

GUIDELINE

# Prevention of fires in underground mines



Government of Western Australia  
Department of Mines and Petroleum  
Resources Safety



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## Guidelines

A guideline is an explanatory document that provides more information on the requirements of legislation, details good practice, and may explain means of compliance with standards prescribed in the legislation. The government, unions or employer groups may issue guidance material.

Compliance with guidelines is not mandatory but they could have legal standing if it were demonstrated that the guideline is the industry norm.

### Who should use this guideline?

This guideline should be used by anyone planning or conducting underground mining, particularly those persons responsible for the occupational health of workers.

### Acknowledgement

This guideline was developed through extensive consultation with industry representatives, and is based on the Chamber of Minerals and Energy of Western Australia's *Hazard management guideline for underground fire prevention*, published in 2004.

## Foreword

This guideline is issued by Resources Safety under the *Mines Safety and Inspection Act 1994*, and has been endorsed by the Mining Industry Advisory Committee.

### The Act

The *Mines Safety and Inspection Act 1994* (the Act) sets objectives to promote and improve occupational safety and health standards within the minerals industry.

The Act sets out broad duties, and is supported by regulations, together with codes of practice and guidelines.

### Regulations

The Mines Safety and Inspection Regulations 1995 (the regulations) provide more specific requirements for a range of activities. Like the Act, regulations are enforceable and breaches may result in prosecution, fines, or directions to cease operations and undertake remedial action.

### Standards

Although specific versions of Australian and other standards may apply under the regulations, references to standards in this guideline are undated and it is good practice to consult the latest versions where applicable.

### Application

The provisions of this guideline apply to all underground mines as defined in section 4(1) of the Act, except those extracting coal.

# 1 Introduction

Fire is a serious hazard in mines and outbreaks of fire underground can be particularly dangerous due to the:

- confined nature of excavations
- potential quantity of smoke and noxious fumes
- restricted ability to evacuate quickly from the mine.

Employers have a duty of care to provide and maintain a safe working environment.

The prevention of fires is a priority for underground mines as they can lead to entrapment, smoke inhalation, serious or fatal burns, asphyxiation and other serious consequences such as explosions.

All underground mines should have a documented underground fire risk assessment that is current and specific to its operations, with appropriate controls in place to manage the risks. This guideline will assist employers and mine operators to:

- prevent the outbreak of fires in underground mines in Western Australia
- minimise the effects should a fire occur.

Chapter 2 describes the hazard of fire, while Chapter 3 describes the risk management process and type of information collected and considered when assessing and addressing fire risk in underground mines.

Chapters 4 to 6 detail controls to help prevent underground mine fires and minimise the impact of fire outbreak, while Chapter 7 summarises the content of a suitable underground fire control plan.

Appendix 1 lists the legislative provisions relevant to the prevention and management of fires in underground mines in Western Australia. Appendices 2 to 4 include information on relevant Australian Standards and other guidance, and an overview of the hierarchy of control as applied to underground fires.

*Note: This guideline applies to all underground mines except those extracting coal.*



## 2 Understanding the hazard

### 2.1 Fire

As shown in the fire triangle (Fig. 1), the three requirements for a fire are:

- fuel
- heat (i.e. ignition source)
- oxygen.

When combined, they result in a rapid chemical chain reaction that releases heat and light, and is accompanied by a flame. An effective fire prevention strategy emphasises the elimination or control of fuel and ignition sources, while the strategy in case of a fire outbreak focuses on removing the heat, fuel or oxygen, or suppressing the underlying chemical reaction.

The identification of underground scenarios that could lead to fires should focus on eliminating or controlling the first two requirements, as oxygen will always be present in air in the underground mine environment and cannot be excluded.

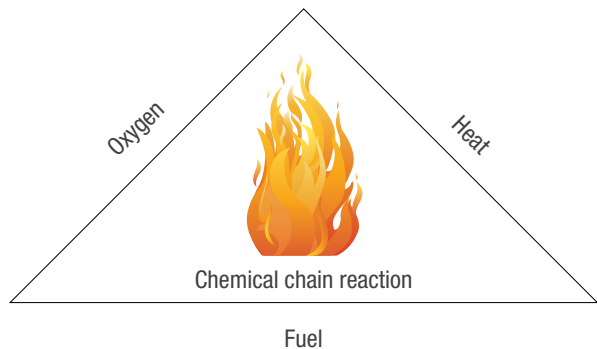


Figure 1 Fire triangle



## 2.2 Fuel sources

When assessing the fire risk, all potential fuel sources should be identified. In fire fighting, fires are classified based on the fuel involved, which determines the best extinguishing agent. Typical fuel sources in a mine include materials that are:

- Class A — ordinary combustibles such as combustible debris, wood, rags, hoses, rubber, tyres, upholstery, seats, ventilation ducting, electrical insulation
- Class B — flammable liquids such as diesel fuel, hydraulic fluid, gear oil, lubricating oil
- Class C — flammable gases such as acetylene and liquefied petroleum gas (LPG)
- Class D — combustible metals such as magnesium
- Class E — electrical equipment such as energised electrical cables and switch gear.

The severity of the fire risk from a fuel source is determined by its flammability, ignitability, combustibility, toxicity, explosivity, and fire retardant or self-extinguishing properties. This information should be available from the material safety data sheet (MSDS) for each product or can be found in technical information provided by the supplier.

## 2.3 Ignition sources

Potential sources of ignition in an underground mine include:

- heat energy — hot surfaces on engines, exhaust systems, pumps and turbochargers, naked flames from welding equipment, cigarettes and matches, induction heating
- electrical energy — electrical discharge in motors, retarders and transformers, short-circuit arcs, earthing faults, static electricity discharge, mobile equipment contact with high-voltage (HV) power cables
- mechanical energy — cutting, friction, mechanical impacts, grinding
- chemical reactions — self-heating, auto-ignition, exothermic reactions, pyrolysis of tyres.



## 3 Risk management process

### 3.1 Risk-based approach

Risk assessment is a structured process that seeks to answer the following questions.

- What are the potential underground fire scenarios?
- What type of fire could occur (based on available fuel and ignition sources)?
- What are the consequences or impacts of the fire in terms of safety and health?
- How probable is this impact?

Effective underground fire risk assessment requires input from a number of specialist areas, including emergency response and mine ventilation. The risk management approach is outlined below.

### 3.2 Risk identification

#### Fire survey

Fuel and ignition sources exist throughout an underground mine and are usually associated with infrastructure, such as fixed plant and installations, and mobile equipment.

To assist in identifying underground fire risks, a fire survey should be conducted regularly to identify the various fuel and ignition sources present at each location. This information may then be used as a basis for the assessment and control of fire risk.



## Ongoing risk identification

To supplement the fire survey, other hazard identification systems should be implemented to ensure that all fire risks are identified. These include:

- employee hazard identification and reporting procedures
- workplace inspections
- monitoring of the working environment
- incident investigations
- monitoring original equipment manufacturer (OEM) bulletins, recommendations and specifications.

To assist in the identification of fire risks, all workers should be provided with training in basic fire theory and how to identify potential fire scenarios in the underground environment.

## Typical underground fire risks

Underground fire risks can occur wherever potential ignition sources come into contact with a fuel source. Such scenarios include:

- mobile equipment — fuel, coolant or oil leaking onto hot exhaust manifolds or turbochargers; engine or turbo failure; tyre pyrolysis
- sound and heat insulation and lagging material — deterioration of material; being soaked with oils, fuels or degreaser products
- fixed mechanical equipment or plant — excessive friction on mono-pumps or fan belts
- maintenance tasks — hot work resulting in hot metal or slag landing on combustible material
- conveyor belts — collapsed bearings or excessive friction on pulleys and rollers
- fixed electrical equipment — electrical short in oil-filled transformers, motor contacts and brushes
- HV power cables — interaction with mobile equipment
- underground re-fuelling and workshop areas — grinding or welding igniting spilt fuel; fuel spilt onto hot parts



- explosives storage areas — hot vehicle exhaust igniting explosives packaging; spontaneous ignition of waste
- combustible and flammable stores — cigarette igniting oil-laden waste
- exploration, development and production drill holes intersecting gas pockets — grinding near diamond drill hole-collars igniting gas emissions.

Not all fuels are obvious, and fuel sources that need to be considered include locations where:

- combustible or flammable dust or gases can accumulate, such as degreasing fumes in workshop pits, and diesel fumes in storage tanks
- potentially combustible sulphide dust can accumulate, such as in airways and ventilation ducting.

Once a fire risk has been identified, also consider whether the materials involved can change over time or with use. For example, deterioration of the material could increase its flammability or potential to produce noxious fumes if burnt.

### 3.3 Risk analysis

At the risk analysis stage, the nature of the risk is assessed and the risk level is determined based on the consequences from a fire event and how likely it is.

#### Fuel characteristics

Once the fuel and ignition sources have been identified, the quantity and type of fuel available will assist in determining the nature and quantity of heat, smoke and fumes or gases likely to be generated. This may have a significant impact on the consequence of the fire and hence the level of risk.



## Fire location

The location of an underground fire can have a significant impact on the level of risk.

Fires located in a main intake airway (e.g. main decline) are likely to pose a higher risk than those located in a return or exhaust airway. Also, fires located close to the main working areas are likely to provide less time for workers to raise the alarm, resulting in limited time for their evacuation to safe locations such as fresh air bases and refuge chambers.

The effects of thermal radiation should also be considered as a small fire in a particular location may provide sufficient heat to initiate a much larger fire.

## Mine ventilation

Mine ventilation should also be considered when assessing the risk of potential underground fires. The impact of ventilation on fires is likely to be different for each location and for each mine. It is possible for the ventilation to reverse due to the impact of a serious fire.

## Operational impacts

Operational conditions can also have a significant impact on the underground fire risk and issues that should be considered include:

- operating environment (e.g. scale and complexity of mining activities)
- maintenance systems and practices (e.g. timing and adequacy of corrective actions)
- competency of personnel (e.g. adequacy of training and supervision).



### 3.4 Risk evaluation and treatment

The expectation is that all identified underground fire risks will be managed, with the most significant risks prioritised for treatment.

Risk treatment is the process of reducing risk as far as practicable. For underground fires, it is based on implementing:

- controls that prevent the outbreak of fire
- contingency controls that minimise the effects should a fire occur.

Options will include those that:

- avoid the risk by deciding not to start or continue with the activity that gives rise to the risk (e.g. prohibiting hot work near combustible material)
- remove the source of the risk (e.g. shielding hot hydraulic components)
- change the likelihood (e.g. restricting the quantity of fuel stored underground)
- change the consequence (e.g. fire suppression system installed on mobile plant).

Underground fire prevention and management controls should be based on:

- good design, construction and installation to consider fuel and ignition sources early in the process (Chapter 4)
- operation and maintenance procedures, such as maintaining plant and machinery to original specifications (Chapter 5)
- competency-based training and assessment of the competency of workers (Chapter 6)
- underground fire control plan and emergency response training, including good housekeeping practices (Chapter 7).

### 3.5 Communication and consultation

Communication and consultation are fundamental to risk management to produce the best outcomes. In particular, it is essential that those with knowledge of the production, engineering, maintenance and local ventilation systems are involved in the assessment of underground fire risk.

### 3.6 Monitor and review

Where controls are determined to be effective, a monitoring and review regime that includes visual inspections and regular auditing should be implemented. The effectiveness of implemented controls should be regularly tested, and not only in a clean-air environment. Simulation equipment can often highlight deficiencies in these controls.

Responsibilities and accountabilities for monitoring and reviewing should be clearly defined and assigned.

As part of the site's validation process, consider independent auditing of all fire control processes, including a reporting and management review.

### 3.7 Documentation

The result of an underground fire risk assessment should be a formal document that details:

- locations of fuel and ignition sources
- types of potential fire
- consequence and likelihood of each fire event
- fire risk based on a consequence and likelihood risk matrix
- controls used to minimise risk.

This information forms the basis of the mine's underground fire control plan (see Chapter 7).



## 4 Design, construction and installation

### 4.1 Mine infrastructure

To minimise underground fire risk, infrastructure that could pose a high fire risk should only be installed following a formal assessment and consideration of the controls necessary to minimise risk. Infrastructure should be located in, or automatically vented to, the return airway in the event of a fire (i.e. fuseable link door or opening). Alternatively, suitable fire-proof ventilation doors should be installed to minimise smoke ingress into working areas.

A high impact function (HIF) audit for underground fire prevention is available from the Resources Safety website to assist in assessing the suitability of planned underground infrastructure.

#### Explosives magazines

Magazines are specifically covered by the Mines Safety and Inspection Regulations 1995 and *Dangerous Goods Safety Act 2004*, and must also meet the requirements of Dangerous Goods Safety (Explosives) Regulations 2007 and Australian Standard AS 2187. Electrical equipment should meet the requirements of Australian Standard AS 2380.1 and wiring must comply with the requirements of Australian Standard AS 3000. Magazines pose a potential fire hazard and the fire risk assessment will include:

- location
- stock levels and turnover
- structure
- fire suppression systems and alarms
- signage
- ventilation
- housekeeping
- prohibition of all ignition sources (e.g. cigarettes, mobile phones, radios, other electronic equipment).



## Explosives precursor storage and handling

The storage and handling of ammonium nitrate emulsion, solid ammonium nitrate and gasser chemicals must be in accordance with the *Dangerous Goods Safety Act 2004* and regulations.

## Fuel storages, refuelling bays and transfer equipment

Fuel storage, refuelling bays and transfer equipment are specifically covered by the Mines Safety and Inspection Regulations 1995 and Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007. The following regulatory requirements and practices will minimise fire risk when storing and handling fuels.

- All equipment used to store, transfer or distribute fuel underground should meet all the relevant sections of Australian Standards AS/NZS 2229 and AS/NZS 3013.
- Electrical control systems associated with fuel transfer and storage should also comply with Australian Standard AS/NZS 2229.
- All electrical equipment and wiring systems are in accordance with Australian Standards AS 2380 and AS/NZS 3000.
- Storage tanks, pipe work and fuel transport vehicles entering refuelling bays should be earthed.
- Permanent storage, supply and refuelling stations should have an automatic fire detection and suppression system that complies with relevant parts of Australian Standards AS 1603 and AS 1670.1. These systems should include a fire alarm and be capable of being manually activated at a safe distance from the refuelling bay.
- Permanent fuel storage locations should have a floor impervious to fuel, capable of being cleaned and with bunding and run-off. Where a storage location is temporary, a risk assessment that deals with fuel spills should be conducted and control measures as identified by the risk assessment implemented.



Appropriate signage at entrances to fuel storage areas should indicate:

- storage of flammables
- access restriction to authorised persons
- no smoking or naked flames
- prohibition of hot work
- engines to be shut down before refuelling
- the emergency procedure in case of fire
- location of nearest refuge chambers
- housekeeping requirements.

Small containers such as jerry cans should not be used for transporting fuel unless they are securely contained in appropriate receptacles that are appropriately labelled and away from potential impact damage. Such containers should only be used at designated refuelling locations or in one-off emergency situations as approved by the mine manager.

Where a mine uses a surface-to-underground fuel delivery system, the pipe should be:

- purpose designed (e.g. clearly identified as a diesel fuel pipeline, constructed with leak-proof joints)
- located so that it is not exposed to ignition sources (e.g. service garage, switch room, magazine) or critical infrastructure (e.g. refuge station, first aid station)
- installed in a free draining and surveyed borehole
- stainless steel with a high-density polyethylene (HDPE) covering
- regularly inspected and tested
- labelled or colour-coded according to Australian Standard AS 1345.

Refuelling locations should be capable of being isolated from the mine ventilation system, and separated physically with the use of a physical barrier. Fire doors should seal off the refuelling bay area to prevent smoke entering intake airways in the event of a fire.

Delivery systems should be designed to prevent overflows or overfills.

Adequate facilities (e.g. water hose, absorbent material) to quickly contain or clean-up any fuel spills should be provided, and subsequent rubbish (e.g. soiled absorbent material) should be placed immediately in clearly marked receptacles and be kept well away from any potential ignition source.

## Workshops

The variety of products stored and the different work carried out in workshops increases the potential fire hazard. Carry out a risk assessment of these areas to minimise this potential. The following regulatory requirements and practices will minimise fire risk in workshops.

- Workshops should contain a minimum storage of combustible liquids and must not exceed one week's supply.
- Any combustible liquids should be stored in segregated locations and banded.
- Dangerous goods must be segregated according to the Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007.
- The storage and use of compressed and liquefied gases underground should be avoided wherever possible, and minimised otherwise.
- Separate locations for hot work (e.g. welding, cutting using oxyacetylene, electric welding) should be provided to meet the requirements of Australian Standard AS 1674.
- Adequate facilities (e.g. absorbent material, fire extinguishers) should be installed to allow the rapid containment or clean-up any fuel spills.
- Suitable barriers (e.g. bollards) or designated parking areas should separate mobile equipment from flammable or combustible liquids.



Appropriate signage at entrances to workshops should indicate:

- whether flammables are stored within
- location of designated hot work area
- emergency procedure in case of fire
- locations of fire fighting equipment
- housekeeping requirements.

A disposal system should be in place for:

- waste oil and hydrocarbon contaminated material
- other flammable waste
- general rubbish.

### Crib rooms and refuge chambers

Crib rooms and refuge chambers pose a potential fire hazard. Critical considerations during their risk assessment include:

- adequate ventilation
- fire-resistant internal fittings
- electrical equipment (e.g. microwaves, refrigerators, heaters) meeting relevant electrical standards
- storage and use of oxygen candles
- good housekeeping.

## 4.2 Mobile equipment

### Fuel sources

All mobile equipment fuel, lubrication and hydraulic systems are potential fuel sources for fires.

Where practicable, these systems should use steel lines. Where flexible hoses are used, they should meet the requirements of Australian Standards AS 1180.10A and 10B and should be:

- fire-resistant or shielded
- securely clamped away from hot surfaces

- located so that impact damage is minimised
- provided with bulkhead fittings where they pass through bulkheads.

Fuel and oil lines and hydraulics should be installed as required by the OEM specifications, and routed so that, in the event of a burst or leak, flammable liquid cannot contact a hot surface. Where routing away from hot surfaces is not possible, all lines should be securely clamped and shielded. They should be kept separate from electrical cables, and routed away from moving parts.

Never use plastic cables ties to secure fuel and oil lines in bundles to other fixtures or to electrical cable sheathing.

All replacement hoses and components should meet OEM specifications.

Assess the fire risk for all vehicle fuel tanks and fuel containers. Tanks and containers should be located so that flammable liquids from any overflow or venting cannot contact hot surfaces. Plastic and rubber fuel bladders in mobile equipment must be identified, maintained and inspected according to OEM recommendations.

Foreign materials (e.g. cleaning cloths) left on hot surfaces are potential fuel sources that can be eliminated through a system of checks.

Radiator coolant that boils off or evaporates can leave a flammable residue. which should be identified during equipment inspections and eliminated.



## Ignition sources

Potential ignition sources in mobile equipment include engine, electrical, drive systems and tyres.

Engine control systems should be designed to reduce their potential to become an ignition source, and may include:

- separation or segregation of components
- automatic fuel shut-off if a fault requires the engine to stop
- monitoring devices to indicate engine, exhaust and retarder temperatures
- monitoring engine oil pressures.

To reduce the potential for electrical systems to become an ignition source, consider:

- using rubber grommets or bulkhead connectors for electrical cables passing through bulkheads
- insulating electrical cables against heat and locating them away from hydraulic or fuel lines
- not using plastic cable ties to secure sheathed electrical cables and wiring looms
- using circuit breakers wherever possible
- securing batteries to prevent movement
- venting battery compartments to minimise the generation of hydrogen
- protecting all circuits, except starter motors, against short circuit and over current.

Electrical systems that derive power from diesel engine alternators or batteries should be designed to Australian Standard AS 4242. This includes:

- automatic disconnection of power from the battery to protect against short circuits
- purpose designed jump-starting systems
- isolating both poles of batteries on faulty equipment.

Where possible, underground mining equipment should have:

- enclosed braking systems
- fire resistant V-belts
- tyres selected to suit their intended application
- operator cabs that inhibit the passage of fire
- at least two exits from the operator's cab
- fire proof engine compartment covers
- heat shields for hot components and elements creating extreme heat
- portable powder fire extinguishers
- on-board aqueous film-forming foams (AFFF) systems.

If the tyres of mobile equipment have caught fire or pyrolysis is suspected, park up the vehicle for 24 hours. The location should be isolated and monitored.

### 4.3 Fixed mechanical plant

Assess the fire risk for all underground fixed mechanical plant and associated equipment, including:

- compressors
- conveyors
- winders
- pumps
- raise borers
- shaft-sinking equipment
- crushers
- materials handling equipment
- refuelling stations
- underground delivery pipework for fuels and other combustible fluids
- ventilation fans
- scrapers and hoists.



## Fuel sources

All lubrication and hydraulic systems are potential fuel sources for fires.

Where practicable, these systems should use steel lines. Where flexible hoses are used, they should meet the requirements of Australian Standards AS 1180.10A and 10B and should be:

- fire-resistant
- securely clamped away from hot surfaces
- located so that impact damage is minimised
- provided with bulkhead fittings where they pass through bulkheads
- colour-coded or labelled to identify liquids and gases being transmitted.

Flammable fluid containers should be located such that any overflow should not contact a potentially hot surface.

## Ignition sources

Potential ignition sources in fixed plant include engine, electrical, conveyor and compressor systems.

Critical items of plant associated with potential fuel sources should have temperature monitoring devices and alarms installed (e.g. main bearings of crusher drives, raise borer driver heads).

Electrical protection against earth leakage and overload should be provided on all fixed mechanical equipment.

Conveyor systems should have:

- fire resistant belts
- belt slip monitoring and drift switches
- automatic fire suppression systems
- sealed idler bearings
- overload prevention devices
- temperature monitoring devices and alarms.



Where possible, compressors should be located on the surface rather than underground. However, where compressors are required underground, they should:

- have thermal monitoring devices installed that can alarm and stop the compressor
- be installed so that the ventilating air flows over them direct to the return airway.

Flow switches in pumps should stop the pump in the event of unexpected flow.

## 4.4 Fixed electrical equipment

Underground fixed electrical and associated equipment include substations, switch-rooms and main distribution boards. This equipment poses a potential fire hazard and must be risk assessed.

Fixed electrical equipment should be designed and installed to Australian Standard AS 3000 and its associated standards. Electric motors should be provided with:

- thermistors with automatic temperature stop functions
- over current, earth-leakage and short circuit protection.

Where possible, transformers should use non-flammable oils and be designed to contain oil leaks. However, where flammable oil is used, fixed electrical equipment should:

- be provided with automatic fire suppression systems
- be located so that the air flowing over them passes direct to return
- have bunds capable of containing the total oil volume with a 20 per cent excess to capture any oil spillage.

The fixed electrical installation should be designed to eliminate the need for maintenance workers to work on live apparatus, and should be located so they cannot be damaged by impact from vehicle collision or blasting. Attached reflectors will make installations clearly visible to operators.

Fire extinguishers, rated to 80 ABE, should be provided for substations and transformers.



## 4.5 Detection and monitoring systems

The design of fire protection systems should be based on a fire survey conducted in accordance with Standards Australia's Handbook SAA HB 37 and Australian Standard AS 2419.1.

Automatic fire detection systems installed in areas where there is a significant fire risk can provide an early warning. Such areas include:

- explosives magazines
- ammonium nitrate emulsion and solid ammonium nitrate storage
- fuel storages, refuelling bays and transfer equipment
- combustible material storage areas
- conveyor haulage
- power sub-stations and oil-filled transformers.

Smoke detection systems placed at the top of vent rise systems can provide a general fire warning.

Continuous thermal monitoring should be installed and maintained on fixed plant where the operation of such equipment poses a significant fire risk underground.

## 4.6 Fire suppression systems

Fire suppression systems must be installed in explosives magazines and ammonium nitrate emulsion storage facilities, as required by the *Dangerous Goods Safety Act 2004*.

It is a regulatory requirement that, where practicable, automatic fixed fire suppression systems be installed and maintained at all underground locations where oil, fuel or lubricants are dispensed.

It is a regulatory requirement that certain equipment is fitted with an effective and properly maintained AFFF or FFFP fire suppression system.

Fit automatic fire suppression system to remotely controlled and automated equipment and in areas where a significant fire risk exists.

Activation of the fire suppression system should trigger an alarm on surface for fixed facilities or in the operator's cabin for mobile equipment.

Inspect and test fire suppression systems in accordance with AS 1851. More frequent intervals may be required for systems installed in adverse conditions.

## 4.7 Fire extinguishers

Portable fire extinguishers should be provided at any location where there is a potential fire risk. There must be appropriate and sufficient portable fire extinguishers on all mobile equipment and fixed plant, including:

- at least two portable fire extinguishers located close to main combustible or flammable store locations or other significant risk areas (e.g. magazines, refuelling bays, workshops) on the intake airway-side
- two appropriately-sized portable fire fighting extinguishers (e.g. 9 kg ABE) installed on mobile equipment
- appropriate and sufficient portable fire extinguishers located on the intake airway-side for areas containing fixed plant.
- Mobile fire extinguishers may be appropriate for some scenarios.



## 5 Operation and maintenance procedures

### 5.1 Operating procedures for mobile equipment

Operating procedures for all classes of mobile equipment, including contractor and hire equipment, should include:

- fire preventative and mitigation measures
- dealing with a tyre fire
- tests for brake and retarder functionality and use
- safe parking of faulty vehicles (e.g. defective brakes, flat tyres, tyre overheating)
- housekeeping standards for operator cabs and engine bays
- fire extinguisher access and usage checks
- weekly shake-up of powder-type fire extinguishers to prevent powder packing.

### 5.2 Explosives storage and transport procedures

In accordance with Dangerous Goods Safety (Explosives) Regulations 2007, develop operating procedures for the safe storage and transport of explosives to minimise the risk of underground fires involving explosives.

### 5.3 Refuelling procedures

Implement safe refuelling procedures covering functions such as:

- operation of fuel transfer systems
- refuelling of vehicles, equipment and fixed plant
- replacement or changing of fuel cells or storage tanks
- any prohibitions
- housekeeping in refuelling bays

- inspection of fire suppression systems and fire extinguishers
- emergency procedures including spill response.

Refuelling outside refuelling bays must be authorised by the underground manager.

## 5.4 Handling flammable and combustible substances

Strategies to minimise underground fire risk associated with the handling and use of flammable and combustible substances include:

- using fire-resistant materials wherever possible
- minimising underground inventory
- locating flammable and combustible substance storage areas to minimise the likelihood and potential impact of a fire
- maintaining good housekeeping (e.g. regularly remove refuse).

Containers should be clearly labelled, purpose-built to prevent spillage, and transported in vehicles appropriate for the task.

Particular care should be taken with flammable gases in underground mines.

## 5.5 Maintenance procedures

The fire risk for equipment is strongly influenced by its maintenance record, and compliance with maintenance systems is imperative. Maintenance systems should be in place to ensure:

- mobile and fixed plant is maintained according to OEM recommendations
- any defects are recorded and promptly repaired.

Systems should also store and manage maintenance information, plan maintenance inspections, and servicing and report on equipment and maintenance performance.



## Mobile equipment maintenance

Maintenance procedures for underground mobile equipment should include inspections, procedures and maintenance as recommended by each OEM.

Run-up procedures should be implemented before equipment is returned to service.

## Electrical equipment maintenance

Maintenance procedures for underground electrical equipment should include inspections, procedures and maintenance as recommended by each OEM.

The maintenance system should ensure continuing compliance with the International Electrotechnical Commission's Ingress Protection Code IP55 and Australian Standard AS 3000.

## Refuelling and recharging equipment maintenance

Formal maintenance procedures, including regular inspections, should be in place for:

- fuel storage systems
- fuel distribution systems
- fuel delivery systems
- spilt fuel containment systems (e.g. bunds, drains, sump)
- flammable refrigerant systems
- battery charging systems.

## 5.6 Pre-start checks

Pre-start checks should be conducted by operators before using any mobile equipment, and should include visual inspections and cover all OEM recommendations.

It is important that pre-start checks include an inspection of the engine bay for signs of leaks and build up of combustible or flammable liquids or solids such as fuel, hydraulic fluids or residue coolants.

The results of pre-start checks, including any defects, should be recorded in the maintenance system and addressed.

All workers should be trained or instructed in pre-start checks at induction.

## **5.7 Operating procedures for explosive gases and dust**

Explosive gases may be encountered during exploration, development or production drilling. Strategies to minimise the risk associated with gas outbursts should consider:

- drilling equipment design
- ventilation requirements
- gas monitoring
- equipment shut-down
- hot work
- no naked flames
- evacuation
- re-entry methods
- drill hole abandonment
- geological modelling
- emergency procedures
- training.

Operating procedures must be developed for underground mines that contain minerals in the form of sulphides by:

- evaluating the risk of a sulphide dust ignition
- developing procedures and work practices that minimise the risk of an explosion
- implementing the procedures and training the workers in the procedures.



## 5.8 Hot work

Hot work includes the use of thermal cutting equipment, grinding equipment, arc-welding equipment, heating devices, naked flames or mechanical friction devices.

An underground mine may have designated hot work areas such as a welding bay in an underground workshop. Any hot work in other areas should be controlled through hot work procedures and associated permits.

For hot work in any part of a mine outside a designated hot work area, a hot work permit system should be applied. The system should be based upon procedures that include:

- risk assessment of the area
- inspection of the equipment for potential fuel sources before commencing work
- removal of any flammable products before commencing work
- provision of fire extinguishers and thermal blankets
- adequate ventilation flow
- use of an observer or fire-watch, where required
- inspection and monitoring of the equipment and work area after work has been completed
- removal of all gas cylinders following the completion of hot work
- use of an appropriate permit system
- sign-off by an appointed person.

There should be a procedure for the inspection and maintenance of all welding equipment used underground, including:

- inspection of oxyacetylene handsets, regulators, flashback arresters and hoses
- three-monthly inspections and tests of electrical welding transformers and leads as determined by regulatory requirements.



## 5.9 Maintenance procedures for fire protection systems

There should be a maintenance procedure for the inspection and maintenance of all fire protection systems used underground. This should follow OEM recommendations, including:

- inspection schedules
- equipment discharge testing
- maintaining an inspection log.

The maintenance of fire protection equipment should be undertaken in accordance with the relevant sections of Australian Standard AS 1851.

## 5.10 Purchasing requirements

Select equipment that is fit-for-purpose or designed for underground use. Manufacturers or suppliers should provide evidence (e.g. equipment specifications indicating key design controls to prevent fires) that fire risks have been considered and addressed.

When making purchases, consider aspects such as:

- the potential fire hazards associated with the equipment or material (e.g. consult MSDS)
- whether appropriate fire response capability exists at the mine
- adequate maintenance and operating information is provided with all equipment.



## 5.11 Inspections

Regular inspections of working areas are essential to monitor compliance with fire controls, including procedures, and aim to identify:

- substandard acts or work practices
- substandard conditions.

It is a regulatory requirement for workplaces to be inspected during each shift, with the inspection conducted by an underground manager or supervisor and any observed defects reported and recorded for remedial action. Checklists may be useful for these shift inspections.

Formal inspections and audits of all workplaces should be undertaken on a regular basis, depending on the level of risk (e.g. magazine inspections), and will generally involve the use of area-specific or task-specific checklists to record any defects.

To help reduce fire risk underground inspections should consider:

- compliance with explosives transport and storage procedures
- adherence to no smoking policy in designated areas
- checks for rags and flammable materials on equipment
- use of hot work procedures and compliance with hot work permit requirements
- compliance with site housekeeping standards
- correct vehicle or parking requirements (e.g. only in designated areas)
- compliance with combustible storage standards (e.g. in workshops and fuel storage areas)
- compliance with fuel unloading and refuelling procedures
- checks for the presence of correct signage (e.g. flammables, no smoking, explosives)
- compliance with maintenance procedures
- pre-handover inspection by trades person and supervisor regarding machine cleanliness

- checks for adequate fire protection (e.g. sufficient number, accessibility and correct type of fire extinguishers)
- checks of emergency equipment such as refuge chambers and the status of escape ways
- explosives and magazine management
- safe parking of explosives-carrying equipment
- explosives-carrying equipment being confirmed as explosives free before hand-over for maintenance
- specific emergency response procedures for magazines and explosives-carrying equipment.



## 6 Competency of workers

### 6.1 Fire prevention awareness

Basic fire prevention awareness training is a critical element of underground mine inductions. Refresher training should be conducted as part of regular safety or toolbox meetings.

It is essential that all workers at the mine have a basic understanding of underground fire prevention, and are trained and assessed for competency in:

- basic fire theory
- basic fire prevention methods
- understanding underground fire potentials
- using first response fire fighting equipment, including portable extinguishers and installed suppression systems
- fire behaviour in the underground environment, including ventilation
- methods for reporting fire potentials and emergencies
- emergency procedures, including use of self-rescuers and refuge chambers.

### 6.2 Explosives crew

In addition to competencies listed for mobile equipment operators in Section 6.3, workers who transport explosives or handle explosives inside magazines are required to be trained and assessed for competency. This should include:

- procedures for the transport and handling of explosives
- explosives fire prevention and response
- refuelling of explosives-carrying vehicles
- secure parking of explosives-carrying vehicles when unsupervised or during shift changes
- access requirements for magazines.

### 6.3 Mobile equipment operators

All workers who operate mobile equipment at the mine are required to be trained and assessed for competency. This should include:

- identification of overheating surfaces
- requirements for minimising temperatures through correct operating techniques
- brake and retarder use during equipment operation
- requirements of electrical isolation
- identification of electrical hazards
- completion of pre-start inspections
- sterilisation procedures before servicing and maintenance
- use of refuelling equipment and refuelling procedures
- prevention requirements for tyre fires
- park-up procedures
- parking in the event of a flat tyre
- response to vehicle fires
- site emergency procedures.

### 6.4 Fixed plant operators

All workers who operate fixed plant at the mine are required to be trained and assessed for competency. This should include:

- identification of overheating surfaces
- identification of electrical hazards
- requirements of electrical isolation
- emergency shut-down procedures
- site emergency procedures.



## 6.5 Mobile equipment maintenance workers

Workers involved in the maintenance of mobile equipment at the mine are required to be trained and assessed for competency. This should include:

- temperature monitoring
- inspecting and checking V-belts
- hose requirements for specific equipment
- use of maintenance system checklists
- use of hose-crimping machines
- use of hot work permits and welding equipment
- pre- and post-maintenance equipment inspections (e.g. checking for loose rags and oil spillage)
- maintenance of AFFF systems and portable fire extinguishers
- isolation, testing and adjusting
- confined space standards
- test procedures for service and park brakes
- fitting of lagging, heat shields, and heat and sound insulation in accordance with OEM.

## 6.6 Electrical maintenance workers

Workers involved in the installation or maintenance of electrical equipment at the mine should be trained and assessed for competency in:

- conducting thermal imaging and other electrical tests
- use of hot work permits
- live testing techniques that comply with Energy Safety's *Safe low voltage work practices by electricians – code of practice*.

Those undertaking such work should also be licensed electricians.

## 6.7 Work involving dangerous goods and combustible substances

Workers responsible for the transport, storage or handling of dangerous goods and combustible materials at the mine should be trained and assessed for competency in:

- transport and storage procedures for dangerous goods or combustible materials present in the mine
- braking limitations and vehicle precautions
- park-up procedure during refuelling
- use of fuel distribution or unloading equipment
- refuelling of vehicles carrying dangerous goods or combustible stores
- access requirements for dangerous goods or combustible stores
- cleaning of equipment before maintenance
- emergency procedures specific to dangerous goods or combustible storage areas.



## 7 Underground fire control plan

Once underground fire risks have been assessed and controls determined, the information relating to the management of underground fires should be consolidated into an underground fire control plan. This plan outlines the fire risks present at the mine and the activities and measures the mine is undertaking to control the risk of underground fires.

The objective of the underground fire control plan is to ensure the systematic planning and effective implementation of fire control systems. It is also a useful document for communicating to workers how fire risks are being managed.

The information contained in the plan should include:

- infrastructure and facilities
- details of underground fire risks (based on a formal risk assessment)
- details of fire prevention controls
- details of contingency controls
- a list of operating and maintenance procedures relating to fire control
- the fire hazard reporting procedure
- provision and testing of alarm systems
- the emergency response procedure
- the training of workers in emergency procedures, fire fighting, mine rescue and other relevant emergency response functions
- details of inspection and auditing programs specific to monitoring fire controls
- a system to regularly review, update and communicate changes to the plan.

Responsibilities and accountabilities for monitoring, reviewing and responding to reports should be clearly defined and assigned.

Mock emergency drills should be regularly undertaken to test and improve the plan. Participation in emergency response competitions provides emergency response teams



an important way to gauge the capacity of mine sites to deal with on-site emergencies. It gives teams good understanding of what their strengths are and the areas where they can improve. This is vital to ensure competence across all areas of mine emergency response.

It is a regulatory requirement for mines to be prepared to respond to potential emergencies such as underground mine fires. There are also statutory response requirements under the Dangerous Goods Safety (Explosives) Regulations 2007 (e.g. explosives magazines) and Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007 (e.g. fuel storage facilities).

A high impact function (HIF) audit for underground fire prevention is available from the Resources Safety website to assist in assessing the effectiveness of underground fire control plans.





# Appendix 1 – Legislative provisions

The parts of the Mines Safety and Inspection Regulations 1995 that are directly applicable to this guideline are listed below.

*Note: The Dangerous Goods Safety Act 2004 and regulations also apply to dangerous goods that may pose a fire risk.*

## **Mines Safety and Inspection Regulations 1995**

### **Part 3 Management of mines**

- r. 3.21 Inspection of other underground workplaces
- r. 3.51 Particulars required in mine plans

### **Part 4 General safety**

#### **Part 5 Electricity in mines**

- r. 5.11 Duties of electrical supervisor
- r. 5.15 Fire extinguishers
- r. 5.21 Trailing cables and reeling cables

### **Part 6 Safety in using certain types of plant in mines**

#### **Part 7 Occupational Health**

- r. 7.15 Waste timber and other materials not to accumulate underground
- r. 7.25 Register of hazardous substances
- r. 7.27 Risk assessment
- r. 7.28 Means of reducing risk of exposure to hazardous substances

#### **Part 8 Explosives**

- r. 8.1A Explosives, requirements in relation to
- r. 8.5 Underground magazines
- r. 8.7 Lights
- r. 8.13 Smoking prohibited



- r. 8.14 Handling and transport
- r. 8.54 Blasting in hot material
- r. 8.55 Blasting in oxidising or reactive ground

**Part 9 Ventilation and control of dust and atmospheric contaminants**

- r. 9.5 Duties of ventilation officer – underground
- r. 9.31 Smoking prohibited in certain workplaces

**Part 10 Specific requirements for underground mines**

- r. 10.29 Sulphide dust ignitions
- r. 10.30 Shift communications
- r. 10.41 Unattended trackless units
- r. 10.42 Maintenance of trackless equipment
- r. 10.45 Remote controlled equipment
- r. 10.47 Terms used
- r. 10.48 Diesel engines only to be used
- r. 10.51 Specifications and testing of diesel units
- r. 10.58 Fuelling and servicing
- r. 10.59 Fire suppression
- r. 10.60 Fuel transport and storage

**Part 11 Winding, winding ropes and signals**

- r. 11.29 Winding engine fire precautions

*Note: The only authorised versions of the Mines Safety and Inspection Act 1994 and regulations are those available from the State Law Publisher ([www.slp.wa.gov.au](http://www.slp.wa.gov.au)), the official publisher of Western Australian legislation and statutory information.*

# Appendix 2 – Selected Australian Standards

## Standards Australia

- AS 1180.10A *Methods of test for hose made from elastomeric materials – Resistance of hose lining or cover to flame*
- AS 1180.10B *Methods of test for hose made from elastomeric materials – Determination of combustion propagation characteristics of a horizontally oriented specimen of hose using surface ignition*
- AS 1345 *Identification of the contents of pipes, conduits and ducts*
- AS 1603 *Automatic fire detection and alarm systems*
- AS 1670.1 *Fire detection, warning, control and intercom systems – System design, installation and commissioning – Fire*
- AS 1674 *Safety in welding and allied processes*
- AS 1851 *Routine service of fire protection systems and equipment*
- AS 2187 *Explosives – Storage, transport and use*
- AS/NZS 2229 *Fuel dispensing equipment for explosive atmospheres*
- AS 2380.1 *Electrical equipment for explosive atmospheres – Explosion-protection techniques – General requirements*
- AS 2419.1 *Fire hydrant installations – System design, installation and commissioning*
- AS/NZS 3000 *Electrical installations (known as the Australian/New Zealand Wiring Rules)*



- AS 3007 *Electrical installations – Surface mines and associated processing plant*
- AS/NZS 3013 *Electrical installations – Classification of the fire and mechanical performance of the wiring system elements*
- AS 4242 *Earth-moving machinery and ancillary equipment for use in mines – Electrical wiring systems at extra-low voltage*
- AS 5062 *Fire protection for mobile and transportable equipment*
- AS/NZS ISO 31000 *Risk management – Principles and guidelines*
- AS 60974.1 *Arc welding equipment – Welding power sources*
- HB 37 *Handbook of Australian fire standards*



## Appendix 3 – Further information

### **Department of Mines and Petroleum**

*Refuge chambers in underground metalliferous mines – guideline*

*Emergency preparedness for underground fires in metalliferous mines – guideline*

*Foam fire suppression systems on mine vehicles – guideline*

*Management of diesel emissions in Western Australian mining operations – guideline*

*Purchase, operation and maintenance of underground diesel engined mining equipment – guideline*

*Tyre safety, fires and explosions – guideline*

*Underground fire prevention – HIF audit guideline and template*

*Mines Safety Bulletin No. 106 Loss of control of service vehicles on declines in underground mines*

*Mines Safety Bulletin No. 75: Fire and explosion in a working party magazine*

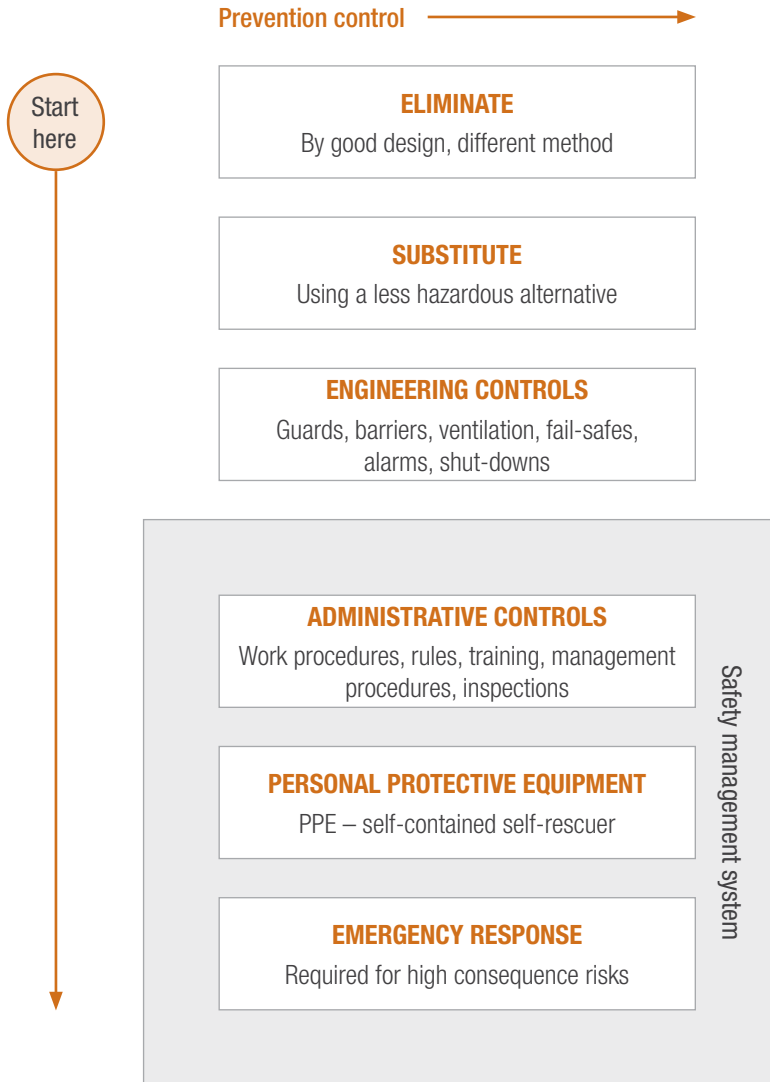
*Mines Safety Significant Incident Report No. 174: Mechanical scaling ignites flammable gas underground*

### **Department of Commerce**

*Safe low voltage work practices by electricians – code of practice*



# Appendix 4 – Examples showing hierarchy of control approach for underground fire risks













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