NSW Resources
Resources Regulator

# Technical reference guide

## Coal dust explosion suppression and prevention

**(MDG3006 MTR5)**

July 2024

**Acknowledgement**

The following Original Equipment Manufacturers (OEM) were consulted as part of the TRG process:

1. Becker-SkillPro
2. Alfabs Engineering.

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| **Amendment schedule** | | |
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| **Date** | **Version** | **Amendment** |
| February2024 | Consultation Draft | This TRG replaces MDG3006MTR5 Coal dust explosion prevention. Updated to new legislative framework and current practice. |
| May 2024 | V1 | Amendment mad to section 7.1 for extra stone dust bags in certain circumstances |
| | | |

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# 1. Introduction

Coal dust explosions occur when mine operators fail to minimise incombustible matter to a level that prevents this hazard eventuating. Coal dust explosions are a significant hazard in an underground coal mine. They have the potential to spread to every part of a mine and can resulting in multiple fatalities.

Suspended coal dust has flammable limits from approximately 35 g/m$^3$ to 1000 g/m$^3$. There are various environmental factors that will influence these flammable limits.

Coal dust explosions are usually a secondary explosion started by a methane explosion. The primary explosion creates shock waves that disperse coal dust into the air and the flame ignites the coal dust. These coal dust explosions are often self-propagating and extremely violent, affecting large sections of the mine.

## 1.1. Purpose

This technical reference guide (TRG) applies to all underground coal operations in NSW and replaces MDG-3006-MTR5 Guideline for coal dust explosion prevention and suppression.

The TRG provides mine operators with guidance on developing and documenting a coal dust explosion control plan (CDECP). Mine operators must develop CDECPs as per section 19 (2) (c) (iv) of the Work Health and Safety (Mines and Petroleum Sites) Regulation 2022.

This TRG keeps technical detail to a minimum in the main body, and further technical information is signposted throughout. This document does not affect a mine operator's obligations to comply with the stone dusting requirements in section 68 of the WHS (MPS) Regulation.

Readers should note that many of the principles of stone dusting and explosion barriers are based on historical research into suppressing a coal dust explosion. While modern mining methods, dimensions and retreat rates have changed since much of the research was undertaken, the fundamentals of those test results remain applicable.

This document should be read in conjunction with:

- NSW work health and safety (WHS) laws, including the WHS (MPS) Act and Regulation[1].
- NSW codes of practice:
  - Work health and safety consultation, cooperation, and coordination (August 2022)
  - How to manage work health and safety risks (August 2019)
  - Safety management systems in mines (February 2015)
  - Roadway dust analysis in underground coal mines (February 2015).
- NSW Resources Regulator guidance material, for example:
  - Guide - Preparing a principal hazard management plan (September 2022)
  - Guide – Airborne contaminants principal hazard management plan (July 2018).
- Australian and International Standards in related fields, for example:
  - AS ISO 31000: 2018 Risk Management — Guidelines

[1] This includes the *Work Health and Safety Act 2011*; Work Health and Safety Regulation 2017; *Work Health and Safety (Mines and Petroleum Sites) Act 2013* and the Work Health and Safety (Mines and Petroleum Sites) Regulation 2022.

- AS/NZ ISO 4501: 2018 Occupational Health and Safety Management Systems – Requirements with guidance for use.

This TRG provides guidance to aid mine operators in fulfilling their obligations under the WHS (MPS) Regulation. Sections 53 and 68 of the WHS (MPS) Regulation set out the specific hazards and management controls that a CDECP must cover. Mine operators must develop CDECPs with reference to these provisions, along with Original Equipment Manufacturer (OEM) guidelines and not this TRG alone. The CDECP must form part of the Safety Management System (SMS) as section 19(2)(c)(iv) of the WHS (MPS) Regulation requires.

## 1.2. Glossary and acronyms

| | |
|---|---|
| **AS:** | Australian Standard |
| **Auxiliary fan:** | means a fan (other than a cooling fan for equipment or a scrubber fan) used underground to direct ventilation in a part of an underground mine. |
| **Barrier Bag:** | a clear plastic bag, containing stone dust, suspended in rows across the width of a coal mine roadway. |
| **CDECP:** | Coal dust explosion control plan |
| **Cut through:** | means a tunnel driven to connect adjacent headings |
| **explosion barriers:** | means —<br>(a) water barriers installed in accordance with Schedule 5, or<br>(b) bagged stone dust barriers installed in accordance with the manufacturers or supplier's guidelines, or<br>(c) barriers installed as a high-risk activity. |
| **Face zone:** | means any area within 200 metres —<br>(a) outbye of a longwall face, or<br>(b) in the case of a panel where mining is being carried out by a continuous miner — outbye of the most inbye completed line of cut-throughs. |
| **Float dust:** | means coal dust that is finer than 75 micrometres that has been deposited on a surface that has received an application of stone dust or other explosion inhibitor. |
| **Hazardous zone:** | at an underground coal mine, means each of the following —<br>(a) any part at the mine in which the concentration of methane in the general body of the air is 1.25% by volume or greater,<br>(b) a return airway,<br>(c) any part of an intake airway that is on the return side of such points that are within 100 metres outbye of —<br>(d) the most inbye completed line of cut-throughs, or<br>(e) any longwall or shortwall face, but only to the extent that the intake airway is on the intake side of that face (but not if the longwall face is an installation face at which the development of the face, and mining for development coal, have been completed and at which longwall mining has yet to commence). |
| **Intake roadway:** | means a roadway used for the intake of air to mine workings. |
| **NATA:** | National Association of Testing Authorities |

| | |
|---|---|
| **OEM:** | original equipment manufacturer |
| **PHMP:** | principal hazard management plan |
| **PCBU:** | person conducting a business or undertaking |
| **return roadway:** | means a roadway used for the removal of air and airborne contaminants from mine workings. |
| **roadway dust:** | means all dust in a roadway including coal dust and stone dust. |
| **SMS:** | safety management system |
| **spot sampling:** | means taking samples of dust from the floor, roof, and sides of a roadway by collecting the dust from a series of spots that—<br>(a) are identified on a plan prior to the sampling occurring, and<br>(b) range in size from 0.1 square metres to 0.5 square metres, and<br>(c) are equally distributed and alternating, and do not overlap. |
| **strip sampling:** | means taking samples of dust from the floor, roof, and sides of a roadway by collecting the dust from a series of transverse strips that—<br>(a) are of equal width, and<br>(b) are spaced apart by equal amounts of no more than 5 metres, and<br>(c) do not overlap. |
| **TRG:** | technical reference guideline |
| **WHS (MPS) Regulation:** | Work Health and Safety (Mines and Petroleum Sites) Regulation 2022 |

## 1.3. Scope

This TRG specifically applies to underground coal mines and aims to aid relevant parties in protecting coal workers from coal dust explosions. This TRG guides the reader on how best to prevent coal dust explosions by managing incombustible matter to a level that prevents the hazard from eventuating.

This TRG covers:

- the operating principles of passive and active explosion barriers
- the principles of explosion prevention and suppression
- the characteristics of a coal dust explosion
- additional controls needed to prevent the propagation of the primary ignition into a coal dust explosion
- the use and limitations of stone dust.

This TRG is not exhaustive, and mine operators will need to consider additional reference material in the management of their mine's coal dust explosion and suppression requirements.

## 1.4. Interactions with other plans and overall safety management system

The CDECP forms part of a mine's safety management system (SMS). For more information about safety management systems see the Safety management systems in mines code of practice.

Before writing the CDECP, the mine operator should consider how the CDECP is to be integrated with other plans. The CDECP would usually interact closely with the following:

- Ventilation control plan
- Fire or explosion PHMP
- Mine emergency plans
- Gas outburst PHMP.

## 1.5. Consultation

When managing risks, the mine operator must consult workers and other duty holders at the mine. This includes other persons conducting a business or undertaking (PCBUs) such as contractors. Further information can be found in section 3.4 of the *Guide – Preparing a principal hazard management plan* and the:

- NSW code of practice: Work health and safety consultation, cooperation, and coordination (August 2022), published by SafeWork NSW
- Contractors and other businesses at mines and petroleum sites guide
- Consulting workers fact sheet.

# 2. Complying with the legislative requirements

## 2.1. Legislative requirements

The mine operator must develop a CDECP per Section 19 (2)(c)(iv) of the WHS (MPS) Regulations 2022. The CDECP is a control plan and must sit within the overall SMS.

Section 14 (1) of the WHS (MPS) Regulation 2022 requires a PCBU at a mine or petroleum site to manage risks to health and safety associated with mining operations or petroleum operations at the mine or petroleum site. They must do so in accordance with Part 3.1 of the Work Health and Safety Regulation 2017 (WHS Regulation).

The CDECP needs to consider other aspects of legislation, including but not limited to:

- section 53 of the WHS (MPS) Regulation 2022 – Management of the risk of dust explosion
- section 68 of the WHS (MPS) Regulation 2022 – Specific to coal mining regarding the management of coal dust explosion
- Schedule 5 of the WHS (MPS) Regulation 2022 – Water barriers in underground coal mines.

# 3. Risk management

A critical control is a control that is crucial to prevent an event or mitigate the consequences of an event. The absence or failure of a critical control would significantly increase the risk of an adverse event despite the existence of the other controls[2]. Critical controls are considered important enough to warrant additional monitoring and reporting to ensure they are implemented and maintained to high levels of effectiveness.

The International Council on Mining and Metals (ICMM) now recommends the critical control approach to risk management. Mine operators are likely to identify stone dusting and explosion barriers as the critical control to the management of several hazards in underground mines.

## 3.1. Hazard identification

Optimum coal dust explosion prevention and suppression methods must be mine site and working area specific. This approach minimises the possibility of an explosion, and rapidly and effectively suppresses the propagation of an explosion, should it occur. As part of the mine planning process, the mine operator should consider the following principles:

- a competent person/s must design the mines explosion suppression system considering all site-specific risks.
- mine operators should pay close attention to prevention measures.
- mine operators should consider ignition control, gas control, dust control.
- stone dusting is the first line of defence, with passive (and active barriers) forming the last line of defence if an explosion occurs.
- high risk areas where coal dust is being generated and deposited continually should be identified and given special attention to prevent accumulation of float dust.
- a stone dusting system should be designed using correct principles, including that:
  - stone dust used must comply with requirements of section 68 of the WHS (MPS) Regulation
  - stone dust is more effective the closer it is to the point of ignition
  - stone dust should be applied continuously (e.g., by Continuous duster) in areas where coal dust is likely to be deposited continuously (e.g., return conveyor belt roadways, longwall return roadways, return roadways)
  - the rate of application of stone dusting via continuous dusting or other method must consider the rate of coal dust deposition and be designed to effectively combat float dust deposition.
  - systems should be devised to detect (and remedy) failure in operation of a continuous duster before dangerous quantities of float dust accumulate
  - dry stone dust should be used in follow up treatments for surfaces initially coated with stone dust slurry
  - stone dusting should cover **all** surfaces (roof, ribs, floors, and structures).

[2] In 2015 the International Council on Mining and Metals (ICMM) released the good practice guide “Health and Safety Critical Control Management” that described how mining and metals industries’ risk management outcomes could be improved by focussing on those controls that are most critical for health and safety. Several subsequent ICMM documents have described the CCM framework, including the “Critical Control Management: Implementation Guide” (ICMM, 2015a) and the “Good Practice Guidance on Occupational Health Risk Assessment” (ICMM, 2015b).

- mine operators should select and use appropriate active explosion barriers and/or passive explosion barriers, namely:
  - distributed stone dust barriers
  - distributed water barriers
  - concentrated stone dust barriers
  - concentrated water barriers
  - active barriers.
- during explosion barrier selection and design, mines should consider:
  - the capability of each individual explosion barrier responding adequately to both strong and weak explosions
  - on-site risks that may influence the placement and protection of conveyor belts, ventilation ducting and longwall monorail systems
  - placement at the appropriate distance from the face
  - the appropriate formation
  - appropriate row spacing for distributed barriers
- appropriate row spacing for concentrated barriers
- any limitations or caveats that the OEM has placed on barrier design and barrier components
- if available, the results and lessons of recent full or large-scale testing conducted on both barrier design and barrier components that are relevant to the mine
- sufficient density/loading of extinguishant for the total area of the roadway the explosion barrier is protecting
- load carrying requirements
- electrical, fire resistance, heat resistance, explosion performance requirements.

## 3.2. Risk assessment

Section 14 (2) of the WHS (MPS) Regulation requires a PCBU at a mine or petroleum site ensures that a competent person undertakes a risk assessment, having regard to the nature of the relevant hazard.

## 3.3. Risk controls

### 3.3.1. Hierarchy of controls

When selecting controls for hazards, the mine operator must consider the hierarchy of controls as set out in clause 36 of the WHS Regulation. The mine operator should implement the highest order controls as reasonably practicable.

### 3.3.2. Elimination/substitution

The mine operator should consider automated work systems that provide a way to remove workers from an area, eliminating their exposure to coal dust explosion risks.

### 3.3.3. Isolation

Many of the typical coal dust explosion hazards are managed through a mixture of isolation and the use of engineering controls. These include:

- automated mining systems
- stone dust barrier bags
- remote mining systems
- ventilation.

### 3.3.4. Engineering

Plant and structures primarily drive coal dust explosion hazard management systems. These include:

- auxiliary fans
- primary fans
- ventilation brattices
- ventilation control devises (VCD)
- dust suppression systems
- ventilation system design
- explosion barriers
- gas drainage
- bulk stone dust pod dusters
- airo (wet) dusters
- flinger dusters, cone dusters, Canton dusters
- continuous dusters.

### 3.3.5. Administrative

Mine operators can use several important administrative controls to manage coal dust explosion risks, such as:

- worker training
- physical maintenance of dusting systems
- operation of dust and airborne contaminants suppression systems
- maintaining current procedures
- maintenance of records and records keeping
- stone dust sampling.

## 3.4. Preventative controls

### 3.4.1. System design

Mine operators at the mine planning stage should ensure they reduce risks to workers by considering how to suppress coal dust explosion efficiently and effectively. The SMS should therefore detail how it meets and/or exceeds the requirements of section 68 of the WHS (MPS) Regulation in the development of any explosion suppression system. This should include, but is not limited to:

- systems and processes to limit coal dust generation, including its generation by mining machines, coal crushers and belt conveyors and at belt conveyor transfer points.
- systems and processes in place to suppress, collect and remove airborne coal dust.
- limiting or removing coal dust accumulation on roadways and other surfaces in mine roadways to ensure that the amount of incombustible material contained in roadway dust at the mine is kept at or above the concentration levels shown in Table 1 below.
- determine the stone dust or other explosion inhibitor application rate necessary to minimise the risk of a coal dust explosion and applying that rate.
- ensure that any stone dust used:
  - is of a type or grade that is suitable for its proposed use, and
  - is white in colour, and
  - does not contain more than 3% by mass of free silica, and
  - has a composition such that at least 95% by mass of the stone dust is finer than 250 micrometres and of that stone dust that is finer than 250 micrometres, at least 60% by mass (and not more than 80% by mass) is finer than 75 micrometres.
- restrict the propagation of any coal dust explosion so that other areas are not affected.
- ensure that explosion barriers are installed and maintained
  - at roadways within a face zone (other than single entry roadways) that are return roadways or that contain belt conveyors, or
  - in any other place as required following a risk assessment.
- ensure that stone dust or other explosion inhibitor is applied to any new section of roadway so that;

- no more than 30 metres of the new section is left without an application of stone dust or other explosion inhibitor at any time while the section is being driven,
- and no part of the new section is left without an application of stone dust or other explosion inhibitor for more than one day (not including any day on which no mining operations occur at the mine).

> Note: The 30-metre measurement of a new section is taken to be measured to the face. This includes any unsupported plunges commenced after the last line of installed strata support. i.e. 20 metres of supported but undusted roadway + a 10-metre unsupported plunge = 30 metres of new section to be treated. Every effort should be made to safely discharge the required amount of stone dust into these areas before continuation of mining.

# 4. Stone dust

Stone dusting is the process of spreading inert, incombustible dust on roadways in an underground coal mine. Stone dusting forms part of a Principal Hazard Management Plan to mitigate the risk of a coal dust explosion propagating throughout a coal mine. All underground coal mine operators are required ensure efficient arrangements are in place to adequately treat every length of roadway with an inertant. This limits the amount of incombustible material in any raised dust from the roadway floor, roof, sides and structures per section 68 (1)(c)(i)-(iv) of the WHS (MPS) Regulation.

Table 1 – Incombustible material levels

| WHS (MPS) Reg 2022 | Zone Examples | Incombustible material levels |
|---|---|---|
| Section 68(1)(c)(i) | Development panel | ≥ 85% |
| Section 68(1)(c)(ii) | Longwall Maingate | ≥ 85% |
| | Longwall Tailgate | ≥ 85% |
| Section 68(1)(c)(iii) | Outbye Return roadway | ≥ 80% |
| Section 68(1)(c)(iv) | Outbye Intake roadway | ≥ 70% |

Preventing explosions in underground coal mines is critical because they can have catastrophic consequences for all workers in a mine. There are three key control areas that should be used to reduce the likelihood or severity of an explosion:

- ignition control:
  - eliminate (as far as possible) all sources of ignition.
- gas control:
  - minimise the volume of methane which can enter the ventilated roadways (for example, by pre-drainage)

  - control accumulations of methane in roadways by effective ventilation.
- dust control:
  - minimise the production of coal dust
  - prevent coal dust from accumulating in the roadways (for example, by using dust scrubbing systems, or washing down surfaces)
  - reduce the ability of a gas ignition to raise coal dust into the air (e.g., by keeping working places wet).

Despite these control measures, breakdowns in protection can sometimes occur and an explosion may still result.

Stone dusting provides the next line of defence in the event of an explosion due to breakdown in the above controls. Sufficient volumes of stone dust will render the coal/stone dust mixture incapable of propagating an explosion. Stone dusting is most effective near the point of origin of an explosion because:

- it requires lower levels of stone dust to stop an explosion in its early stages than after it has developed into a strong explosion
- if the explosion area is well stone dusted, the negligible coal dust may confine the gas ignition to a small area
- while mine workers frequently survive gas explosions, they rarely survive explosions where coal dust has a major involvement
- suppressing an explosion at its source minimises the quantity of carbon monoxide produced. The combustion in a gas explosion may be relatively 'clean,' producing little carbon monoxide. Coal dust explosions usually produce massive concentrations of carbon monoxide - up to 5 per cent or 50,000ppm.
- the pressure front from an explosion generally travels ahead of the flame, and usually more quickly. So as an explosion flame travels further, its blast is acting over a rapidly increasing area much greater than that travelled by the flame. Unless the flame is extinguished early, damage is likely to disrupt ventilation controls such as stoppings over a wide area. This exposes those in the area to the carbon monoxide from the explosion, with little or no incoming fresh air.

To be effective, stone dust must prevent coal dust from forming a layer on top of it. This is because it is possible for an explosion to selectively remove the overlying coal dust from the surface.

Stone dusting is most effective in production panel face zone return roadways where it is applied continuously (e.g., by spear duster) rather than periodically.

Stone dust particles must be at least as small as the 'particle' size of the fuel creating the explosion, or finer. Coarse stone dust particles will not adhere to surfaces and are much less effective in suppressing an explosion.

Readers should note that section 68 (e) of the WHS (MPS) Regulation places limits on the fineness of stone dust because very fine limestone tends to cake when exposed to moist air.

Explosions may still occur despite all of the above measures. This is a possibility in places where there is continuous coal dust generation or deposition so that at any time stone dusting may be inadequate. The high production rates and modern longwall systems in modern mines highlights this problem.

Mine operators should ensure that both sides of a roadway, surfaces behind a brattice, and both sides of a conveyor belt are stone dusted. This is because explosions can travel in roadways with substantial strips of untreated coal dust running along the floor.

Mining machines with dust scrubber systems make a great contribution to safety as they remove lots of the dust from surfaces in a roadway. Those managing the risk of coal dust explosion should always ask themselves whether there is enough dust left to propagate an explosion.

The minimum quantity of coal dust required for an explosion is about the thickness of a sheet of paper or less. Determining the amount of coal dust left in a roadway can be difficult as a sampling brush will always leave some behind. The safe position is to assume that there is enough coal dust to be a danger, and to apply stone dust. The amount of coal dust will match the amount of stone dust required to treat it.

It is important to stone dust **all** surfaces - roof, ribs (including behind brattice), floor and structures. While stone dust on ribs and other surfaces may counteract untreated coal dust on the floor, the reverse does not apply. Stone dust on the floor does not neutralise untreated coal dust on the ribs

Methane in the air acts a fuel that can propagate a dust explosion. While extra stone dust is needed to suppress a dust explosion where some methane is normally present in the air in a roadway, stone dust alone **cannot** suppress a gas explosion (i.e., where methane is present at a concentration in its flammable range of 5 to 15% by volume).

## 4.1. Wet stone dusting systems

Stone dust can be applied in the form of a slurry or aerated wet dust. Advances in available technologies has made stone dust in a wet form[3] a more accessible and acceptable alternative to dry stone dusting.

When dry stone dust is mixed with water and an additive and aerated to make wet dust, it is then spayed as a foam onto roadway surfaces. By changing the method of stone dust application, the wet dust process prevents the formation of dust clouds that can prevent work inbye as workers vacate dusty areas to protect their respiratory health. The traditional method of broadcast stone dust application is by pneumatic transfer (i.e., aerating dry stone dust and dry spraying it onto the exposed surface of the mine workings). Inevitably, some of the stone dust remains airborne and the mine ventilation inbye carries it into downwind areas.

[3] **Wet dust** is a system of blending surfactants, water and stone dust and then aerating the product to apply in underground coal mines. The Wet dust process is a wet stone dusting method that assists in the prevention and suppression coal dust explosions in underground coal mines. Wet dust uses an additive that enables the wet stone dust to be foamed onto coal mine surfaces and also works to inhibit the re-crystallization of the calcium carbonate. When dry, the stone dust in combination with the additive inhibits caking and assists dispersion during an explosion.

Wet dust also improves adhesion of stone dust to the sides and roof of the workings compared to dry stone dust. After about 24 hours the foam has dried to form a friable low-density coating of dry-stone dust. This can be dispersed in a similar way to stone dust applied by the traditional dry stone dusting method[4].

Wet dust may be a useful initial treatment as it can be used in intake roadways with people working on the return side and will bind the underlying coal dust. It may be necessary to apply follow-up dry or wet dust treatments. This is because over time, all applications of stone dust may accumulate a layer of coal dust on the surface[5].

## 4.2. Float dust

*Definition*

Float dust is coal dust that is finer than 75 micrometres, deposited upon previously stone dusted surfaces.

*Sources of float dust*

The main sources of float dust are the mining and transportation of coal. Float dust is most likely to be deposited on immediate face return airways and belt conveyor roads. Float dust is also readily transportable by air currents and dust generated on conveyor roads may not remain confined to that heading. It could also be deposited in adjoining roadways. This phenomenon is particularly noticeable at belt transfers located at the splitting point of ventilating currents. The movement of vehicles, particularly on main transport and shuttle car wheeling roads is a third but still significant source of float dust.

*Float dust hazards*

Research suggests that float dust concentrations above 50 g/m$^3$ will reduce or completely negate the explosion suppression capacity of underlying stone dust.

In practical terms, a 50 g/m$^3$ float dust concentration (generally on horizontal surfaces):

- is clearly visible, or
- is thick enough to leave a noticeable indent when making a cross with a person's finger in the accumulation, or
- leaves clear footprints when a person walks across a hard surface.

*Legislative requirements*

[4] Testing has been performed for the purposes of assessing the likely difference in the ability of stone dust applied by the wet dust process to suppress a coal dust explosion compared with that of stone dust applied as a dry dust. To do this a series of coal dust explosions were staged in the CSIR Kloppersbos 200m tunnel and the flame extension into a zone of wet dust or stone dust was determined.

[5] *SkillPro - Analysis of Comparative Explosion Suppression Abilities of Stone dust and Airodust – 28/2/2014.*

In complying with section 14 of the WHS MPS Regulation in relation to coal dust explosion, the mine operator must:

- limit coal dust generation, including its generation by mining machines, coal crushers and belt conveyors and at belt conveyor transfer points.
- suppress, collect and remove airborne coal dust.

In managing risks to health and safety associated with dust at the mine, the mine operator must implement control measures that, as far as reasonably practicable:

- minimise the generation of potentially explosive dusts
- suppress, collect and remove potentially explosive airborne dusts
- suppress dust explosion
- restrict the propagation of a dust explosion so that other areas are not affected.

## 4.3. Stone dusting application systems

Section 68(1)(d) of the WHS (MPS) Regulation 2022 requires the mine operators to determine the stone dust or other explosion inhibitor application rate necessary to minimise the risk of a coal dust explosion and apply that rate.

Continuous stone dusting involves continuously intermixing stone dust into the ventilation stream at or close to the dust source (i.e., behind auxiliary fans in development return roadways, longwall tailgate roadways). This can be an effective control measure to combat float dust deposition. Continuous dusting is also an effective control measure for float dust along return conveyor roadways and conveyor roadways in general when used in conjunction with other stone dust application methods.

The required stone dust application rate dependents on several factors. These include (but are not limited to) seam volatility, production rates, friability of coal and seam moisture content.

The mine operator should determine specific dust loads that are generated at the coal face. The mine operator can then use these to calculate the volume of stone dust or other explosion inhibitor required to intermix with return air, at or close to the face.

Mine operators should assess and document the stone dust application rate required for their mining operations to ensure they maintain that ongoing compliance with section 68 of the WHS (MPS) Regulation 2022.

This should be reviewed if mining operations are varied (e.g., where a single unit continuous miner panel has a second miner and auxiliary fan added to create a dual continuous miner operation).

# 5. Stone dust incombustible content sampling and analysis

Underground coal mine operators must establish procedures in relation to the following:

- the regular inspection, sampling, and analysis of roadway dust layers by an individual nominated to exercise the statutory function of roadway dust sampler at the mine

- where laboratory analysis of roadway dust is required for incombustible material content — ensuring that a laboratory accredited by the National Association of Testing Authorities (NATA) analyses the incombustible material content of roadway dust
- the application of stone dust or another explosion inhibitor for suppressing coal dust explosion
- the intervals at which dust sampling and analysis referred to in paragraph (a) must be carried out
- the keeping of records of samples taken at the mine that identifies the following in relation to each sample:
  - the date it was taken
  - the location at the mine from which it was taken
  - the incombustible material content of the sample
  - the methods used for analysing the sample.
- in each case that spot sampling is used — the keeping of records of the reasons why strip sampling was not used
- the keeping of a plan of the mine that shows the percentage of incombustible material at various parts of the mine and revising the plan as soon as reasonably practicable after obtaining new sample results
- the treatment of float dust on structures and surfaces that have been dusted with stone dust.

The statutory function of roadway dust sampler[6] is to take roadway dust samples at the mine and ascertain the level of incombustible material in the samples.

## 5.1. Preparation and equipment required to take a sample

### 5.1.1. Equipment required to take an effective stone dust sample.

Roadway dust samplers require the following equipment when taking a sample:

- brush (150 millimetres wide)
- dustpan (200 millimetres wide)
- sieve 2.8 millimetres
- sieve 6.7 millimetres (Wet samples)
- paint scraper or Similar (75 millimetres) wide for taking of wet samples.
- plastic bags (300 millimetres x 475 millimetres) to both fit the sieve and to collect the sample in
- sampling record notebook with labels
- pens, chalk, or marker pens as required.
- bag to carry equipment.

[6] The requirement for nomination to exercise the statutory function is that the individual nominated must have completed a course, approved by the regulator for the purposes of Schedule 10 of the WHS (MPS) Regulations 2022, on the sampling and testing of roadway dust.

## 5.2. Methodology of taking an incombustible content sample

### 5.2.1. Methods used to take an incombustible content sample.

There are currently two available methods used for the taking of an incombustible content sample:

- strip sampling
- spot sampling.

Strip sampling means using a series of transverse strips to take samples of dust from the floor, roof, and sides of a roadway where reasonably practicable and safe to do so. The transverse strips:

- are of equal width, and
- are spaced apart by equal amounts of no more than 5 metres, and
- do not overlap.

Spot sampling means taking samples of dust from the floor, roof, and sides of a roadway where reasonably practicable and safe to do so by collecting the dust from a series of spots that:

- are identified on a plan before the sampling occurs, and
- range in size from $0.1m^2$ to $0.5m^2$, and
- are equally distributed and alternating, and
- do not overlap.

The strip sampling method should be used in the first instance, where reasonably practicable. The strip sampling method may not be reasonably practicable due to a physical impediment such as rib mesh. In such a case it would not be possible to get representative and accurate sample[7] and the spot sampling method should be then employed. The reasons as to why strip sampling was not used should be recorded.

### 5.2.2. Safety considerations before and during the taking of a sample.

In the collecting of Incombustible content strip samples as with any work, your priority is for your personal safety.

The roadway dust sampler when undertaking the collection of an incombustible content strip or spot sample should:

- always carry a dust mask and wear if conditions warrant.
- use Hearing protection, particularly near auxiliary fans, running conveyors or where sign posted.
- exercise caution around operating mining and ancillary machinery and trailing cables
- work with care around and near conveyor belts
- watch for loose ribs and poor geological conditions which may be disturbed when brushing and collecting the dust sample.
- avoid rib bolts and protruding supports e.g., torn mesh and straps.

---

[7] *An example of the rib mesh being an impediment would be where the rib has fallen away from behind the mesh creating a large enough void thereby not allowing access with the brush to make sufficient contact with the roadway surface to gather an accurate roadway dust sample.*

- working from a ladder to take a stone dust sample should not be undertaken as you cannot safely maintain 3 points of contact.
- check those areas, in which you will be working, have been inspected; this is particularly the case when working in isolation or entering return airways.
- wear eye protection, as dust collection creates airborne particles.
- when sampling on transport roads, if required place indicators or signs to inform vehicle drivers, who may be entering the area.

**These are obvious hazards; mine operators should conduct a thorough assessment to identify and document other hazards at their individual mine operations.**

### 5.2.3. Strip sampling method

The roadway dust sampler should ensure that:

- where practicable and safe to do so samples must be taken over a length of roadway of at least 45 metres
- samples must not be taken from a depth of more than 5 millimetres
- the areas from which samples are taken must not be less than 1 per cent of the total area to which the sampling relates
- samples must not be taken from points at which samples have been taken on a previous occasion
- dust from a floor of a roadway must be sampled and tested separately from dust on the roof or sides of the roadway if it appears the dust on the floor contains a different incombustible content than dust on the roof or sides
- samples are to be of equal width
- samples are to be spaced apart by equal amounts of no more than 5 metres
- samples do not overlap
- a sufficient mass of the individual sample is to be taken so that when a colour sample fails after analysis via Colourmetric method on the mine site, there is adequate remaining dust to provide to a NATA accredited laboratory for analysis.

The roadway dust sampler should undertake all sampling safely.

To ensure as far as reasonably practicable that an unbiased sample is taken the following steps are recommended:

- the sample starting point should commence at a given point and be taken while advancing into the direction of ventilation flow to prevent bias contamination of the sample. (See Fig 1)
- machinery should not be used to aid in taking a roadway dust sample as this will cause a contamination bias in the in-situ sample. Machinery can stir up roadway dust in the sample area. This is because it can cause an obstruction in the roadway that can lead to an increase in ventilation velocity in the roadway, potentially remove dust, and cause sample contamination.

### 5.2.4. Spot sampling method

The roadway dust sampler should ensure that:

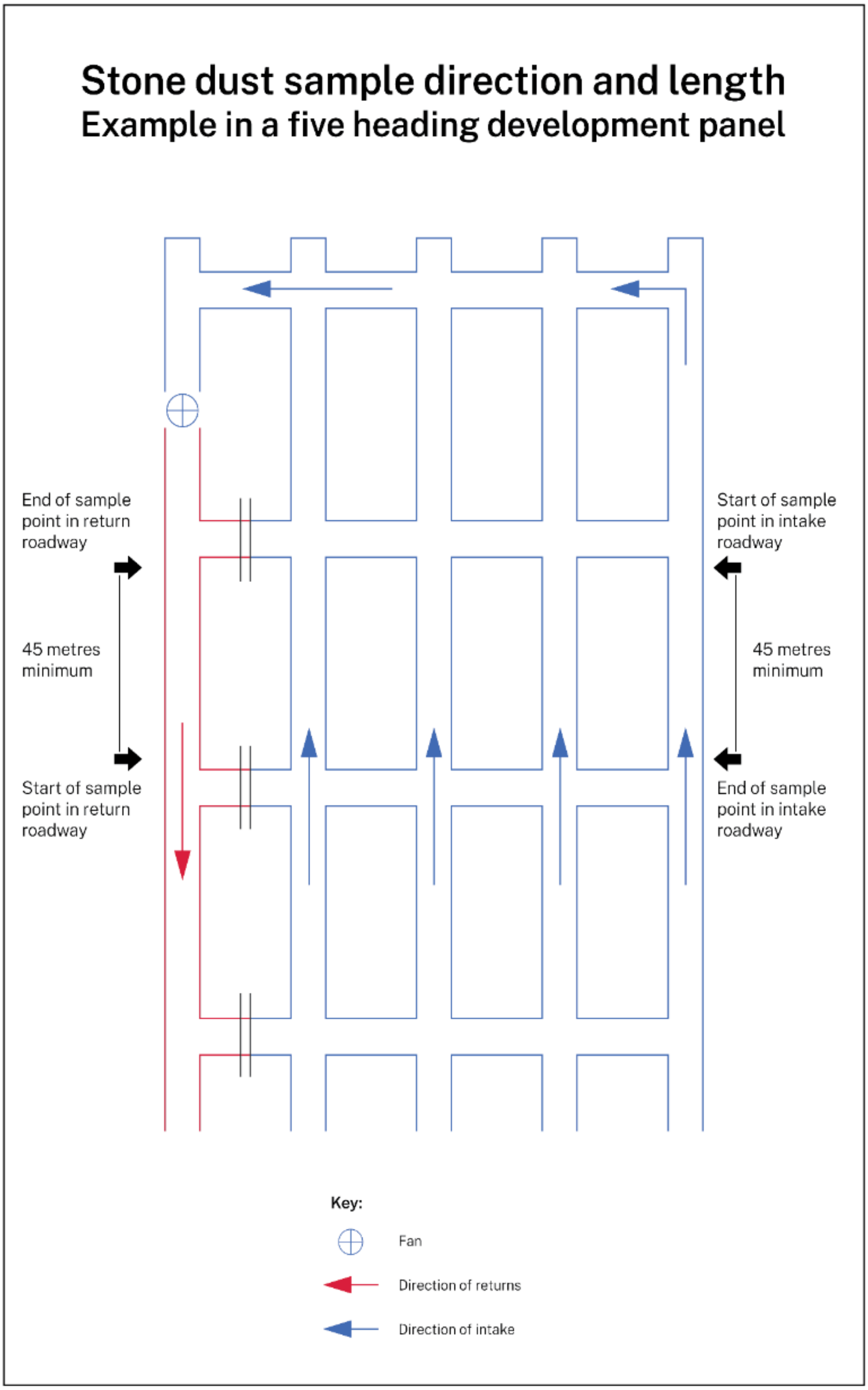
- samples are taken over a length of roadway of at least 45 metres
- samples must not be taken from a depth of more than 5 millimetres
- the areas from which samples are taken must not be less than 1 per cent of the total area to which the sampling relates
- samples must not be taken from points at which samples have previously been taken
- dust from a floor of a roadway must be sampled and tested separately from dust on the roof or sides of the roadway if it appears the dust on the floor contains a different incombustible content than dust on the roof or sides
- are identified on a plan before the sampling occurs
- range in size from $0.1m^2$ to $0.5m^2$
- are equally distributed and alternating
- do not overlap
- a sufficient mass of the individual sample is to be taken so that if a colour sample fails after analysis via Colourmetric method on the mine site, there is adequate remaining dust to provide to a NATA accredited laboratory for analysis.

The roadway dust sampler should undertake all sampling safely.

The following steps are recommended to ensure the most reasonably practicable unbiased sample is taken:

- the sample starting point should commence at a given point and be taken while advancing into the direction of ventilation flow to prevent bias contamination of the sample. (See Fig 1)
- machinery should not be used to assist in taking a roadway dust sample as they will cause a contamination bias in the in-situ sample. Machinery can stir up roadway dust in the sample area. This is because it can cause an obstruction in the roadway that can lead to an increase in ventilation velocity in the roadway, potentially remove dust, and cause sample contamination.

Figure 1 Example of most practical direction to take stone dust sample to avoid contamination.



# 6. Methods of analysing the incombustible content of a roadway dust sample

## 6.1. Analysis by NATA accredited laboratory

Mine operators should ensure that a NATA accredited laboratory analyses all roadway dust samples for incombustible material, where required.

## 6.2. Analysis by Colourmetric method at a mine site

Road dust samplers should report any sample colours and/or visual indications of a sample area of concern to the statutory official in charge, the shift undermanager and the mining engineering manager. The roadway dust sampler should then conduct an immediate Colourmetric analysis of the sample taken on site.

The process for Colourmetric testing of dust samples at a mine should include:

1. Equipment:

- a sieve of nominal aperture 250 micrometres, that complies with AS 1152-1993 “Specification for test sieves”
- a supply of clean white paper
- a device that is capable of heaping as much dust as possible onto a surface the size of a 5-cent coin
- the mines Colour standards that is unique to the mine and seam inspected, prepared by an independent testing facility.

2. Method:

- air dry or microwave (for a nominal two minutes) the dust sample to remove any moisture that would prevent the successful sieving of the sample. Wet samples may require more drying time to allow the sample to pass through a 250-micrometre sieve. Note: the water (moisture) content of the sample is not calculated for this test method
- pass the sample through the 250-micrometre sieve and mix the sieved sample thoroughly, but do not grind it
- place a five-cent piece-sized part of the dried and sieved dust sample onto a clean sheet of white paper
- place a five-cent piece-sized part of the mine’s Colour standards next to the sample taken underground
- press the portions of dust flat with a spatula or similar device to form a smooth surface
- examine the portions of dust and record whether the sample is, or is not, lighter in colour than the standard colour sample (or that the two are indistinguishable)
- the comparison should be made under good and even lighting conditions

- obvious differences between the colour of the sample dust and the standard colour sample should be recorded (i.e., the sample dust is, or is not, lighter in colour than the standard colour sample)
- if both the sample and the colour standard are indistinguishable then the sample should be sent to a NATA accredited laboratory to determine the incombustible content of the roadway dust sample.

# 7. Passive explosion barriers

A passive explosion barrier is a last defence after an initial explosion has occurred.

Passive explosion barriers rely on the explosion's pressure wave or other means to trigger dispersal of the inhibitor into the air before the flame of the explosion arrives.

A mine operator must ensure that explosion barriers are installed and maintained—

- at roadways within a face zone, other than single entry roadways, that are return roadways or that contain belt conveyors, or
- in another place as required following a risk assessment.

Other areas may also fall into this category. These include longwall goaf bleeder points or return roadways that regularly contain levels greater than 1 per cent methane in the general body.

Passive explosion barriers provide a last defence against an explosion propagating throughout the mine. To be effective, they need to be designed, constructed, and maintained correctly.

The manner of installation can vary, usually with the intention of making installation easier. Often the variations also have the effect of reducing the ability of the barrier to suppress an explosion.

Table 2 Examples of explosion barriers

| **Examples of explosion barriers** | |
|---|---|
| **Passive stone dust barrier** | **A device or system using stone dust barrier bags or shelves[7] erected at relevant locations in the mine roadways to arrest a propagating coal dust explosion.** |
| **Water barrier [8]** | **A device or system using water troughs erected at relevant locations in mine roadways to arrest a propagating coal dust explosion. *Mine operators are to refer to the WHS (MPS) Regulations 2022 Schedule 5 for Water barrier requirements and dimensions.*** |
| **Passive concentrated barrier – Fixed or Advancing** | **A stone dust barrier in which a series of barrier bags or shelves[7] are spaced at intervals closer than that of a distributed barrier. This is further described within this document.** |

[8] No water barriers or stone dust shelves are currently in use in NSW underground coal mines.

| Examples of explosion barriers | |
|---|---|
| Passive distributed barrier – Fixed continuous or Advancing | **A stone dust barrier in which a series of barrier bags or shelves[7] are more widely spaced than in a concentrated barrier. This is further described within this document.** |
| Active barrier | **A transducer triggered device or system used to contain and suppress an explosion (methane and/or coal dust explosions) and a fire (e.g., a conveyor fire).** |

## 7.1. Passive explosion barrier design parameters

There are design parameters that apply to all types of passive barriers covered by this document.

These parameters, outlined by OEMs[9] and results of historical research are listed below:

- the number of bags in the barriers in the worked examples provided later in this document are based on the figure of 6kg of stone dust per barrier bag.
- unless specifically stated otherwise, all distances (either between individual stone dust bags or between rows of bags) are measured from hook to hook.
- the horizontal distance between the hooks of the bags in a row, should be not less than 0.4m and not greater than 1.0 metres, when measured across the roadway width.
- the distance between the bags and the side of the roadway should not be greater than 0.5m.
- for nominal roadway heights up to 3.5 metres, each row should have a single level of bags suspended with the hooks not more than 0.5 metres from the roof.
- for nominal roadway heights between 3.5 metres and 4.5 metres high, the bags should be distributed evenly amongst two layers, suspended with the hooks at not more than 0.5m and 1.0m below the roof level.
- for nominal roadway heights between 4.5 metres and 6.0 metres high, the bags should be distributed evenly in three layers suspended with the hooks at not more than 0.5 metres, 1.0 metres and 1.5 metres below the roof level.
- the distance measured along the roadway between rows of bags should be not less than 1.5 metres and not more than 3.0 metres.
- bags should be suspended so the hook and bag can swing freely inbye/outbye, ideally with the open part of the hook facing inbye. The hook should never be attached so it faces across the roadway.
- the minimum total mass of stone dust used in a barrier should be based upon the values of either 200kg/m$^2$ of roadway cross-sectional area, or 1kg/m$^3$ of roadway volume between the extremities of the barrier, whichever amount is greater.
  *It should be noted that for any barrier longer than 220* metres, *the stone dust mass should be calculated based on roadway volume i.e., 1kg/m$^3$.*

[9] OEM guidelines must be followed as required by section 68(6) of the WHS(MPS) Regulation 2022

- the design of the fixed continuous distributed barrier system requires a stone dust loading based on a ***minimum*** stone dust density of 1kg/m$^3$ in the mine roadway.
- a mixture of different manufacturers barrier bags is not to be used within the same barrier.
- a barrier should ideally contain either all short or all long bags only, within the individual barrier.
- ***all*** hooks and bags suspended along a conveyor belt should be free-hanging and be incapable of touching any part of the conveyor belt structure or belting, even if accidentally bumped
- acceptable means of suspension from belt structure might include a looped cable tie or twisted flexible steel wire loop, so long as the minimum breaking strength of the loop/hanging device is greater than or equal to 30kg.
- In a roof cavity, additional bags should be hung evenly from either the roof mesh, a chain installed across the top of the cavity or by using an approved hanging method from the OEM.
- Where a cavity exists at roof level, barrier bags should be installed on a tight chain across the roadway below the cavity or by using an approved hanging method from the OEM.
- Where the Explosion barrier is used to provide explosion protection in a conveyor belt roadway, additional stone dust bags must be suspended on the conveyor belt structure to provide additional protection against passage of an explosion between the belts, or between the belt and roadway side. The number of bags installed should be ***two bags per corresponding row installed at roof level, installed either side of the conveyor***. *(See example image below)*
- For suspended belt structure, wherever there is clearance to do so, ***additional*** bags must be suspended ***at a level lower than the return belt*** to provide additional protection against passage of an explosion beneath the conveyor system. If there is insufficient clearance these bags can be suspended from the side structure and as low as practicable. The number of bags installed should be ***two bags per corresponding row installed at roof level, installed either side of the conveyor.*** *(See example image below)*
- The same conditions apply whenever a ventilation duct or large pipe is suspended above the roadway floor - ***one*** additional bag should be suspended under the vent duct/pipe per corresponding row installed at roof level in the Explosion barrier.
- There is no direct research data showing the need or otherwise for additional protection around a monorail system or a single pipe, that penetrates the barrier, other than that noted above, but there should not be an unprotected “passage” between the rib and side of any large obstruction such as a suspended belt, ventilation duct, Flexible conveyor train (FCT) or monorail system.

Figure 2: Example of a fixed concentrated barrier with suspended structure.

### 7.1.1. Explosion barrier loadings

Since early 2000, the length of development chain pillars in NSW coal mines has progressively reached 200 metres in some instances, with chain pillar widths reaching anywhere from 30 to 75 metres.

The OEM guidelines of the bagged barriers call for the barriers to be located (commenced) no further than 120 metres outbye of the last completed cut-through. This means that depending on the explosion's ignition point an explosion barrier in a development gateroad panel could potentially commence up to 395 metres outbye of the development face. In a Longwall panel with a face width of 400 metres, an explosion barrier in either gate road might be located as far as 320 to 520 metres from the explosion's ignition point.

Even though an explosion barrier may comply with the regulations and the OEM guidelines in terms of last cut-through/longwall face-to-inbye-end of barrier distance, the effectiveness of the barrier could be compromised by inadequate inertant loading[10]. This situation is exacerbated when it is considered that the point of ignition could be considerably further inbye from the barrier that the last completed cut-through.

Research[11], indicates that at the start of development an explosion barrier that commences at 120 metres outbye of the last cut-through loaded at 100kg/m$^2$ is adequate, but is only adequate until mining proceeds about 20 metres inbye the cut-through.

Explosion barriers are most effective when they are installed as close to the potential ignition point as the OEM installation guidelines and this TRG allow.

Explosion barriers with an inertant loading of ***200kg/m$^2$*** will provide the highest reasonably practicable level of safeguarding against coal dust explosion propagation when used in combination with an effective ongoing stone dusting campaign.

For the passive explosion barriers as described in Section 7.2 of this TRG:

- an advancing distributed explosion barrier and both the fixed and advancing concentrated explosion barriers as described in section 7.2 should contain enough stone dust or water to cover the full length of the barrier. This should be a minimum of ***200kg/m$^2$*** of the roadway cross sectional area ***or 1kg/m$^3$*** of the roadway volume over the full length of the barrier, ***whichever is the greater***. This same loading applies to a barrier which is protecting a place other than a face, where the barrier commences within the same distances applicable to a face (e.g., a goaf bleeder point or other area as determined by a Risk assessment).
- explosion barriers that *do not* commence within the distances described in section 7.2 should be loaded with stone dust or water to a minimum ***400 kg/m$^2$*** of the roadway cross-sectional area (e.g., when a longwall is approaching the take off point, or a set of development roadway entries is being driven off a mains heading).

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[10] Coal Dust Explosions and Their Suppression (Cybulski, Waclaw 1975)

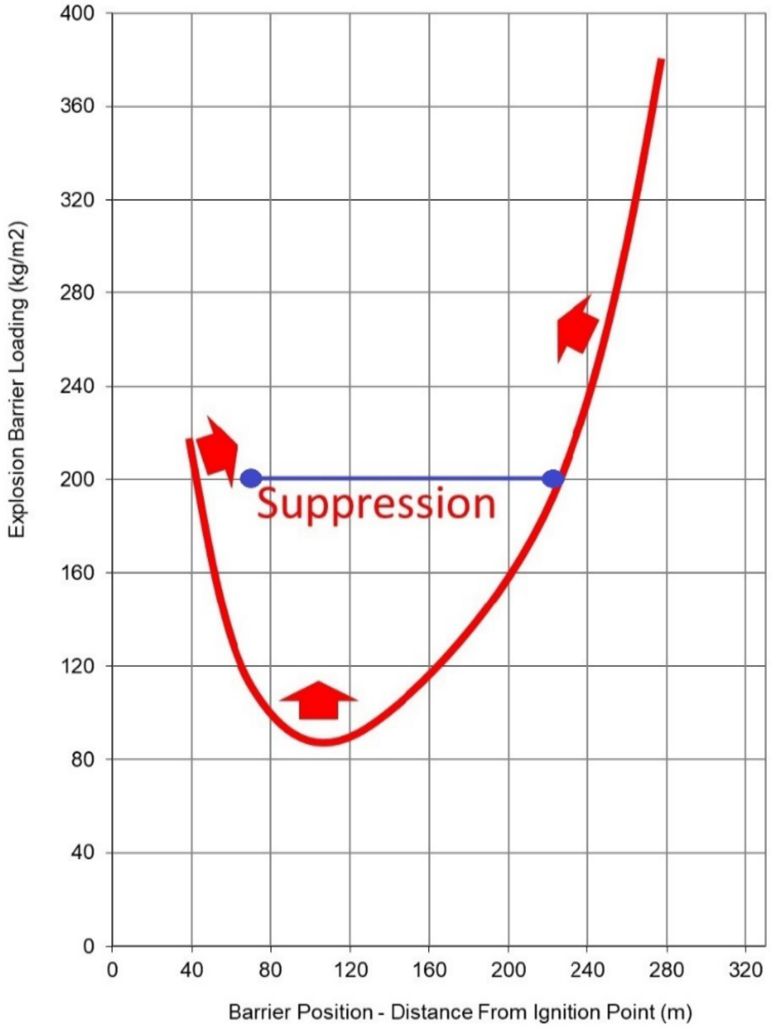
[11] Coal Dust Explosions and Their Suppression (Cybulski, Waclaw 1975) supported by The Influence of Initiation Point-to-Barrier Separation Upon the Required Loading of Passive Explosion Barriers, and of, Inerting Levels Upon the Effectiveness of Stone dusting. Prepared by David Humphreys BE (Mining Hons), MEngSc (Res), PhD (2020)

- the stone dust density loading required of a fixed distributed explosion barrier is, ***1kg/m³*** x total roadway volume ***over the full length of the barrier***.

Passive explosion barriers with materially different designs to those described in section 7.2 must be loaded in accordance with the manufacturer or supplier's documented recommendations. The manufacturer and/or supplier must be consulted to ensure stone dust density loading is suitable for the explosion barrier in its intended location.

The abovementioned stone dust densities will provide for a greater level of safeguarding against coal dust explosion propagation in current modern NSW underground coal mines.

Figure 3: Explosion barrier loadings kg/m² vs Barrier Position – Distance from ignition point[12][13]




[12] Coal Dust Explosions and Their Suppression (Cybulski, Waclaw 1975)

[13] *The Influence of Initiation Point-to-Barrier Separation Upon the Required Loading of Passive Explosion Barriers, and of, Inerting Levels Upon the Effectiveness of Stone dusting. Prepared by David Humphreys BE (Mining Hons), MEngSc (Res), PhD (2020)*

Figure 4 – Typical barrier bags placement

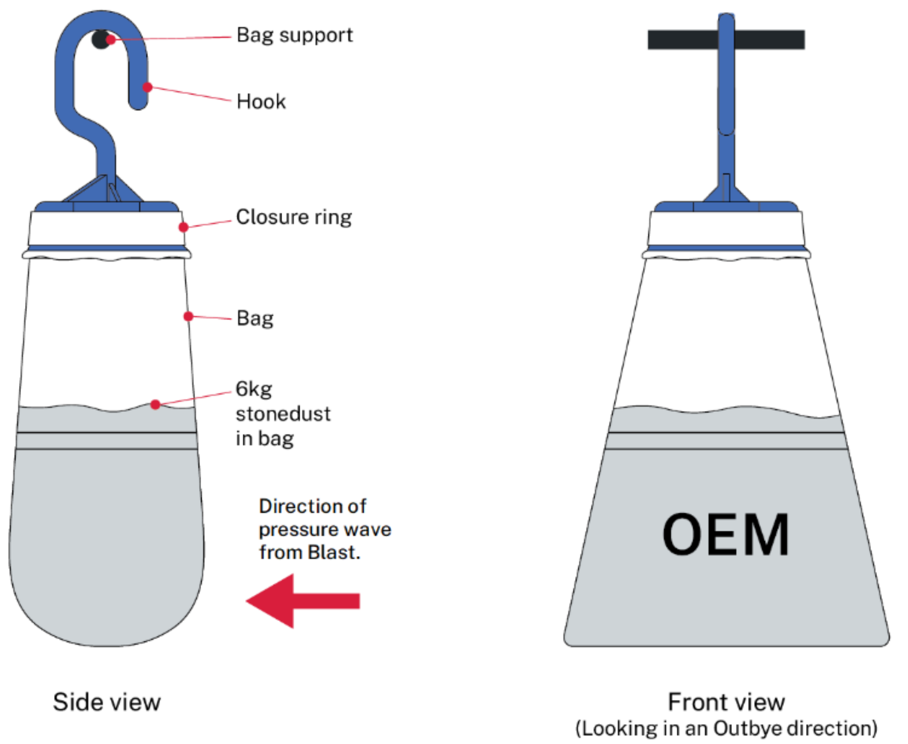



Figure 5 – Spacing of individual barrier bags.

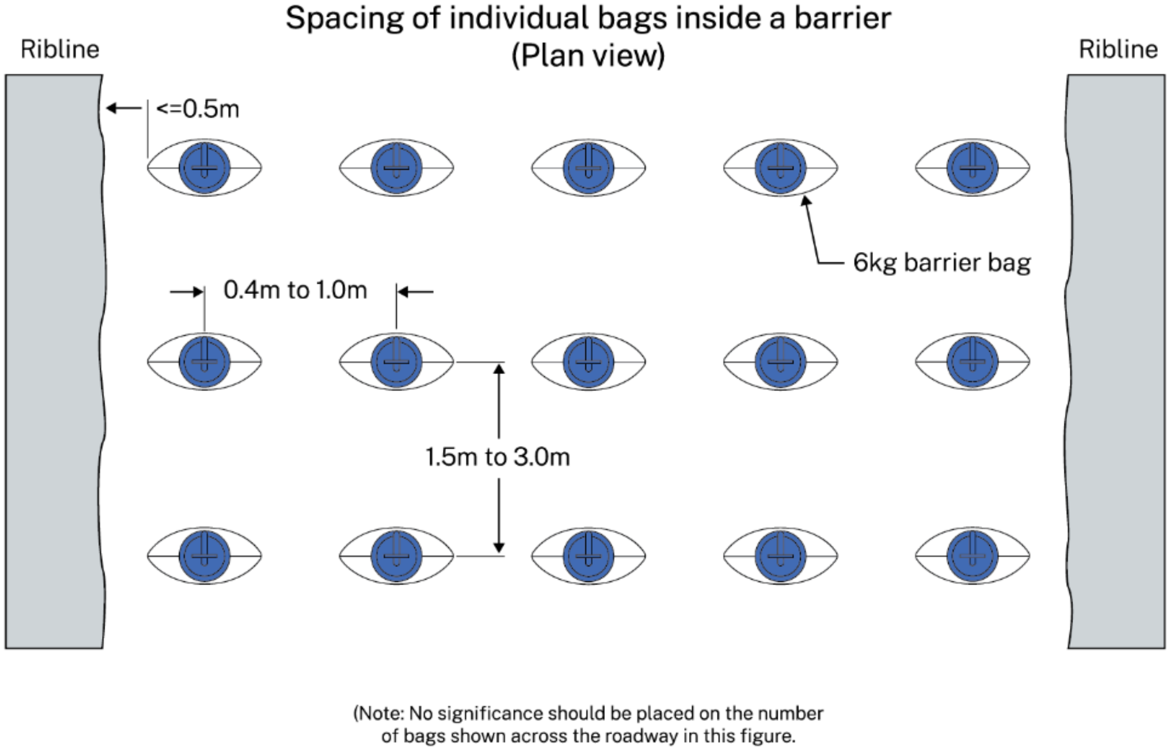
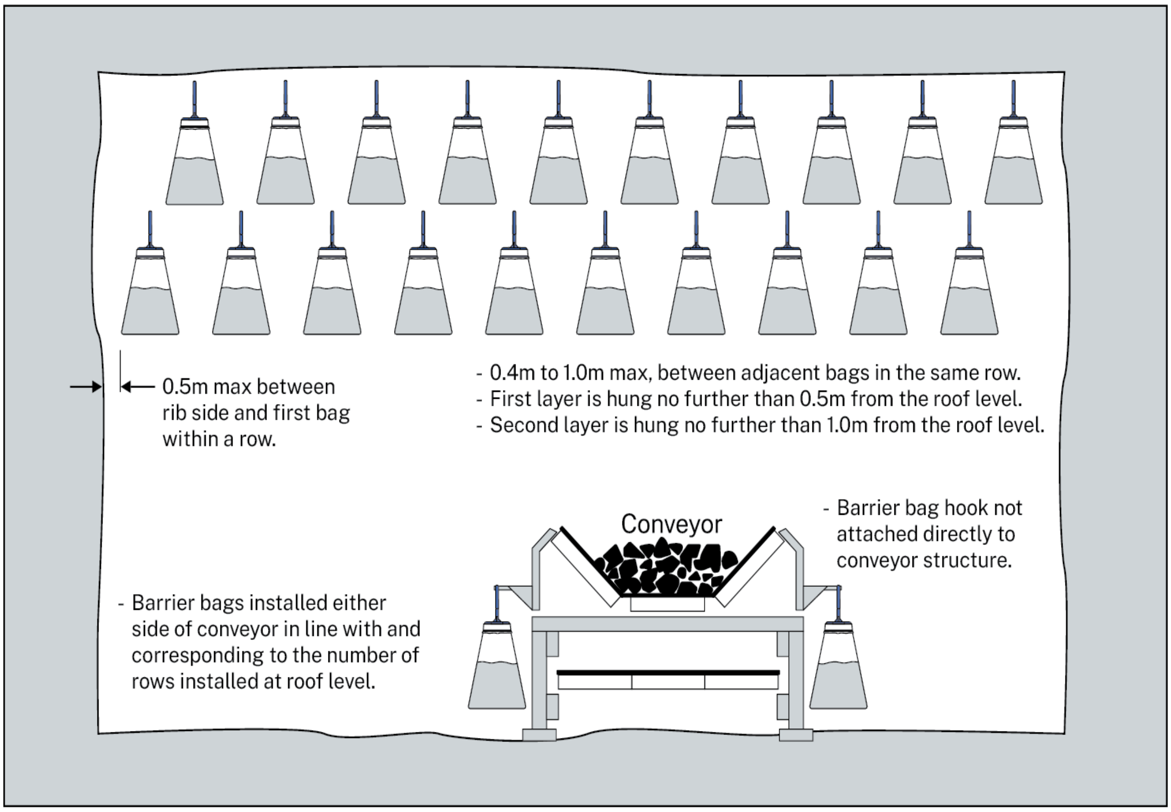
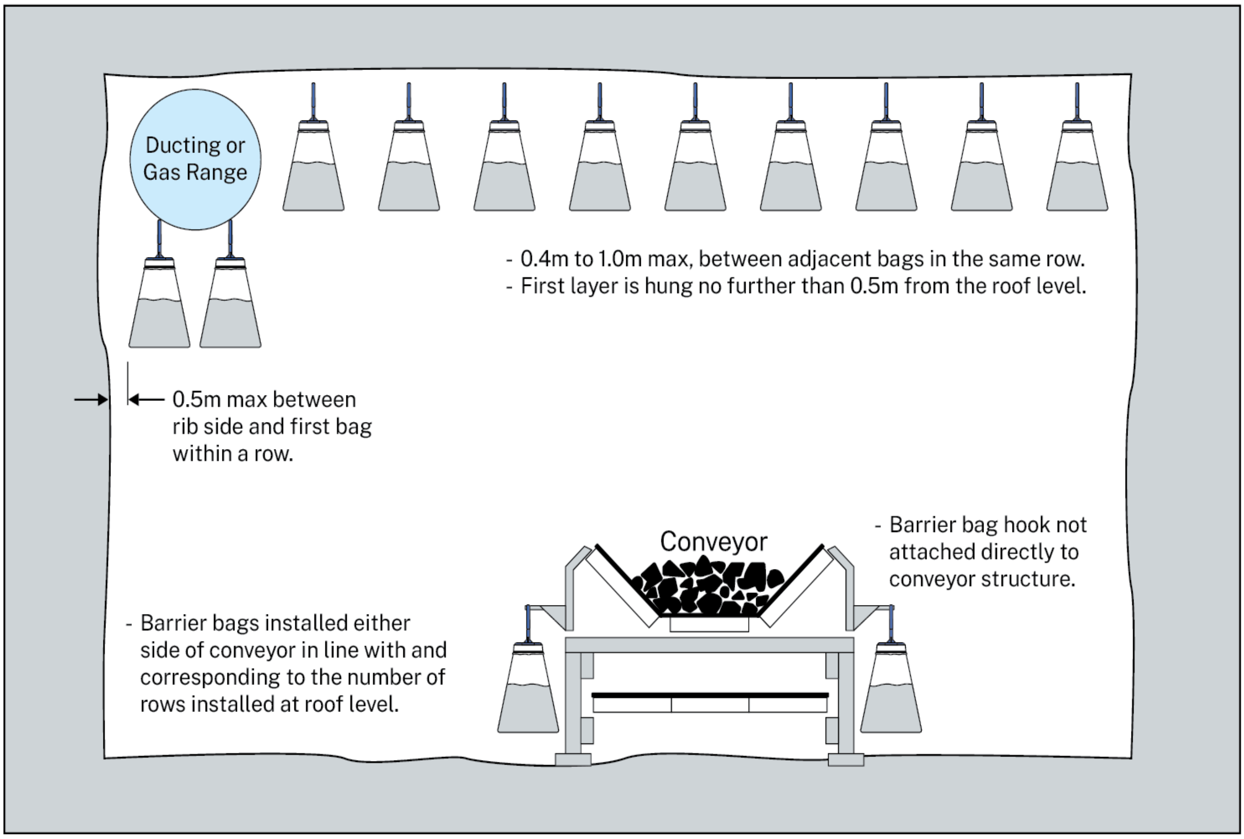


Figure 6 – Typical barrier bag placement in roadways between 3.5 metres and 4.5 metres in height



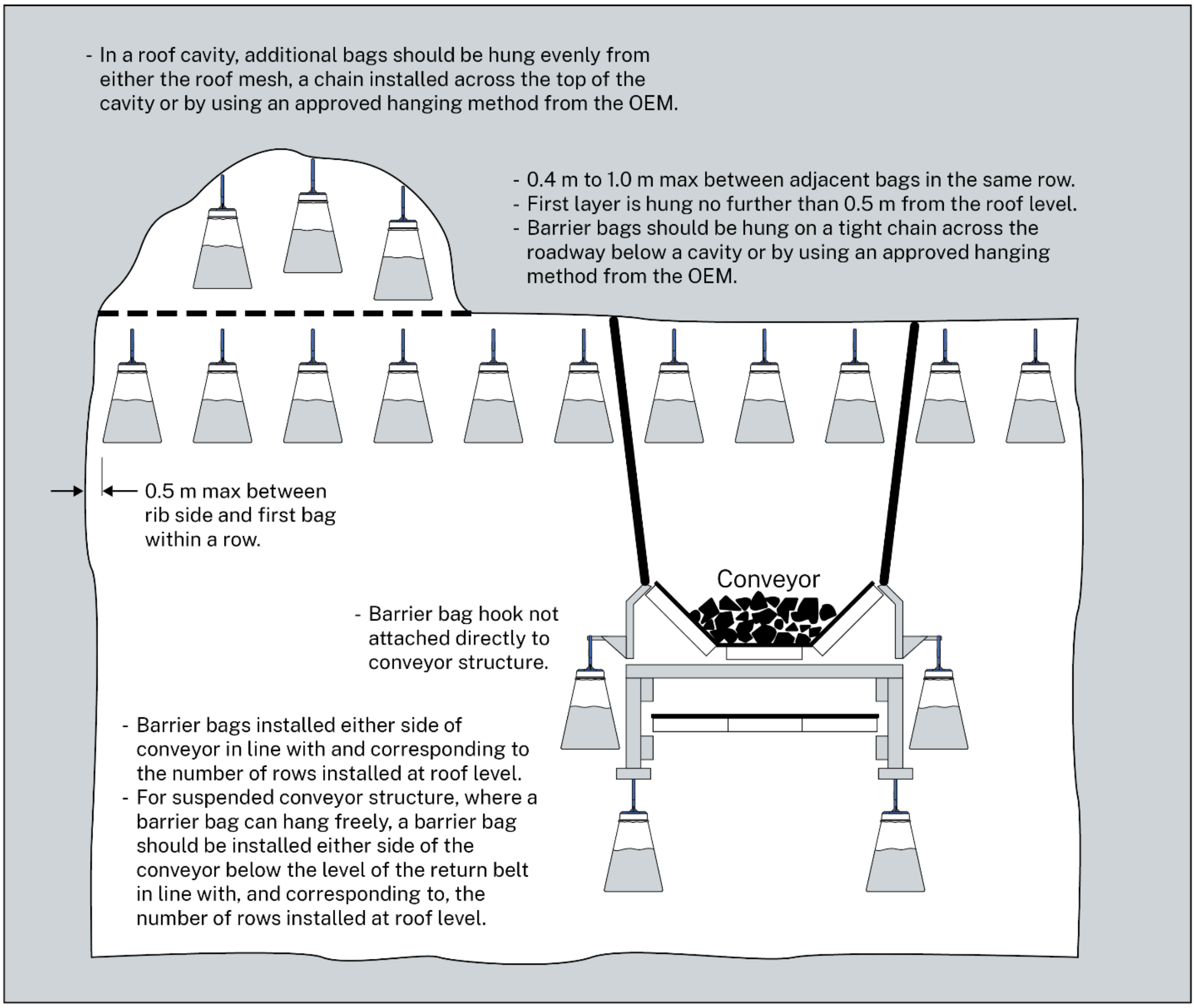

Note: No significance should be given to the number of bags shown across the roadway in the above figure.

Figure 7 – Typical barrier bag placement in roadways with obstructions




Note: No significance should be given to the number of bags shown across the roadway in the above figure.

Figure 8 – Typical barrier bag placement in roadways with cavities and/or suspended conveyor structure




Note: No significance should be given to the number of bags shown across the roadway in the above figure.

## 7.2. Types of passive barriers

The passive bagged barrier system can be configured in several different ways depending upon the application, mine requirements and how the mine operator applies the guidelines.

Listed below are four alternatives that can be applied:

- an advancing distributed barrier,
- an advancing concentrated barrier,
- a fixed concentrated barrier, or
- a fixed continuous distributed barrier.

All barriers must comply with the typical barrier design parameters in Section 7.1. Relevant information on four types of barriers is set out below.

### 7.2.1. Advancing distributed barrier system

An advancing (or retreating) distributed barrier consists of four sub-barriers, installed over a maximum distance of 120 metres of continuous roadway.

Four complete sub-barriers must always remain in position. The original concept was that the fourth barrier would be moved only during non-production shifts when the probability of ignition is greatly reduced. If this is not the case, a fifth sub-barrier should be added to have confidence that the barrier meets the required dust loading all times.

The following should be maintained:

- the first row of the first sub-barrier should be installed no closer than 60 metres and no further than 120 metres from the last completed line of cut-throughs, or coal face of a producing longwall panel
- the last row of the fourth sub-barrier (furthest from the last completed line of cut-throughs or face line) should be installed no more than 120m from the first row of first sub-barrier
- the two intermediate sub-barriers should be equidistant between the first and fourth sub-barriers
- the presence of cut-throughs other than the last completed cut-through is not a consideration in determining distances
- the maximum distance between the end of one sub-barrier and the start of the next sub-barrier should not exceed 30 metres
- the minimum total mass of stone dust used in the barrier is based upon the values of either 200kg/m$^2$ of the roadway cross-sectional area, or 1kg/m$^3$ of roadway volume between the extremities of the barrier, whichever amount is greater.

The dimensions listed above are illustrated in Figure 9 below.

## Example calculation for an advancing distributed barrier

The following worked example of the required calculations will illustrate an advancing distributed barrier design.

This example describes a bagged stone dust barrier that is to be installed in a bord-and-pillar section. The first row of the first sub-barrier will be located between 60 and 120 metres from the last completed line of cut-throughs and the last row of the fourth sub-barrier will be at 120 metres from the start of the first sub-barrier.

The belt road is 3.0 metres high and 5.2 metres wide.

Thus, the cross-sectional area of the roadway is 15.6m$^2$ (i.e., 3 x 5.2 = 15.6m$^2$).

The distance between the barrier extremities is 120 metres and the cross-sectional area is 15.6m$^2$. The volume between the extremities of the full barrier is therefore calculated as 1872m$^3$ (i.e., 120 x 15.6 = 1872m$^3$).

Based on the cross-sectional area requirements of 200kg/m$^2$ and the roadway volume requirements of 1kg/m$^3$, the barrier will require either 3120kg or 1872kg of stone dust, whichever is the greater. In this case the barrier will require 3120kg of stone dust.

Calculated on each bag containing 6kg of stone dust, a total of 3120kg/6kg = 520 bags are needed.

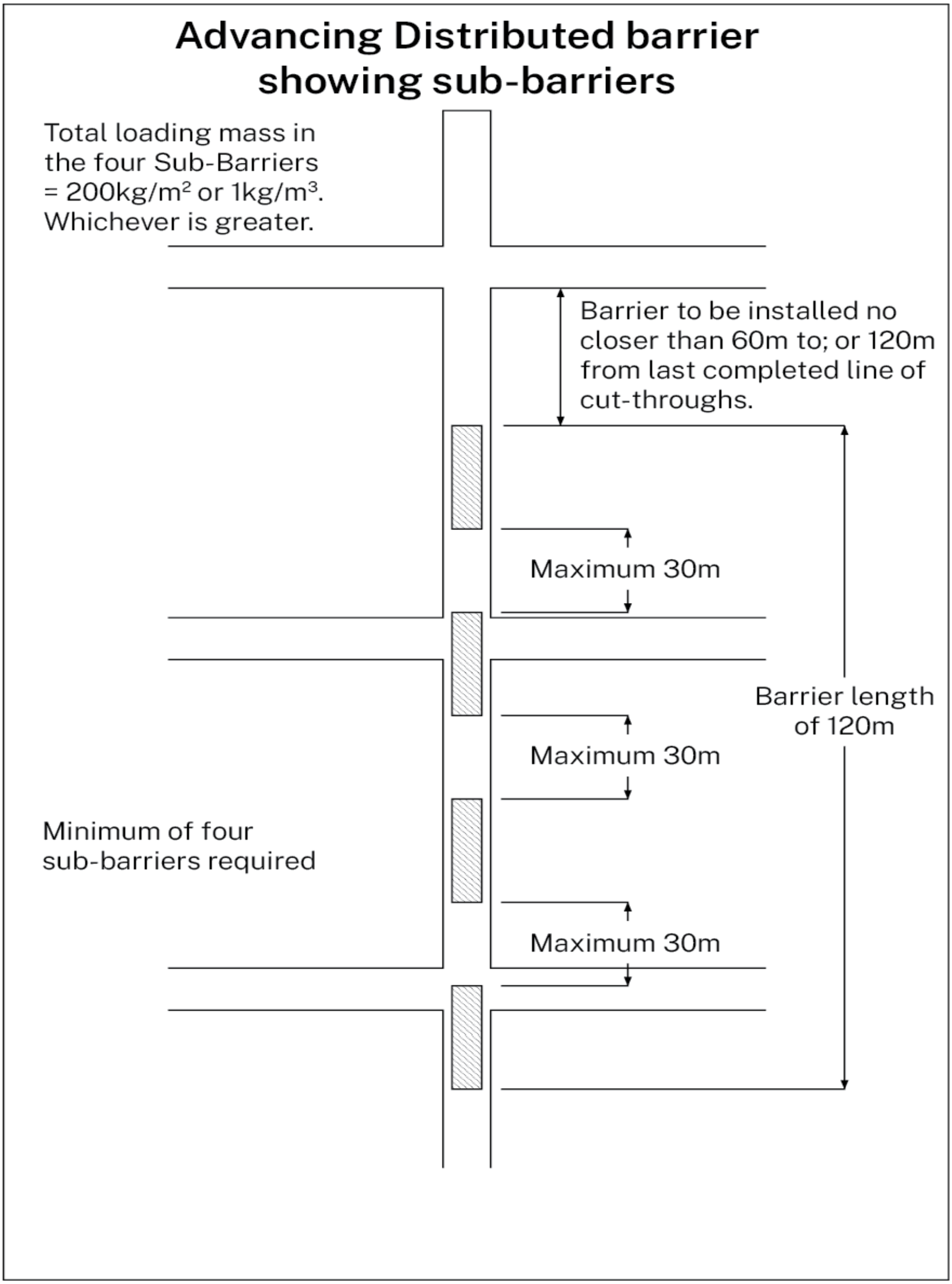
With four sub-barriers, there would be 520/4 = 130 bags per sub-barrier.

Each sub barrier needs 130 bags which is best arranged as 11 rows of 12 bags (rounded).

If for example only 9 or 10 bags can easily be hung across the road, additional rows will be needed. Additional bags may be needed in some rows to make up to 130 bags in the sub-barrier.

Assuming the 11-row x 12 bag arrangement, and if rows in sub-barriers are 2 metres apart, then each sub-barrier will be 20 metres long.

Figure 9- Advancing Distributed Barrier Bag System



> Individual OEMs of the current explosion barrier bag systems available have different distance requirements for a concentrated explosion barrier ranging from no closer than 60 metres to no closer than 70 metres between the first row of a concentrated explosion barrier and the last completed line of cut-throughs or longwall face. This individual OEM requirement should be considered during the design phase of the mines explosion suppression and prevention systems.

### 7.2.2. Advancing concentrated barrier bag systems

The advancing concentrated barrier is an alternative to the advancing distributed barrier.

Instead of the stone dust being distributed among four or five sub-barriers spread over about 120 metres of roadway, the stone dust is placed in two concentrated barriers.

To facilitate panel advance/retreat, the second concentrated barrier is installed and used to leap-frog (or remain in place) the first barrier. This maintains the correct distance from the last completed line of cut-throughs.

Each of the individual barriers are to be designed based on 200 $kg/m^2$ of stone dust loading, the required amount for the stone dust to act as a discrete explosion barrier.

Installing a ***minimum*** of two compliant barriers will allow removal of one barrier for advancing or retreating as the face moves without compromising the barrier stone dust loading.

Sub-barriers should be left in-situ rather than being removed when a new barrier is built upon advance. This further enhances the protection of the mine's roadways.

There must always be greater than 60 metres (see note above) but less than 120 metres distance between the last completed line of cut-throughs or longwall face and the first row of bags, both advancing and retreating.

The next barrier in the sequence must start no further than 120 metres from the inbye end of the first barrier, so the exact distance between them will be dependent on the barrier length chosen.

The **advancing concentrated barrier bag system** dimensions are illustrated in Figure 10 below.

## Example calculation for an advancing concentrated barrier

The following is an example of the calculations undertaken to design an advancing concentrated barrier.

Consider a roadway in which the barrier is to be installed and which has a height of 3 metres and width of 5.2 metres.

Thus, the *cross-sectional area* of the roadway is 15.6m$^2$ (i.e., 3 x 5.2 = 15.6m$^2$).

Based on the cross-sectional area requirements of 200kg/m$^2$ x the roadway cross sectional area, each barrier will require 3120kg of stone dust (i.e., 15.6 x 200 = 3120kg).

Calculated on each bag containing 6kg of stone dust, a total of 520 bags are needed (i.e., 3120kg/6kg).

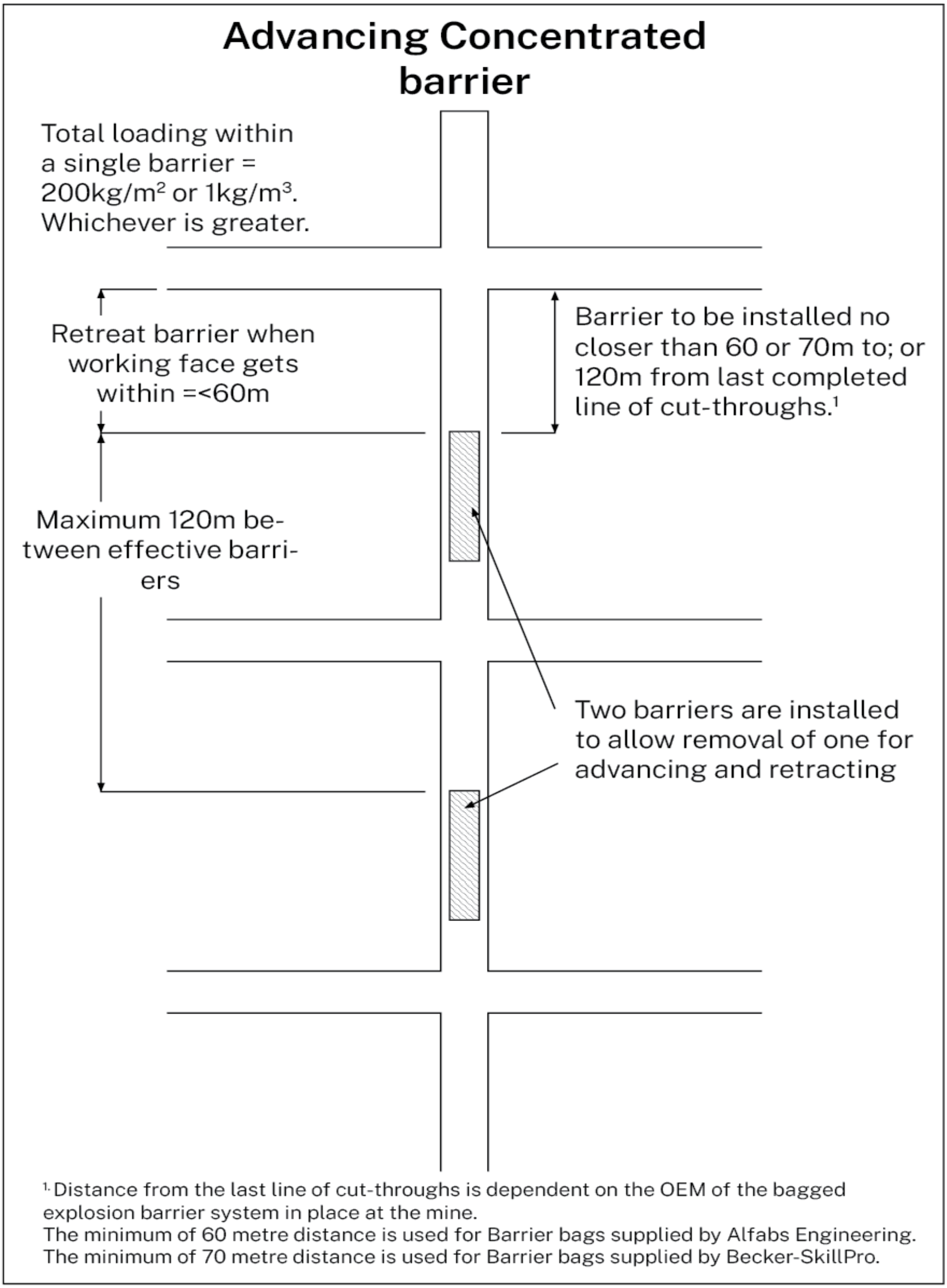
Allowing 0.4 metres between the ribs and the nearest bags and 0.4 metres between adjacent bags, it is possible to install 12 bags in each row. Therefore, the final barrier consists of 44 rows and each row holding 12 bags (44 x 12 = 520bags). Allowing a spacing of 1.5 metres between rows each barrier will be approx. 65 metres long.

Two barriers are installed to allow removal of one barrier for advancing or retreating as the face moves without compromising the barrier dust loading. The design details of the second barrier will be the same as the first barrier.

Both barriers (each consisting of 520 bags in this example) must always be in place during the production of coal.

> The second barrier should be left in-situ rather than removed and a new barrier built upon advance to further enhance the protection afforded to the entirety of the mine and its roadways.

Figure 10 - Advancing concentrated barrier system



### 7.2.3. Fixed concentrated barrier bag systems.

The fixed concentrated barrier presents a more suitable alternative to the advancing concentrated barrier for NSW coal mining methods and conditions.

Instead of the stone dust barrier moving upon advance or retreat, the barrier bags are placed in two fixed concentrated barriers.

To facilitate panel advance, a new fixed concentrated barrier is installed and remains in place the first barrier to maintain the correct distance from the last completed line of cut-throughs.

Each of the individual barriers are to be designed based on 200 kg/m$^2$ of stone dust loading required to act as a discrete explosion barrier.

A ***minimum*** of two compliant barriers are to be always installed. This allows for correct barrier design and loading within a face zone, without compromising the barrier stone dust loading.

The two previously installed barriers are left in-situ rather than removed and a new barrier is built upon advance to further enhance the protection of the mine's roadways.

The distance between the last completed line of cut-throughs and the first row of bags must always be greater than 60 metres but less than 120 metres, both advancing and retreating.

> Individual OEMs of the explosion barrier bag systems available have different distance requirements for a concentrated explosion barrier of; no closer than 60 or 70 metres between the first row of a concentrated explosion barrier and the last completed line of cut-throughs or longwall face. This individual OEM requirement should be considered during the design phase of the mines explosion suppression and prevention systems.

The next barrier in the sequence must start no further than 120m from the inbye end of the first barrier, so the exact distance between them will be dependent on the barrier length chosen.

The stone dust requirement in each barrier is calculated based on 200kg/m$^2$ of cross-sectional roadway area.

The Herringbone mining method presents the challenge of providing a sufficient explosion barrier loading of stone dust suspended in barrier bags, within smaller roadway dimensions.

It is considered reasonably practicable to meet the loading requirements in a Herringbone mining panel by installing a single fixed concentrated barrier in the return roadway that meets the requirements of both the loading and dimensions by installing a second layer of barrier bags below the first layer installed at roof level. (See worked example B)

The dimensions for a fixed concentrated barrier are illustrated in *Figure 10b*.

### Example A: calculation for a fixed concentrated barrier in Mains headings.

The following is an example of the calculations undertaken to design a fixed concentrated barrier.

Consider a roadway in which the barrier is to be installed and which has a height of 3.5 metres and width of 5.2 metres.

Thus, the *cross-sectional area* of the roadway is 18.2$m^2$ (i.e., 3.5m x 5.2m = 18.2$m^2$).

Based on the cross-sectional area requirements of 200kg/$m^2$ x the roadway cross sectional area each of the two barriers will require 3640kg of stone dust (i.e., 18.2m2 x 200kg/$m^2$ = 3640kg).

Calculated on each bag containing 6kg of stone dust, a total of 607 bags (rounded) are needed (i.e., 3640kg/6kg = 607 bags).

Allowing 0.4 metres between the ribs and the nearest bags and 0.4 metres between adjacent bags, it is possible to install 12 bags in each row.

Therefore, the final barrier consists of 51 rows and each row holding 12 bags (51 x 12 = 607bags).

Allowing a spacing of 1.5 metres between rows each barrier will be approx. 75 metres long.

Two barriers are always installed to and left in-situ as the face moves without compromising the barrier dust loading.

The design details of the second barrier will be the same as the first barrier.

Both barriers (each consisting of 607 bags in this example) must always be in place and compliant during coal production.

> The second barrier should not be removed but left in-situ and a new barrier is built upon advance to further enhance the protection afforded to the entirety of the mine and its roadways.

### Example B: calculation for a fixed concentrated barrier in Herringbone Panel return roadway.

The following is an example of the calculations undertaken to design a fixed concentrated barrier in a herringbone panel return roadway.

Consider a roadway in which the barrier is to be installed and which has a height of 3.1 metres and width of 5.4 metres.

Thus, the *cross-sectional area* of the roadway is 16.74m$^2$ (i.e., 3.1m x 5.4m = 16.74m$^2$).

Based on the cross-sectional area requirements of 200kg/m$^2$ x the roadway cross sectional area each barrier will require 3640kg of stone dust (i.e., 16.74m$^2$ x 200kg/m$^2$ = 3348kg).

Calculated on each bag containing 6kg of stone dust, a total of 3348kg/6kg = 558 bags are needed.

Allowing 0.4 metres between the ribs and the nearest bags and 0.4 metres between adjacent bags, it is possible to install 13 bags in each row.

As there is limited distance to install the barrier in a herringbone method return roadway to allow for the number of bags required and barrier row spacings, the barrier will need to consist of two layers.

Therefore, the final barrier will consist of a first layer of barrier bags at roof level of 23 rows and each row holding 13 bags (23 x 13 = 299 bags).

Then a second layer consisting of 20 rows each row containing 13 barrier bags (20 x 13 = 260 bags) is hung at approx. 500 millimetres below the first layer at roof level.

Allowing a spacing of 1.5 metres between rows the barrier will be approx. 33 metres long.

A fixed concentrated barrier in a Herringbone Panel return is always to be installed so the most inbye row of the next barrier in the sequence to be installed, starts no further than 120m from the inbye end of the previous return roadway explosion barrier in the mining sequence.

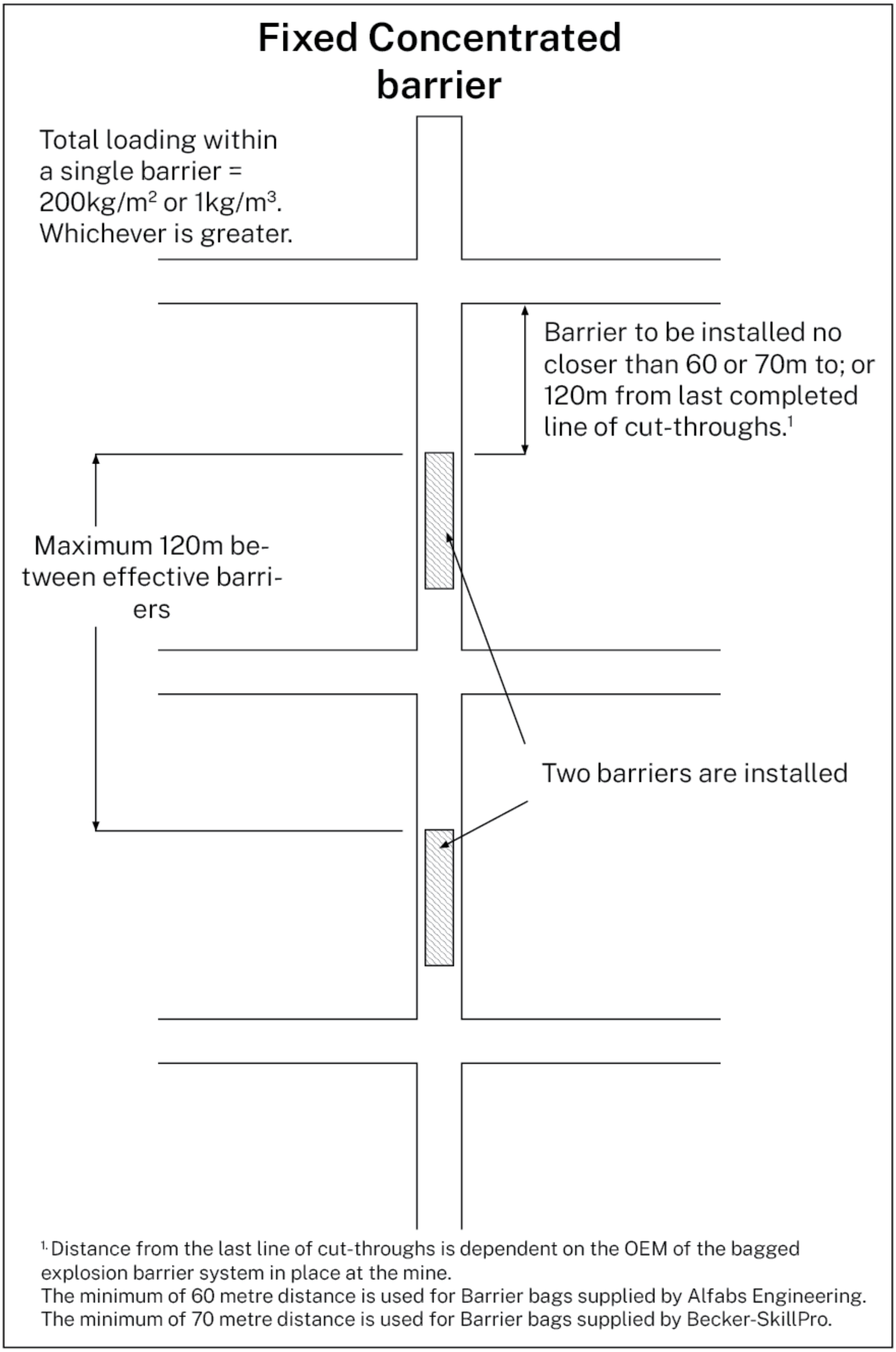
All barriers installed in return roadways should be left in-situ as the roadways advance, as this provides a greater degree of explosion protection for that roadway.

The design details of each return barrier will be the same on both return sides of the panel.

Two barriers (each consisting of 559 bags in this example) must always be in place and compliant during coal production.

> The second barrier should not be removed but left in-situ and a new barrier is built upon advance to further enhance the protection afforded to the entirety of the mine and its roadways.

Figure 10b - Fixed concentrated barrier system




## 7.2.4. Fixed Continuous distributed barrier bag systems.

Fixed continuous distributed barrier bag systems should be used in mining situations where there is a rapid advance or retreat. For example, Longwall and Flexible conveyor train (FCT) development panels, and/or where mining sequence, and/or pillar sizes make either of the previous choices difficult.

> This explosion barrier bag system is the recommended application for use in longwall maingate and tailgate roadways.

This barrier bag system avoids the need to relocate or install sub-barriers used in the explosion barrier systems explained above. Relocating or installing sub-barriers can create safety risks and production delays.

***The fixed continuous distributed explosion barrier offers the lowest net risk to a mine***.

The fixed distributed barrier places a continuous array of stone dust bags in a roadway, potentially over its entire length. These would usually be installed during development and left in place for the retreat phase of mining.

By leaving the already installed bags in place, there is no requirement to advance or retreat barriers as described previously. This provides a very high degree of explosion protection for that roadway.

The distance between the start of the fixed distributed barrier and the last completed line of cut-throughs or longwall face ***must not*** exceed 120 metres.

Fixed continuous explosion barriers can be installed immediately outbye of the face at a convenient position. The first-row location should not be more than 120 metres outbye of the last completed line of cut-throughs or longwall face line.

A fixed continuous distributed barrier should commence and be compliantly maintained as close reasonably practicable to the last open line of cut throughs or the longwall face line in both the maingate and tailgate roadways. This will offer the lowest risk to a mine.

To be effective, the barrier must run for a ***minimum*** distance of 220 metres.

It is not always possible to maintain the barrier length for 220 metres as a longwall panel sets off or as a longwall face line approaches its end. For such cases, the mine can increase the density and convert the outbye end part of the barrier to the specifications given for a fixed concentrated barrier.

Some part of this amended explosion barrier may also have to project beyond the gate road being protected and into the mains development roads. In this case the barrier may have to split and extend into a number of roadways to ensure the proper overall length.

The mine operator should consider the planning of longwall gate road explosion barriers for the retreat phase of mining. A minimum distance of 330 metres of compliant barrier is recommended to be maintained in front of the Longwall face line in both the maingate and tailgate roadways. This allows for the ever-increasing production/retreat rates achieved through modernisation and automation methods being employed in NSW Mines.

This 110-metre buffer on the 220-metre minimum requirement will allow sufficient time for the installation and maintenance of the explosion barrier in both the Maingate and Tailgate roadways for continuous compliance.

> The design of the fixed distributed barrier requires a stone dust loading based on a minimum stone dust density of 1kg/m3 in the mine roadway.

**The dimensions for a fixed continuous distributed barrier are illustrated in *Figure 11.***

**Example calculation for a fixed continuous distributed barrier.**

The following is an example of the calculations undertaken to design a fixed continuous distributed barrier.

Consider a tailgate roadway in which the barrier is to be installed and which has a height of 3.4 metres and width of 5.5 metres.

Thus, the *cross-sectional area* of the roadway is 18.7m$^2$ (i.e., 3.4m x 5.5m = 18.7m$^2$).

Based on the barrier loading requirements of 1kg/m$^3$ x the roadway cross sectional area, the barrier will require a stone dust loading of 18.7kg/m of roadway length.

Based on 6kg per bag this will require 3.12 bags per metre (i.e., 18.7 / 6 = 3.12 rounded).

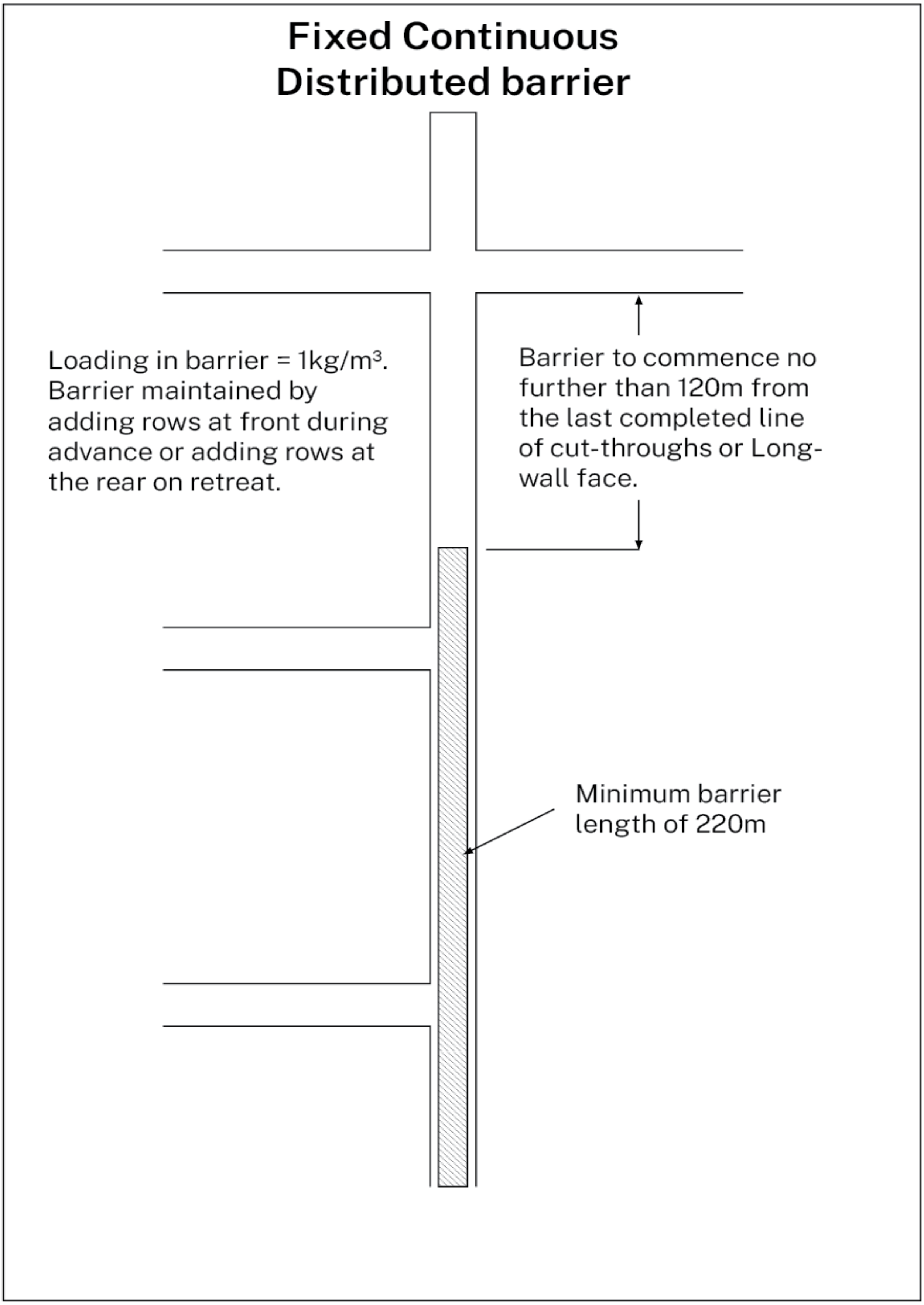
If the row separation is to be 3 metres between rows, then each row will require 3 x 3.12 bags per row (i.e., 3 x 3.12 = 9.36 bags per row rounded up to 10 bags per row).

Calculated on the minimum barrier length of 220 metres, a total of 74 rows x 10 bags per row will be needed.

These can be installed immediately outbye of the face at a convenient position, but the first-row location should not be more than 120 metres outbye of the last completed line of cut-throughs or face line.

A fixed continuous distributed barrier should commence and be compliantly maintained as close as reasonably practicable to the last open line of cut throughs or the Longwall face line in both the maingate and tailgate roadways. This will offer the lowest net risk to the mine.

Figure 11 - Fixed distributed barrier bag system



### 7.2.5. Non-standard or non-compliant installations

There will almost certainly be circumstances in a mine that are not adequately covered by these or the manufacturers guidelines.

This is particularly so in the following situations:

- when a longwall panel approaches completion and is close to the main headings
- the case of single-entry development over about 100 metres
- longwall face installation roads present unique hazards as the face can be up to 350+ metres away from the gate road where the barriers would normally be expected
- where the herringbone mining method is employed.

It is impossible to anticipate every mine layout and configuration in which a bagged explosion barrier may be placed.

When a gate road or single entry drivage sets off, there will be times when it cannot easily comply with the guidelines in this document.

The fixed continuous distributed barrier arrangement can usually rectify any issues caused by increasing chain pillar lengths that are making the use of either of the advancing systems more problematic. This is especially the case for barrier separation distances.

For any unusual or apparently non-compliant circumstances, the mine should seek professional advice from the OEM of the explosion suppression system.

### 7.2.6. Validation and testing

The PCBU or mine operator must ensure:

- the barrier system installed must be an independently tested and proven system and method to suppress a coal dust explosion with supporting evidence of testing conducted by a recognised testing facility
- that testing of bagged stone dust barrier components including the hook, ring and barrier bag rupture characteristics have been undertaken by the OEM of the supplied product as per section 25 of the *Work Health and Safety Act 2011*.

Barrier system design

An explosion barrier system design must be based on peer-reviewed research and have been tested at a large-scale explosion testing facility. For example, those previously used in Germany, Poland, South Africa, the UK, or the USA. Stone dust barrier bags have been tested at several of these facilities. Manufacturers are expected to be able to provide documentary evidence they have either conducted such tests or that their system meets and/or exceeds the original design of a similar system tested at one of these facilities.

Stone dust bag testing

A mine must keep documentary evidence as to the source and verification of the quality (including test data) of each batch of bags purchased. Section 68 of the WHS (MPS) Regulation mandates that any stone dust used:

- is of a type or grade that is suitable for its proposed use, and

- is white in colour, and
- does not contain more than 3 per cent by mass of free silica, and
- has a composition such that at least 95 per cent by mass of the stone dust is finer than 250 micrometres and of that stone dust that is finer than 250 micrometres, at least 60 per cent by mass (and not more than 80 per cent by mass) is finer than 75 micrometres.

## 7.3. Mitigating controls

Mitigating controls are needed when monitoring systems identify that the coal dust explosion and prevention system is not performing to the required standard. This ensures the health and safety of workers. Mitigation controls often take the form of a trigger action response plan (TARP). For example, work systems are modified or repaired where explosion barriers are not compliant for normal work systems, depending on the circumstance.

The CDECP also interacts with any emergency plan, particularly for methane ignition, outburst, and fire events. It is important that the CDECP consider these events in its development and training of workers.

Administrative controls will often underpin the CDECP. If monitoring via observation reveals conditions are outside those prescribed in the CDECP, the mine must have a system in place to ensure the non-compliance is rectified. For example, observing explosion barriers or face areas reveals stone dust is not adequately applied. The CDECP or the overall SMS should describe how such defects are to be rectified when identified.

The need for constant observation of the explosion suppression and prevention systems means that all workers must be trained in the basic operation of the mine's explosion suppression controls. They must also be able to monitor and report any defects they may observe.

## 7.4. Review of controls

The CDECP must be reviewed in accordance with section 15 of WHS (MPS) Regulation.

The mine operator of an underground coal mine must ensure the effectiveness of the explosion suppression and prevention system and the CDECP for the mine. The mine operator must ensure they are audited at least once every 3 years by an individual nominated to exercise the statutory function of ventilation auditor at the mine. The mine must review control measures if a deficiency has been identified in an audit of the CDECP.

Identified and installed controls need to be continually reviewed to measure their effectiveness. Any deterioration of CDECP controls should be identified during a mine operator's routine inspections.

## 7.5. Effectiveness of controls

Mine operators should regularly review communications issued by the Regulator, other authorities, and OEMs (i.e., safety alerts and incorporate recommendations into the site's review processes). This approach encourages mines to proactively review the effectiveness of their respective control measures.

Monitoring process should determine the effectiveness of controls.

Mine operators need to remain up to date on changing standards and improved controls. For example, the change in respirable silica dust from 0.1mg/m$^3$ to 0.05mg/m$^3$ which took effect in July

2020 will likely mean the effectiveness of current dust controls at mines will need to be reviewed. Whenever a control is considered in the risk assessment process, mine operators are required to assess its effectiveness.

New and emerging technologies provide greater risk controls associated with coal dust explosion suppression and prevention. When a mine operator employs these technologies, they are required to review the site's existing control measures using the hierarchy of controls, as far as is reasonably practicable. For example, dust suppression systems of underground crushing units are improving to provide greater suppression and suspension of airborne contaminants.

## 7.6. Documentation and records management

The mine operator is to have a-documented SMS that includes a CDECP. Mine operators should adopt an integrated, computerised document management system. This ensures the easy identification of the risk assessment and controls identified within it, along with all the assumptions relevant to the CDECP. Having a clear flow of documents and references to how each is developed makes any review process more efficient to ensure the CDECP is based on the latest mine plan and risk assessment.

Integrated and computerised document management systems can alert and assign responsible people when changes are made. They can also reference relevant documentation from OEMs, or third-party consultants. The importance of the CDECP in managing a host of hazards in an underground mine makes effective document management critical to the CDECP's effective use and the mine operator being able to consider individual and cumulative principal hazards.

## 7.7. Information and training

The CDECP should be included as a part of all training and competence packages for statutory officials employed on a mine site. Ongoing workforce training in the important aspects of a mines CDECP should be included in site inductions and training days.

Specific types of training for explosion suppression and prevention systems should be considered in the risk assessment process. This is because workers constantly interact with and rely on these systems if there is an ignition. This training should be provided to workers as part of the mine's SMS. Incidents have been reported where workers have failed to install or have been operating without using explosion suppression controls. This would typically be because they are trying to improve production rates without understanding how such actions or omissions can affect the mine. Workers should be given clear expectations around the use and maintenance of the explosion suppression system, such as the requirement to maintain explosion barriers in their prescribed state.

# Appendix A – Case studies

Below are examples of mine disasters that included a coal dust explosion.

## Dudley colliery explosion

On Monday 21 March 1898 at 9.20am an explosion at the Dudley Colliery in the Redhead area of Newcastle killed 15 mine workers. The subsequent Royal Commission Report concluded that the ignition of firedamp at a naked light caused the explosion, which the agency of coal dust intensified.

## Mount Kembla colliery explosion

On 31 July 1902, an explosion at Mount Kembla Coal Mine killed 96 mine workers. The incident happened when a large section of the unsupported roof in a goaf collapsed with considerable force, pushing air and methane gas into the main tunnel. The rush of air and gas stirred up the coal dust, which clinged to the roof and walls of the mine. The methane in the air rush contacted an exposed flame light. The gas ignited and combined with the airborne coal dust, setting off the initial explosion that blew down the main tunnel with such force that it destroyed everything in its path.

## Appin Colliery Explosion

On 24 July 1979, a methane ignition induced a coal dust explosion killed 14 mine workers at the Appin Colliery.

At the time of the explosion there were 45 workers underground.

The explosion occurred three kilometres from the pit bottom and 600 metres underground. Three mine workers were killed as a direct result of the explosion and another 11 mine workers died from carbon monoxide poisoning.

Many of the 31 workers who made it to the surface suffered severe burns.

## Links to other incidents

Below are links to investigations into recent coal mining incidents in Australia.

- Investigation Report Fire and Explosion Blakefield South Coal Mine 2011 (Resources Regulator 2012)
- Queensland Board of Inquiry Grosvenor Coal Mine (Coalmines Inquiry 2021)

# Appendix B – Stone dusting and explosion barrier installation standard examples

All images taken by NSW Resources Regulator inspectors during an assessment.

Image 1: Example of a high stone dust application standard maintained to the roof and ribs within a development panel face zone. (Note: *The roadway floor in this image is wet slurry*)

*Roadway dust sample taken in this location returned result of >90% incombustible content.*

Image 2: Example of a high stone dust application standard maintained to the roof, ribs, and floor within an operational Longwall Tailgate outbye zone.

*Roadway dust sample taken in this location returned result of >90% incombustible content.*

Image 3: Example of a high standard of installation of a Fixed continuous distributed barrier in an operational development panel face zone.

*Roadway dust sample taken by Resources Regulator in this location returned result of >85% incombustible content.*

Image 4: Example of a high standard of installation of a Fixed Concentrated barrier in an operational development panel face zone.


*Roadway dust sample taken by Resources Regulator in this location returned a result of > 85% incombustible content.*

Image 5: Example of a high standard of installation of a Fixed concentrated barrier in an operational development panel face zone.

*Roadway dust sample taken by Resources Regulator in this location returned a result of > 85% incombustible content.*

Image 6: Example of a poor standard of installation of a Fixed Concentrated barrier in an operational development panel face zone.

- Barrier bags within an individual row too close together
- Barrier Bags closest to the right-hand side of image are installed outside the maximum distance allowable from the rib, leaving a flame path along the length of the barrier
- Barrier bags not installed with open end of hook facing inbye direction

*Roadway dust sample taken by Resources Regulator in this location returned a result of > 85% incombustible content.*

Image 7: Example of a poor standard of installation of a Fixed Continuous distributed barrier in an operational development panel face zone.

- Barrier bags within an individual row too close together
- Barrier Bags within an individual row not installed within correct distance parameters
- Barrier bags not installed with open end of hook facing inbye direction

*Roadway dust sample taken by Resources Regulator in this location returned a result of > 85% incombustible content.*

Image 8: Example of a poor standard of installation of a Fixed concentrated barrier in an operational Longwall panel face zone.

- Barrier bags within an individual row too close together
- Barrier Bags within an individual row not installed within correct distance parameters
- Barrier bags not installed with open end of hook facing inbye direction
- Barrier bags of different manufacturers used within the same barrier
- Barrier bags not installed above monorail leading to flame path

*Roadway dust sample taken by Resources Regulator in this location returned a result of > 85% incombustible content.*

# Appendix C – References


- Work Health and Safety Act 2011
- Work Health and Safety (Mines and Petroleum Sites) Regulation 2022
- Work Health and Safety Regulation 2017
- SkillPro-CSIR Bagged Barrier Suggested Installation - Final November 2017
- SkillPro-CSIR Bagged Barrier Suggested Installation - Amendment 2018
- SkillPro-CSIR Bagged Barrier Suggested Installation - Amendment 2020
- SkillPro - Analysis of Comparative Explosion Suppression Abilities of Stone dust and Airodust – 28/2/2014
- Recommendation for the effective use and installation of Alfabs Mining Equipment's "BAT BAGS" Stone Dust Barrier Bag System (2020)
- Development and implementation of the bagged stone dust barrier. JJL du Plessis (Author) & Prof. HR Philips (Supervisor), University of the Witwatersrand (2000)
- ACARP report C 7030 Testing of South African Stone Dust Barrier (2000)
- ACARP report C 10018 Stone Dust Requirements (2003)
- Coal Dust Explosions and Their Suppression (Cybulski, Waclaw 1975)
- The Influence of Initiation Point-to-Barrier Separation Upon the Required Loading of Passive Explosion Barriers, and of, Inerting Levels Upon the Effectiveness of Stone dusting. Prepared by David Humphreys BE (Mining Hons), MEngSc (Res), PhD (2020)

**NSW codes of practice:**

- Work health and safety consultation, cooperation, and coordination (August 2019)
- How to manage work health and safety risks (August 2019)
- Safety management systems in mines (February 2015)
- Roadway dust analysis in Underground coal mines (February 2015).

**NSW Resources Regulator guidance material, for example:**

- Guide - Preparing a principal hazard management plan (January 2020)
- Guide – Airborne contaminants principal hazard management plan (July 2018).

**Australian and International Standards in related fields, for example:**

- AS ISO 31000: 2018 Risk Management — Guidelines AS/NZ ISO 4501: 2018 Occupational Health and Safety Management Systems – Requirements with guidance for use.