working over the fill to compress and stabilise the fill material prior to drilling operations.

6.3.4 Geological and mechanical properties

Varying material types typically require different powder factors and pattern design, as well as timing to achieve desired results. This difference in material characteristics and blast design inputs can cause misfires due to dislocation prior to hole initiation.

To mitigate the potential risks due to geological and/or mechanical properties, the following should be considered in the design development phase:

- Geological structures and discontinuities that can cause ground movement cut-offs.
- Materials with significantly different attenuation/mechanical behaviours.
- Identify any areas that may undergo shunting along weaker interfaces such as coal, weathered horizons, tuffs or weaker clay bands that may react in a manner significantly different to surrounding host materials.
- Regularly review and update drill and blast domains with revised geological input.
- Consider the use of stemming decks through identified dislocation risk zones.
- Where inert material decks are required, verify they are of sufficient length to reduce the potential for desensitisation from adjacent decks (consider initiation timing, TDS (Technical Data Sheet), OEM recommendation).

Figure 5: Example of variable geological conditions with hard igneous basalt overlying soft sedimentary formations

6.3.5 Groundwater and water management

Water, if not managed correctly, can be a ready cause for misfire through numerous mechanisms, including but not limited to:

- Erosion or damage to bulk explosive products or columns resulting in:
  - partial or complete detonation failure; or
  - slumping of the column of explosives

- Damage to initiation systems and water ingress to sensitive initiating componentry.
- Loss or damage to initiating systems as a result of water flows both down hole and across work areas or benches.
- Burying of initiating systems beneath subsequent silts and muds.

In the presence of dynamic water (continually entering the blast hole) the effects above can be worse or accelerated).

To mitigate the potential risks due to groundwater or inadequate water management, the following should be considered in the design development phase:

Appropriate water-resistant explosives are used as per manufacturer's recommendations, and the following is applicable:

- An effective water management plan, example suitable pumping systems, break through holes, suitable gradient for water run-off.
- Consideration of the effects of local bodies of water and their potential impacts to shot conditions and ground conditions. For example, the pH of the water.
- Use of hydrogeological information from previously mined areas to inform product selection and subsequent drill pattern design parameters.
- Blast scheduling practices that consider the risks and controls for the anticipated environmental conditions.

6.4 Dynamic Desensitisation

Dynamic desensitisation (dead pressing and shrink wrapping) is a known misfire mechanism by which sensitised bulk explosives, packaged emulsions and initiating systems are desensitised and/or damaged through exposure to excessive pressure during the blast. Typically, desensitised explosives are not identified until excavation.

Blast geometry considerations and initiation timings may be required to manage dynamic desensitisation.

6.4.1 Bulk / Packaged Explosives

Pressure from earlier firing holes can desensitise bulk/packaged explosives in later firing holes. Desensitisation from dynamic pressure occurs due to the compression of the bulk / product sensitisers.

Some examples of these sensitisers may include:

- gas bubbles
- glass and/or plastic micro balloons
- polystyrene beads.

The application of excessive dynamic pressures to bulk explosives will initially lead to poor blast performance through loss of energy (deflagration and low order detonation), increased fume production and ultimately misfires as critical density is exceeded.

Parameters such as the distance between charges, hole depth, blast timing and planned average in hole densities may contribute to desensitisation. Elevated hydrostatic pressures may increase the potential for dynamic pressure desensitisation.

Refer to explosive manufacturers TDS for application limitation of explosives and follow guidance.

6.4.2 Detonators

The application of excessive dynamic pressures to all detonator types may lead to:

- collapse of detonator shell
- damage to internal components.

These impacts will compromise the functionality of the detonator.

Parameters such as the distance between charges, blast timing and presence of water may contribute to dynamic pressure impacts to detonators.

Location of detonators within proximity to ground conditions (such as geological/geotechnical anomalies, clay seams, etc.) that transmit blast energy, can increase the potential for dynamic pressure impacts.

Refer to explosive manufacturers TDS for application limitation of explosives and follow guidance. This may include understanding the dynamic pressure limitations of the detonator proposed to be used.

Figure 6: Examples of shrink-wrapped detonator

6.4.3 Dynamic Desensitisation Controls

To mitigate the potential for dynamic desensitisation of both bulk and packaged explosives and detonators, the following should be considered in the design development phase:

Cause	Bulk/Packaged	Detonators
The potential for drill hole deviation, especially in poor ground conditions, broken ground and areas with high variable geology, which may allow holes to interact during firing.	Yes	Yes
The potential for pressure, via gas, water or other means, to be transmitted through the specific geology i.e. weaker clay or tuff bands and rider seams.	Yes	Yes
The minimum inert deck length and properties between charges firing on different delays should be determined. Deck properties should consider the following:	Yes	Yes

Cause	Bulk/Packaged	Detonators
a) blast hole diameter b) linear charge density c) the presence of water d) decking material specifications.		
Limiting blast depth.	Yes (Especially for depth)	Yes
Avoiding blast shapes that restrict voids.	Yes	Yes
When using angled shots (i.e. cast blasts), bearing and angle should remain consistent where possible.	Yes	Yes
When a blast includes various blasthole angles and azimuths within the same pattern, ensure sufficient separation between explosive columns along the entire length of the blasthole(s).	Yes	Yes

6.5 Ejection of explosives from blast holes

Explosives can be ejected from blast holes when subject to blast pressures from adjacent holes. Blast designers should consider the following:

- blast timing
- ground conditions – water, faults, joints, pre-conditioned ground, etc
- effectiveness of stemming or explosives retention devices or retention properties of bulk explosives for planned blast hole diameter
- intersecting blast holes, exploration holes or previous mine workings.

6.6 Drill Pattern Design

6.6.1 Blast hole and pattern design – misfire mechanism overview

Appropriate design of blast holes is critical to prevent misfires. To mitigate this risk during the blasthole design phase, a blast hole design standard should consider the following potential risk factors:

- ground and geological conditions
- pattern configuration (including redrills) that allows for adequate blast hole separation distance
- blast hole depth and diameter compatible with intended explosive products
- inadequate critical diameter to allow for product detonation (refer to TDS)
- channel effect due to decoupled explosives in blast holes;
- appropriate geotechnical input into the drill and blast process, including ensuring drill holes are located outside any relevant exclusion zones. geotechnical information can be obtained from exploration drilling.

Ineffective blasthole naming conventions can lead to failures in:

- execution of drill design
- execution of load design and reconciliation process

- execution of initiation design.

Establish a simple, sequential and consistent blast hole naming convention, which should be done in consultation with shotfirers responsible for execution. Operational procedures should correctly apply the naming conventions.

6.7 Charge Design

6.7.1 Explosive Product Selection

Explosive products selection is crucial to achieve the desired blast objectives. To minimise the risk of misfires, explosive products should be selected based on:

- initiation system limitations and communication hazards
- required explosives and density for the hole depth and diameter (including critical diameter)
- ground conditions (hot/reactive, wet, gaseous)
- dynamic desensitisation limitations
- adverse weather forecasts
- sleep time – production scheduling, access back following adverse weather or other events
- product availability.

Note: Use of surfactants (detergents) or other product destabilisers can be detrimental to emulsion products, which may result in a misfire.

6.7.2 Initiating system selection

To minimise the risks, the following should be considered:

- Use initiation systems of appropriate for the intended task/ application (e.g. durability, compression strength, temperature, etc.).
- Use compatible initiating systems in accordance with explosives supplier's specification.
- The type and limitations of various initiating systems, for example:
  - number of detonator strings per electronic system control boxes
  - maximum number of detonators software systems can fire
  - maximum length of harness wire used for the blast.

6.7.3 The design of charge

Once the correct explosives have been determined for the blast, the blast designer must determine the most effective way to use the energy to achieve the desired blast outcomes.

To mitigate the potential risks of misfires during the charge design phase, the following should be considered:

- accurate blast hole data from drilling QA/QC and blast hole measuring to enable appropriate explosive product selection.
- previous blast history, latest spatial data and relevant geotechnical/ geological information.

The placement of an explosives deck should consider the relevant misfire mechanisms detailed in previous chapters of this guideline, such as:

- location of the charge in relation to adjacent charges
- location of the charge in relation to adverse ground conditions
- stemming requirements (type, length, size, quality)
- uncharged collar length in underground blasting to manage separation between hole collars
- blast holes in underground coal mines should be measured and crack tested prior to loading, to identify methane leakage or areas of geological weakness
- if holes that leak are required to be loaded, these holes should be clearly demarcated and fired/numbered at the same time delay.

6.8 Timing design

A purpose of the timing design is to generate required relief across the blast. However, extended firing time sequence can increase the risk of misfires, due to the increased time allowance for ground movement or blast energy propagation.

The Blast Timing Design must consider the initiating systems, the likely interaction between blast holes, surrounding conditions and the desired blast objectives as outlined in Section 6.1.

6.8.1 Dislocation

Where timing designs do not fire from a free face or partially free face (soft wall/blasted ground), the risk of column dislocation is increased.

If not firing from the void/face or reamer/relief hole, the following should be considered:

- initiation points and relief rate for the design
- geological conditions in the location being blasted
- initiation system being used and primer locations within the hole.

To prevent dislocation, the following should be considered:

- reviewing relief rates for the entire shot with a timing design program/software, if possible, to uncover any locations that are outside of desired rate
- manage burden relief timing to a level that minimises the potential for blast hole dislocation/interaction;
- when using non-electric systems, ensure downhole delay provides adequate surface burning front time for existing ground conditions (for example a 4-row burning front is considered to be sufficient in most cases to minimise the risk of surface cut-off)
- understand geological/geotechnical parameters (such as rock joint set orientations) in relation to firing direction to manage dislocation risk
- in relation to the initiation sequence working against ground conditions, consider the orientation of holes (vertical vs angled) and how this relates to resultant initiation sequence from timing design.

6.8.2 Desensitisation

Timing design can lead to desensitisation of explosives, where impacts from blast pressure impact the explosives products prior to the designated timing initiating the explosive.

6.8.3 Ejection of explosive products from blast hole

To prevent misfires resulting from the use of pocket charges (small decks near the top of the blast hole to remediate cap rock, or small decks used in pre-split holes), the following should be considered:

- zero or almost zero delay between the pocket charge and the main charge
- initiation system being used in relation to the location of primers in the stem deck and main column.

To prevent misfires resulting from the use of detonator cord trunklines, the following should be considered:

- use 2 path tie-up for all detonating cord trunkline systems
- leave an uncharged hole between delayed groups of presplit holes to reduce the risk of blast energy transmission impacting next timing group (desensitisation or ejection).

To prevent misfires when utilising mid-splits in a timing design, the following should be considered:

- the initiation system to be used in the main pattern and associated burning front (if any)
- when using shock tube initiating systems, the delay between each packet of split holes and the non-electric holes in the local/immediate area;
- where possible, avoid a long delay between groupings of holes that may allow cut-off of detonating cord in surface blasting applications
- the overall time taken for the blast and any likelihood of interaction with flyrock.

If firing “over” lower benches or adjacent/secondary blasts, the following must be considered:

- where adjacent surface blasts are to be initiated using non-electric systems, consider the burning front of both blasts to eliminate potential surface cut-offs from flyrock
- firing bench by bench using last hole of lower bench to initiate the first hole on the higher bench for non-electric systems. in these cases, the flyrock hazard must be effectively managed to prevent cut-off of surface leads/connections on the bench above
- ensure that secondary blasts are timed and fired as a single shot for electronic systems
- avoid splices on lead in lines/starter lines with dependent shots
- implement effective clearance zones to ensure that loaded blast holes or sleeping shot are not within another nominated blast zone
- for underground mines, consider the possibility of initiation cut-off for an adjacent blast while firing from a single initiation point for multiple blast
- best practice is the use of a single control row for blasts initiated using a non-electric initiation system. multiple or incorrectly located control rows create an additional failure point for non-electric initiation systems.

Scatter associated with detonators that utilise a pyrotechnic element, can lead to misfires through dislocation and desensitisation. To prevent incorrect initiation sequence, as a result of scatter, the following should be considered:

- shorter surface delay timing combined with longer down-hole delays for non-electric scenarios increases the risk of out-of-sequence firing
- ensure that the in-hole delays are matched appropriately to the surface delays used from a blast timing perspective
- for underground blasting, there must be a total burning front for the given design.

To prevent misfires resulting from confined decks firing first and dislocating/compressing/ impacting adjacent decks, evaluate the effect of one deck upon the other in relation to timing, relief and confinement.

6.8.4 Non-electric initiating systems

Always point detonator tails toward the direction of firing for ease of identification during the secondary check process.

6.8.5 Electric Firing

Electric detonators are susceptible to accidental initiation by sources of stray extraneous electricity (AS 2187.2 (6)). To reduce the risk of accidental ignition during the tie in process, the following controls need to be addressed and maintained:

- resistance measurements for samples of each delay detonator from each new batch shall be tested to determine the average baseline. where large shots utilise electric detonators, the overall resistance must be calculated. if an accurate resistance for each detonator is not used, the total system resistance can easily hide a non-responsive detonator
- ensure that firing cables have been periodically tested for earth leakage and resistance to ensure compliance with explosives supplier's recommendations and firing cable requirements as detailed in as2187.2 (6)
- ensure that the firing circuit is in series connection
- prevent other sources of stray current/rf inadvertently entering the shot during tie-in by establishing personnel or equipment access control.

6.8.6 Electronic initiation system

To reduce the risk of accidental ignition during the tie in process, the following should be considered:

- manufacturer's warnings and instructions, especially relating to testing, logging, connection, communication validation and safety precautions
- use the wires, connectors, and coupling devices specified by the manufacturer
- keep detonator leads, coupling devices, and connectors protected
- keep wire ends, connectors and fittings clean and free from dirt or contamination prior to connection
- keep the firing circuit completely insulated from ground or other conductors
- address any warnings, notifications or error messages prior to firing
- when firing multiple blasts, synchronise the blasts to ensure all are timed and fired as a single shot.

6.9 Design approval and verification process

Blast designs and plans should be developed and reviewed by competent persons and approved prior to execution. This process should ensure potential hazards are Identified and controls implemented for the prevention of misfires.

The blast designs and plans should include:

- version control and naming conventions
- review and approval process for any changes to designs/plans resulting from variations.

To prevent misfires, as a result of incorrect blast design, the following should be considered:

- reconciliation of blast holes as drilled compared to design
- reconciliation of loaded holes to design prior to final tie-in approval
- model or review of relief rates across the entire blast
- avoid overly complex designs and tie-ups wherever possible
- do not rely solely on software functionality for tie up design
- auditable multi-party review process involving relevant/competent personnel
- peer review of explosives loading design prior to release of design for field implementation.

To prevent misfires resulting from misallocation of timing sequence to initiation system hardware prior to tie-in, the following should be considered:

- validation of the initiation sequence within the software through simulations
- validation option to re-import in-hole, as loaded information into the software to verify correct timing download
- validation and verification recording in an auditable system.

6.10 Change management from original design

Controls for the prevention of misfires when change occurs include:

- review the design and plans whenever there is a variation or change from those plans or designs, and evaluate the impact of change (e.g. changes to pattern, spatial change, geology, explosive products and/or suppliers, software changes to initiation systems, etc.)
- update version numbers on blast design documentation
- ensure minimum density and critical diameter, as well as blast energy/powder factor, remains as per plan when changing explosive products.
- communicate details of design and plan changes to all relevant personnel to ensure adequate management of the changes.

7.0 Blast Hole Drilling

7.1 Preparation of drill and blast work areas

Adequate work area preparation and demarcation prior to commencing drill and blast activities is critical in the prevention of misfires. During the preparation of blasting areas, care must be given to identify, manage and assess risks to identify applicable work area hazards.

To mitigate the potential of misfires during the work area preparation phase, the following should be considered:

- development and implementation of a documented drill and blast work area preparation procedure that includes:
  - acceptable fill tolerances (i.e. how much fill can be left in the floor prior to remediation)
  - where building a pad to raise drill height, ensure:
    - the material is adequate to maximise drill stability, to maintain drill pattern design
    - pad is sufficient dimensions to minimise subsidence risk impacting drill accuracy
  - nomination of tail room or required drift or development room for plant/ equipment
  - maximum or desired gradients and other traffic requirements to ensure drills can achieve a level position or operate from within manufacturer specifications
  - provision of a stable or supported work area
  - water management practices.
- maximum bund heights if required around crest and split benches
  - supporting checklists for work area preparation and or/handover.
- Specification of any required ground support, remediation or additional excavation activities required to be completed prior to commencing drilling activities. This may include a reconciliation process to verify planned excavation limits are achieved.
- Confirmation that there is no excess blasted fill or poor-quality material after excavation (mud or excess broken ground).

To mitigate the potential of misfires during underground blasting activities, the following should be considered:

- confirmation that developed mining grades adhere to plan
- drill breakthrough hole to remove water and drill fines in production blasts
- for development headings a secondary pump may be required to remove excess water.
- floor clean-ups may be required to remove built-up drill fines
- when working on fill, to prevent hole deviation ensure:
  - the ground support is in place
  - paste fill meets the designated standard and strength, and is cured
  - adequate drainage exists to prevent water pooling and slumping
- ensure any draw points where fill can potentially be removed are barricaded and signposted to prevent movement of fill material when drilling or blasting activities are conducted on top of the fill.

To mitigate the potential risks around drilling quality control, the following measures should be considered:

- provision on actions when survey equipment is, or suspected to be, dysfunctional (for example faulty GPS)
- calibrate level sensors and hole angle sensors
- removal of bent, worn or damaged drill rods from service
- ensure correct size drill bits are in stock and serviceable
- inspection of drill bits to ensure correct size is used as per design
- use of equipment within manufacturer's specifications
- consistent pattern marking and naming convention (including colour schemes)
- qa/qc on drilling data including:
- drill collar location
- drill depth
  - drill angles
  - drill bearing
- blasthole identification method and accuracy.
  - breakthrough hole location (if applicable)
  - downhole survey for hole deviation
- recording and reporting of ground conditions, including:
  - excessive fall back
  - hole collapses and redrills
  - loss of bit pressure/no cuttings
  - broken ground
  - difficulty retracting drill rods
- competent and consistent rock/ground
- shuddering of drilling equipment (vibration of drill string)
- correct drill set up for intended work (i.e. deck is level, and drill is positioned in correct direction).
- operating practices which support cleaning the blast hole appropriately
- update blast hole locations with actual survey data
- reporting variations to planned drilling outcomes
- in operations using paste/fill, paste should be left to cure to enable solid floor conditions prior to commencing drilling activities. paste should be of sufficient strength and characteristic to support planned drilling equipment and any water or hydrogeological impacts
- use of appropriate weight on bit, compressor pressures and bit rotation speeds
- conduct verification each shift to make sure blast hole labelling is correct
- drill holes clearly marked / demarcated with either paint or pegs, as required
- drill peg labels should include hole names and drill depths, at a minimum
- ensure break through holes are fully broken through and demarcated (i.e. as required when drilling around voids or above/around underground workings).
- reporting areas of suspected hot or reactive ground
- reporting areas with excessive dynamic water.

7.2 Protection of blast holes

To mitigate the risks the following should be considered:

- when collaring in poor ground conditions (broken, wet or muddy conditions), collaring can be performed with a larger drill bit and a casing inserted

- minimise time between drilling and loading in areas of potentially unstable ground
- use of adequate water or additives where required to assist in stabilising blast hole wall conditions.
- look for signs of geotechnical failure
- conduct work area inspections
- use of protection methods (blast hole cones /gas bags / collar pipes / hole savers etc.) throughout the drilling process, to provide stability to blasting collars
- ensure traffic management plans for equipment working near drilling operations are providing protection to blast hole collars.

8.0 Blast Hole Loading

8.1 Design control, verification and management of change

When spatial change/variation occurs, the design should be reviewed accordingly. This should be supported by a process to manage version control.

When using electronic load or dip sheets, a process should exist to ensure connectivity/information is regularly updated.

8.2 Measuring and monitoring of blast holes directly prior to charging

To minimise the risks, the following should be considered:

- Correct number of blast holes are physically available and in the correct location, as per the plan.
- Replace dipping or measuring consumables as required (as they may stretch or deteriorate over time).
- Re-dipping/re-measuring of blast holes when left for extended periods of time or if exposed to ground movement from adjacent blasts or adverse weather events. Holes that are found to be shorter or deeper or contain obstructions during the lowering of the primer down the hole must be communicated to the Shotfirer.
- Use calibrated thermocouples/temperature probes to confirm hole temperatures prior to scheduling loading activities where required. Further information can be found in Elevated Temperature and Reactive Ground AEISG Code of Practice (9).
- Where working around potential voids or historical workings, blast holes must be checked that they have not "broken through" into the void or historical workings. The depth at which the break-through occurs must be recorded.
- For underground applications, clean blast holes (blow or wash holes) prior to loading to ensure no loose material exists. This may require use of water to remove dust that can impact 'stickiness'.
- There may be a requirement to drill breakthrough holes to ensure cuttings can be effectively removed to prevent transfer into adjacent blast holes.
- Where blast holes contain water or wet sides, this should be recorded and may trigger a review of explosives selection.
- Where there is a risk of dynamic water, the blast hole must be re-checked for signs of recharge. These holes should be loaded last to minimise potential for damage to explosives.
- Drilled blast holes should also be checked for correct angles against design. Where deviance is identified, this should trigger a review of the loading design and blast risk assessment.
- An auditable process for the quality assurance and quality control of blast hole measuring information.
- Where changes to any of the above are identified directly prior to loading, then a change management risk assessment may be required.

8.3 Priming of blast holes

Priming blast holes is nominally defined as the introduction of an initiation device and a high explosive, commonly referred to as the primer, into a blast hole. Holes should be primed just prior to loading, to reduce risk of lost explosives, slumping or dislocation related misfires.

Consideration should be given to hazards associated with damage to primers and leads during loading activities, especially when loading pumped bulk explosives using a hose.

The correct selection, handling, placement, and protection of both the primer and the leads (often covered in the relevant OEM guidelines relating to primers), is essential in ensuring intended initiation.

To avoid incompatibility of primary initiation system and secondary explosive, where there is a change in explosives products, the following should be considered:

- Review blast management plan (including reference to explosives supplier product technical specifications for detonation sensitivity and explosive product compatibility).

8.3.1 Placement of primer within blast charge

When planning the placement of primers, the following should be considered:

- When using pumped bulk product, check that primer is immersed in product and not being floated on the top of the charge, by checking tension on downline to ensure primer is “caught”. Primer should be lifted an adequate height to ensure the primer is not in mud/debris at the bottom of the hole. (Note: attempts should be made to locate primers above final planned dig horizon).
- Use explosives supplier’s recommendations for primer centralising devices.
- Locate primers in a position that provides protection from dynamic dislocation from earlier firing holes.
- For long, continuous columns of explosives, additional primers should be used to minimise the length of column without a primer, which minimises the potential for a misfire due to discontinuity of the explosive’s column during the blast.
- Use of electronic detonators in areas prone to shearing.
- If using electric or electronic detonators, test for positive communications prior to stemming, as well as after stemming will identify whether the detonator has been damaged during the loading phase.
- Place primers above and below geological or geotechnical factors with the potential to cause column dislocation, to reduce the likelihood of undetonated bulk explosive.
- In holes with multiple decks, consider double priming the lower decks due to the exposure to multiple stemming/loading processes of loading the upper decks.
- Shotfirers should inspect Initiating Explosives (IE)/High Explosives (HE) for any abnormalities and/or defects when handling; Quarantine explosives products where abnormalities and/or defects have been identified.
- Primers are assembled at the blasthole collar and lowered individually, in a controlled manner, into the blasthole.
- Stemming activities should be conducted in a systematic, controlled manner, to ensure that primed, unloaded blastholes are not stemmed. Stemming of primed, unloaded blast holes may directly impact the primer, causing an unplanned initiation hazard.

8.3.2 Limitations and application of initiating systems

The limitations and application of the intended initiating system need to be considered.

If using an electronic system, the following should be considered:

- firing windows on electronic systems between control and firing boxes
- signal interference with wireless communication
- risks associated with assigning incorrect timings on electronic systems or with introducing change into variable timings systems.
- risks associated with incompatible systems and firing lines.

The system (depending on selected product) may produce messages to indicate errors, notifications, or warnings, which require remediation, such as:

- system faults – missing, new, duplicated or non-communicating detonators
- unfavourable test results e.g. leakage.

Non-electric signal tubes are prone to attack by diesel, which may result in a misfire. Consult with the product supplier for compatibility and sleep time duration.

Non-electric signal tubes may also be susceptible to methane ingress. Where there is potential for this impact, undertake the following:

- verify the presence of methane with correctly calibrated gas detectors
- refer to explosives supplier for appropriate initiation system selection for use in such conditions.

8.3.3 Handling of initiating systems

To mitigate the risks, the following should be considered:

- prevent rough/reckless handling of explosive products i.e. no throwing, dropping, stretching (this includes products such as harness wire and other components that form part of the initiating system)
- prevent pinching cords/shock tube lines which may create acute angles
- do not use excessive force while tamping as this may result in misalignment of detonator within the packaged high explosives
- do not 'booster dip' or bounce boosters
- do not drop rocks or any other objects onto detonating cord
- minimise physical handling of explosives cartridges of packaged emulsions as excessive handling may desensitise the product.

8.3.4 Use of detonating cord

When using detonating cord during charging, the following should be considered:

- remove factory joins and use a knot as approved by the explosive's supplier
- avoid joins/knots down the hole that adds potential to introduce a potential failure point
- ensure detonating cord is not rubbing against sharp collar edge or dislodged rocks at the hole collar
- ensure that all tails are taped to avoid any 'whipping'

- prevent loops, kinks or sharp angles in the cord which might direct the cord back toward the connecting line of detonation;
- sharp angles may also result in cut-off of the cord
- ensure proper location and correct installation of anchor points for detonating cord trunkline
- consider rates of relief, e.g. detonating cord (9ms) and electronic detonators (23ms).

8.3.5 Preventing loss / connection of initiating systems

To mitigate the risks, the following should be considered:

- Secure downlines near the hole collar to prevent the downline falling in the blast hole (e.g. wooden pegs or rocks of larger than the diameter of the blast hole). Ensure downline is not damaged by the securing method used.
- Placement of the IE/HE on the shot, ensuring a systematic approach that is effectively communicated to the crew and controlled by the Shotfirer.
- Use of blast aids/retainer systems.
- Implement effective traffic management to eliminate interactions between vehicles and initiation systems.
- Establish explosives reconciliation processes to ensure all products are accounted for and not lost.
- When using large, packaged emulsion cartridges, affix or tape cartridges to the downlines to maintain continuity between large, packaged emulsion cartridges and the initiation system.

8.4 Charging blast holes

8.4.1 Adverse environmental conditions

Monitor weather prior to and during loading activities and be prepared to change products if required. Where rainfall or dynamic water is expected, use water-resistant products and drill cuttings to provide a protective cap on the blast holes.

Large scale, open-cut shots may need to be cut off and fired early to prevent misfires.

8.4.2 Risks during charging

To mitigate the risks during charging, the following should be considered:

- during loading, all downlines need to be taut / straight in the blasthole to avoid any slack which may be impacted by falling material and / or the product delivery hose
- consideration of existing ground conditions, and avoid loading holes in adjacent blast that may be impacted by ground movement during firing
- consider hole protection methods (section 8.4.9)
- remediate any areas affected by water prior to loading
- where a hole is suspected to have bridged during loading, initiating systems should be slackened and pegs/retainers appropriately secured in case of slumping.

8.4.3 Breakthroughs and hole plugs

To mitigate the risks, the following should be considered:

- Use appropriate plug to support the mass of charge or back-fill the column.
- For underground metals, best practice is to ensure diamond drill holes are grouted to fully seal the hole; Where this is not possible, the blasting design must consider the risks associated with holes unable to be grouted.
- Exploration holes with potential or known intersection with blast holes should be backfilled prior to explosives loading.

8.4.4 Excessive groundwater and water management

To mitigate the risks, the following should be considered:

- To prevent slumping with dynamic water, ensure downline length is adequate to allow sufficient slack and tail length. Consideration should also be given to the use of hole liners and/or the use of water-resistant product.
- In geologically unstable areas, allow holes to stabilise post drilling prior to loading.
- In underground applications, consider loading high flow holes last to avoid water pressures building up that may eject/damage charges. Consider drilling relief holes to drain water from the development face during face preparation for boring.

If dewatering activities are required, consider the following:

- recharge rates
- discharge locations
- use of gasbags to protect explosive product;
- do not auger into water
- use water-resistant product where water ingress into a hole is unknown as opposed to split loading of HANFO (Heavy ANFO) toe topped with a dry product.

8.4.5 Charging in unstable or poor ground conditions

To mitigate the risks of misfires when charging in potentially unstable ground, the following should be considered:

- minimise time between priming, loading and stemming
- work area inspections to identify any holes with potential for failure/collapse
- increase the number of primers used to ensure detonation of full charge
- identify where initiating systems should be slackened and pegs/retainers appropriately secured in case of slumping.
- in broken ground consider use of hole liners, gas bags and stemming material to deck out voids/broken ground.

In addition, unstable ground conditions could result in mass wall failure (corners, faults). The following should be considered in the blast charging process:

- load areas of geotechnical/geological concern last or on day of firing to reduce exposure time
- identify and exclude expected areas of instability
- review any variations of the explosives loading plan
- identify and record broken ground to enable implementation of effective controls.

8.4.6 Hot and reactive ground

- Use calibrated thermocouple/temperature probes to confirm hole temperatures prior to scheduling loading activities.
- Monitor holes with an elevated temperature (AS2187.2 (6)) to identify temperature increase.
- Implement measures to cool strata to an acceptable temperature prior to commencing loading activities.
- Consult with the explosive's supplier where elevated temperatures/ reactive ground/ acidic water is present to identify suitable products and recommended sleep times.
- Minimise time between drill and loading.
- Ensure a clear identification method for clearly marking hot and/or reactive holes (i.e. painted collars, flag, coloured cones, etc).
- In extreme temperatures open hole measurement may only be measuring open hole temp, not the rock mass temperature. There can be a vast difference between open hole and rock mass temps.
- More information can be found in Elevated Temperature and Reactive Ground AEISG Code of Practice (9).

8.4.7 Stemming material selection

When selecting stemming material, the following should be considered:

- size – rule 1/10th of blast hole diameter
- risk of stemming material reacting if it contains sulphides, pyrites or other incompatible substances
- ensure stemming is not contaminated by large rocks/foreign material
- use appropriate clay material to stem holes in underground coal applications.

8.4.8 Loading rates

Rates of hose retraction should be monitored to ensure discharge rates allow for continuous column of explosive.

Consider reducing auger discharge rates when multiple priming blast holes. Detonators and boosters have been known to separate due to bouncing/interaction with dropping product. Load in accordance with explosives supplier specifications.

8.4.9 Use of blast hole liners

When using blast hole liners, the following should be considered:

- ensure hole liners are the correct diameter for the blast hole
- ensure hole liners are correctly placed into the blast hole (no twists) and the bottom of the liner is at the base of the hole

- ensure the opening is anchored at the collar of the hole:
  - control discharge rate during loading to ensure explosives are flowing freely to the bottom of the hole
- discard and replace damaged hole liners.

8.5 Explosive manufacture

8.5.1 General

This BPG assumes that factory manufactured explosives and precursors are fit for purpose to function as intended. It is recommended that critical manufacturing processes, factory quality assurance and production process/line quality control follow Quality Management System Standard ISO 9001 and legislative requirements (*the Act* (2) and the Regulation (1)).

A description of the manufacturing and key components used in bulk commercial explosives is provided in A.2 Manufacturing and key Components used in bulk commercial explosives on page 44.

When explosives are manufactured at the place of use in a mobile or portable processing unit, the manufacturer should give regards to the best practices recommended in this BPG.

Consideration to misfire mechanisms must be given during on site explosives manufacture to prevent the failure modes, outlined in Table 1 below.

Table 1: Failure Modes & Hazardous Issues – Explosives Manufacture (on-site)

Failure mode (cause)	Hazardous issue (risk source)
Degradation of explosive product and potential loss of sensitivity	1. Water damage to manufactured bulk product 2. Excessive handling leading to changes in prill characteristics (i.e. excessive AN fines) 3. Excessive pumping 4. Contaminants within mixture 5. Aging product and inadequate stock rotation
Failure of bulk product to function as intended	1. Temperature cycling of explosives products 2. Unintended use of expired or degraded raw materials 3. Excessive handling or mishandling of explosives 4. Incompatibility of key product constituents 5. Use of different quality diesel/oil and other constituents such as a change in sensitising agents 6. Over-sensitising or not adding chemical sensitiser

8.6 Ensure explosives will function as intended

Consider the pH of ground water (Alkaline or acidic) and place appropriate controls in place to protect explosive products. Alkaline ground water affects emulsion, which may result in a misfire.

Acidic ground water will accelerate effects of reactive ground.

Where a change of fuel/oils is to be undertaken, the change management should also incorporate input from the explosives' supplier/ product manufacturer. The use of surfactants (detergents) around emulsion products is not recommended.

When using surfactants in or near ammonium nitrate storage facilities, ensure explosives manufacturer decontamination processes are adhered to.

Implement Quality Assurance/Quality Control (QA/QC) or record keeping processes when conducting on-bench explosives manufacture activities. Ensure a process to capture product/ quality abnormalities is implemented.

Where suppliers have provided raw materials and precursors that have deviated from design specifications, this may lead to non-ideal detonation or misfires. Compliance certificates for raw materials or precursors should be available from the product manufacturer.

8.7 Sleeping of loaded shots

When preparing or planning to sleep loaded shots, the following should be considered:

- timeframe between loading of areas and firing the blast
- control/prevention of unauthorised vehicle and equipment incursions
- earth mounding, signage, flashing lights, geofencing, barricades, etc
- ensure communication is established at shift meetings, handovers, crew changes (provide maps and other documentation)
- prevent degradation of explosives due to inclement weather, hot and reactive ground, water ingress or water in the strata etc
  - weather forecasts from the time of loading to the time of firing including any possible micro-climate considerations
  - use storm/lightning tracker systems
  - ongoing monitoring of hole temperatures
- for large scale surface blasting, do not cast a blast into a body of water, that is in close proximity to an adjacent loaded blast
- consider early firing of shot if other control options are not available or effective (consider loading the blast in blocks)
- damage to surface explosives due to wildlife, flyrock from adjacent blasts, fall of ground, sabotage/ security or tampering implications etc
- impact to explosives due to excavation beyond the design profile, associated works. e.g. removal of pumping equipment, electrical cabling, etc
- ensure that the explosives manufacturer's specifications for sleep time are adhered to
- shotfirer to inspect the shot daily for increased slumping, escalation of shot deterioration and lead lengths.

9.0 Tie-in and firing

9.1 Tie-in

While designing and implementing the tie-up plan, the following should be considered:

- minimising the complexity of the tie-up plan
- peer review of design prior to release
- engagement of relevant stakeholders (designers/supervisors/shotfirers) during the development of the plan
- review historical blast plans in the same location
- transfer of data and information between design and implementation teams before releasing a tie up plan
- version control and change management of the tie-up plan.

When tying in blast holes, the following should be considered:

- adequate allocation of time to complete the blast tie-in
- not commencing tie in until all operating equipment has left the blast area
- section to be tied-in has been clearly isolated and defined
- use of a documented, approved tie-up plan
- laying out/stringing or bunching of tails so that detonators not connected to the system can easily be identified
- never mixing electronic detonators and electric detonators in the same blast, even if they are made by the same manufacturer
- follow manufacturer's instructions for connections and tie-in
- consider weather forecasts and actions to be taken in the event of inclement weather during tie-in
- checking to reconcile and confirm tie-up has been carried out as per the approved plan and to ensure all connectors, harness wire, leg wires and downlines are connected
- a video of the tie-in of the shot to assist in identifying any non or improper connections.

9.2 Firing of blasts

To minimise the risk of misfires during firing, the following should be considered in the design development phase:

- use firing systems and initiating systems that are compatible
- for electronic initiation systems (excluding wireless detonator systems):
  - conduct a radio frequency (rf) signal survey prior to firing to identify any signal interference
  - ensure maximum distances between sending/receiving systems is within acceptable limits
  - ensure initiation systems are inspected, calibrated, charged and fit for purpose
  - ensure electrical wire or harness wire length and diameter is within oem acceptable limits
  - pre-blast reconciliations are conducted to confirm that the number of detonators communicating with firing systems reconcile with the number loaded into the shot.

10.0 Reconciliation and record keeping

Reconciliation should be supported by tracking and availability of historical blasting reconciliations and records[4] (1) such as:

- relevant ground conditions
- blast hole locations and details
- charge location and details
- design vs. actual data including deviations (drilling, explosives loading, electronic system reconciliations and logs, etc.)
- equipment or initiation system performance
- incidents and blast results
- digital video recording of blast performance.

Misfire records should be captured within a misfire register to support comparison and trending of causes and effective control improvement.

[4] Section 153 Explosives Regulation 2017

11.0 Investigation of misfire events and ongoing audit and review

11.1 Contributing factors

Previous reviews of misfire investigations have identified that many investigations fail to determine an exact cause and therefore unable to implement effective controls to prevent reoccurrence.

It is important that all misfire events are reported and recorded and that they are thoroughly investigated to:

- prevent further misfires being generated
- minimise the potential for unplanned initiation events
- minimise the potential for unsecured explosives
- determine and understand the potential causes of misfires.

Blasting authority holders and explosives companies must ensure effective controls are implemented and incorporated into the safety and health management system to prevent future occurrences.

Note: This investigation guide will assist with understanding the relationship between failure mechanisms and misfires. Using elements of this guideline, can assist in identifying relevant factors to scope the investigation of each misfire outcome experienced.

The relationship between failure mechanisms and risk sources can be found in A.3 The main failure modes and risk sources associated with commercial explosives.

11.2 Composition of Investigation Team

This will be determined by the Manager appointing a lead investigator and team members. Persons appointed to an investigating team should have appropriate experience, knowledge of the operation and training to undertake the investigation. A term of reference should be given to the lead investigator.

The investigation of a misfire event may be undertaken by the following:

- Mine Operator (as part of mine SMS or a statutory direction from the regulator)
- Site Senior Executive
- Explosives company whose explosives were used in the blast
- Blasting contractor (may be an Explosives company that was conducting the blast for the mine)
- A consultant or external content expert
- A combination of the above.

RSHQ may undertake investigations of misfires.

11.3 Audit and review

Regular inspections and audits need to be undertaken across all blast activities, to identify and prevent areas of potential uncontrolled deviations from the blast plan.

Results of audits undertaken by supervisors, superintendents and SSEs should be recorded, actioned and retained.

Monitoring of trends associated with inspections/audits, blast performance and misfires should be undertaken to inform the need for audit and review.

12.0 References

1. **Government, Queensland**. Explosives Regulation 2017. s.l., Queensland : Queensland Government, 2017.

2. —. Explosives Act 1999. s.l., Queensland : Queensland Government, 1999.

3. **AEISG**. Code of Practice Storage and Handling of UN3375. s.l. : Australasian Explosives Industry Safety Group Inc., 2018.

4. **Government, Queensland**. Coal Mining Safety and Health Act 1999. s.l. : Queensland Government, 1999.

5. —. Mining and Quarrying Safety and Health Act 1999. s.l. : Queensland Government, 1999.

6. **Standards, Australia**. AS2187.2 Explosives—Storage and use, Part 2: Use of explosives. Australian Standard Explosives—Storage and use, AS2187.2. s.l. : Standards Australia, 2006.

7. **Dr Ken, Patterson and Gillian, Wigam. Loss Prevention** Bulletin 267 - Management of Change - What does 'good' look like? IChemE. [Online] 2019. https://www.icheme.org/media/11514/lpb267_pg07.pdf.

8. **AFER, Australian Forum of Explosives Regulators**. Australian code for the transport of explosives by road and rail – 3rd edition. s.l. : Workplace Relations Minister's Council, Commonwealth of Australia, 2009.

9. **DNRM**. Guidance Note QGN10, Handling Explosives in Surface Mines and Quarries. [Online] 2008. https://www.resources.qld.gov.au/__data/assets/pdf_file/0017/240353/qld-guidance-note-10.pdf.

10. —. Guidance Note QGN11, Handling Explosives in Underground Mines. [Online] https://www.rshq.qld.gov.au/__data/assets/pdf_file/0018/240354/qld-guidance-note-11.pdf.

11. **AEISG**. Elevated Temperature and Reactive Ground Code of Practice . s.l. : Australasian Explosives Industry Safety Group Inc., 2020. Edition 5.

12. —. Various Codes of practice. Australasian Explosives Industry Safety Group Inc. [Online] https://www.aeisg.org.au/aeisg-codes-of-practice.

13. **International Labour Organization, SafeWork**. Chapter 15 Explosives. Explosives: Definitions, Classification & Hazards.

14. **RSHQ**. List of authorised explosives. [Online] September 2025. https://www.business.qld.gov.au/industries/mining-energy-water/explosives-fireworks/safety-security/authorised-explosives/list.

15. —. Authorisation of explosives and trials of unauthorised/prohibited explosives in Queensland. [Online] RSHQ, 2025. https://www.rshq.qld.gov.au/safety-notices/explosives/auth-explosives-trials-unauth-explosives.

Appendix

A.1 Functional Responsibilities Table

Table 2: Blasting activities responsibilities by function

Function	Role	Responsibility
SSE	The most senior officer engaged by the operator, who has the responsibility for the mine	• Establish and implement appropriate Site Safety Management System, to identify hazards and implement effective controls, to achieve an acceptable level of risk. • The obligation of the SSE as defined in ref Coal Mining Safety and Health Act 1999 s42, and Mining and Quarrying Safety and Health Act 199, s39.
Mine Planning	Plan the mine operations to effectively extract material	• Ensure adequate resourcing, equipment and time is allocated to perform the entire blast process with acceptable level of risk
Explosives Supplier/ Manufacturer	Provide blasting explosives to industry	• Ensure appropriate design, calibration and operation of explosives manufacturing equipment within design specifications. • Quality assurance and quality control processes – sampling and testing. • Undertake development work on explosives technology to improve products ability to perform in robust conditions. • Provide specification of accessories – product compatibility information.
Blast Designer	Design a blast to provide optimum extraction of material and prevention of misfires.	• Work with mine planning or client to determine the desired blast outcomes. • Select appropriate explosives and initiation systems to achieve the desired blast outcomes. • Ensure that the explosives to be used have been authorised by the Chief Inspector of Explosives. Refer to List of authorised explosives (10) or follow the authorisation process (11) • Understand the limitations, application and failure modes of explosives and initiation systems planned to be used and design blasts within these limitations. • Ensure that blast designs incorporate the following: • Previous Blast History • Elevated Temperature/Reactive Ground/Gaseous Ground • Geological, Geotechnical and Hydrological modelling and mapping • Previous misfire investigation Prevention Controls • Blast area preparation standards

Function	Role	Responsibility
		• Drill accuracy and variance to design • Blast hole measuring data • Physical explosives loading data versus design data • Blast timing contour
Geologist	Provide data on ground conditions to assist blast designer in the layout of the blast.	• Accurate provision of ground data across the proposed shot. • Review of data after firing to determine if data was as predicted. • Determine whether any elevated temperature/reactive/gaseous conditions are present. • Provide soil moisture index data for site.
Geotechnical Engineer	Provide data on ground conditions to assist blast designer in the layout of the blast.	• Accurate provision of geotechnical assessments across the proposed shot. • Review of geotechnical assessment of area, after the shot has been fired. • Continually monitor the blast areas for potential changes in ground stresses/exposure of potential ground failure zones/etc.
Drill and Blast Superintendent	Manage all drill and blast operations at site	• Setting explosives inventory. • Maintaining explosives storage capacity. • Manage significant change that may occur during the blast process and involve the blast designer where required. • Authorise the blast design. • Ensure adequate resourcing of blasting activities. • Competence of the drill and blast teams. • Implement improvement processes. • Investigate blasting incidents, including misfires. • Provide advice to address incidents. • Ensure drill and blast activities are conducted in accordance with site and legislative requirements.
Drilling Contractor/Driller	Provide drilled holes for the loading of explosives for a blast.	• Accurately drill the blast pattern in accordance with the design. • Report any variations from design. • Report adverse ground conditions to the blast designer. • Ensure drilling activities are conducted in accordance with the design and site SSMS requirements.
Drill Supervisor	Supervise the on-bench drilling activities	• Conduit from drill activity to blast designer. • Approve bench preparation standards prior to drilling activities commencing.

Function	Role	Responsibility
		• Ensure drilling activities are conducted in accordance with the design and site SSMS requirements.
Blast Contractor	Provides a blasting service to clients	• Maintain an effective SSMS, that covers the prevention of misfires, not just remediation. • Ensure delivery of explosives products in accordance with the blast design. • Deliver a blast outcome in accordance with the blast plan and legislative requirements.
Blast Supervisor	Manage day to day blasting operations	• Conduit from explosives loading activities to D&B Superintendent and Blast Designer. • Approve bench preparation standards after drilling operations. • Ensure explosives loading activities are conducted in accordance with the design and SSMS requirements.
Shotfirer	Oversight of all explosives loading activities	• Management of on-bench water. • Compliance with design. • Variations from design. • Recording explosives loading data. • On-bench explosives quality. • Supervision of explosives loading activities. • Calibration of explosives loading equipment. • Conduit from bench to Blast Supervisor/D&B Superintendent /Blast Designer. • Make continual assessments of the explosives loading to ensure an acceptable level of risk. • Communicate significant change in the blast parameters to the D&B Superintendent and Blast Designer. • Oversee the correct tie-in/initiation system connection. • Where required in UG applications, ensure scats cannot impact explosives leads where ground support mesh is cut. • Fire the blast.
Magazine keeper	Oversight of all Class 1 explosives storage activities	• Ensuring housekeeping, maintenance, materials handling equipment, management and maintenance of records are in accordance with the appropriate legislative requirements. • Withdrawing and returning to the keys for the magazine and the security of the magazine while in possession of the keys. • Maintenance of copies of current legislative requirements and relevant Standards. • Maintenance of licence and conditions.

Function	Role	Responsibility
		• Displaying and maintaining safety procedures inside the magazine. • Observing any site-specific requirements. • Restricting access to authorised persons.
MMU Designer	Design MMU to produce explosives to specification	• Equipment appropriate and explosives produced to specifications.
MMU Operator	Manufacture blasting explosives as directed by the Shotfirer	• Compliance with explosives loading information. • Recording and reporting variation to explosives loading design. • Calibrations of MMU. • Quality checks of explosives precursors. • Compliance checks of explosives manufacturing equipment and associated plant/equipment. • Adequate and correct process chemicals. • Manufacture Quality Control checks. • Generate delivery/production records.
MMU Maintainers	Maintenance of MMUs	• Ensure that equipment is maintained and calibrated as per maintenance schedule. • Vehicle maintenance conducted to design and operational criteria.
Bench Assistant (Open Cut)	Support shotfiring activities.	• Undertaking activities as directed by the Shotfirer. • Measuring and recording of the depth of blast holes. • Recording of water conditions down hole. • Dewatering blast holes. • Measuring water recharge rates for wet holes. • Marking of blast hole information. • Positioning of primers in blast holes. • Accurately placing of gas bags/hole liners/etc. • Stemming of blast holes. • Installation of collar protection. • Preventing contamination of the explosives already loaded. • Identify slumping of loaded holes and any other adverse conditions.
UG Service Crew/ Blast Crew	Blast area preparations	• Ensure area is appropriately set up for explosives loading activities. • Accurately measure and clean out production holes, so that the Blast Designer has accurate information. • Installation of hole savers/collar protection where required.

A.2 Manufacturing and key Components used in bulk commercial explosives

Table 3: A description of the manufacturing and key components used in bulk and commercial explosives

Explosive	Description and manufacturing process
ANFO	A blend of Ammonium Nitrate (AN) and Fuel Oil (FO) at a practical ratio of 94% AN and 6% FO respectively. This blend gives a balanced explosive with just enough oxygen to ensure that all the fuel is consumed.
Emulsions	Emulsions consist of a continuous oil phase (fuel and waxes) with dispersed droplets of oxidiser. The oil phase resists the ingress of water that could affect the oxidiser. The oxidiser is a supersaturated solution of ammonium nitrate. Emulsifying agents are used to make the mixture homogenous and stable and prevent the crystallisation of the nitrates. An emulsion becomes an explosive after it is sensitised. Sensitisation is generally achieved by entraining air bubbles, using chemical gassing agents or through the addition of glass micro-spheres.
Heavy ANFOs	A mixture of an emulsion and ammonium nitrate or ANFO. When an emulsion phase is added to ANFO it initially fills the pore space between the prills. The addition of this liquid phase adds weight but not volume to the mixture, so the density of the explosive increases. Heavy ANFOs are generally used between 1.0 gm/cc and 1.35 gm/cc.
Water gels	Water gel explosives consist of sensitisers added to a solution of ammonium nitrate in water and mixed with a guar gum to thicken the mixture. Sensitisation can be provided by either entraining air into the explosive by vigorous mixing at the point of delivery, generating air bubble by introducing a chemical gassing agent at the point of delivery or by using glass microspheres.
Diluted ANFO and Emulsions	ANFO can be mixed with a low-density diluent to make a low density and low VOD ANFO product. Different diluents have been employed over the years including sawdust, puffed wheat, peanut shells, rice husks, perlite and expanded polystyrene beads (EPS). Advances in diluted or low VOD explosives have also been made with emulsions by using EPS and other constituents in the manufacturing and delivery process.
Packaged explosives	Detonator sensitive packaged explosives are manufactured using similar techniques as bulk products. They are generally sensitised with glass micro balloons to achieve the required density and sensitivity. Packaged emulsions have waxes included in their fuel phase to produce a firm consistency to provide the required handling characteristics. These emulsions are water resistant, enhanced by the plastic packaging material. Packaged emulsions can be reliably detonated using a standard No. 8 detonator or 10 gm/m detonating cord and are more widely used in hard rock underground environments.
Permitted explosives	This is a separate group of explosives used in specific underground coal mining applications; their availability and manufacturing is limited in Australia. Group P1: Single, simultaneous firing or delay firing in shafts or drifts Group P3: Single, simultaneous firing in undercut coal, rippings, dintings and scouring Group P4: Primarily for delay firing in undercut coal and rippings Group P5: Primarily for delay firing in solid coal Group P4/5: Delay firing in undercut coal and rippings and delay firing off-the-solid.

A.3 The main failure modes and risk sources associated with commercial explosives

Table 4: Summary of main failure modes and risk sources associated with commercial explosives leading to a misfire.

Failure Mode (Cause)	Hazardous Issue (Risk Source)	Reference Chapter
Acid Ground Water	• Hot/Reactive Ground • Unsuitable and/or incompatible explosives products	8.4.6 Hot and reactive ground 8.6 Ensure explosives will function as intended 6.9 Design approval and verification process
Blast Firing Sequence or Timings	• Cut-offs • Desensitisation of explosives or shrink-wrapping of detonators	6.7 Charge Design 6.8 Timing design 6.9 Design approval and verification process 9.2 Firing of blasts
Column or Hole Dislocation	• Geological and/or geotechnical anomalies • Blast timing issue • Bulk product continuity	6.3.4 Geological and mechanical properties 6.6 Drill Pattern Design 6.7 Charge Design 6.8 Timing design
Column, Hole Collapse or Fallback	• Geological and/or geotechnical anomalies	6.3.2 Inadequate blast hole stability 6.3.3 Inadequate blast hole collar stability 6.3.4 Geological and mechanical properties 7.2 Protection of blast holes 8.4.5 Charging in unstable or poor ground conditions
Complex or Irregular Hole Naming Convention	• Execution of drill design • Execution of load design and reconciliation process • Execution of initiation design	6.6.1 Blast hole and pattern design – misfire mechanism overview 6.9 Design approval and verification process
Damage to Explosives	• Failure of explosives to function as intended • Degradation • Impacts from adjacent blasts • Damage during storage, transport, handling, loading, stemming	8.2 Measuring and monitoring of blast holes directly prior to charging 8.3 Priming of blast holes 8.3.1 Placement of primer within blast charge 8.3.3 Handling of initiating systems 8.4.2 Risks during charging 8.6 Ensure explosives will function as intended
Damaged Harness Wire	• Damage during loading	8.3.5 Preventing loss / connection of initiating systems

Failure Mode (Cause)	Hazardous Issue (Risk Source)	Reference Chapter
	• Damage during tie-in	9.2 Firing of blasts
Damaged Leg Wire	• Deviation from approved traffic management plan • Damage during loading • Damage during stemming process • Damage during tie-in	8.3 Priming of blast holes 8.3.5 Preventing loss / connection of initiating systems 8.4.2 Risks during charging 8.4.7 Stemming material selection 8.4.8 Loading rates
Degradation of Explosives	• Unforeseen weather events (i.e. heavy rainfall) • Excessive pit water leading to • unexpected dynamic water and seepage into charged blastholes • Excessive hole contamination • Hot or reactive ground conditions and unknown heat/elevated temperatures • Unsuitable and/or incompatible stemming products • Excessive handling leading to changes in prill characteristics (i.e. excessive AN fines) • Excessive pumping • Potential contaminants within explosive product • Aging product and inadequate stock rotation • Excessive sleep time	5.0 Storage, transport and handling of explosives 5.1 Storage of Class 1 6.2 Scheduling of blasting activities and excessive exposure time 6.3.1 Hot and reactive ground 6.3.5 Groundwater and water management 8.2 Measuring and monitoring of blast holes directly prior to charging 8.6 Ensure explosives will function as intended
Desensitisation of Explosives	• Inappropriate product selection for prevailing ground conditions and existing mining constraints including charge length and diameter. • Inadequate stemming length between decks. • Drill deviation from design. • Distance between charges. • Insufficient in-hole densities.	6.4 Dynamic Desensitisation 6.6 Drill Pattern Design 6.7 Charge Design 6.8 Timing design 6.9 Design approval and verification process 8.3 Priming of blast holes 8.4 Charging blast holes 8.5 Explosive manufacture
Design did not account for Geotech, geological or hydrogeological anomalies	• Inadequate blast design and approval process	6.3.4 Geological and mechanical properties 6.9 Design approval and verification process 8.1 Design control, verification and management of change

Failure Mode (Cause)	Hazardous Issue (Risk Source)	Reference Chapter
		8.2 Measuring and monitoring of blast holes directly prior to charging
Detonator received firing signal but did not initiate	• Blast timing issue • Drill deviation from drill design • Inadequate stemming length between decks. • Distance between charges.	6.4 Dynamic Desensitisation 6.6 Drill Pattern Design 6.7 Charge Design 6.8 Timing design 8.3 Priming of blast holes 8.4 Charging blast holes 8.5 Explosive manufacture 9.2 Firing of blasts
Dynamic blast vibration	• Ineffective blast timing • Excessive Maximum Instantaneous Charge	6.6 Drill Pattern Design 6.7 Charge Design 6.8 Timing design 6.9 Design approval and verification process 8.4 Charging blast holes
Excessive powder factor	• Geological and/or geotechnical anomalies • Blast timing issue • Deviation from charge design	6.6 Drill Pattern Design 6.7 Charge Design 6.8 Timing design 6.9 Design approval and verification process 8.4 Charging blast holes
Explosives failure	• Damage during storage/ handling/ transport • Due to dynamic pressure crushing the detonator. • Lightning Strikes • Temperature cycling of explosives products • Unintended use of expired or degraded explosives • Excessive handling or mishandling of explosives • Incompatibility of key product constituents • Use of different quality diesel/oil and other constituents such as a change in sensitising agents • Incorrect strength detonator/ cord • Damage during loading techniques	5.0 Storage, transport and handling of explosives 6.3.2 Inadequate blast hole stability 6.3.3 Inadequate blast hole collar stability 6.7 Charge Design 7.1 Preparation of drill and blast work areas 7.2 Protection of blast holes 8.3 Priming of blast holes 8.6 Ensure explosives will function as intended 9.2 Firing of blasts
Explosives fell into hole and not recoverable	• Deficient explosives loading practices	6.3.2 Inadequate blast hole stability 6.3.3 Inadequate blast hole collar stability

Failure Mode (Cause)	Hazardous Issue (Risk Source)	Reference Chapter
	• Blast hole or blast collar stability	6.3.4 Geological and mechanical properties 8.4.2 Risks during charging 8.4.5 Charging in unstable or poor ground conditions 8.4 Charging blast holes 8.4.8Loading rates
Faulty detonator or booster	• Defective from manufacturer	1.4 Scope 4.0 Explosive's procurement 5.0 Storage, transport and handling of explosives
Fauna or Vermin Attack	• Potential unknown risk source where fauna or vermin may damage initiation systems.	8.7 Sleeping of loaded shots
Hole Deviation	• Geological and/or geotechnical anomalies • Deviation from drill design	6.3.2 Inadequate blast hole stability 6.3.3 Inadequate blast hole collar stability 6.3.4 Geological and mechanical properties 6.6 Drill Pattern Design 6.9 Design approval and verification process
Impact from adjacent blast	• Failures in blast scheduling • Blasting a single section of earth but in multiple separate shots, each designed differently for direction of throw. • Fly rock • Geological and/or geotechnical anomalies	6.2.2 Scheduling – blast interaction 6.5 Ejection of explosives from blast holes 6.8.3 Ejection of explosive products from blast hole 6.9 Design approval and verification process 8.4.2 Risks during charging
Impact to Detonator	• Damage during storage/ handling/ transport • Damage during loading activities • Due to dynamic pressure crushing the detonator. • Deviation from approved traffic management plan	8.3 Priming of blast holes 8.4.2 Risks during charging 8.4.5 Charging in unstable or poor ground conditions 8.4 Charging blast holes 8.4.8 Loading rates
Incompatibility of Explosive Components	• Mixture of incompatible initiation system components • Incorrect detonator/ detonating cord strength for secondary explosives • Using initiation systems updated with different firmware/software versions	4.0 Explosive's procurement 6.7.1 Explosive Product Selection 6.7.2 Initiating system selection 8.6 Ensure explosives will function as intended 9.2 Firing of blasts

Failure Mode (Cause)	Hazardous Issue (Risk Source)	Reference Chapter
	• Using detonators of different versions (where design changes may impact performance compatibility)	
Incorrect Tie Up	• Human error • Complacency • Inattention	9.1 Tie-in
Initiating System Failure	• Mixture of incompatible initiation system components • Incorrect detonator/ detonating cord strength for secondary explosives • Using initiation systems updated with different firmware/software versions • Using detonators of different versions (where design changes may impact performance compatibility)	4.0 Explosive's procurement 6.7.1 Explosive Product Selection 6.7.2 Initiating system selection 8.3.4 Use of detonating cord 8.6 Ensure explosives will function as intended 9.2 Firing of blasts
Initiation System Line Impacted, Severed or Damaged	• Deviation from approved traffic management plan • Damage during loading • Damage during stemming process • Damage during tie-in	6.7.1 Explosive Product Selection 6.7.2 Initiating system selection 6.8.4 Non-electric initiating systems 6.8.5 Electric Firing 6.8.6 Electronic initiation system 8.3 Priming of blast holes 8.3.5 Preventing loss / connection of initiating systems 8.4.2 Risks during charging 8.4.7 Stemming material selection 8.4.8 Loading rates 8.3.4 Use of detonating cord 9.1 Tie-in
Logging Failure after Loading Bulk Product	• Damage during loading •	8.3.5 Preventing loss / connection of initiating systems 8.4.2 Risks during charging 8.4.8 Loading rates
Logging Failure After Stemming	• Damage during stemming process	8.3.5 Preventing loss / connection of initiating systems 8.4.2 Risks during charging 8.4.7 Stemming material selection
Logging Failure Prior to Loading Bulk Product or Straight Out of Package	• Defective from manufacturer	1.4 Scope 4.0 Explosive's procurement

Failure Mode (Cause)	Hazardous Issue (Risk Source)	Reference Chapter
		5.0 Storage, transport and handling of explosives
Mixed Type of Detonators. Not limited to Electronic, Non-electric or multiple electronic versions	• Using detonators of different versions (where design changes may impact performance compatibility) • Mixing incompatible initiation systems	4.0 Explosive's procurement 6.7.1 Explosive Product Selection 6.7.2 Initiating system selection 6.8.4 Non-electric initiating systems 6.8.5 Electric Firing 6.8.6 Electronic initiation system
Oversleeping of Explosives	• Blast scheduling • Inclement weather • Production scheduling	6.2.1 Scheduling – exposure and sleep time 6.9 Design approval and verification process 8.6 Ensure explosives will function as intended 8.7 Sleeping of loaded shots
Poor Drilling. Not limited to directional or deviation	• Deficient blast area preparation – drill cannot achieve level • Deviation from drill design	6.3.2 Inadequate blast hole stability 6.3.3 Inadequate blast hole collar stability 6.3.4 Geological and mechanical properties 6.6 Drill Pattern Design 6.9 Design approval and verification process
Shot not prepared as per design	• Blasting or production scheduling pressures • Deficient blast area preparation – drill cannot achieve level • Deviation from drill design	3.0 Resourcing, training and competency 6.1 Blast objectives 6.9 Design approval and verification process 7.1 Preparation of drill and blast work areas
Slumping in blast hole or explosives or stemming	• Degradation of explosives • Blocked/Bridged Blast Holes • Gas bag failure	4.0 Explosive's procurement 6.3.2 Inadequate blast hole stability 6.3.3 Inadequate blast hole collar stability 6.3.4 Geological and mechanical properties 6.3.5 Groundwater and water management 6.7.1 Explosive Product Selection 7.1 Preparation of drill and blast work areas 7.2 Protection of blast holes 8.2 Measuring and monitoring of blast holes directly prior to charging 8.4.2 Risks during charging 8.4.3 Breakthroughs and hole plugs

Failure Mode (Cause)	Hazardous Issue (Risk Source)	Reference Chapter
		8.4.5 Charging in unstable or poor ground conditions 8.4.8 Loading rates 8.4.9 Use of blast hole liners