NSW GOVERNMENT

NSW Resources Regulator

Opal and gemstone mining

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AMENDMENT SCHEDULE

Date	Version	Amendment
1994	1	First published as Lightning Ridge Miners Handbook
1996	2	Updated to current legislation and industry standards
2002	3	Updated to current legislation and industry standards
2010	4	Updated to current legislation and industry standards
2020	5	Rebranded and updated to current legislation and industry standards
8 Sept 2020	6	Updated to DRNSW branding and inserted addendum pages (59a - 59i)
23 Nov 2020	7	Updates to page numbers, TOC and disclaimer (reprint)

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Foreword

This guide is designed to provide material focussing on practical guidance and best practice in opal and gemstone mines. However, mine operators can use and vary these practices to assist them to meet work, health and safety laws.

This guide deals with common health and safety issues at opal and gemstone mines but does not cover all hazards or risks that may arise at each mine. The health and safety laws require mine operators and others to consider all risks associated with working at opal or gemstone mines and not only meeting Regulations, codes of practice or guidance material.

Compliance with the work, health and safety (WHS) laws may be achieved by following another method, such as another guide or an industry standard, particularly if it provides an equivalent or higher standard of work, health and safety.

Contents

Scope and application

The main objective of this guide is to advise an opal mine operator on applying best practice in planning and operating such a mine.

A secondary objective is to advise mine operators and contractors who work at opal or gemstone mines about methods of planning and working an opal or gemstone mine in ways that meet work health and safety (WHS) laws.

Contractors and other persons conducting a business or undertaking (PCBU), and workers at an opal mine could refer to this guide to assist in achieving the best health and safety outcomes during consultation, co-operation and co-ordination of their activities with mine operators.

The mine may be a surface or underground mining operation that may use mechanical means, involving plant, to extract opal or other gemstones. This guide covers all opal mines and can be useful for other mines that are small-scale mining operations.

The small mines and quarries sector include quarries, surface metalliferous, alluvial and gemstone mines as well as dredging operations. However, regardless of the size of the mining operations, all mines still need to systematically manage their hazards to eliminate or minimise risks arising from those hazards. This guide would be useful in identifying commonly recognised hazards for other small gemstone mines as well.

Relationship to other codes and guides

This guide compliments requirements and recommendations that are stated in NSW codes of practice that relate to opal or underground gemstone mines and the associated safety management system (SMS).

Throughout this guide, reference is made to other publications and Australian Standards. Further details can be obtained by referring to these publications.

Definitions

The meaning of some words used in this guidance material is explained below.

TERM	MEANING
Contractor	A person conducting a business or undertaking (PCBU) who provides goods and/or services to a workplace. In this guide the workplace is the mine.
Job safety analysis (JSA)	A risk assessment technique generally carried out in the workplace before the start of a job. The JSA is used to identify hazards for each job step and how they are to be eliminated or controlled. A JSA could be used for managing risk with work practices, plant and/or conditions at a mine. Often a JSA is used to develop safe work procedures as well. A JSA can be known as a Job Hazard Analysis (JHA).
PCBU	Person conducting a business or undertaking.
Safe work procedure (SWP)	Safe operating procedure or safe work method statement (SWMS). A written outcome of a risk assessment technique, such as a JSA, with a greater description of the job steps, hazards and actions to take to eliminate or control risks associated with that job.
Safety management system (SMS)	The mine operator must establish and implement a safety management system before mining operations take place. The safety management system must manage all aspects of risks to health and safety, in relation to the operation and have appropriate regard to the nature, complexity and location of the mining operations.
Small scale title	A mineral claim or an opal prospecting licence.
Mine holder	The mine holder is the person with the right to mine (e.g. landowner). The mine holder is the mine operator unless another person (generally a company) is appointed to be the mine operator.
Titleholder	See mine holder.
Mine operator	The mine operator is the company or individual who is conducting a business or undertaking, has the skills, knowledge, experience and resources to exercise the functions of the mine operator, is authorised to have management or control of the mine and to discharge the duties of the mine operator under the WHS laws.

Laws affecting opal or gemstone mine holders

As a mine holder (separate to a mine operator), even if you do not actively mine the claim yourself, there are several laws that relate to you either directly or indirectly.

While some laws cover the obligations or legal duties of being a mine holder, other laws outline the responsibilities of being a mine operator, such as all matters relating to health and safety, liability and environmental management. There are also laws that include the partners and the workers themselves.

As a mine holder and/or a mine operator, you should make yourself familiar with your legal duties under the WHS laws in NSW as well as the following legislation:

- *Work Health and Safety Act 2011*
- Work Health and Safety Regulation 2017
- *Work Health and Safety (Mines and Petroleum Sites) Act 2013*
- Work Health and Safety (Mines and Petroleum Sites) Regulation 2014
- *Mining Act 1992*
- Mining Regulation 2016
- *Explosives Act 2003*
- Explosives Regulation 2013

The legislation

The Mining Act

This is the principal Act regarding mining titles and environmental management by which the opal fields are managed and administered. It allows for the registration of mineral claims and other mining and prospecting titles.

This Act and associated Regulations specify procedures for granting a claim, the conditions that can be imposed on a claim, and claim holder's rights and obligations. At the time a claim is granted, the claim applicant signs an undertaking to comply with the conditions under which the claim is granted.

In effect, this Act provides a claim holder with the authority to search for and mine opal, or other gemstones. It also allows for compensation to be payable to the affected landholder and provides for various fees to be charged for registration, renewal, transfer etc.

The Mining Act also provides for penalties for failing to comply with the provisions of the Act, including failing to rehabilitate the mine to the satisfaction of the Regulator.

Work health and safety legislation

The WHS laws are the primary health and safety laws to maintain health and safety at workplaces, including opal or gemstone mines.

All WHS laws provide for people at work to be protected against risks to their health and safety by requiring that risks in the workplace be identified, assessed and then eliminated or controlled. It also promotes consultation and co-operation between the mine operator, contractors and workers and even visitors.

The WHS laws prescribe the duties for mine operators, partners and contractors (persons conducting a business or undertaking, referred to as a PCBU) and their workers. For example, at mineral claims, opal prospecting licences and those who have plant or equipment in another person's workplace - that is the suppliers or hirers.

The WHS laws require that all workers are adequately trained and competent to do all tasks, including knowledge in managing risks.

The WHS laws also provide for the Regulator to serve notices on people at a mine when the Regulator believes there are health and safety issues that are not being addressed by the mine operator or other persons.

Mine-specific WHS laws

Mine-specific laws, such as the Work Health and Safety (Mines and Petroleum Sites) Act and Regulation in NSW create additional protections, rights and obligations necessary because of the special risks associated with mining.

Once a claim has been granted under the Mining Act, the mineral claim holder becomes a mine holder under these mine-specific WHS laws.

A mine holder must not allow any work to be undertaken at a mine unless the mine holder has appointed a person who is the mine operator. The mine operator is the person (or corporation) that is appointed to carry out mining operations at the mine on behalf of the mine holder and is authorised by the mine holder to have management or control of the mine and to discharge the duties of the mine operator under the WHS laws.

The mine holder can appoint themselves or another person (or corporation) as the mine operator.

In NSW, before a person can be appointed as an opal mine operator and operate a mine, they must have attended the safety training conducted by the NSW Resources Regulator.

Both the mine operator and mine holder have duties in the way they conduct their mining operations under the provisions of the WHS laws. All mine holders are encouraged to make themselves familiar with the mine-specific WHS laws.

Management of a mineral claim (mine)

A mine operator is responsible for matters relating to health and safety, not only for themselves, but also for contractors, partners, other people working the claim, visitors and those entering or travelling through the claim area.

The mine operator must, before any work can start at the mine, prepare and implement a safety management system (SMS) in consultation with those who work at the mine. This document must include:

- the health and safety policy for the mine
- the arrangements for controlling risks or hazards such as ground control and having safe machinery and electrical installation (if applicable) and when working with dust, noise, exhaust fumes and extreme temperatures and other issues, such as fitness for work (fatigue, drug and alcohol issues), site safety rules, etc
- a ventilation plan
- an emergency plan, including a general emergency procedure to be kept at the mine
- a mine plan
- managing contractors
- information, training and instruction arrangements, including safe work procedures for regular activities when working at mines and agitator/puddling sites
- consultation with workers
- a mine record and managing records, inspections and reviewing of the SMS
- managing specific matters such as health, mechanical, electrical, and explosives (if used).

In NSW, the Regulator holds safety training at Lightning Ridge with samples and templates included for the mine operator to assist in developing an SMS for the mine(s). The mine operator can use these templates and samples and follow other instructions given at these workshops to comply with all WHS laws and develop best practice in health and safety when operating the mine(s).

The mine operator must ensure that work directly related to mining is not carried out by any person at the mine unless an SMS that complies with WHS laws has been implemented for the mine.

The WHS laws require that the mine operator of a mine must ensure that all equipment and machinery at the mine is designed, used, maintained, repaired and/or replaced to protect the health and safety of people at the mine.

Workers at a mine have a responsibility to comply with the mine's SMS, which comprises of the systems the mine has for managing health and safety.

Duties

Duties are imposed on people in a workplace who have the potential to influence the health and safety of others. More duties may be imposed on some people depending on the nature of that influence.

The following people have duties:

- a person conducting a business of undertaking (PCBU)
- an officer
- a worker
- others.

Persons conducting a business or undertaking

The primary duty of care resides with the person conducting a business or undertaking (PCBU) due to their influence on when, where, and who works at the mine. They also influence how work is done and must, so far as is reasonably practicable, ensure the health and safety of those in the workplace. There are further duties for PCBUs in relation to:

- the control of a workplace
- management of fixtures, fitting and plant and/or equipment
- plant and/or equipment design, substances or structures
- plant and/or equipment manufacturing, substances or structures
- plant and/or equipment importation, substances or structures
- supplying plant and/or equipment, substances or structures
- installing, constructing or commissioning plant and/or equipment or structures.

Consultation

PCBUs also have duties to consult with workers, other PCBUs or other people where the nature of business or undertaking may impact on their health and safety.

The nature of consultation should include sharing relevant information, providing an opportunity for those affected to express their opinions, raise issues to the matter and contribute to the decision-making process. The views of workers are taken into account by the PCBU and workers are advised of the outcomes of the consultation.

Officers

Officers are workers who have decision-making powers and hold general control that significantly influences the workplace. An officer must demonstrate reasonable steps to avoid committing an offence in:

- keeping up-to-date knowledge of work, health and safety matters

- gaining an understanding of the nature of the operations of the business or undertaking and the hazards and risks associated with it
- ensuring the PCBU has appropriate resources and processes to eliminate and/or minimise risks to health and safety as a result of the business or undertaking
- placing appropriate processes for receiving information regarding incidents, hazards and risks and responding in a timely way to that information
- ensuring the PCBU has processes in place for complying with any duty or obligation of the PCBU under the WHS Act and WHS (MPS) Act
- verifying the provision and use of resources and processes.

The duties of the PCBU and officer, in practical terms, in opal and gemstone mining, is that the claim holder is the officer and holds the duties of an officer and an operator has the all the duties of a PCBU. Where the claim holder is also the operator, both duties of PCBU and officer apply.

Workers and others

Workers also have a duty to take reasonable care of their health and safety and ensure that their actions or omissions do not adversely affect the health and safety of others. They must comply where possible with any reasonable instruction given by the PCBU and cooperate with the procedures of the PBCU.

Principles that apply to duties

Duties imposed by the WHS Act:

- are not transferable
- can apply more than once
- can apply to more than one person
- must so far as reasonably practicable eliminate risk to health and safety, to minimise risk.

Reasonably practicable

The legislation references ‘reasonably practicable,’ which is a decision-making term to assist people to determine the minimal requirements about how issues are addressed. What would be reasonable to expect of a person given the situation to manage health and safety risks, taking into consideration:

- the likelihood of a hazard or risk occurring
- the degree of harm from a hazard or risk
- knowledge about ways of eliminating or minimising a risk
- the availability and sustainability of ways to eliminate or minimise a risk
- cost.

Incident reporting

Where there is a serious incident at the mine of a kind prescribed by Regulation, then the mine operator must inform the Regulator. The mine operator has the ultimate responsibility for informing the Regulator. However, he or she may need to delegate that function to another person if they are not at the mine site. The following should be reported:

- first aid injuries
- lost time injuries
- restricted duties
- near misses
- high potential incidents
- dangerous incidents
- serious injuries
- fatalities.

It is a requirement that information about incidents, near misses, injuries and deaths at mine sites be reported within specified time frames. The Regulator requires the notification of deaths, serious injuries, notifiable incidents immediately via the centralised reporting phone number - 1300 814 609.

Explosive incidents that include loss, theft, suspicious activity that threatens security, or serious incidents involving explosives or explosives precursors, must be reported under the explosives legislation and also reported to SafeWork NSW and NSW Police.

In the event of a death, serious injury or illness or a dangerous incident, the PCBU must preserve the site until directed by the Regulator to release the site.

Non-serious injuries must be reported to the Regulator as soon as possible online but must not exceed 48 hours. An inspector from the Regulator may request that the site be preserved.

If a PCBU reports an incident within 48 hours and the Regulator decides the incident could have been reported sooner, the Regulator may take action for late reporting.

Other incidents must be reported to the Regulator online as soon as possible but no later than seven days. The Regulator may request that the site be preserved.

Report an incident or injury

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Notifying the NSW Resources Regulator

Serious safety incidents that occur at NSW mines, extractives or petroleum sites **must be reported** to the Resources Regulator under work health and safety legislation.

MORE INFORMATION

SCAN FOR MORE INFORMATION ON REPORTING AN INCIDENT OR INJURY TO THE RESOURCES REGULATOR.

WHAT HAPPENED?	PHONE	REPORT ONLINE	PRESERVE SITE
DEATH, SERIOUS INJURY OR ILLNESS (S 14 WHS (MP) Act, Cl 178 WHS (MP) Reg)	IMMEDIATELY	AS SOON AS POSSIBLE (NO LATER THAN 48 HOURS)	YES
DANGEROUS INCIDENT (S 14 WHS (MP) Act, Cl 179 WHS (MP) Reg)	IMMEDIATELY	AS SOON AS POSSIBLE (NO LATER THAN 48 HOURS)	YES
NON-SERIOUS INJURY (Cl 128 WHS (MP) Reg)	NOT REQUIRED	AS SOON AS POSSIBLE (NO LATER THAN 48 HOURS)	ON REQUEST
OTHER INCIDENT (Cl 128 WHS (MP) Reg)	NOT REQUIRED	AS SOON AS POSSIBLE (NO LATER THAN 7 DAYS)	ON REQUEST

PHONE: If there is a serious injury or illness, a death or a dangerous incident, you must report it to us immediately on **1300 814 609** as an urgent investigation may be needed. The incident site must be preserved until an inspector attends or the inspector or regulator directs otherwise. Operators of coal mines must also notify an industry safety and health representative.

ONLINE: For other types of notifiable incidents, complete the Resources Regulator's online incident notification form on our website as soon as possible.

WHS (MP) Act - *Work Health and Safety (Mines and Petroleum Sites) Act 2013* | **WHS (MP) Reg** - Work Health and Safety (Mines and Petroleum Sites) Regulation 2014

Reporting requirements

FOR EXPLORERS

Exploring for minerals is a 'mining activity' which is considered to be a 'mining operation' for the purposes of the *Work Health and Safety (Mines and Petroleum Sites) Act 2013*. Exploration may involve mining activities conducted either by mechanical or non-mechanical means.

Notifiable incident

Must report a notifiable incident:
- the death of a person
- a serious injury or illness of a person
- a dangerous incident
- an incident that results in injury or illness requiring medical treatment
- a high potential incident.

Reportable events

- The commencement of mining operations
- Any significant interruption to, or suspension of, mining activities at the mine
- The recommencement of normal mining operations at the mine (following above)
- The commencement of intermittent mining operations at the mine
- The connection of an electricity supply to the mine.

Notification of operator

You must nominate a 'mine operator'. If no operator is nominated then the 'mine holder' is considered to be the mine operator.

REPORT AN INCIDENT TO THE RESOURCES REGULATOR

1300 814 609

Online notification form: **resourcesandenergy.nsw.gov.au/safety**

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What is a dangerous incident?

A dangerous incident includes certain types of incidents that are inherently dangerous. It also includes other incidents where a person is exposed to a serious risk to their health or safety due to an immediate or imminent exposure to the hazard.

For most hazards, such as plant or a structure collapsing, a worker will need to be in the immediate vicinity to be exposed to a serious risk to their health or safety.

Some hazards, such as an uncontrolled leak of a hazardous gas or a fire, can travel towards a worker and expose them to a serious risk to health and safety away from the original source.

A dangerous incident can include situations in which there is an immediate exposure to the hazard, but the potential harm to a worker's health or safety may not materialise until later, such as exposure to asbestos or chemicals.

If a person is exposed to a serious risk to their health or safety from immediate or imminent exposure to a hazard, the following are reportable as dangerous incidents:

- an uncontrolled escape, spill or leak of a substance
- an uncontrolled implosion, explosion or fire
- an uncontrolled escape of gas or steam
- an uncontrolled escape of a pressurised substance
- a fall or release from height of any plant and/or equipment, substance or thing
- the collapse, overturning, failure or malfunction of, or damage to, any plant and/or equipment that is required to be authorised
- a collapse or partial collapse of a structure
- a collapse or failure of an excavation or of any shoring supporting an excavation
- rock falls, instability of cliffs, steep slopes or natural dams, occurrence of sinkholes, development of surface cracking or deformations or release of gas at surface, due to subsidence
- a vehicle or plant and/or equipment making contact with an energised source having a voltage greater than 1200 volts (not including testing equipment applied to energised equipment in accordance with the WHS Regulation)
- an inrush of water, mud or gas in workings at an underground excavation or tunnel
- an unintended interruption of the main system of ventilation at an underground excavation or tunnel
- a loss of control of heavy earthmoving machinery (including any failure of braking or steering)
- an unintended activation, movement, or failure to stop vehicles or machinery

- a collision involving a vehicle or mobile plant
- damage to, or failure to any part of a powered winding system or a shaft or shaft equipment
- damage to any plant or structure
- a failure of ground, or of slope stability control measures.

The following incidents are also dangerous incidents that must be notified to the Regulator, even if no-one was in the vicinity at the time of the incident:

- an electric shock to a person (other than a shock from an extra low voltage source)
- an unintended overturning of any vehicle or plant weighing more than 1,000 kilograms
- any initial indication that there may be a fault in the cementing of a casing string forming part of the cement casing of a well.

Exemptions

In general terms, the directives given in the WHS and WHS (MPS) legislation apply to all, except where the legislation specifically identifies a group where the directive does not apply.

There are certain exemptions to the WHS and WHS (MPS) Act and Regulations that are particularly relevant to opal and gemstone miners. These exemptions are driven by 'what is reasonably practicable'.

Principal hazard management plans and principal control plan

An opal mine is exempt from developing and integrating into its safety management system a principal hazard management plan (PHMP) and a principal control plan (PCP).

Managing risks

An opal mine is exempt from implementing procedures for communication between outgoing and incoming shifts. Opal mines also have different requirements for winding systems and ropes.

Air quality

Opal mines have different requirements for the standards for quality in ventilated air and the development of ventilation control plans.

Emergency management

Opal mines are not required to record all people working at the mine at the time that they are working and are not required to consult with workers when they are preparing an emergency management plan. Opal miners are not required to use self-rescuers.

Mine survey plans and mine plans

Opal mines are not required to prepare a survey plan of the mine.

Notifying the Regulator

Opal mines are only required to notify the Regulator of incidents and are exempt from notifying the Regulator regarding all other matters.

Quarterly reports

Opal mines are not required to submit quarterly reports to the Regulator.

Underground mines

Opal mines are not required to develop a new mine entry.

Statutory positions

Opal mines are not required to appoint workers in statutory positions.

Explosives Act

The Explosives Act and Regulations provide for the regulation and control of the handling, supply, storage and use of explosives and explosive precursors (such as ammonia nitrate) and for related purposes. Severe penalties apply to people using explosives without authorisation to do so.

Protection of the Environment Operations Act 1997

This Act is administered by the NSW Environmental Protection Authority (EPA) and regulates all forms of pollution.

The Act has relevance to the gemstone or opal fields in relation to puddling sites and mining operations. For the mining industry, the main issues relate to dust and noise affecting people near the mine.

As an operator, there is an obligation to ensure that dust levels are kept below the standards set. This would be particularly relevant in open cut operations where use of heavy equipment for loading and haulage is necessary on unsealed roads.

Dust from mining operations should be kept within the boundaries of the mining title. If necessary, the mine operator should be prepared to water the haulage roads or take other steps to reduce dust levels. The Act also defines the upper limits of noise emission and sets out the times of day during which operators must meet particular limits.

Environmental Planning and Assessment Act 1979

This Act has relevance to anyone wishing to obtain a title to prospect, mine or treat minerals from a mine. This includes opal or gemstone fields in the granting of licences or claims in new prospecting areas; and in the granting of mining leases for puddling purposes.

Under Part 5 of the Act, a determination must be made as to whether the proposed development will have a significant impact on the environment. For opal mining and prospecting, especially at Lightning Ridge, the determining authority is the Environment Minister. This determination requires that each proposal be examined for such things as impact on the community, effect on any historical sites, possible endangering of threatened species of flora or fauna, long term environmental effects on its own, or in combination with other activities.

Where it is considered that there will be a significant impact, an Environmental Impact Statement (EIS) must be prepared by the applicant. Information on how to apply for a mining lease for puddling is available at the Regulator's Lightning Ridge office.

Biodiversity Conservation Act 2016

The Act establishes a new regulatory framework for conservation of aboriginal heritage, plants, animals, communities and habitats within NSW. This Act replaces the previous regulatory regime under the *Threatened Species Conservation Act 1995* and *National Parks and Wildlife Act 1974*. Opal authorisation holders have obligations under this Act to protect and notify the Regulator of any instance where there are threats or impacts on aboriginal heritage or listed species or communities.

Hazard identification and risk management

There are specific laws about managing the health and safety risk of everyone in the workplace. A duty holder (PCBU) has the responsibility to identify and manage risks to health and safety associated with plant and/ or equipment, so far as reasonably practical in accordance with the hierarchy of controls.

In order to manage risk under the WHS Regulations, a duty holder must:

- identify reasonably foreseeable hazards that could give rise to the risk
- eliminate the risk, so far as is reasonably practicable
- if it is not reasonably practicable to eliminate the risk, minimise the risk, so far as is reasonably practicable, by implementing control measures in accordance with the hierarchy of control
- maintain the implemented control measures so that they remain effective
- review, and if necessary, revise the risk control measures to maintain, so far as is reasonably practicable, a work environment that is without risks to health and safety.

Refer to the risk management chapter for further guidance. Source information from the Work Health and Safety Act and Regulation.

Safe mining is about properly managing risk. Many activities on a mine site can be potentially hazardous. You can actively reduce the probability of injury by taking a risk management approach to these hazards.

The concepts of hazard identification and risk management are tools that all mine operators should become familiar with. It provides a systematic way to evaluate and manage safety at opal mines.

This chapter will provide guidance material to understanding how to manage risks arising from hazards at an opal mine and will assist in compliance with WHS laws.

Risk assessments

Risk assessments help mine operators identify high, medium and low risk levels at their mine. By understanding what the risks are and being able to assess them, a miner can manage their operation to eliminate or minimise risks of injury or death. It is essential that the highest possible levels of control be used once hazards are identified.

What is risk?

Risk is the chance, great or small, that someone will actually be harmed by a hazard.

What is a hazard?

A hazard is defined as anything (including work practices or procedures) that has the potential to harm the health or safety of a person.

What is a risk assessment?

A risk assessment is a process to identify and assess risks after a mine operator makes a detailed examination of the mine and the equipment they are using.

There are several identified hazards and risks associated with mining and processing operations at an opal mine. Not all the potential hazards and risks can be identified, as these will vary from mine to mine depending on location, geology and the equipment being used.

A primary objective of this guide is to provide miners with the basic concepts required for managing safety within their mine. Risk assessment is one of those concepts. It is also required to be completed by law.

How to carry out a risk assessment

In a risk assessment, the probability of a risk being there can be ranked from high to low. This allows decisions to be made if risks are high, by managing them first and more thoroughly than risks with lower rankings. An essential component of a risk assessment is the process of recording all hazards, then recording the maximum potential consequences if an incident occurred with each hazard and recording the probability of a potential incident occurring.

When to use risk assessment

A risk assessment should be done before any work is undertaken to ensure all risks are identified and controlled. The risk should be controlled by elimination, substitution, isolation, engineering control or administrative control.

A risk assessment should be carried out during the planning stage of a mine or after hazards are identified in the workplace. The risk assessment will assess the risk of injury occurring or plant and/or equipment being damaged. A risk assessment should also be done after any incident at the mine or a near miss or when advised of an incident occurring at a similar mine.

Hazard control

When making decisions about controlling hazards, it is best to consider the control types in the order that is stated in the WHS laws, as follows:

- Eliminate the hazard altogether should be the first consideration.
- Replace the hazard with a lesser hazard.
- Isolate the hazard from the person put at risk.
- Minimise the risk by engineering means.
- Minimise the risk by administrative means (for example, by adopting

safe working practices or providing appropriate training, instruction or information).

- Use personal protective equipment.

The use of one hazard control measure does not prevent other control measures being used for the same problem. Once controls are in place, regular monitoring of them is important to ensure that they are effective when put in place and remain effective, particularly if conditions change.

Evaluating the risk

The mine operator should evaluate each risk, categorise them into high, medium and low risk, and act to eliminate the risk, or if that is not possible, to minimise the risks. This is done by:

- working out the worst case if an incident did occur, how bad it could be (i.e. consequence)
- working out how likely it is to occur (i.e. probability or likelihood)
- determining the risk level or ranking (high, medium or low) from the Risk Ranking Matrix
- implementing appropriate actions and reviewing the risk ranking to ensure no new risks are introduced and that the solutions reduce the risk in the work place. The WHS laws state that the hierarchy of controls is to be used when establishing control measures to control the risk and what action should be taken
- taking further action as suggested in the table, which may be of assistance in deciding when and what responses could be made.

Once the risks are understood in the mine, decisions can be made about how to manage them. Obviously, those hazards with the highest risk ranking should be dealt with first. Also, if the risks are high, the implementation of the most effective controls are essential to eliminate or minimise the risks to injury or plant damage. For high risks, it is worth using more than one type of control measure.

Table 1 - Risk Ranking

RISK RANKING MATRIX

Step 1: Assess the Consequence of the risk

Level	Typical Classification	AS 4360	Example / Detail / Description
C1	Fatality	Outstanding	One or more deaths
C2	Permanent injury	Major	Extensive (serious) injury
C3	Temporary to permanent injury	Moderate	Lost time injury (LTI) of more than one shift
C4	Temporary injury	Minor	Lost time injury (LTI) less than one shift with first aid and/or medical treatment
C5	Minor injury	Insignificant	No lost time with first aid treatment or less

Step 2: Assess the Likelihood of the risk

Level	Typical criteria	AS 4360	Description
L1	Happens every time we operate	Almost certain	Event is a common problem at the mine
L2	Happens regularly (often)	Likely	Event is known to occur at the mine or "it has happened"
L3	Has happened (occasionally)	Moderate	Event could occur at the mine or "I've heard of it happening elsewhere"
L4	Happens irregularly (almost never)	Unlikely	Event is not going to occur at the mine or "I have not heard of it happening"
L5	Improbable (never)	Rare	Event is practically impossible

Step 3: Rank the risk (Likelihood x Consequence = Risk Ranking)

	Consequence				
Likelihood	**C1**	**C2**	**C3**	**C4**	**C5**
L1	High	High	High	Medium	Medium
L2	High	High	Medium	Medium	Low
L3	High	Medium	Medium	Low	Low
L4	Medium	Medium	Low	Low	Low
L5	Medium	Low	Low	Low	Low

Table 2 - Heirachy of control

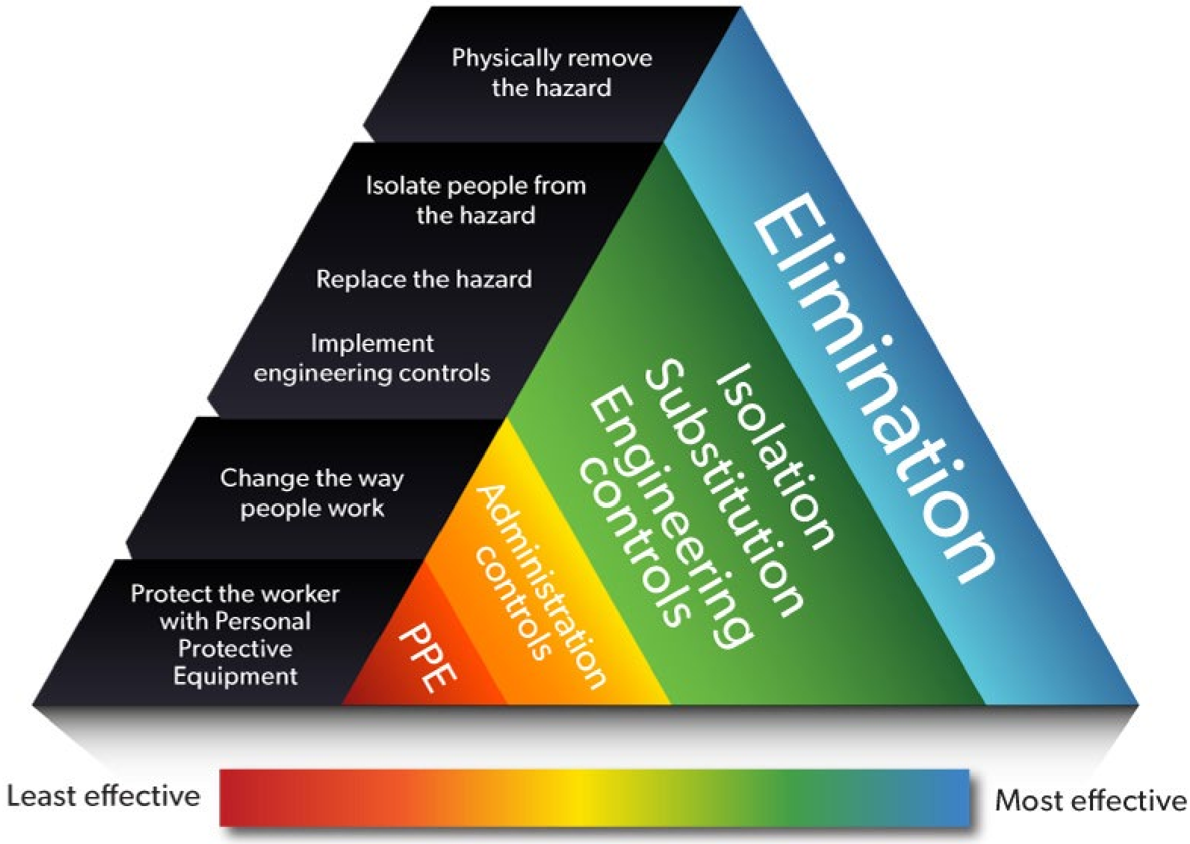


Table 3 - Action steps

Risk Rating	Action Step
High Risk	Stop work. Take immediate action to minimise risk. Notify mine operator. Select highest possible control as in the hierarchy of control table. Record hazard in **MINE RECORD BOOK**, noting date when fixed.
Medium Risk	Take required temporary action. Select highest possible control as in the hierarchy of control table. Notify mine operator. Record in **MINE RECORD BOOK** with fix by date.
Low Risk	Select highest possible control as in the hierarchy of control table. Notify mine operator. Record in **MINE RECORD BOOK**. Review during next workplace inspection.

Emergency planning

Opal or gemstone miners often work alone. This is dangerous because they may not be able to raise the alarm if an incident occurs. Even where people work in pairs, in some incidents, both have been injured.

A fundamental rule of safe opal or gemstone mining is to always let your family, the adjacent worker, or a friend know where you are working and what time you will be home. If you have a general emergency procedure, consider giving a copy to family or friends. A general emergency procedure template is available from the Regulator's Lightning Ridge office.

If you are late returning home for any reason, people can make prompt arrangements to determine what has happened. If you have been in an accident and you have life threatening injuries, early medical attention can be arranged, which may be critical for your survival.

Hazards during emergencies:

- Remoteness and poor access to the mine, and into the mine, can delay rescue operations.
- Delays in administering appropriate first aid may make injuries worse and/or result in death.
- The cause of an incident may be a threat to the safety of rescuers.

Dealing with emergencies

In an emergency, where someone may require medical assistance, ring 000 and ask for the ambulance. Read from the mine's general emergency procedure and tell the operator the following:

- You are at an opal (or gemstone) mine (or mining claim) - give them the claim (or title) number, the opal field, the nearest survey peg number and the distance from that peg. If available, state the GPS co-ordinates as well.
- The nature of the incident, the number of people injured and the type of injuries.
- Directions, including recognised landmarks.
- Your phone number.
- If necessary, state the location where someone will meet the ambulance.
- If injured person(s) are underground or trapped, tell the operator that the SES Mines Rescue Unit will be required.

An incident at an opal mine

An underground rock fall injured a miner. His partner did not think the injuries were serious and tried to convince him to climb out of the mine. As the injured miner did not want to climb out, the partner went to the surface and sought assistance from a third miner. When the partner and the third miner returned underground, they decided that the injuries were significant and they should contact the ambulance and mines rescue team.

As a result, time was lost before the decision was made to get help, even though the miner had undoubtedly been injured in the rock fall. It was later found that the injured miner's condition was critical with several broken bones, internal bleeding and seriously damaged organs. Don't delay getting help. If you can sort out the problem before help arrives, you can call and update them of the change in the situation. Calling early can literally mean the difference between life and death in some instances.

It is also important to know in advance the nearest location from where mobile reception will work reliably. Ensure your phone is always charged. Alternatively, it may be possible to use UHF radio to raise the alarm. In NSW, Channel 5 is an emergency channel that is sometimes monitored by emergency services. Know in advance from where you can summon help.

- Always call for help before getting involved in any incident.
- Do not enter the mine without arranging for someone to remain on surface.
- Do not risk injury to yourself or others by trying to assist the injured without first carefully assessing the scene of the incident.
- Where there has been a roof collapse, satisfy yourself that you will not be injured by a further collapse.
- Where machinery is involved, ensure that power is turned off.
- Ensure shafts and ladder ways are safe to use.
- If gassing is suspected, do not enter the mine without first testing for gases. There could be insufficient oxygen levels or poisonous gases in the mine.
- Do not allow a person with head or back injuries to climb to the surface using the ladders, whether help is given or not.
- If the SES is called to the site, wait for their help.

Rescue operations can be severely hampered by poor access. Unsecured ladders, ladders that are too short, blower pipes hanging free, crowded shafts and equipment lying around or in the shaft collar, may slow the entry and exit of rescue workers, as well as being a hazard to their welfare. On several occasions rescue workers have had to shift or remove mining equipment to allow a stretcher to be brought up to the surface. Make sure that a stretcher can be brought out from your mine at all times.

An up-to-date diagram of the mine drives/shafts, along with information containing the nearest phone reception point, detailed directions to the mineral claim (from the nearest public road) and instructions to isolate equipment, prove very useful in the event of an emergency. These details will assist anyone contacting emergency services and emergency personnel in the rescue. This information should be displayed in an obvious and accessible place on the mine site.

Certain incidents or near-misses are required by law to be reported to the Regulator. Do not interfere with the accident scene, except to effect rescue.

First aid

It is desirable that all miners have some training in basic first aid. This knowledge may assist in reducing the impact of injuries and/or keep an injured person alive. Contact the Red Cross or local ambulance station for details on first aid courses that are being run in the area.

All mines are required to have adequate first aid equipment for the workplace and ensure each worker has access to the equipment.

It is the law to provide first aid equipment.

Mines rescue units

For many opal and gemstone areas, the State Emergency Services (SES) Mines Rescue Units consist of specially trained volunteers who provide first aid and rescue services when called upon by the police and/or ambulance services. Each member of the group has been trained and certified by the SES in first aid and rescue techniques. Members of each group are required to participate in regular exercises and training sessions to maintain and increase their skills for dealing with mine incidents, road accidents and natural disasters.

All incidents, including mine incidents, can require specialised equipment and training to rescue the person involved, stabilise their condition and minimise further injury. The rescue unit may have 'acro' props, spine boards, and rope access equipment. Rescue operations in NSW are coordinated by the NSW Police Force, who will activate these resources and further specialist rescue resources as required.

In a significant number of mine incidents, people have ignored safe mining practices and warning signs. The volunteers of the SES Mines Rescue Unit have then been called upon to retrieve the fatally injured or injured person, with potential risk to themselves.

In an emergency, remember the following:

- If there is any chance that someone is injured, call 000 and ask for an ambulance.
- Assess an incident site for hazards prior to rendering first aid.
- Good access to your mine will make rescue operations quicker and safer.
- Prompt medical attention may reduce the potential impact of injuries.
- Having a first aid kit and knowing how to use it may help the injured.
- Having an emergency plan with your family or friends, and at the site, can assist others to gain vital information in an emergency response.
- DO NOT allow a person with head or back injuries to climb to the surface. Call for help.

Environmental management

Mining authorisations within NSW are granted under the *Mining Act 1992*, with the objective of encouraging ecologically sustainable development. Mining activities associated with mineral claims and prospecting licences have a small environmental impact. However, cumulatively they can have profound consequences on environmental sustainability and the future land use.

Sound environmental management during mining operations and rehabilitation and restoration of disturbances is fundamental to achieving the agreed final land use (i.e. natural ecosystem and pastoral production). For this reason, mineral claims have environmental conditions imposed as part of the licence and sound environmental practices during opal mining activities is required by law. Some environmental issues such as subsidence can also affect health and safety of people at or near a mine.

Requirements under law

Some general requirements for environmental management and effective rehabilitation of the opal prospecting and mining areas are:

- The mineral claim holder must progressively rehabilitate operations on the mineral claim area, as soon as reasonably practicable, following completion of any prospecting and mining operations.
- The mineral claim holder must ensure that any topsoil that is disturbed in the course of prospecting or mining operations is set aside and reused in the rehabilitation of the mineral claim area.
- Upon the completion of prospecting or mining operations, the mineral claim holder must remove all structures, buildings, mining plant and equipment, tools, vehicles, personal belongings, waste and fences.
- The mineral claim holder must implement all measures to prevent, so far as reasonably practicable, harm to Aboriginal cultural heritage and non-indigenous cultural heritage.
- The mineral claim holder must minimise the extent of any vegetation clearing and surface disturbance, to as low as reasonably practicable.
- Any cleared vegetation is not to be burned. Cleared vegetation should be left on the claim so that it may be used after mining, to provide habitat and organic matter for revegetation to grow.
- The mineral claim holder must ensure that any waste oils, lubricants or liquids are collected in a sealed container and disposed of at a recognised waste disposal site.
- The mineral claim holder must ensure that any old batteries or tyres are disposed of at a recognised receiving facility.
- The mineral claim holder must ensure that the mineral claim area is always

maintained in a proper state of cleanliness. All waste must be regularly removed from the claim area and be disposed of at a recognised public waste disposal site.

Environmental awareness training

It is important that all miners have an appreciation of local environmental issues and understand the principles of environmental management as applied to opal and gemstone mining. This awareness is an important first step to better plan mining activities to ensure there is less disturbance, better management of soil, vegetation and water and eventually a better rehabilitation outcome on mined land.

Practical application

Below is practical guidance to better managing impacts of opal and gemstone mining.

Access

Compaction of soil from vehicles is one of the key environmental impacts resulting from opal mining. Access to titles should only be by approved routes shown on the access management plan. Access tracks to individual claims should be kept to a minimum. Driving off well-established routes is discouraged. If a new track is started, then others will surely follow, aggravating soil erosion and destroying vegetation.

Figure 1 - Multiple vehicle tracks at Coocoran opal field, Lightning Ridge.

Vehicular travel around the fields during wet weather should be minimised or eliminated to prevent damage to roads. This applies especially to black soil plain areas where roads may be closed after a small amount of rain.

Soils and vegetation management

Top soil (red gravels) must be salvaged, stored in stockpiles separately, and not be permitted to mix with sub soil or mullock (white dirt and waste rock). This can be used in the subsequent rehabilitation of the claim. Following mining, topsoil can then be respread over disturbed areas of the claim undergoing rehabilitation. Stockpiles should be low mounds and stabilised to ensure the longevity of the seed stock and to minimise erosion. Vegetation re-establishment is always more successful where top soil has been used.

Stockpiled mullock is to be used to fill excavations and shafts. Where there is an excess of this material, miners must dispose of this excess to an approved mullock dump.

Any cleared vegetation should be spread on rehabilitated areas to serve as a seed source and a habitat for fauna. Cleared vegetation should not be burnt as it is a valuable resource.

Minimise vegetation removal and site disturbance. With fewer disturbances created in operating a mineral claim, rehabilitation will be less costly. Furthermore, it is more likely that the security bond will be refunded in its entirety. It is important to ensure that the conditions of the mineral claim are met. Understand the limitations regarding surface area disturbance and the size specifications regarding tree removal.

Water management

Natural drainage lines, such as water flow resulting from rain, must not be interfered with. Claim conditions stipulate minimum distances within which miners can operate, usually 10 metres. Wherever possible, ensure that natural drainage patterns are not altered. If soil, waste or mullock is located near a water course, entry of this material can cause impacts such as sedimentation downstream.

Be aware of the various improvements on the land, such as drainage channels, contour banks, tanks and dams. Most plans require that these are not interfered with.

Cultural heritage

It is an offence under the law to destroy, remove or damage any Aboriginal relic or site. Where items or locations of potential indigenous heritage value are found, advice should be sought from the regulator that manages National Parks.

Weeds

Prevent the introduction of noxious weeds and pests into the opal fields. Be familiar with the weeds that cause problems in the area and look out for them. Mineral claim holders are responsible for controlling weeds on their claims. Hudson Pear is a significant problem within the Lightning Ridge district. It propagates by attaching its thorns to shoes, vehicle tyres, native animals and stock. It is important to ensure that activities are not also causing the movement of this weed from one location to another.

Figure 2 - Hudson's Pear is a significant problem in the Lightning Ridge district

Mullock or waste storage

Mullock or waste rock material should be taken to an approved mullock storage area. Generally, the amount of mullock stored on a claim should only be that required to effectively backfill shafts, with some extra to allow for settling. Where mullock is temporarily stored on a mineral claim, it should be done in such a way as to not smother top soil. It must not be spread out over the surface. It must not be used for temporary road construction.

Puddling operations

All puddling operations must be carried out in accordance with the conditions of authorisation. All silt generated as a result of puddling operations must be contained within the bunded designated storage area. Bunds should not be constructed from the highly dispersive silt. When puddling operations cease, rehabilitation must be carried out as per conditions of the authorisation.

Rehabilitation

Opal mining is a temporary land use. Following mining, all authorised mines must be rehabilitated to a standard that meets the agreed final land use. Effective environmental management, using best practice standards of final rehabilitation, ensures that environmental values and pastoral productivity will not be impacted. The future viability of the opal industry is reliant on meeting community, landholder and environmental expectations of sustainable development. In Lightning Ridge, almost all mining areas are on pastoral properties and final land use outcomes usually default to ongoing pastoral use.

Figure 3 - Back filled open cut at Canfells, NSW, eight years after being planted with native vegetation

Enforcement

Bonds or security deposits are only released when it has been demonstrated that the obligations of final rehabilitation have been met and claim conditions fulfilled.

Compliance audits of mineral claims are routinely conducted by the Regulator.

Geology and prospecting

It is important that opal or gemstone prospectors and miners understand the basic geological concepts associated with the opal or gemstone fields in NSW.

Understanding the geology can assist mine operators with managing safety, especially with ground instability, as well as making decisions regarding prospecting, to minimise time and effort. There are several factors that may have contributed to opal formation which will be highlighted below.

Characteristics of opal and examples of geological characteristics

Opal is composed of silica and water. The water content is usually between 3 and 10% by weight and may be as high as 20%. The silica in precious opal occurs in very small spheres (50 to 500 X 10-6 millimetre in diameter) arranged in a regular pattern. Partial cementing of the spheres traps the water within the spaces between them.

Precious opal is translucent to transparent and exhibits bright spectral colours or a play of colours when rotated. In precious opal, the spheres are generally greater than 150 x 10-6 millimetres in diameter and packed in a regular way. This regular arrangement of spheres and voids (spaces between spheres) deflects white light and separates it into a range of colours. The colour observed is largely determined by the sphere size.

The ground conditions in Australian opal fields vary considerably between mines and even within individual mines.

South Australian opal fields

The claystone and sandstone around the South Australian opal fields range in strength from ‘very weak’ when weathered near the surface to ‘weak’ at depth. No matter how strong it is in compression (‘squeezing’), it is about 15 times weaker in tension (‘pulling’). If the rocks fail in tension, they give little warning of failure. Typical mines are located at a depth of less than 20 metres but some go to 35 metres. At these depths, the rock in the roof of the excavation is usually under strain.

The wider the excavation is, the greater the tension. Too much tension and the rock fractures, geological structures open up and rock-falls occur. These falls occur rapidly and can involve a large amount of rock. They have killed many people on the South Australian opal fields.

The strategies outlined in this guide aim to minimise the likelihood for these rockfalls occurring by limiting the height and width of the tension zone and by designing the excavation in such a way that the ground can carry the loads.

Lightning Ridge and White Cliffs opal fields, NSW

At Lightning Ridge, opal mainly occurs as horizontal seams and in nodular form ('nobbies') within claystone ('opal dirt') layers ('levels') beneath relatively thick sandstone layers. At White Cliffs, opal tends to form horizontal seams within claystone and sandstone/siltstone. At both locations, opal is also found replacing various types of fossils – those at White Cliffs (along with other features) are clearly consistent with a cold marine environment of deposition for the host rocks, whereas those at Lightning Ridge (along with other features) are consistent with a riverine environment.

The weathering model of opal formation best explains the occurrence of opal at both Lightning Ridge and White Cliffs. In this scenario the rock sequence has been weathered (or kaolinised), tens of millions of years after its deposition, to release silica into the groundwater, which has then passively pooled in voids with permeability barriers (typically within claystone layers) to precipitate opal from solution. The exact controls on the groundwater flow and localisation have been subtle and complex. At Lightning Ridge, the base of the overlying sandstone may be silicified to form what is referred to as 'steel band' and is clearly related to the formation of opal.

The weathering event which formed opal pre-dates the deposition of overlying riverine gravels which have later silicified to form silcrete. The formation of 'shin-cracker' (silicified claystone/sandstone beneath the gravels) appears to have accompanied silcrete formation.

There is some evidence to support the association of opal occurrence with faults (or lineaments as they appear at the surface) but as faults are common throughout the opal fields this connection is tenuous. There is evidence at Lightning Ridge that some faults may define the boundaries of prospective and non-prospective areas and were active after the weathering event which formed opal.

Along with lineaments (in places, identified as lines of box trees), other surface features such as 'blows' and 'box hollows' have been assumed to be related to opal-prospective areas. Blows are gravel- and clay-filled fractures which penetrate for many metres into the ground. In places, they cross-cut opal seams and clearly have formed after opal. Box hollows are circular to elliptical internal drainage areas, which also post-date opal formation.

Figure 4 - Example of a fault exposed in a mine drive

Elementary prospecting

Without prior knowledge of where any opal is located, the claim holder is only prospecting for opal. In these circumstances, the layout of the mine should be planned to assist with the discovery of the opal. Once opal has been found, true mining for opal can commence.

Prospecting on the opal fields of Australia has been traditionally carried out by sinking a shaft to intersect the prospective opal-bearing rock, such as claystone, then developing drives horizontally to test the value of the opal dirt. The shafts were traditionally sunk by hand or by Caldwell drill as shown in figure 6, which bored a 1 metre diameter hole. The process is relatively slow and expensive.

Figure 5 - Caldwell drill

The end of the 1980s saw the rapid introduction on to the fields of the 230 millimetre diameter auger drill, as depicted in figure 7. This technology redirected the emphasis in prospecting away from shaft sinking, and gaining access to the opal clays, towards testing for the existence of the necessary overlying sandstone and looking for 'colour' in the small sample of clays that the auger drill produced.

In most cases, the use of auger drills to assess the opal bearing potential of an area is quicker and more cost effective than shaft sinking. Layers of silcrete up to a few metres thick, that are common on 'plateau' areas, slow the rate of drilling considerably. Silcrete may occur as large slabs or as scattered boulders through the soil profile as shown in figure 8.

Figure 6 - Soil overlying blocks of silcrete

Smaller diameter (+120 millimetre) percussion drilling rigs (figure 9) have also been used with some success. Although they create a smaller hole, with smaller samples than auger drills, they are quicker and readily penetrate silcrete and deliver a more accurate sample.

Figure 7 - Percussion drill

Mine planning and design

Planning a mining operation is important regardless of whether the operation is large or small. Planning should be carried out by all mine owners and/or mine operators before any serious effort is put into developing a mine. It should also be done at every stage during the life of the mine, where decisions are taken which change the way the mine will operate.

It is an essential process which allows the mine operator to consider many factors which will influence the overall safety, ground stability, economic viability, life and production of a mine. It includes the selection of suitable equipment, layout of surface installations, location of shafts, means of entry and exit, mining and ground control methods and ventilation of workings.

A map of the mine needs to be drawn by a competent person and kept up-to-date. This plan is often kept with the Mine Record Book on the surface (usually in a vehicle) in case it is necessary for emergency services to have access to it.

Competent opal or gemstone miners should be regarded as an important source of information for relatively inexperienced miners.

Planning and design for an underground mine

Mine planning has three main purposes:

- It gives the operator the opportunity to consider the situation at hand and determine methods, resources and capabilities to reach the desired outcome in the future.
- It creates a reference point to look back on and determine what worked, what didn't work and what could be improved.
- By designing and planning the mine layout as well as the mining activities, the stability of mine workings can be maximised and the richest opal bearing areas can be extracted with minimal risk.

Shaft location

The first consideration is the location of the access shaft, because it is around the shaft that other facilities need to be placed.

With a new mine area, the shaft location will be determined by the best available information. It is poor planning to establish the shaft directly over any potential opal bearing ground. It should be placed some distance from any area that may be extensively worked later. This will avoid stability problems near the shaft.

Any mine that has been previously mined will usually have mine shafts. Prior to starting work, check the following:

- ventilation is adequate
- ground conditions at the base of the shafts

- whether there is a shaft pillar present (for example, with a room and pillar design)
- the amount of ground support required.

This information determines which shaft to use as an access shaft. Other points to consider are the proximity of workings in neighbouring claims and the potential for the slope of the land, to allow surface water to flow into mine shafts.

Remember, the shaft is the most frequently used travelling way at the mine and takes time and money to set up. It needs to be safe and secure for a long time to ensure a good return on investment.

The next consideration is the need for a second means of access. A secondary shaft should be established as soon as practicable after underground mining starts to ensure there are two means of exit in case of an emergency. Planning the location of a secondary shaft may also be influenced by ventilation requirements.

When these planning decisions have been made, it is possible to begin laying out surface facilities to provide the most efficient configuration for temporary stockpiles, loading areas, work benches, generator set and compressor. When making these decisions, consider that some facilities should be well away from the shafts to avoid the hazard of working around deep open holes.

Ventilation

Ventilation considerations should be an integral part of the overall mine plan. The location of ventilation shafts or drill holes should be based on the mining sequence throughout the life of the mine. Any secondary ventilation system should be designed to deliver fresh air to all active headings.

Where mining will occur on a new mine area, it will not be possible to determine the direction of flow of the natural ventilation until at least two shafts or drill holes have been connected underground. However, where underground workings already connect to two or more shafts or boreholes, a check on the ventilation flow should be carried out before the final decision about the access shaft is made. It is generally preferable to have the access shaft set up on the intake side of the ventilation circuit. This ensures fresh air always travels down an access shaft.

The design considerations for a ventilation system are discussed in more detail in this guide to assist in developing a ventilation plan. The risks associated with ventilation must be addressed in the mine SMS.

Mine layout

A mine layout design should include the size of the openings and the time and effort required to develop the drives. The layout of drives should be designed to effectively prospect the entire claim and allow a decision to be made as to whether it contains opals or gemstones.

The most effective way to achieve this is to design the drives on some form of grid pattern based on a plan before work underground begins. Where drives intersect at an angle less than right angles, there is a risk that fretting of the corner will rapidly occur, reducing support for the roof.

The width of any opening underground should be carefully considered before it is mined.

If the mine operator suspects that there could be water in old workings alongside the mine, then auger drilling from the surface, along the boundary of the claim or mining title, can be carried out to determine the exact location of these workings, if access to them cannot be made. This will identify these workings, as well as, a build-up of water. It is an important safety consideration to know where other workings finish and the amount of water in those workings. Then the location of underground drives can be planned to ensure that there is enough distance between the mine's drives and the old workings (especially if they are filled with water). This would make sure that when mining, there is no breakthrough into those old workings. This could otherwise cause a very dangerous underground water or mud inrush.

Materials handling

It is critical to install hoisting equipment which has enough capacity and is compatible to the mining method. It must be designed to hoist varying sizes, shapes and quantities of equipment, as well as the mined rock. Hoisting rope capacity must satisfy the prescribed safety factors and meet the necessary duty without overloading.

Attention should be paid to the requirements for transporting and storing explosives and flammable liquids around the gemstone fields. This is extremely important for the protection of people and property.

Power distribution

The development plan should include provision for power distribution. This may include the generation of electricity and compressed air.

Power requirements must be determined with consideration to calculated maximum demand. The installation and progressive extension of any services should be carefully costed and installed to minimise maintenance.

Ballrooming

Historically, the mining method often used on the gemstone fields was 'ballrooming'. Ballrooming (i.e. when large unsupported spans are opened up) is strongly discouraged. This outdated and unsafe method of mining has been one of the contributing factors in many of the fatalities that have occurred in the past.

Other problems associated with this method are:

- There is no forward planning and the excavation proceeds at random.
- Unsupported brows of shafts creep and rock layers part, creating unstable ground conditions at the most important opening of the mine.
- Large unsupported roof spans may become unstable and may cause a fall of ground.
- People are required to work in an unsafe environment.
- Developing the mine even further will cause openings of further ground and increase the roof spans, risking roof falls.

Operator training for plant use and maintenance

Safe work procedures (SWPs) should be developed for operating plant and equipment and utilised by all workers. These procedures should be developed from a job safety analysis. Refer to the manufacturer's or supplier's information.

All workers should be trained to a suitable level of competency appropriate to their work functions.

Control of noise from plant

Excessive noise can damage hearing, whether by being exposed to a single loud noise (such as a gunshot), or by a moderately loud noise over a period of time.

Noise is measured in decibels (dBA) and the recommended dosage (exposure) is set at 85dBA over an eight-hour period. It should be remembered that every increase in noise level by 3dBA is a doubling of the noise level.

A spot measurement of an electric jackhammer on the gemstone fields gave a reading of 101-112 dBA. At this dosage, permanent damage would occur within 10 minutes.

Damage to hearing can, depending on severity, be a ringing in the ears (tinnitus), unable to hear what others are saying or others having to shout.

Standards in noise can be found at Safe Work Australia's website. Mine operators should determine the conditions and sites where hearing protection must be worn at their mine for both workers and visitors. Hearing protection devices should conform with Australian Standard AS 1270 Acoustics - Hearing Protectors.

It is the mine operator's responsibility to provide hearing protection.

The best type of protection is to reduce or eliminate the noise at its source. This may be as simple as fitting a new muffler to a petrol or diesel engine or by placing distance or a barrier between the engine and people. A noise suppression jacket can be fitted to a pneumatic jackhammer. Earmuffs are very effective when worn properly, however should be used as a last resort.

Guarding on plant

Guarding of plant to reduce the risk of injury or fatality is a legal requirement under WHS laws. Inadequate guards on plant and/or equipment can cause amputation of limbs or entanglement of clothes and body or ejection of objects propelled from moving parts. Most incidents of this nature can be avoided by using equipment that has fitted guards to prevent body parts and clothes from becoming caught up in drive mechanisms.

To be effective, guards must have certain characteristics:

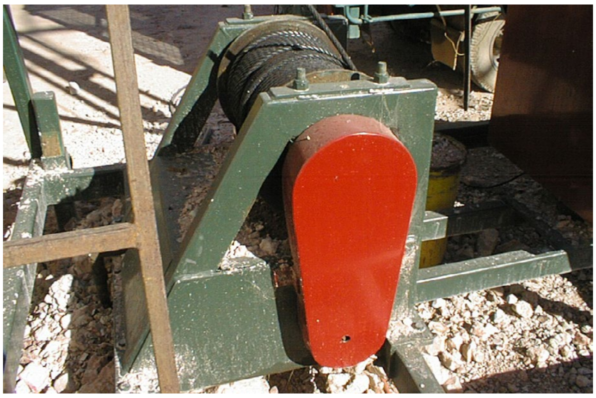
- Be considered a permanent part of the machine or equipment.
- Require a tool to be removed from the machine or equipment.
- Prevent access of a hand or body part to the danger zone during operation.

- Be convenient and not interfere with efficient machinery operation.
- Be designed for the specific job and machine, with provisions made for oiling, inspections, adjustments and repairs.
- Be durable and resist normal wear.
- Not present a hazard to the worker.
- Have suitable guarding of hydraulics hoses, valves and pipes to prevent fracture.

The guarding method to be used depends on a number of things, such as space limitations, production methods, size of material available, frequency of use. Moving machine parts must be guarded individually, rather than restrict access to areas by installing railings or fencing. As a rule, when selecting mesh for guarding, it should be small enough to prevent body parts, such as fingers, contacting moving parts. Otherwise, a hand, hair or piece of loose clothing can easily become caught in the drive mechanisms and cause substantial injuries or fatality.

Figure 8 - Exposed belts and pulleys on a hoist

Figure 9 - Guards on a hoist



Mechanical blowers

All machinery, including blowers, must be operated in accordance with the manufacturer's recommendation.

Cyclone blowers are large truck mounted single or duplex fans, driven by diesel engines of approximately 150 HP. and connected to a cyclone type hopper. They operate like a giant vacuum cleaner, sucking excavated claystone from underground and drawing it to the surface through pipes about 22.5 centimetres in diameter. In the process, they draw large volumes of air through the mine workings. Ventilation is generally good along drives where a blower is operating. However, this air flow will cause an accelerated drying of the claystone walls, often resulting in fretting walls and pillars. When operating a blower, regularly check for noisy bearings which may indicate imminent failure. This will put the fan out of balance and, under high rotation speeds, could result in violent disintegration of the fan, potentially resulting in injury. If in doubt, have the fan checked by a qualified mechanic, or return it to the manufacturer for examination.

Hydraulic diggers

Manufacturers' or suppliers' information regarding operation and maintenance should be adhered to. Hydraulic diggers are usually powered by an electric or diesel hydraulic power pack, or directly from a blower. Because of hydraulic diggers' superior output, they eliminate the hard work associated with using electric or pneumatic jackhammers. They are more commonly used by professional miners. Diggers have been responsible for the amputation of fingers, crushed hands and feet, as well as severe lacerations to operators and persons standing nearby.

Below are safety points to consider when using a digger:

- Diggers must be operated in accordance with manufacturer's recommendations.
- Hydraulic diggers should only be operated by people who have been properly trained and are competent.
- Use piping rather than flexible hydraulic hoses if possible, to reduce the risk of hose and coupling failure, which may result in injury or fatality.
- Route hydraulic hoses away from the access shaft if possible, to reduce exposure to potential 'pinhole' failures of hydraulic hoses. If routing hoses away from people is not possible, consider a barrier guard such as running hoses inside a pipe.
- All hoses should be in good repair. Be aware that an injection of hydraulic oil can cause gangrene, resulting in loss of limbs or fatality.
- The machine should not be modified without obtaining the manufacturer's consent in writing.
- Understand the manufacturer's operating instructions before using it.
- Keep all workers behind the operator at all times. Retracting digger arms can crush so keep hands and feet clear.
- The mechanical action of digging a gemstone layer transmits shock loads via the tower to the roof (backs). This can cause falls of ground above and around the digger.
- Beware of being caught between the digger and props or pillars. If the digger kicks free from the roof, workers can become pinned against them.
- Diggers can, and do, tip over. Be prepared at all times.
- Be aware of any rock that may become dislodged, as this could indicate an area of unsafe ground.
- Always wear a hard hat, hearing protection, safety boots and goggles. Gloves may also be needed, as scratches associated with gemstone dirt tend to become infected.
- Before going forward with the digger, or doing any maintenance, the bucket should be lowered and the machine isolated from the power source.
- Regularly check hydraulic hoses for any damage. Don't hang them over a ladder or pinch them on sharp corners. Bursting hoses can be a safety

hazard.

- When reversing the digger, reduce the oil flow at the divider to stop the digger bucking and help prevent crushed toes.
- Always lower the bucket before leaving the machine.

Mining practice

Underground mine practices, for the purposes of this guide, includes work relating to shafts, ladderways, room and pillar design, ground support, roof support, barring down and ventilation, as well as related surface activities to support the underground operations.

Safe mining is about properly managing risk and by following known systems and strategies that have worked to minimise injury or plant damage for the mining industry over many years. Most activities on a mine site can be potentially hazardous. By taking a risk management approach to these hazards, the probability of injury can be reduced.

HAZARD - MINING PRACTICE

- Open mine shafts represent a potential threat to people and animals.
- Objects falling down shafts represent a potential threat to miners.
- Poorly set up shafts are difficult to access.
- Shafts without a pillar at their base are prone to collapse.
- Rock in the mine roof moves and settles over time. Loose rock may fall at any time.

Conducting mine inspections

Regular inspections and documentation of the mine workings, and the equipment used, are ways of using a risk management approach. Regular inspections should be conducted to ascertain the condition of plant, structures, services and equipment used in connection with mining.

Close attention should be paid to ground conditions both in the shafts and mine workings. Inspections should be carried out at least once a day when the mine is working.

The date, time and who carried out the inspection should be recorded in a mine record book so that comparisons can be easily made that may indicate changes in the work area. These may be subtle changes that might not be recalled from previous inspections if they are not documented.

Planning the surface layout

A tidy and well-organised mine site results in many benefits, such as improved safety and increased efficiency.

Plant and equipment should be located in areas where they are of most use, where they do not interfere with surface traffic or contaminate air entering the mine. Some basic rules:

- Situate your working areas on the surface well away from the shaft(s) to reduce the risk of falling down the shafts.
- Always keep generators, operating blowers, compressors and any stationary engines away from a shaft or drill holes so down casting air does not carry exhaust contamination underground into the mine air.
- Flammable liquids such as petrol, diesel and other toxic or explosive solvents should be stored away from the mine. This will remove risks associated with seeping fuels, volatile vapours, fires and explosions.
- LPG gas cylinders are of concern, because the gas, being heavier than air, can drop to the ground and sink into a mine shaft. The gas behaves like a liquid as it 'flows' along the floor of a drive. If a match is struck to light a cigarette, an explosion may occur.
- Gas cutting equipment, such as cylinders of oxygen and acetylene, should be stored on the surface and only be used in well-ventilated areas.
- Chemicals and batteries should be stored and disposed of in a responsible manner.
- Explosives should be stored in properly constructed containers or licensed magazines.
- The surface area around the shaft collar should be free of tools, rocks and objects that could accidentally fall, or be knocked down the shaft.
- Vehicles should be parked away from the shaft collar to keep this work area free of obstructions and allow emergency vehicles to park next to the shaft, if required.

With any chemicals or substances, mine holders and mine operators are advised to obtain safety data sheets (SDS) from suppliers to become fully informed about the hazards, storage requirements and other matters relating to the use of each product.

Shafts

A shaft is a vertical opening from the surface to the underground workings. It maybe square, rectangular, oval or circular in cross section and can be used as an access for people, equipment, services and ventilation. The cross section of a shaft plays an important role.

- Square shafts are the simplest to excavate by hand and the walls are readily supported by timber. Used where a single compartment is required.

- Rectangular shafts are similar to the square shaft. They are popular where more than one compartment is required.
- Oval shafts are ideal where principal horizontal ground stresses acting on a vertical excavation would differ greatly at 90 degrees to each other. The flatter part of the oval would be directed to the lower principal stress.
- Circular shafts are best where the principal horizontal stresses acting on a vertical excavation are uniform in all directions.

Safe method of excavation

With predominantly ‘soft’ ground conditions (such as at Lightning Ridge, NSW), most mine shafts are excavated by Caldwell drilling rigs. These drills are mounted on trucks and excavate circular mine shafts that are typically one metre in diameter and up to 30 metres deep. They provide a cost-effective method of gaining access to underground workings.

Caldwell drills produce a circular hole with minimum disturbance to the surrounding ground, usually eliminating the need to reinforce the shaft. Other advantages include quick excavation and the elimination of hazards associated with shaft sinking by hand.

Caldwell drills will not efficiently excavate tough rock formation of varying thickness, which may be found near the surface on some gemstone fields. With this type of ground conditions, mine shafts are usually drilled by hand and shattered with explosives to allow the Caldwell drill to get through.

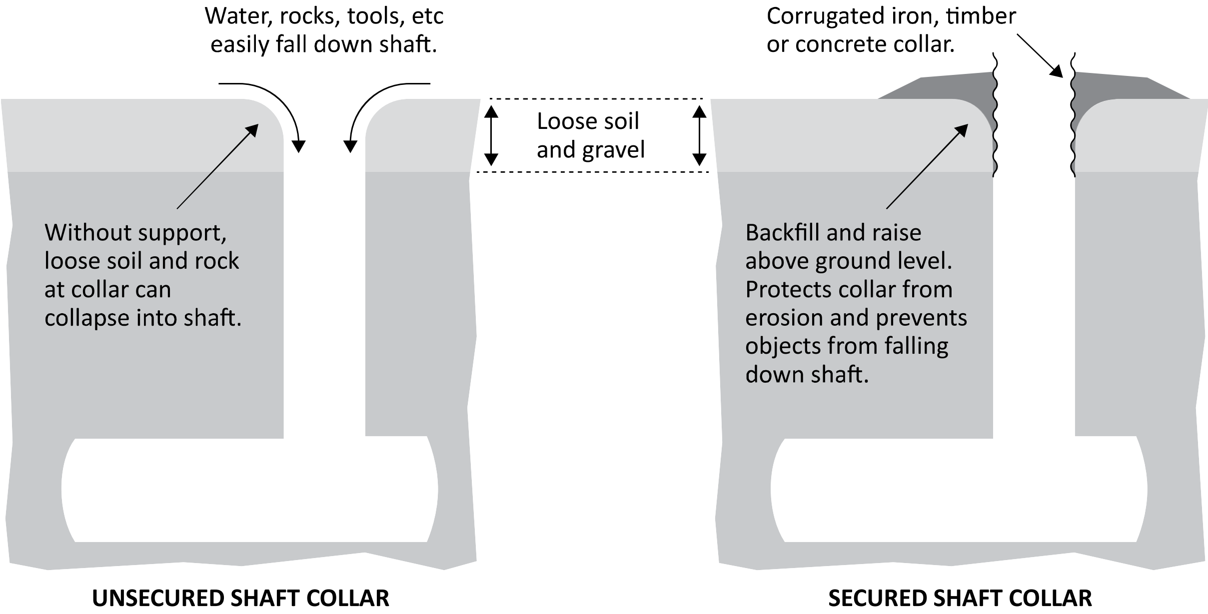
Where ground conditions are not suitable for a Caldwell drill, shafts can be sunk with hand tools and/or by hand drilling and blasting. Blasting involves the drilling of a pattern of inclined and vertical blast holes, typically one to two metres deep.

Shaft safety

When installing shaft collars and ladders, consider using fall arrest or restraint equipment. When installing ladders there should be a restraint device and harness that is independent of the shaft structures.

When using ladder ways to access and egress the mine, wearing this equipment can prevent injuries in the event of slips, trips or falls. See below anchorage lines or rails. If the design of the shaft will allow it, consider erecting staging platforms every six metres. A hard hat should always be worn while in a shaft.

Figure 10 - Shaft collars



Fitting out a shaft

The equipment used to fit out a shaft will depend on its application. The following practices are regarded as essential to manage equipment, materials and allow people access.

Stabilising unconsolidated ground

Unconsolidated ground is commonly found at the top of the shaft. To prevent falls of ground and collar erosion, timber, corrugated iron tubing or a concrete ring should be installed to reinforce and retain loose material at the collar.

Figure 11 - Hazardous shaft collar with loose gravel

Figure 12 - Collar protected by galvanised iron

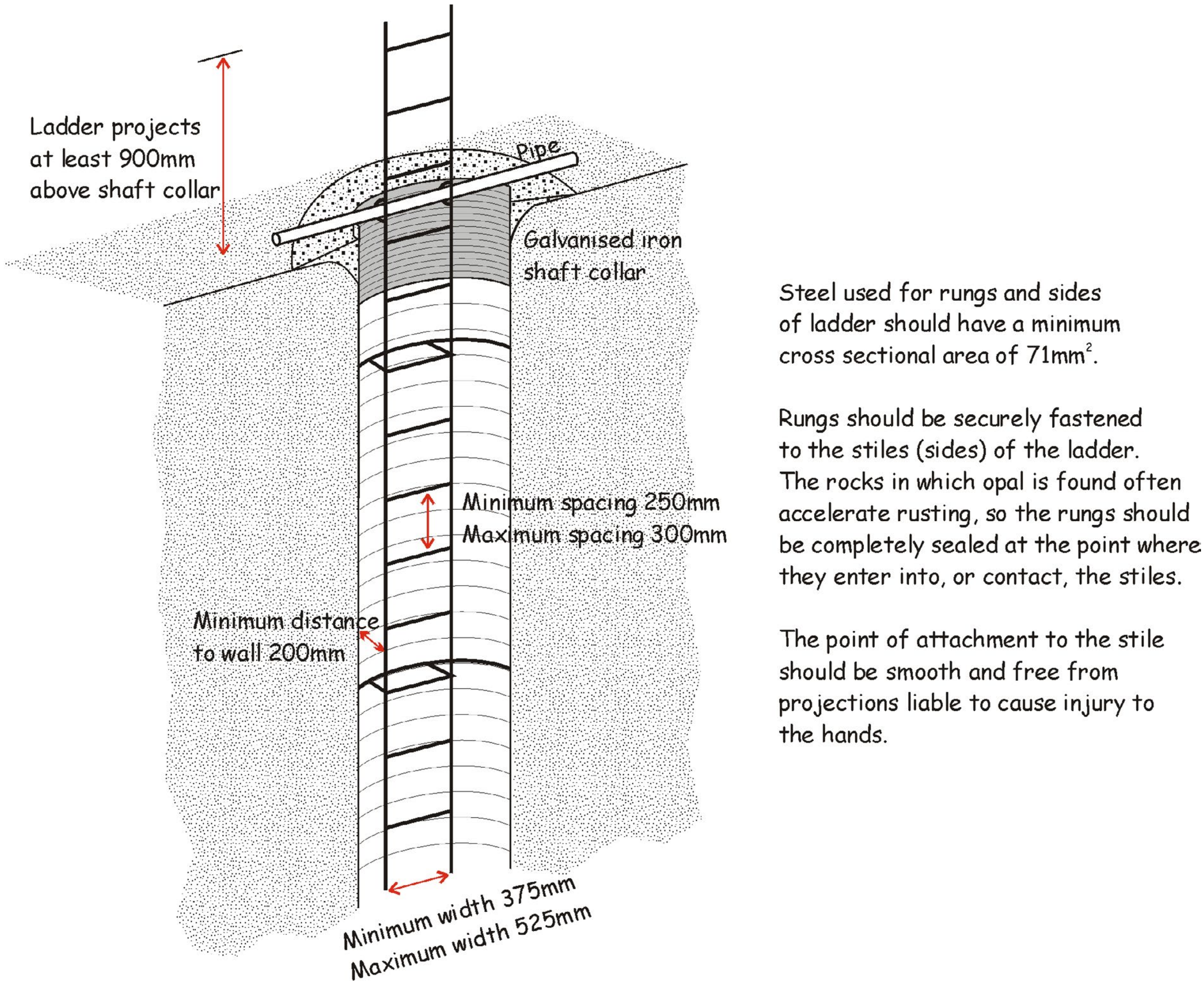
Snakes are more likely to fall down mine shafts with unsecured collars. Preventing them from getting into a shaft tends to be simpler than dealing with them after meeting them unexpectedly underground.

Ladders

Strong, rigid ladders constructed of steel should be used for people accessing and exiting shafts. The ladder must be securely fastened to a load bearing steel crossmember (50 millimetres by 50 millimetres). The steel crossmember must overhang either side of the shaft diameter by at least 20%. The ladder must overhang at least 900 millimetres above the collar of the shaft. The ladder should be securely fixed at regular intervals to the wall of the shaft, and securely coupled to each other.

When climbing a ladder safely, it is important to have three points of contact at all times. Only one person should be on the ladder at any time.

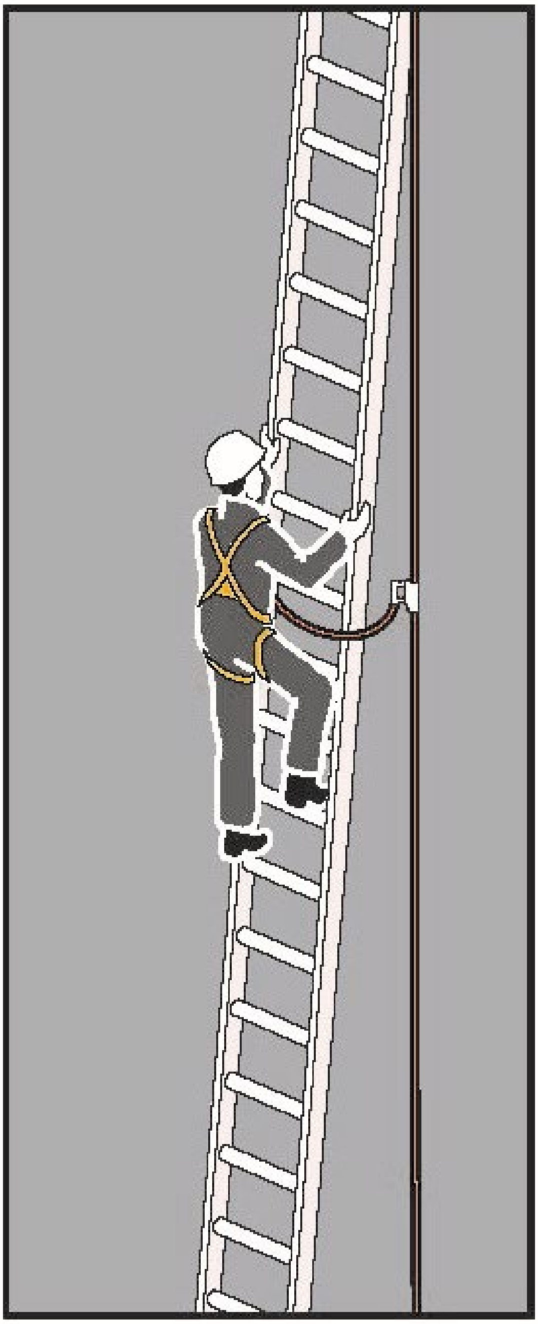
Figure 13 - Recommended layout for access ladders



Safe Work Australia has a model code of practice - Managing the risk of falls at workplaces. It suggests the use of anchorage lines or rails when using ladders. The following explains what the code of practice suggests could be used to minimise the risks when using a ladderway in an opal or gemstone mine:

Anchorage lines or rails (when using ladders every day)

The code of practice recommends that anchorage lines or rails are used with a long vertical ladder. Anchorage lines or rails are temporary or permanent fall-arrest systems, which can be installed to provide continuous fall protection for people using ladders (see figure 15).



Safety considerations:

- temporary systems comply with the AS/NZS 1891 series of Standards
- the locking device is attached to the frontal attachment point of the harness and the lanyard assembly is a maximum of 300 millimetres length
- the point of connection onto the ladder by the climber is near the base of the ladder to allow the connection before ascending begins and to provide continuous connection to the disconnecting point when at a higher level
- free fall is limited to a maximum of 600 millimetres
- permanent systems are made of wire or rail construction and are installed according to the manufacturer's instructions.

After a fall, remove the system from service and have it inspected by a competent person before it is used again.

Figure 14 - With the use of an anchorage line system, the person climbing has continuous fall protection by being attached to the anchorage line and harness

Hoisting equipment

Suitable hoisting equipment should be installed at the surface to raise and lower equipment and materials. Hoisting equipment is discussed in detail later.

Services in shafts/auger holes

A shaft/auger hole provides the shortest distance from the surface to the underground workings. It is most convenient to fix electric cables, communication wires and compressed air hoses to the wall of the shaft. Using the shaft/auger hole reduces the length of services, capital and maintenance costs. Services should be securely fixed to the wall of the shaft/auger hole and away from shaft conveyances.

Keep your main shaft free of services.

The shaft that the services are installed in should not be the main shaft used daily to access the claim workings, but the second shaft, used in emergencies to access the surface.

Ventilation ducting

Ducting of various diameters can be fixed to the shaft wall to ventilate shafts and drives. When small diameter ventilation drill holes intersect workings, other means of ventilation may be used. These options are discussed in more detail later.

Shaft access

The main access shaft should be kept free of unnecessary equipment to allow free and easy movement of materials and personnel. Blower pipes are often used in the main shaft to raise broken material. This restricts access for people and makes it difficult to manage equipment being lowered to underground workings.

Figure 15 - Poor surface layout resulting in restricted shaft access

Rescue services are also unable to readily enter the mine with their equipment and raise injured people to the surface. The success of any rescue depends very much on prompt treatment and the rapid evacuation of injured people to professional medical care. Do not get caught in a situation where a rescue is delayed by poor mine access. Blower pipes should be kept out of the main access shaft. Suitable drill holes or a second shaft can be maintained for the blower pipe.

Shaft protection

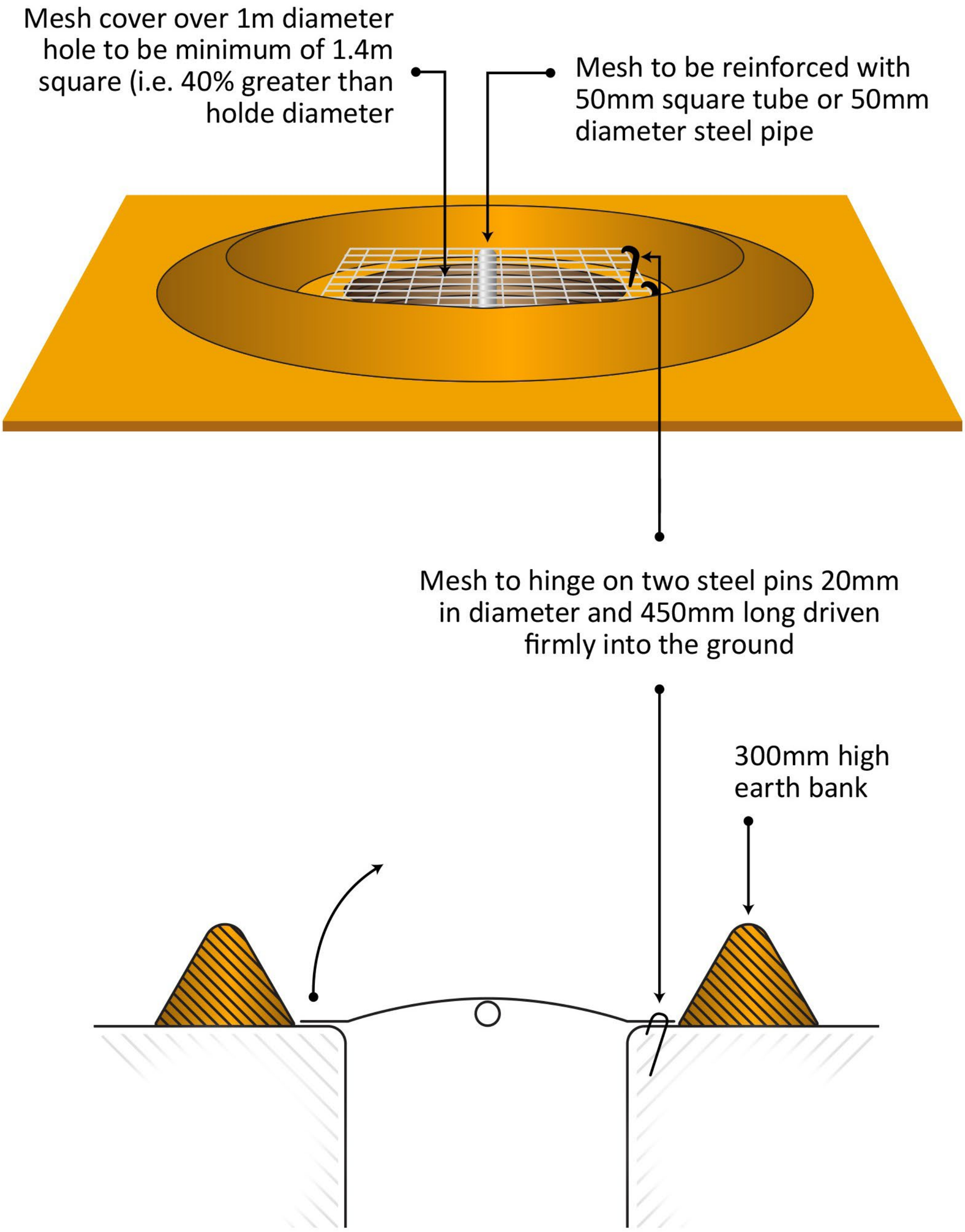
Adequate shaft protection should be used to prevent falls into the mine and to discourage theft. Refer to figure 14 for an example. Suggested protection methods include:

- extending the collar sleeve, cribbing or tubing above the ground level by at least 500 millimetres
- installing a lockable gate arrangement over the top of the shaft that can be locked when no one is working the mine
- providing a fenced enclosure around the collar area that is kept clear of tools and equipment
- installing a sign at the collar indicating that someone is working below.

An open mine shaft represents a serious hazard. When working near one, cover it to remove the risk of falling in. Immediately cover shafts when underground work is finished to remove the risk of people or animals falling in.

Protection of openings and holes

Figure 16 - An example of protecting openings and holes would be wire mesh supported by posts with a reinforced top edge.



Shaft pillar

Although a shaft is a vertical excavation in solid ground, it needs to be protected and adequately supported. Shaft pillars serve the purpose of ensuring the integrity of the bottom section of the shaft. As shown in figure 16, a good shaft pillar forms a support area around a substantial part of the shaft.

Figure 17 - Example of a bad and good mining practice in relation to shaft pillars

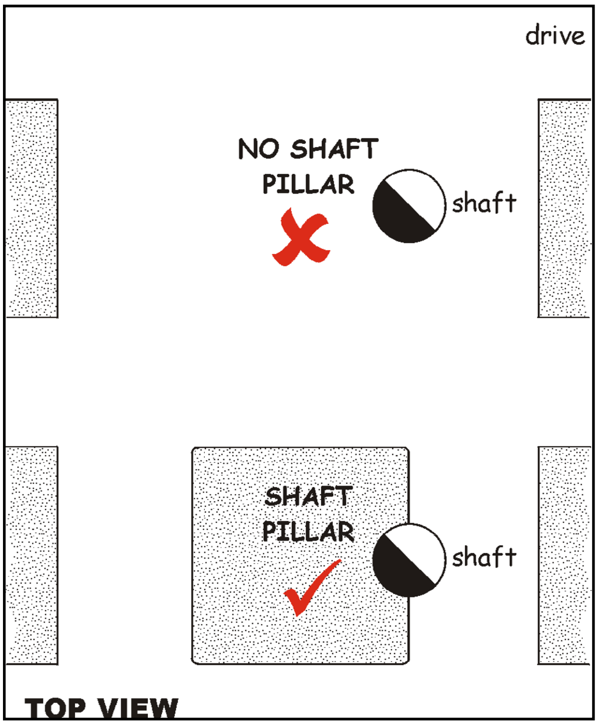
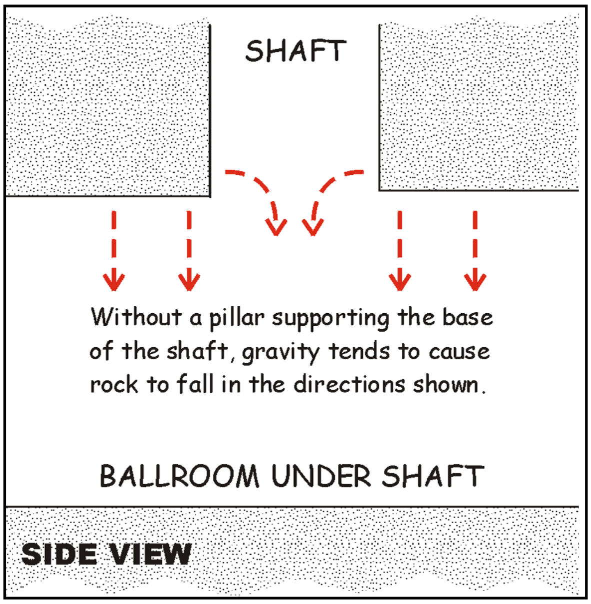


Figure 18 - Tendency for rock to fall when a shaft pillar is missing



For maximum effectiveness, there should be only one drive intersecting the shaft. The practice of 'ballrooming' at the bottom of the shaft is not recommended because it takes away all support, leaving exposed ledges of rock at the base of the shaft.

The ledge is prone to failure when the rock cannot support its own weight and/or it contains lines of weakness. This has caused serious incidents and fatalities.

HAZARD - SHAFTS

Cracks in the bottom of a shaft are indicative that it is failing and should be regarded as unsafe. The shaft should no longer be used and work should stop.

Size of underground drives and openings

Without knowledge of the geological structures, the strength of the roof strata and the stresses surrounding the opening, it is difficult to know what width the drives should be.

To overcome this lack of knowledge, it is good mining practice to design mine openings to be of a minimum width until a thorough understanding of the ground conditions in the particular claim are known.

There are also other benefits from keeping drives narrow.

In the same mine, consider two drives of differing width. Drive A is taken 2.4 metres wide, while drive B is mined only 1.2 metres wide. The volume of material that has to be dug, transported to the shaft, hoisted to surface and then taken to a mullock dump or stockpile will be twice as much in drive A as in drive B. Put another way, it will take twice as long to advance the drive 1 metre in A as it will in B.

REMEMBER

Small roof spans reduce:

- the risk of roof collapse
- the need for support (such as props)
- the cost of mining by saving on roof support and saving on the cost of handling unbroken material.

Barring down

Barring down or scaling is the process of removing loose rock from the side and back (roof) of underground mine workings.

The type of tool to use for barring down is a good pinch bar that is sharp at both ends. The bar should be long enough to reach the back (roof) without standing too close to the suspect ground. Never use a blunt bar.

Barring down should be carried out:

- at the start of each day
- at a new workplace
- whenever ground conditions require.

Barring should be done at the face to be worked, and along all routes that will be using for access to the face. It should be done at least once a day before work starts.

Figure 19 - An example of a loose end – a rock layer that needs to be barred down

Figure 20 - Barring down

Reading the ground is an important aspect of barring down. Before starting to bar down, thoroughly examine the ground to determine the pattern of cracks or joints in the rock. Look for the smaller blocks that may be easily removed first. These may be acting as keystones for a large and unstable block.

Before beginning work:

- ensure that the roof immediately above your head is sound
- without putting yourself at risk, clear the area that may fall of any equipment
- ensure that you have good footing and a clear escape route
- 'read the ground' before starting work.

When the job has started:

- work from safe ground towards the bad
- remember to 'sound the rock' before and after, standing in a safe area to do so. A hollow 'drummy' sound will be heard from unsafe rock that needs to be barred down.
- be sure your bar is in a line away from your body. Falling rock can slide down the bar or push the bar away from you.
- don't take chances.

Ventilation

An adequate amount of air should be provided to remove airborne dust, heat, gases and fumes.

During development of the mine, forced ventilation through ducting can be used. However, this should be replaced by ventilation holes, where air is exhausted, as soon as practicable. Mines using diesel equipment will need to comply with specific limits. More detail regarding ventilation is provided later.

Training for the mine operator

Miners require training, an understanding of safety procedures and a good working knowledge of equipment. They must learn to work in confined spaces that have no natural light and are artificially ventilated. Caring for health and safety should be a prime concern.

The best training a new gemstone miner can get is to work with a competent and experienced miner to 'learn the ropes' for a while.

Unfortunately, not all experienced miners are necessarily competent, as some take unnecessary risks when dealing with hazardous situations.

REMEMBER

- Shafts need to be secure so people or animals cannot fall into them.
- Good access is important so shafts and ladders must be maintained.
- A shaft pillar is needed to maintain the integrity of the bottom of the shaft.
- Regular barring down is essential to locate loose rock and remove it.

Mine surveying

Surveying involves taking measurements of points, or features, on the surface and underground to determine their location in relation to each other.

Surveying is important, because inadequate surveys may cause the following:

- Insufficient ground pillars to be left that would destabilise workings and/or surrounding areas.
- Poor development and exploitation of room layout.
- Mining into an adjoining mine or claim without consent, possibly resulting in criminal charges, civil legal action and loss of personal credibility.
- Wasted time and effort in trying to link up with ventilation drill holes and mine shafts.

Survey measurements can be used to :

- Locate an area on the ground so that it can be registered as a mining title, such as a mineral claim or a similar mining title.
- Locate features of a claim or proposed mine area, such as corner pegs, the boundary, shafts and drill holes.
- Locate underground workings relative to the surface boundaries of the claim.
- Determine where new mine workings will intersect older mine workings.
- Locate the position of geological structures within mine workings. This is useful for safety and optimising opal or gemstone recovery.
- Plot the above items on paper as maps drawn to scale. These maps can then be used for planning mine workings.

The basic surveying procedures outlined offer reasonable accuracy and use relatively inexpensive instruments. Not confident about using these methods? Seek assistance from more experienced miners or friends.

Basic mine surveying instruments

The quality of instruments and the procedures used will influence the accuracy of any survey. When working on small areas, such as claims that are 50 metres by 50 metres, which contain shallow and uncomplicated underground workings, professional survey accuracy is not required.

Magnetic compass

A magnetic compass is used to determine the direction of features and reference points relative to magnetic north. It consists of a magnetised needle suspended so that it spins freely. It provides a measurement of the direction that the compass is pointed, ranging from zero degrees up to 360 degrees.

On every magnetic compass:

- North is 0°
- East is 90°
- South is 180°
- West is 270°

All compasses point to magnetic north, provided they are held in a horizontal position, are of reasonable quality, undamaged and are not used near steel or iron (e.g. claim posts, vehicles, hats with steel wires, glasses with iron frames or screws).

Two popular types are the survey and prismatic compasses.

Figure 21 - An example of a magnetic compass

The direction of any feature or reference point, relative to the position of the compass, can be determined by holding the compass and viewing the object through the sighting line of the compass. The magnetic bearing of the object, in degrees relative to north, can then be read from the compass.

The correct procedure for using a compass is normally given by the manufacturer and may vary from the above description

There are many compasses available commercially, including many that are unsuitable for accurate surveys. A poor-quality compass will often be inaccurate by a few degrees and will be difficult to read consistently.

Checking a compass

It is good practice to regularly check the accuracy of a compass. This can be done by comparing readings from your compass against another compass, over the same lines.

Measuring tape

A measuring tape is designed to measure linear distances in metres. The tape can be constructed from steel, linen or fibreglass or a length of string knotted at regular intervals. The length of a tape may vary from three metres to 100 metres depending on the intended use.

A measurement can be made between two or more points by placing both ends of the tape over the points and noting the reading. For an accurate measurement, the tape should be held horizontal, appropriately tensioned to remove excess slack and read over the reference point, to avoid a parallax error.

Figure 22 - Parallax error

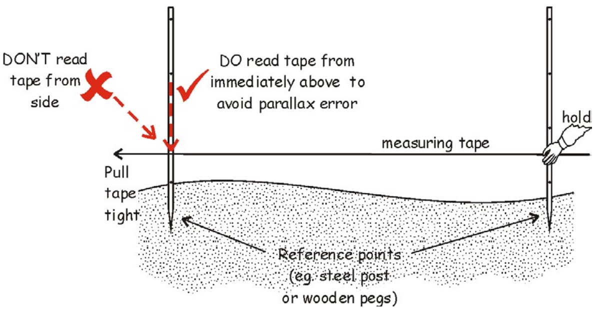


Figure 23 - 100metre measuring tape

As the difference in height between two points increases, so does the measured linear error. In cases where there is a large variation in the height between points being measured, a correction to the linear measurement may need to be applied to maintain accuracy.

Long tapes, such as a 100-metre tape, are very useful for surface surveying while 30-metre tapes are better for underground surveying.

Protractor

This instrument is usually made of plastic, is calibrated in degrees and is used to measure angles in the horizontal and vertical planes. Horizontal angles can be measured on a plan or between two lengths of string, at the point of intersection.

Vertical angles can be measured by fixing a nail at the centre of a protractor and suspending a length of string, with a small weight attached, from the nail. If the base of the protractor is held in a horizontal position, then the plum bob line measurement will read 90o.

A piece of string running from the intersection of the horizontal reference line and the plum bob line will then indicate the angle of the item being measured.

Figure 24 - Horizontal angle measurement using string and a protractor

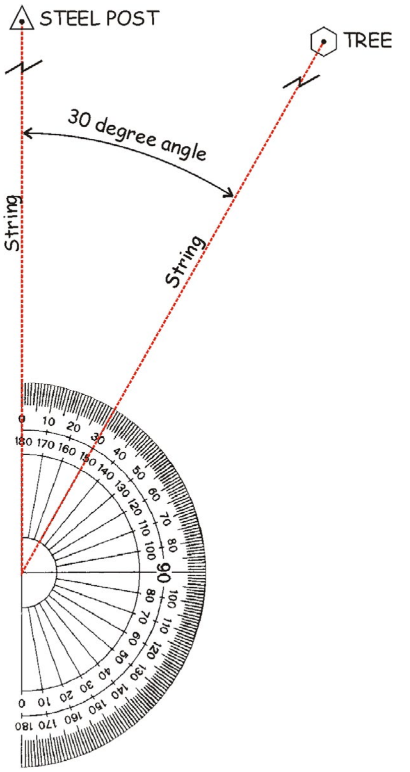
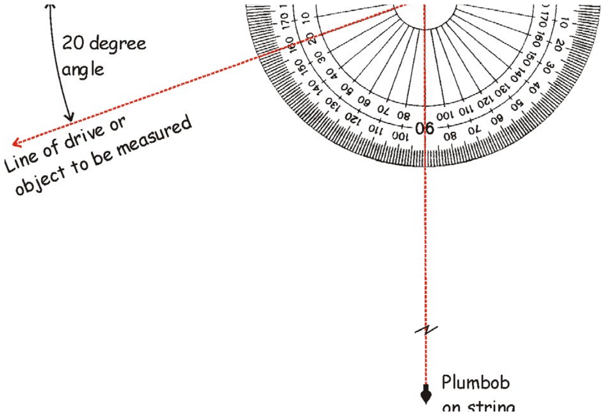


Figure 25 - Vertical angle measurement using string, plum bob and a protractor



Builder's twine

Builder's twine is useful in linking two or more reference points for measuring angles, defining the shape of an area, and observing the difference in elevation between points.

Ordinary string may be used, but reasonable strength is required to tension the string and remove the slack over long distances.

Levels

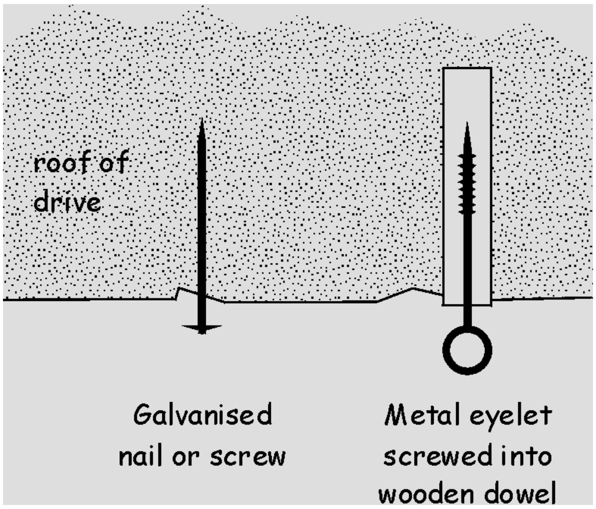
A string level can be used to determine the level of a length of string suspended between two points. A spirit level will do the same task.

A level between points can also be established by using a length of clear rubber tubing filled with clean or coloured water.

Station pegs

Station pegs are required to fix reference points on the surface and underground. These can be made of wood, steel or plastic depending on the application.

Figure 130 - Example of station pegs fixed in the roof of an underground opening



Accurately recording the location of a shaft

There are two methods of locating a shaft in relation to the boundaries of a claim are:

- bearing and distance method
- triangulation method.

Bearing and distance method

This method requires a measurement of the distance and bearing from a "known" point such as the corner peg of the claim (refer to Figure 25b).

Where reference points are not visible at ground level, steel posts can be used to provide the required clearance. Where reference points are not accessible, underground traversing can be used which may require the establishment of temporary reference points.

The information obtained may be plotted on paper using basic geometry instruments. This will help to prepare a surface plan and refer to underground workings.

Instruments required are:

- measuring tape and magnetic compass
- pencil and paper
- ruler and protractor.

Triangulation method

This method uses the intersection of two measuring tapes, attached to two separate reference points, to form a triangle. It can be used to locate features on the surface, provided the reference points are accessible

Instruments required are:

- two measuring tapes
- pencil and paper
- drawing compass
- ruler.

As shown in Figure 25c, measure from the first corner post to the centre of the shaft and then measure to the second corner post. The position of the shaft can be plotted on paper, with a ruler and compass, to allow further planning to take place. It is also necessary to know the distance between first and second corner posts so that the triangle can be drawn.

Figure 131 - Using bearing and distance to locate a shaft in relation to a claim boundary

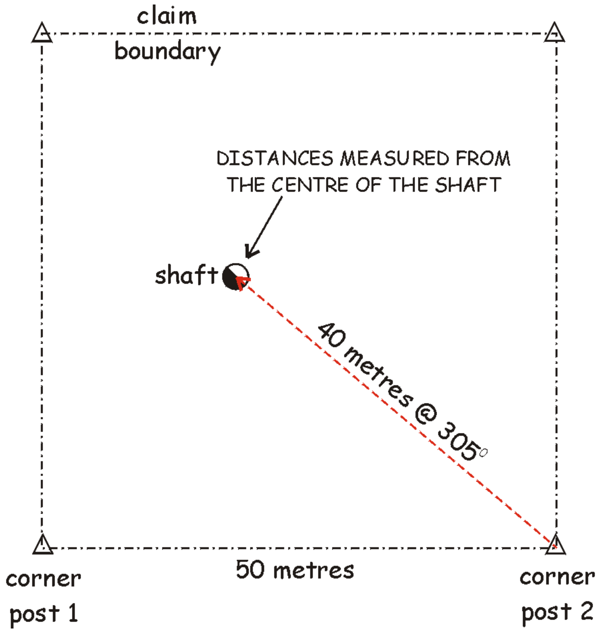
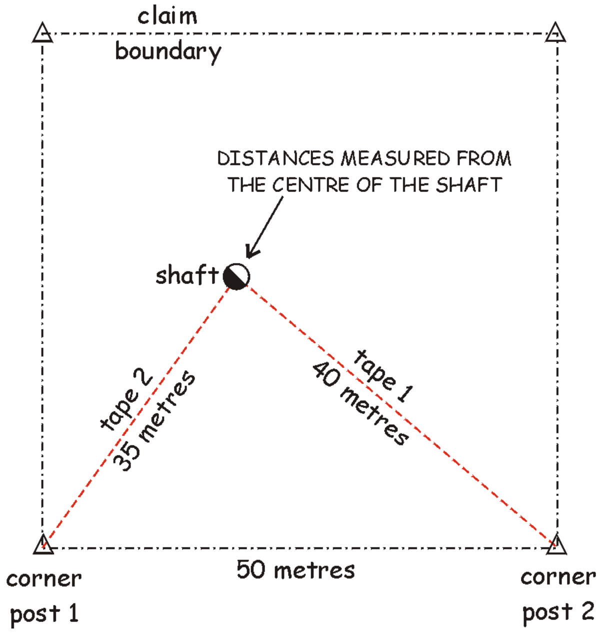


Figure 132 - Using triangulation to locate a shaft in relation to a claim boundary



Establishing references points above and below ground

Once a mining claim has been obtained, all corners of the area must be defined on the surface. It is strongly suggested that permanent reference points be established, particularly those close to the access shafts.

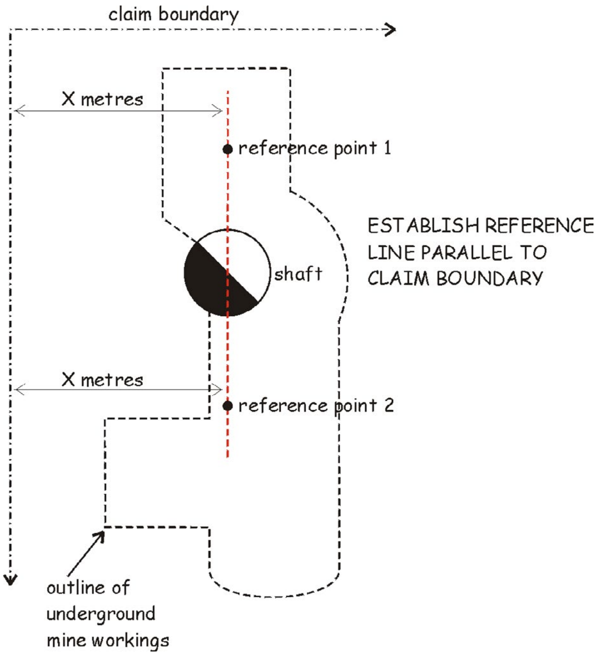
To ensure the integrity of a survey, the following is recommended:

- Ensure all station pegs are in the correct location and securely fixed.
- Ensure station pegs are readily accessible for measurements to significant mine features.
- Establish at least three permanent reference points from which linear, angular and level measurement can be made.
- To transfer reference points underground, it is recommended that at least two reference points be fixed at the collar of the main shaft or opening and used to begin underground survey.
- Establish temporary reference points to locate surface openings, if it is not practical to use the main points.

Reference points at the shaft should be measured from the closest boundary and be parallel to that same boundary. They should be constructed so that the direction of the lines between these can be accurately transferred underground.

Reference points at the shaft should be measured from the closest claim boundary (to improve accuracy) and should be fixed to give a line parallel to the claim boundary.

Figure 133 - Establishing a reference line on the surface with reference points at the shaft



Transfer of surface reference points to underground

This procedure involves transferring a reference line, between the two reference points situated at the collar of the shaft, to one or more levels below ground. The reference line will have a direction at the surface and can be linked to the boundary of the claim area (refer to Figure 25e).

To complete this task a straight, rigid length of wood, preferably with a regular cross section, can be placed between the two points at the shaft collar. Two lengths of builders' twine are tied to the piece of wood and dropped to the depth of the required workings. Another length of wood is tied to the bottom of the twine. Ensure that the bottom length of wood is balanced and that the knots are in line. Align the top piece of wood parallel to the reference line on the surface.

After the bottom wood has stopped moving, mark the roof or floor of the workings with two or more points and then fix two station pegs as permanent markers. Figure 25f shows an alternative location of reference stations underground where there is only access to one side of the shaft.

A reference line can also be transferred underground by using the shaft ladder, provided the ladder is installed vertically and not twisted.

Figure 134 - Establishing a reference line underground

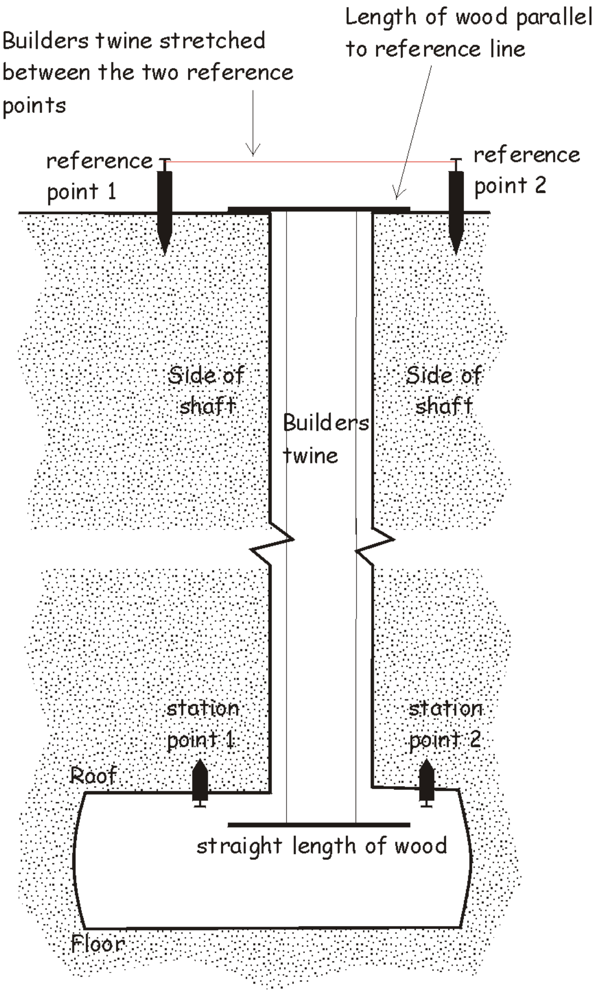
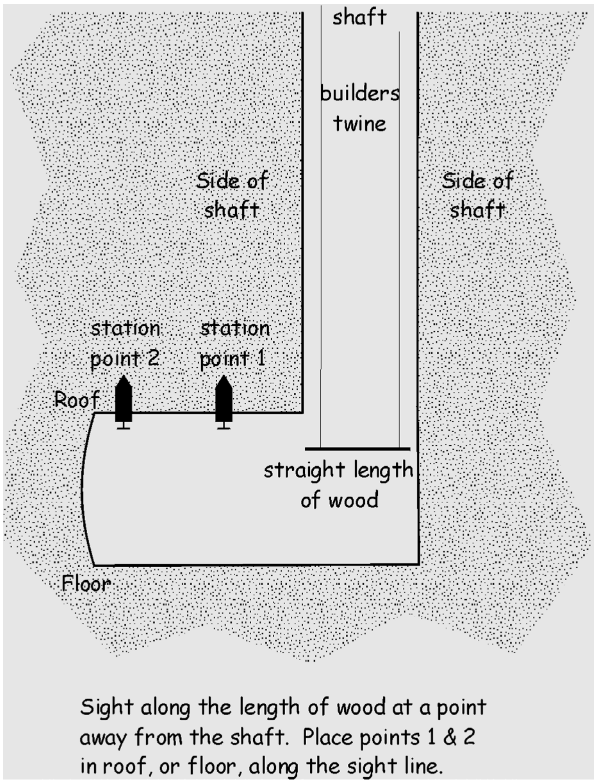


Figure 135 - Establishing a reference line where access is restricted to one side of the shaft



Establishing an underground traverse

Traversing is a surveying method which uses linear and angular measurements to determine the distance and direction of underground workings. It allows the information to be plotted on a plan, if required. This method is accurate provided all reference points are accessible, rigidly fixed and preferably on the same plane to minimise linear measurement errors.

Where the elevation between the starting point and finishing is substantial, a linear correction may be required. In most cases, this would not cause a problem.

Underground surveying can often cause problems for gemstone miners, as there can be variations in readings from magnetic compasses due to the influences from steel ladders, electrical cables, tools and jackhammers. A degree variation over fifty metres can result in a 0.75 metre error in the survey.

For this reason, methods of underground surveying have been devised which do not require a magnetic compass to be used in the mine workings. One of these methods is the Lok and Leo method which uses a shaft ladder as a reference line.

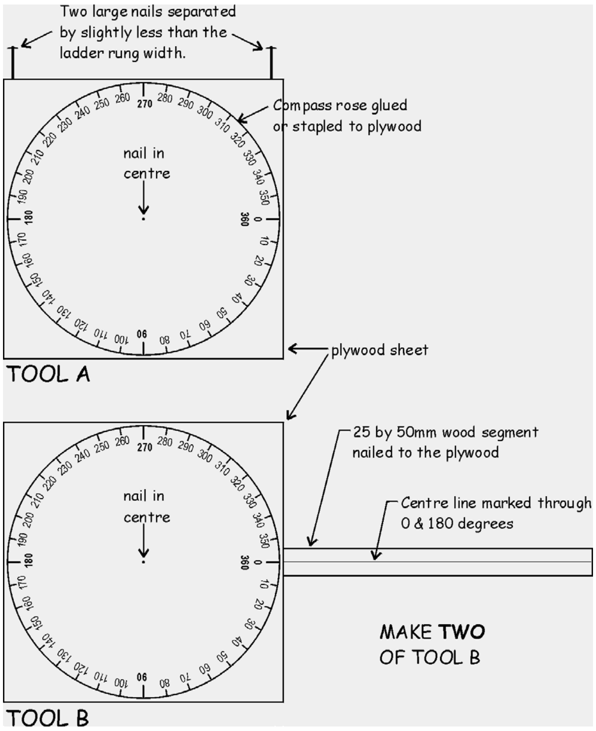
Lok and Leo method

For this method to be successful, it is important that the ladder be vertical and not twisted.

Items required to build the survey tools shown in Figure 25g include:

- two survey sheets (compass roses) as used when registering a claim
- three pieces of marine or form ply of similar size
- two pieces of 50 millimetre by 25 millimetre softwood up to one metre long
- nails
- one roll of black cotton or fishing line.

Figure 136 - Equipment used for Lok and Leo survey method



Take tool A and place it on a rung of the ladder in a horizontal position and have an assistant hold it in place (refer to Figure 25h). Make a loop on the end of the string line and place it over a small nail in the centre of tool A. Run the cotton to tool B which you have already placed at point 2.

Move tool B so that the string line runs along the centre line on the timber to the small nail in the centre (refer to Figure 25j). Record the bearing from tool A and the distance between the two centre nails, making sure to stabilise tool B so that it doesn't move (refer to Figure 25i).

Place the second tool B at point 3 and repeat the process (refer to Figure 25k). If necessary, take tool B and use it at point 4.

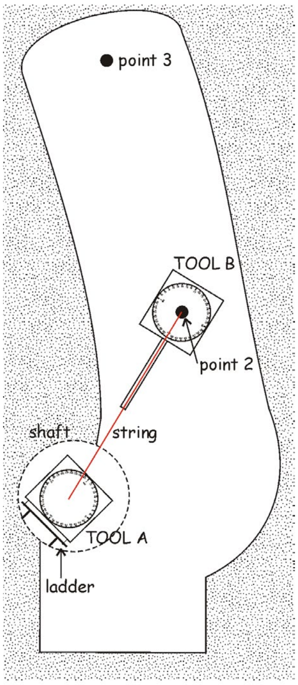
Once finished with the measurement of the points underground, take the equipment to the surface. Use the readings from underground to mark out the same pattern on the surface. This will show your position underground on the surface. With practice, this process becomes quick, precise and can be used for several other applications.

To avoid having to repeat the whole process each time a survey is required, it is recommended that permanent reference points be established in the roof at each set up location.

Figure 137 - Tool A being held on hoist ladder

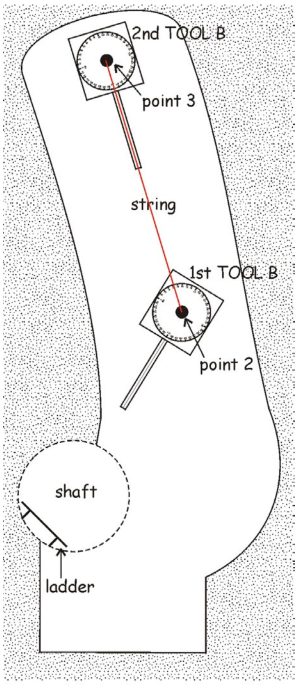
Figure 138 - Taking the first reading

Figure 139 - Equipment set up for the first reading



Between the nails on tools A & B;
(1) Record the distance
(2) Record the bearing

Figure 140 - Equipment set up for the second reading

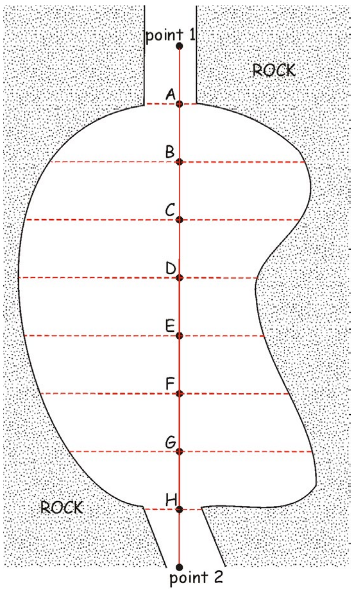


Between the nails on tools B & B;
(1) Record the distance
(2) Record the bearing

SURVEYING A LARGE OPENING

Surveying a large opening can be completed by measuring the walls of the opening area. Another simpler method is involves establishing a reference line divided into a number of reference points at set intervals (refer to Figure 25l). The distance from the reference points to the wall is then measured, perpendicular to the reference line.

Figure 141 - Reference line method of surveying a large opening



POINT 1 TO POINT 2 - Reference line.
Measure the length & angle.
POINTS A TO F - Points from which measurements to both walls are taken, perpendicular to the reference line..

Planning the workings and surveying them underground

Using the traverse method

Traversing takes place after the workings have been dug to allow the workings to be plotted on a plan.

However, by carrying out the process in reverse, it is possible to plan the underground workings on paper first, carry out the necessary survey underground and then mine according to the plan.

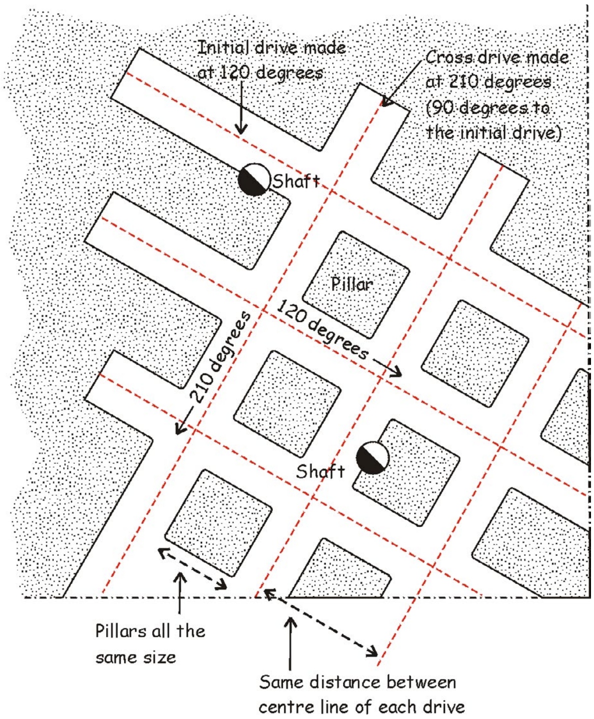
This becomes important when designing a room and pillar layout, or when mining multiple levels to place pillars in line with those on the other level. It also allows planning for the percentage of ground extraction which will be undertaken or when the claim boundary will be reached.

To carry out drawings for mine planning, use a scale ruler. A good scale for this work is 1 to 200 (1:200) (i.e. 1 centimetre = 2 metres (or 200 centimetres)) but any other useful scale can be used.

Designing room and pillar layout for an opal or gemstone mine

- draw the boundaries of the claim
- decide the position of the access shafts
- decide on the width of the rooms (drives) and pillars
- plot the room and pillars on the plan
- take measurements and angles off the plan and transfer the information underground using the methods described previously (refer to Figure 25m).

Figure 142 - Example of laying out angles for a room and pillar design



REMEMBER

- Good survey technique allows planning and accurate development of room and pillar layout. Appropriate size rooms and pillars maximises the stability of the mine workings.
- Accurate surveys will assist in avoiding boundary disputes that involve criminal or civil legal action.
- Having an accurate survey of any nearby workings, as well as your own underground workings, is vital if there is a body of water found in the adjoining mine. This will enable control measures to be put in place, such as keeping an accurate distance from those workings, to prevent any potential water inrush which could be fatal.
- Ferrous (iron based) metals will cause substantial errors in surveys undertaken with a magnetic compass. Care must be taken to keep away from these metals when undertaking a survey.

NOTES

Roof failure

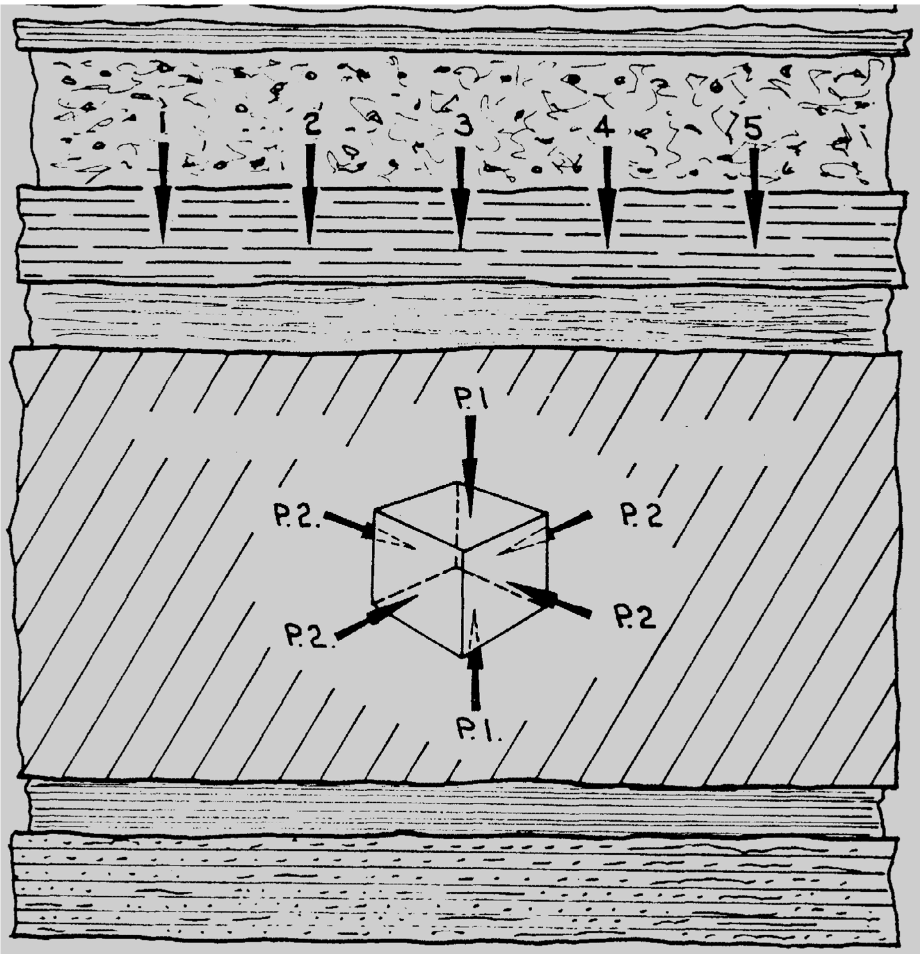
The primary objective of ground support is to prevent or control roof collapse. From the point of view of safety, the roof is the most critical component. The mine's walls, and to a lesser extent the floor, must also be considered.

Ground conditions vary between opal fields and claims, due to different stress distributions and rock types.

Forces to be controlled

The rock strata surrounding an opal level has different strengths and characteristics. As the workings become deeper, the weight of the upper strata acting on the opal level increases. As demonstrated in the example below, the vertical compressive force on a cube of rock within the opal level is denoted by P1. The effect of this pressure is to compress the cube in a vertical direction. Because the cube cannot expand horizontally when 'in constraint', there is a horizontal compressive force denoted by P2.

Figure 26 - Forces acting on opal level

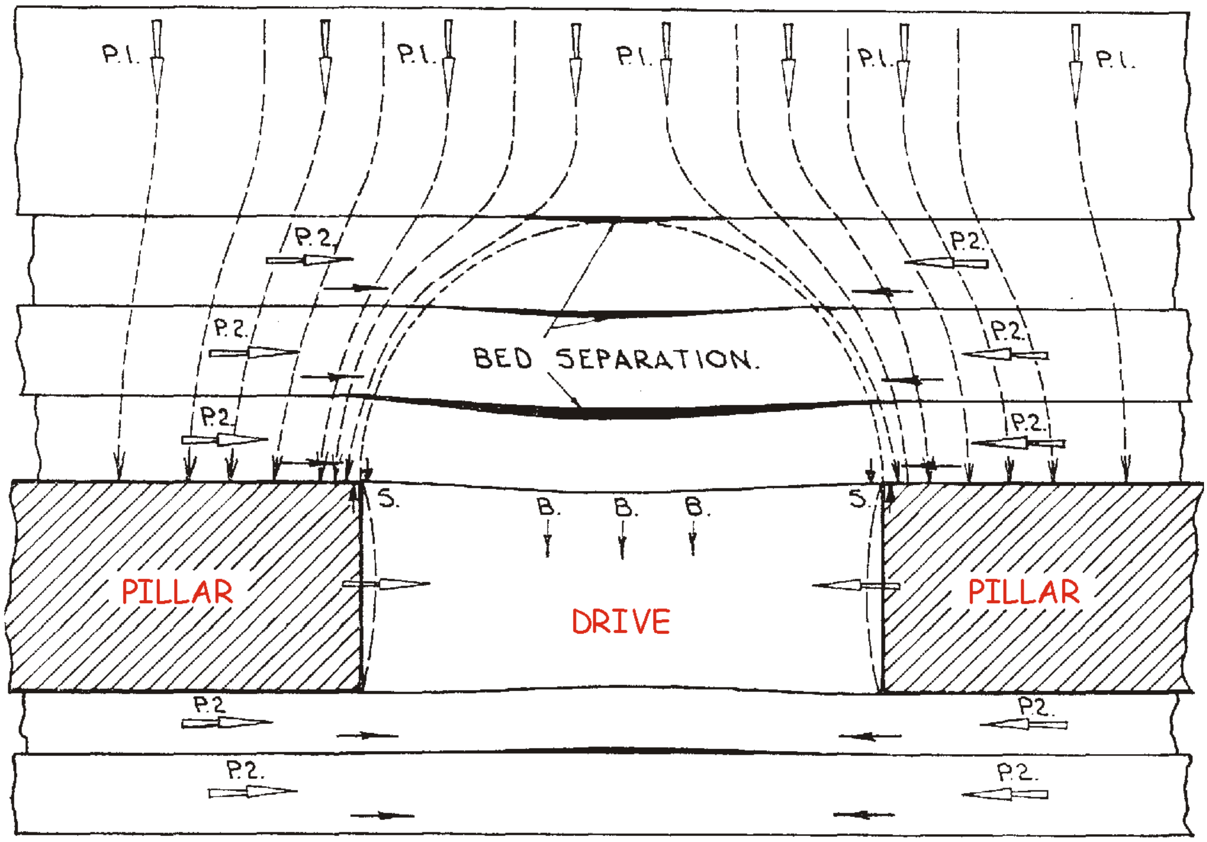


When the opal level is removed by mining, the overlying strata is disturbed and tends to move downwards, acting under the force of gravity and sideways into any void because of horizontal pressure.

Stress distribution around underground openings

If a void is excavated in rock underground, the load previously carried on the rock in the opening will be transferred to the rock surrounding the opening, or to the pillars (supports) within the opening, or both.

Figure 27 - Redistribution of forces around a narrow excavation



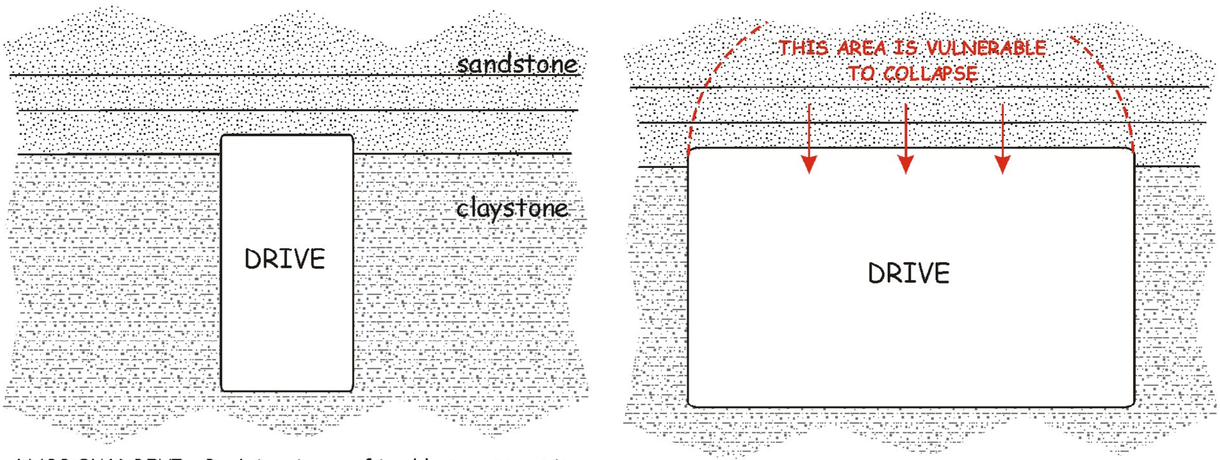
The redistribution of stress causes deformation of the roof, walls and floor, all tending to move towards the void. Immediately above the opening is a relieved zone that is caused by bedding plane separation, said to be de-stressed. The de-stressed strata will be in the form of an arch and the vertical compressive forces P1 will skirt the de-stressed region and form a 'pressure arch'.

When the strata that forms the roof of an excavation fails, it tends to fall out roughly in an arched shape. The beds forming the roof tend to bend under their own weight, forming a zone of tension. Rocks are much weaker in tension than in compression. If the rock strength is unable to support the weight, then the rock will fall.

Figure 28 - Arch formation following a roof fall

In the de-stressed area above narrow mine drives, the strength of the rock is generally more than adequate to support the weight of the rock. With increasing drive width, the weight of rock in the de-stressed area increases substantially, inevitably to a point where its strength can no longer support its weight. In this situation, a roof failure or rock fall will occur.

Figure 29 - Relationship between roof failure and drive widths



NARROW DRIVE - Rock in mine roof is able to support its own weight.

WIDE DRIVE - Rock does not have the strength to support its own weight. When this stage is reached the roof will fail.

Discontinuities

A discontinuity is a natural area of weakness in the rock formed as a result of a fault, bedding plane, blow, joint or similar feature. Discontinuities substantially reduce rock strength.

In the Lightning Ridge opal fields, most of the rock falls that have injured people or caused a fatality, are associated with one or more significant discontinuities. Miners must be able to recognise discontinuities as hazards and plan their mining operations to minimise the risks associated with them. The ability to identify and understand these hazards is known as being able to 'read the ground'.

Significantly, many opal miners have reported that their best opal has been found in disturbed ground where there were numerous discontinuities.

A discontinuity related movement is a rock fall that occurs as a result of the presence of these areas of structural weakness. Rock movements in these circumstances can loosely be referred to as secondary failures.

Discontinuities need to be identified and managed by either not working in the area, or by providing additional roof/ secondary support.

Generalised descriptions of the major discontinuities found on the Lightning Ridge opal fields are provided below.

Bedding plane

A bedding plane is a horizontal, or near horizontal, surface that separates each successive rock horizon in a layered body of rock.

Figure 30 - Bedding planes

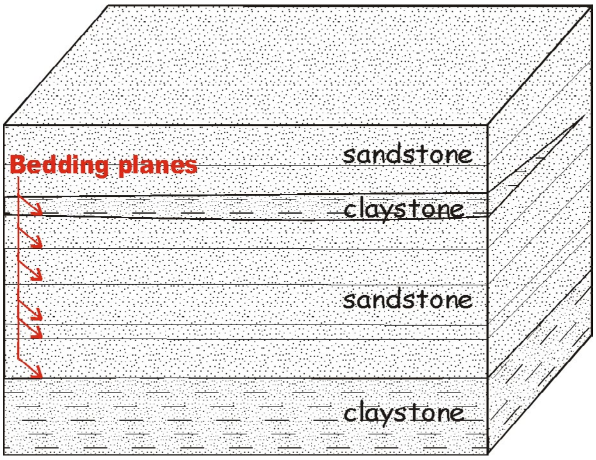


Figure 31 - Bedding planes in roof of a drive

Recognition features include:

- different coloured layers
- different textures, such as clays and sands, between layers
- a separation crack visible along the bedding plane.

Fault

A fault is a break or fracturing of rock that has resulted in two rock masses moving against each other. Some faults show obvious vertical movement of rock layers while others do not. Miners also refer to faults as slides, slippery backs, steps and walls.

Figure 32 - Faults

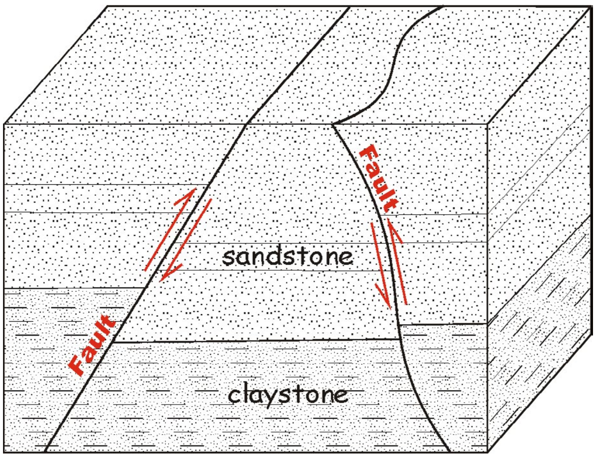


Figure 33 - Exposed fault plane in a mine roof

Joint

A joint is a break or fracture in rock that has not moved or rubbed against each other. Commonly, there may be semi-parallel joints that form a set or system over a given area.

Figure 34 - Joints

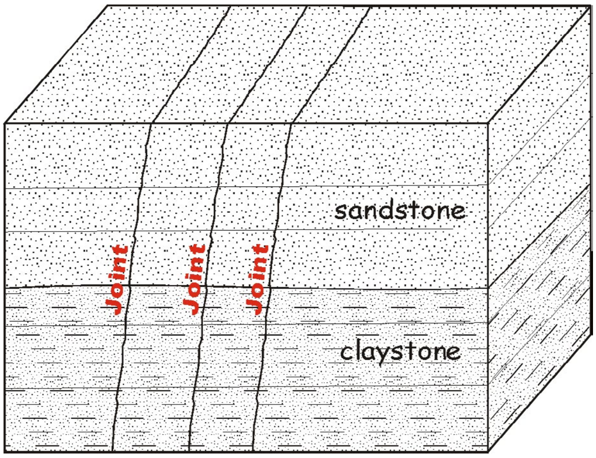


Figure 35 - Joints in a mine roof

Recognition features for joints include:

- cracks with rough textured surfaces
- coated with iron oxide stains
- bleached and lighter coloured than surrounding rock

- tend to run for shorter distances than faults
- show no evidence of relative movement, vertical or horizontal
- old workings may have fine tree roots protruding from the joints.

Blow

Also known as a breccia pipe, a blow consists of rock that has been fractured and deposited in a vertical pipe-like formation. Although there are a range of opinions on how blows form, there is no doubt that they represent fractured or disturbed rock.

Characteristic features of blows include:

- broken fragments of rock scattered through a matrix of clay
- bleached and lighter coloured than surrounding rock
- circular in horizontal cross section
- range from 0.1 to more than 10 metres in diameter.

Blows are commonly quite soft and unstable but can also be quite hard and cemented. Tertiary quartz gravel is sometimes found scattered throughout.

Figure 36 - Blow

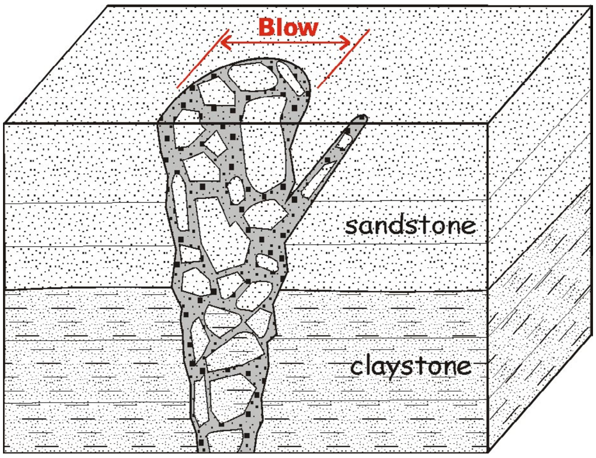


Figure 37 - Blow in the roof of a mine drive

Steel band

In many opal mines, the lowest part of a sandstone layer, overlying a claystone layer, is silicified. This is locally known as a steel band because it is much harder than the surrounding rock.

Unfortunately, some opal miners have made the assumption that it is also stable. Sheets or slabs of steel band have been known to fall and injure people. Furthermore, its presence does not prevent more substantial rock falls.

Figure 38 - Steel band

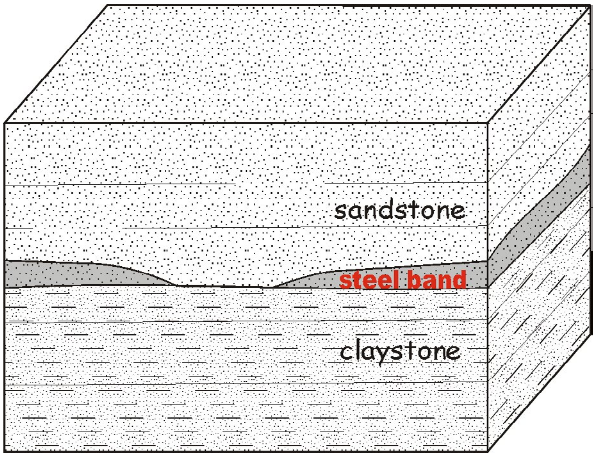
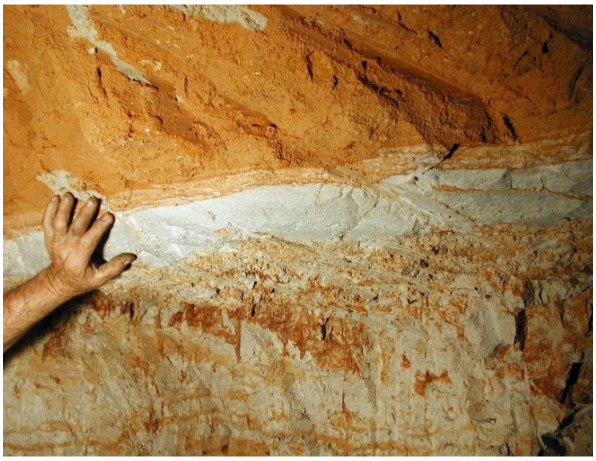


Figure 39 - Steel band (middle layer, light coloured)



Recognition features of a steel band include:

- found at the bottom of sandstone layers
- commonly a grey colour that is distinct from the overlying sandstone
- harder than surrounding rocks and will make a distinct sound when struck with a pick and act differently when being excavated
- presence of traces of potch or precious opal
- may be up to 0.3 metres thick, often varying substantially in thickness over relatively small areas
- a separation crack may be visible between steel band and the overlying sandstone.

Case studies of roof failures

The following case studies are examples of incidents where falls of ground occurred which resulted in a serious injury or fatality.

Glengarry field, 1988

At Glengarry in 1988, a slab of ground about 1.5 metres wide, 5 metres long and 0.1 to 0.6 metres thick fell from the roof when a nearby pillar was being jackhammered. One person was operating the jackhammer while another was observing. The observer was partially buried and suffered serious internal injuries.

The rock fell away from a fault plane that crossed the roof of the drive, which was about 4 metres wide. There were no props under or near the area that fell. It had been open for several years.

Figure 40 - Before view of rock fall

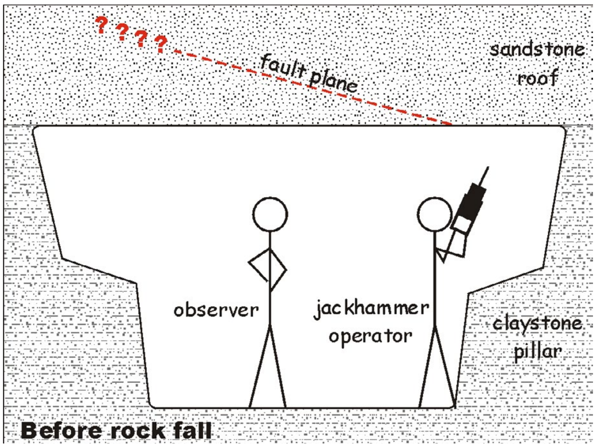
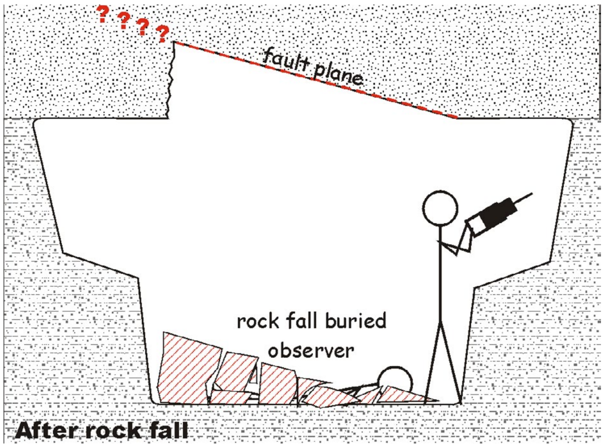


Figure 41 - After view of rock fall



The miners were aware of the fault plane but assumed that it was not a threat. The depiction shows the fault plane after the fall and the fallen rock on the floor of the drive.

Factors contributing to the incident:

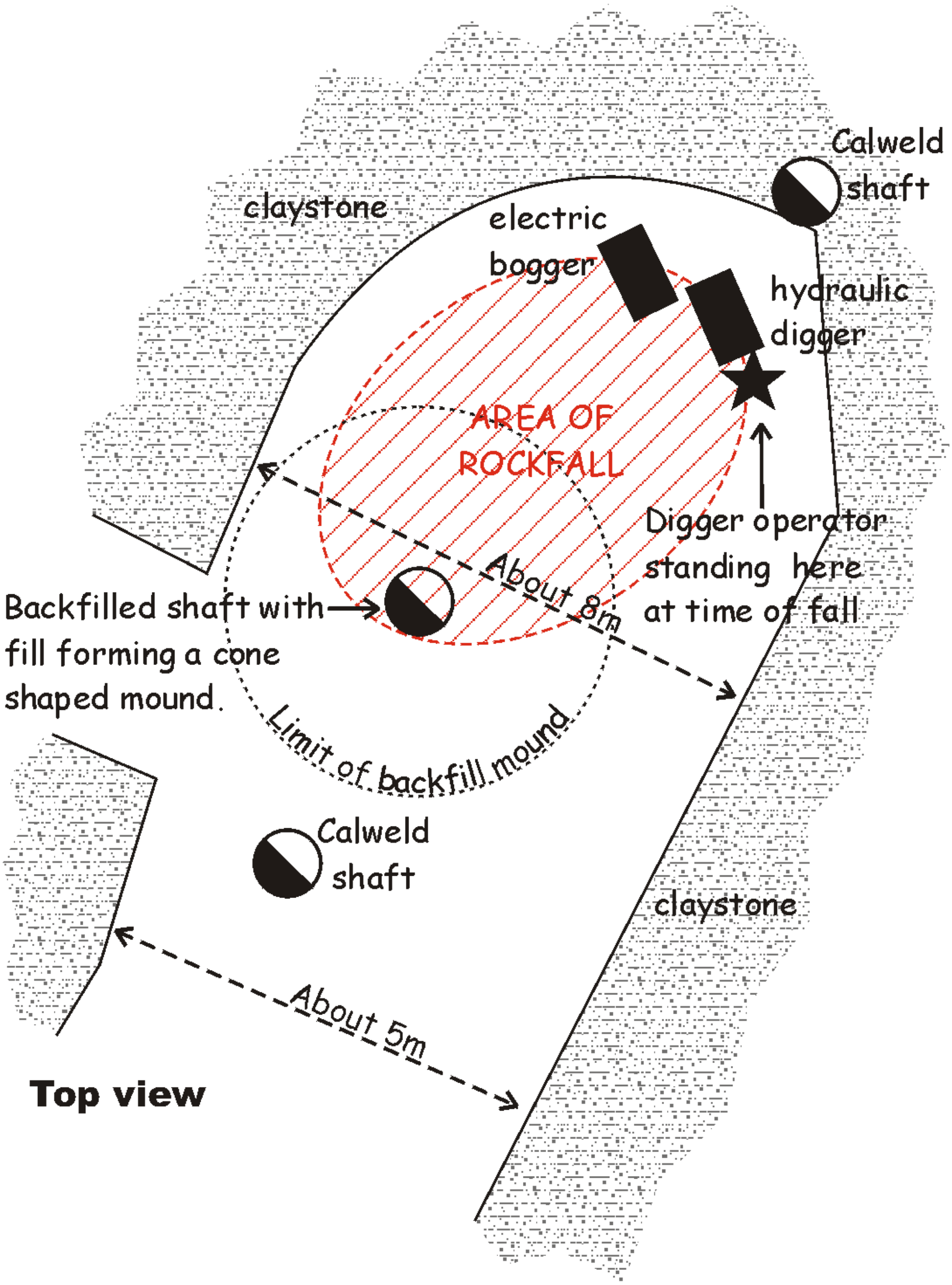
- large unsupported area
- area unsupported for some years
- miners appeared to ignore risks associated with the discontinuity (fault) in the mine roof.

Figure 42 - View of fault plane and fallen rock at Glengarry.

Wyoming field , 1966

An oval shaped area of rock about 5 metres wide by 6 metres long and up to 0.75 metres thick fell from the roof in a ballroomed area at least 8 metres wide by 10 metres long. There were no props or secondary support in the ballroom.

Figure 43 - Top view of the Wyoming rock fall



A person was operating a hydraulic digger when the rock fall occurred. The worker was at the edge of the ground that fell and was only hit by a small proportion of rock. However, he suffered serious spinal injuries.

Factors contributing to the incident:

- A very large, unsupported area
- Part of the area was unsupported for several years
- No pillars left in the ballroom
- Caldwell shafts into the ballroom area created additional weakness in the roof
- No pillars were left to support the Caldwell mine shafts
- The roof contained several discontinuities in the form of joints
- Miners appeared to ignore discontinuities (joints) within the sandstone roof
- Miners' apparent lack of planning.

Figure 44 - Large blocks of sandstone that fell from roof resting on mound of backfilled shaft.

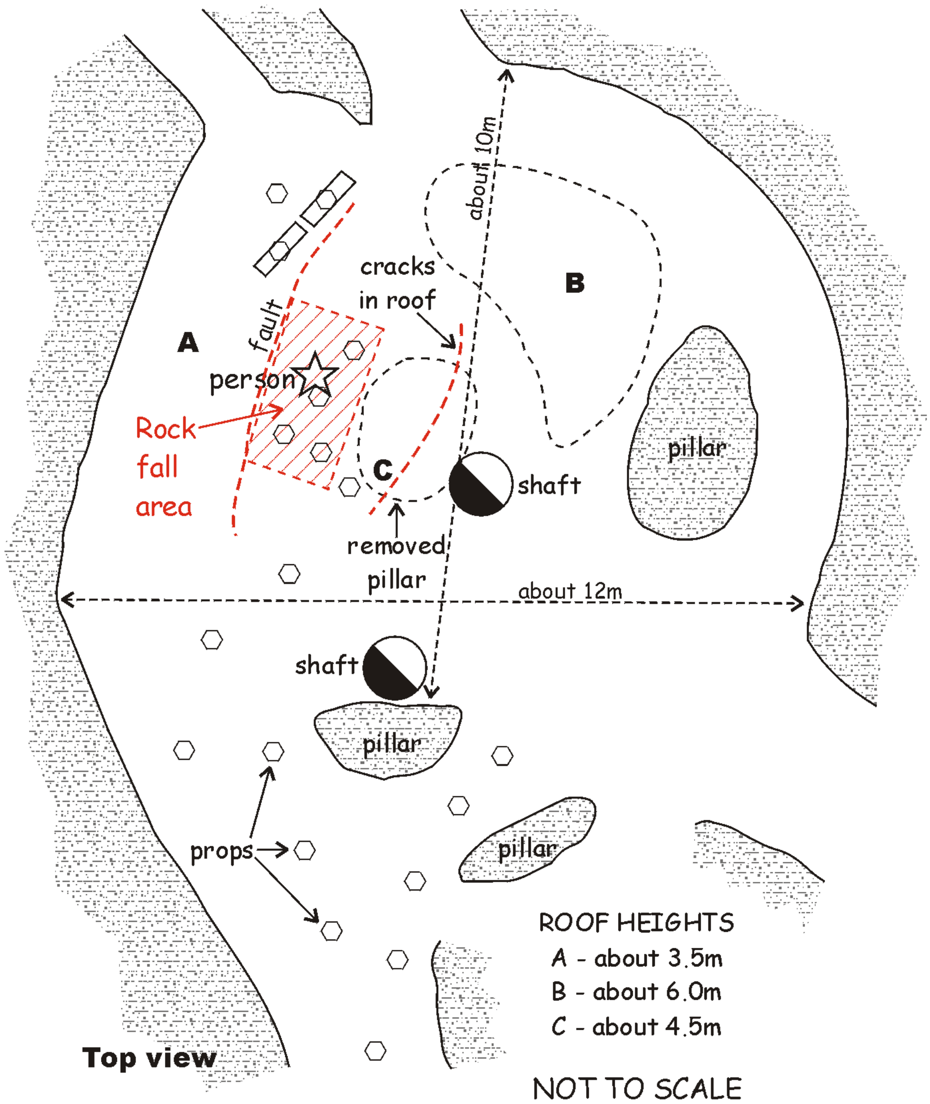
New Years field, Lightning Ridge, 1990

At New Years field, a slab of ground 2 metres by 1.5 metres fell from the roof. The thickness of the slab was 1.5 metres. The depth of the shaft was about 15 metres. The main ballroom measured about 10 metres by 12 metres, with a very uneven roof varying in height from 3.5 metres to 6 metres.

The main support for the ballroom was a pillar adjacent to a safety shaft. This pillar was removed. This resulted in a fall from the roof where the pillar had been. The day following the rock fall, the miners were working under the fallen area when a second rock fall occurred in an adjoining area, burying and fatally injuring one of the miners.

The roof had several discontinuities and loose ends. The loose ends were created by the steps in the roof. There was an 18-millimetre-wide crack about 0.5 metre up the safety shaft. An adjacent claim had subsided through to the surface.

Figure 45 - One miner was killed in this rock fall



Factors contributing to the incident:

- Removal of the main support pillar
- Roof contained several discontinuities (faults and cracks)
- Miners appeared to ignore discontinuities
- No alternative support was installed to replace removed pillar(s)
- Unevenness of the roof created loose ends
- Large, unsupported area
- In some places, the roof was uncontrollable due to its height
- Proximity of fall to shaft
- Miners appeared to disregard the rock fall that occurred on the previous day
- Miners' lack of planning
- Transferred stress from collapsed adjacent claims.

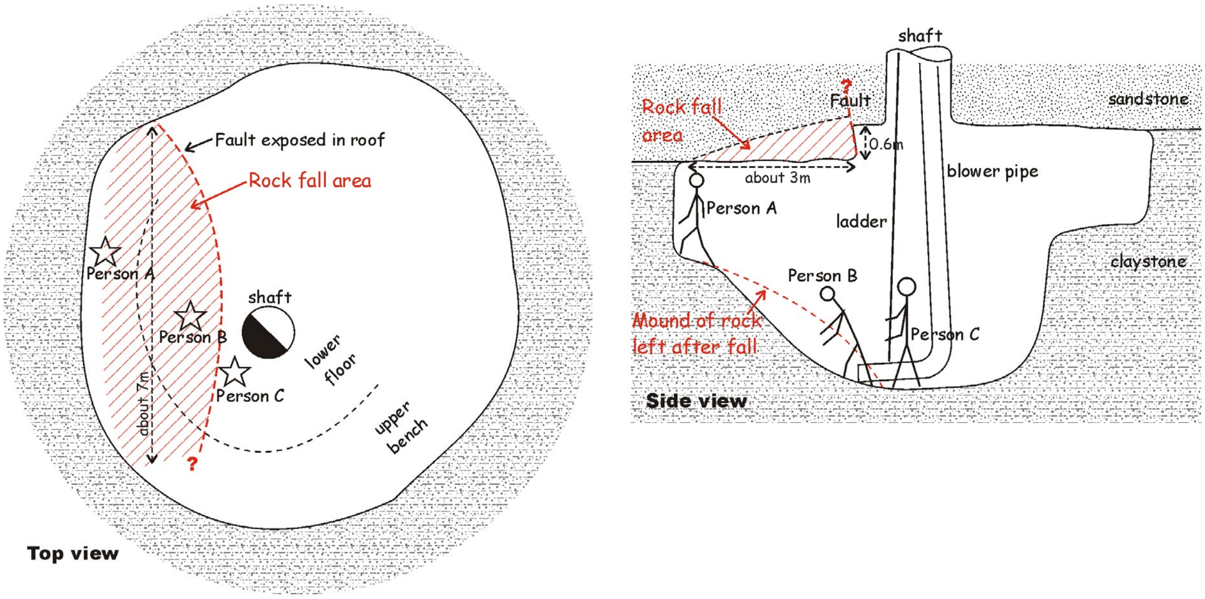
Ken's Retreat field, Coocoran, 1991

At Ken's Retreat field, a slab of ground 7 metres long by 3 metres wide fell from the roof. The slab was up to 0.9 metres thick. The depth of the shaft was 19.2 metres.

Underground work on the claim had been in progress for two weeks. The excavation was circular and roughly 7.5 metres in diameter with the access shaft in the centre. The maximum height of the roof was 7.2 metres.

The miners were aware of a fault in the roof adjacent to the shaft. As a result of the fault, the sandstone roof on one side of the shaft was 0.6 metres lower than on the other. There was no roof support in the area.

Figure 46 - Ken's Retreat rock fall



Factors contributing to the incident:

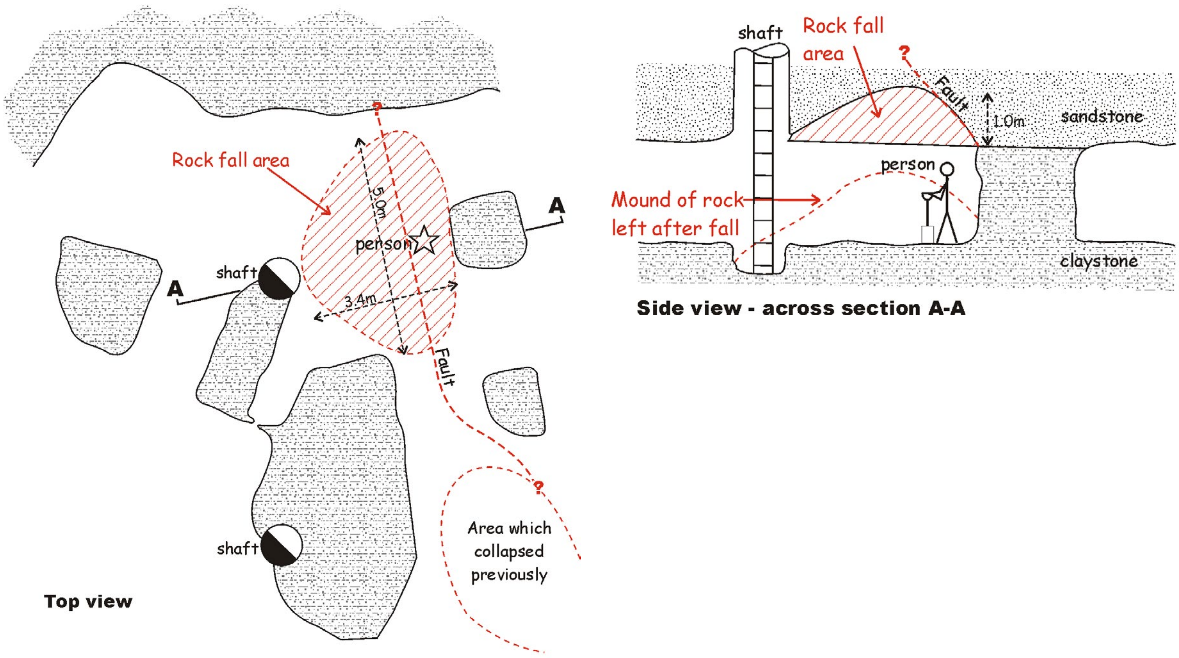
- Discontinuity (fault) in roof adjacent to shaft
- Miners ignored discontinuity
- Loose end created by mining
- Large unsupported area
- Height of roof prohibited propping
- Miners' lack of planning.

Dead Bird field, Coocoran – incident A

A slab of ground 5 metres by 3.4 metres fell from the roof. The slab was dome-shaped and 1 metre at its thickest point. The depth of the shaft was 21 metres. The height of the roof was 1.6 to 2 metres. The claim was worked in a room and pillar style, with randomly spaced pillars.

The miners were working in an area that had broken through to an adjacent claim. The claim was triangular-shaped, about half the size of a normal claim and surrounded on all sides by working or worked claims. A fall of similar size had occurred in an adjacent claim about six weeks earlier. A discontinuity in the form of a fault ran through both fall areas. There were also numerous joints in the mine roof.

Figure 47 - Dead Bird rock fall, incident A



Factors contributing to the incident:

- Roof contained a substantial fault and numerous joints (discontinuities)
- Miners ignored discontinuities and relevance of fall in adjacent claim
- Distance between pillars was too large

- Proximity to shaft
- Stress being transferred from adjacent claims
- Lack of miners' planning (i.e. effect of breakthrough to other claims).

Dead Bird field, Coocoran – incident B

A portion of sandstone roof about 4 metres wide by 5 metres long and 1.6 metres thick fell from the roof, on the edge of a large oval shaped ballroom. The depth of the shaft was about 22 metres.

A pillar was being extracted at the time the rock fall occurred. Although the removal of the pillar was near completion, no props had been installed. Three miners were partially or fully buried when the roof fell.

Factors contributing to incident:

- No support had been installed under the pillar when the pillar was being extracted
- Unevenness of the roof created a major loose end that hung from the roof
- In some places, the roof was uncontrollable due to its height
- Miners' lack of planning
- Discontinuities (joints) in roof
- Miners appeared to ignore discontinuities, both above and surrounding the pillar being extracted.

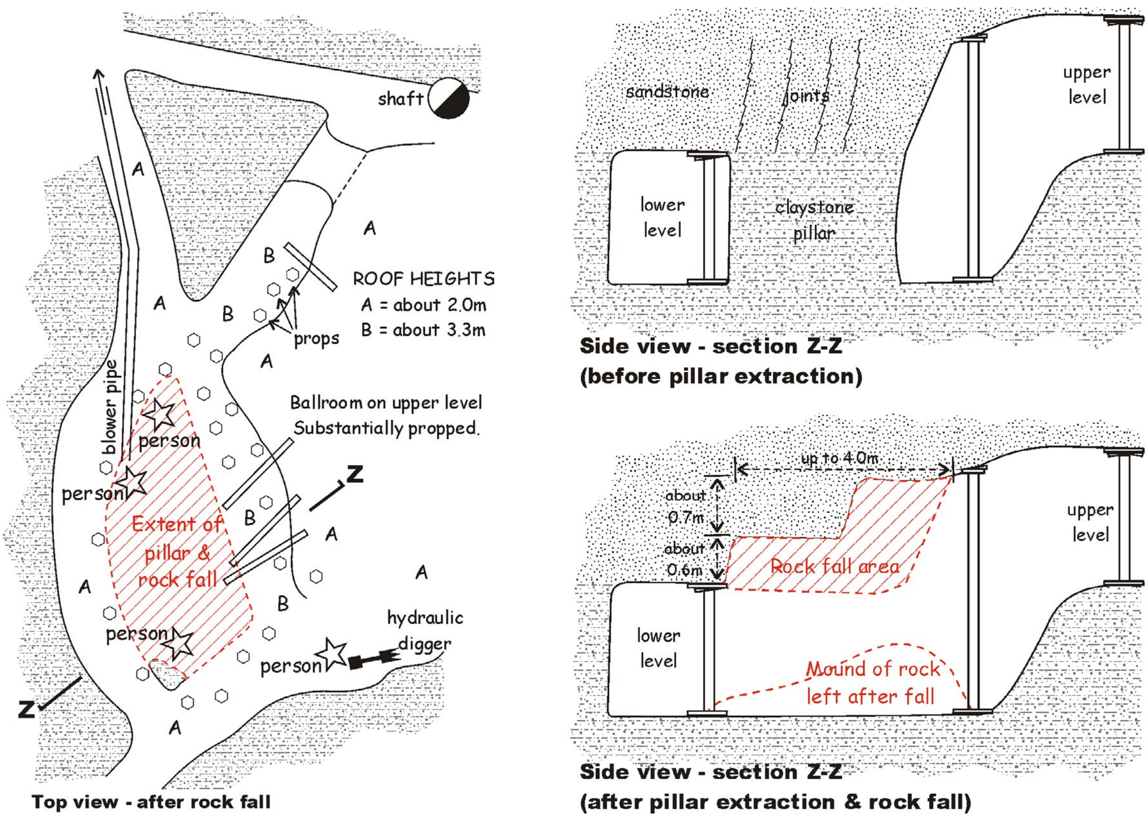


Figure 48 - Dead Bird rock fall, incident B

Common factors contributing to roof falls

Common factors contributing to the above incidents and many other rock falls on opal fields include:

- Miners unaware of or ignoring potential instability problems associated with discontinuities
- Miners assuming the roof was stable because it visually looked stable, giving justification for the lack of secondary support, such as props
- Large areas left unsupported
- Unsupported areas, worked some years before, mined again after there had been an opportunity for the ground to destabilise
- A substantial pillar not left in the workings adjoining the mine shaft, thereby providing another area of weakness
- No allowance made for stress transfer from adjoining claims
- The roof level is too high.

In several incidents, rock falls occurred close to mine shafts, especially where a substantial pillar was not left adjoining the shaft to provide support. Mine shafts provide a point of weakness that can readily combine with horizontal bedding and/or a vertical discontinuity, to result in a rock fall.

In these situations, a crack is often visible up to one metre from the bottom of the shaft. Rifling of the hole, caused by the rotation of the truck mounted drill rig, makes it difficult to observe such cracks. It is recommended that the bottom two metres of the shaft be cleaned, making cracks easier to see.

Cracks in the bottom of a shaft are indicative that it is unstable. It should not be used and work should stop in that area.

As drives become wider, rock in the roof does not have enough strength to support itself. Large openings require support.

Discontinuities within rock substantially reduce its strength. They need to be identified and managed properly by either not working in the area or by providing additional support.

Once cracks appear in the bottom of a shaft, it should be regarded as unsafe and no further work should be undertaken in that area.

Figure 49 - Rifling effect in a Caldwell hole

Ground support

Generally, there are two groups of ground support - primary and secondary.

Primary support is required to hold up the mass of ground between the underground mine workings and the surface. Only pillars can provide primary support. Where primary support is inadequate, mine subsidence will occur on the surface.

Figure 50 - Mine workings that subsidised due to inadequate primary support

Figure 51 - Rock that fell from the roof as a result of discontinuities and inadequate secondary support

Secondary support is required to hold up the roof within the destressed zone between the primary supports. It is required where rock is not strong enough to support its own weight under gravity. Forms of secondary support are discussed later. When secondary support is inadequate rockfalls will occur.

HAZARDS - GROUND SUPPORT

- Insufficient primary or secondary support may result in subsidence of a mine, injuries, fatalities, lost equipment and an inability to recover productive gemstone bearing ground.
- Too few, or poorly placed, ground support may result in a false sense of security.

Primary support

The most effective primary supports are pillars of ground left behind during the mining cycle. The characteristics of the pillars should be determined during the planning stage and could be:

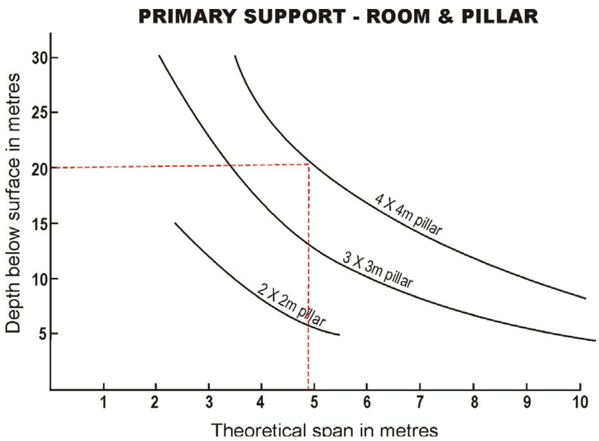
- randomly spaced
- regularly spaced
- square, rectangular or round.

Adequately sized and regularly spaced square pillars are strongly recommended.

For example, a pattern of 4 metre by 4 metre pillars has the capacity to support the overlying rock layers if the span between pillars is no greater than 4.8 metres.

Pillar sizes, in relation to opening sizes, are discussed later.

Figure 52 - Relationship between working depths, pillar sizes and maximum spans



Secondary support

Secondary support is required to support the mine roof between pillars. Props and rock bolts are the two most practical methods of secondary support for many gemstone regions. They may be used on their own or together. Both methods have advantages and disadvantages.

Secondary support should be installed at the time an opening, such as a drive, is created. The objective is to support ground before it has a chance to settle or relax.

Figure 53 - Rock bolts and props being used in a drive for roof support either side of a fault

Ground support with props

Props are used to prevent the roof, between pillars in the destressed zone, from falling out under its own weight, especially if there are geological discontinuities present. Props can also be used to support irregularities in the height of the roof (i.e. loose ends and localised loose rock).

Props are generally made from wood, free of bends. As an example, in the Lightning Ridge area, cypress pine (Callitris globulus) is a relatively common and straight timber often used.

Figure 54 - Planned installation of props

Generally, props should have a minimum diameter of 25 millimetres for every 300 millimetres of their installed height.

Props must be set securely and on a proper foundation. All props must have a cap on top and be securely tightened, using wedges either between the cap and the roof, or between the cap and the prop, depending on the circumstances.

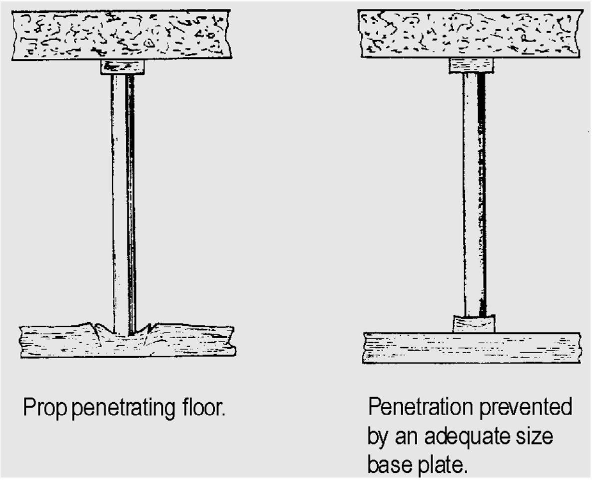
The cap is a block of wood that serves to spread the support of the prop over a larger area than just the top of the prop. It is crushed more easily than the prop because it is loaded at right angles to the grain and permits the roof to lower a little without damaging the prop. All spaces between the roof and the cap should be tightly filled using wedges.

When the floor is soft, the prop should be set on a base (sole) plate that is at least as wide as the diameter of the prop. This will prevent the prop from sinking into the floor when it comes under pressure from the roof settling.

Figure 55 - Props with a softwood cap

Figure 56 - Props with a base plate

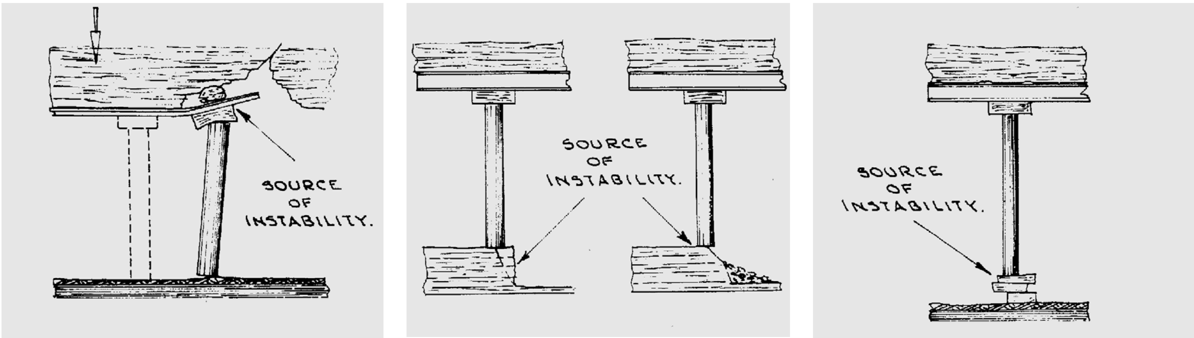
Figure 57 - Prop penetration and prevention



Stability of props

Props should always be installed at right angles to the roof.

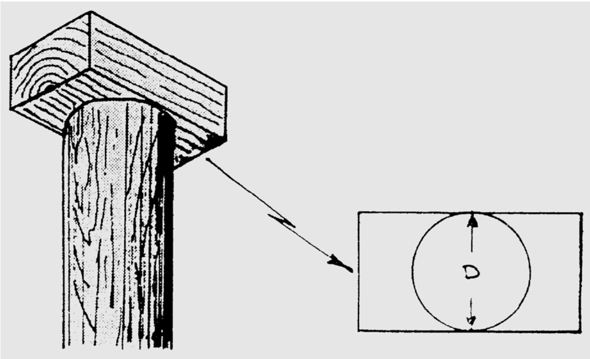
Figure 58 - Examples of how props should NOT be installed



Caps

The cap dimension should be approximately 450 millimetres in length, no less than the diameter of the prop in width and 51 millimetres thick and preferably made of hardwood.

Figure 59 - Caps must be as wide as the prop



Wedges

Wedges should be 80 to 100 millimetres wide, 250 millimetres long and vary from 0 to 38 millimetres in thickness. Wedges should be ideally placed over the vertical line of the whole prop.

Figure 60 - Wedges filling gap between the mine and the hardwood cap on a prop.

Prop failure

In all mines, rock settles and moves as time passes, becoming no longer strong enough to support its own weight. Where props are installed, they are affected by the pressure of the settling rock. Although evidence that props are taking significant pressure can be obvious, the initial signs may be subtle. Evidence of pressure on props includes:

- bark peeling from the outside of the upper portion of the props
- wedges cracking and/or distorting
- caps becoming compressed and/or splitting
- base plates cracking and/or distorting
- vertical cracks in the props
- bends developing in previously straight props
- the floor of the mine developing waves, or undulations, as the pressure of the props being driven into the floor forces the underlying rock to buckle.

Mining should stop in areas where props are showing signs of failing due to pressure.

Figure 61 - Prop showing substantial pressure

Fungus

Figure 62 - Initial stages of fungus growth on a prop.

A white coloured fungus, which looks like cotton wool, commonly grows on props. The fungus consumes wood as a food source and steadily destroys the props.

About one to two years after fungus growth begins, props may become so rotten that they can be broken apart by hand. At this stage, the affected props no longer provide any significant support.

Strength of props

Tests were carried out in November 1991 on cypress pine props obtained from the Lightning Ridge region. The tests were carried out at Londonderry Occupational Safety Centre in NSW to ascertain their strength to resist a vertical crushing load.

It was intended to simulate the convergence of roof and floor in hard rocks. The tests were carried out on 2.44 metre and 1.83 metre-long props of 200 millimetres and 150 millimetres diameter without a cap, with a 51 millimetres hardwood cap and with a 102 millimetres softwood cap.

Figure 63 - Graph representing results of prop tests 1-6

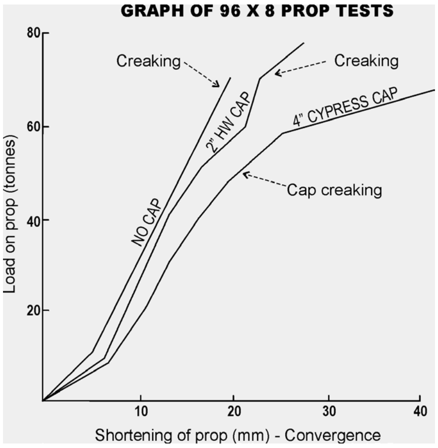


Table 4 - Crush test results for cypress pine props from Lightning Ridge

TEST NO.	PROP SIZE LENGTH X DIAMETER	CAPS	MAX LOAD (TONNES)	CONVERGENCE (MM)	REMARKS
1, 2, 3	2.44 X 0.20	None	73	23	Creaking at 70t, sudden failure 0.5m from top.
4, 5	2.44 X 0.20	51mm hardwood	90	35	Creaking at 70t, sudden failure 0.5m from top.
6	2.44 X 0.20	102mm cypress	67	42.5	Load dropped to 50t for further 12mm, to 30t for further 25mm then 20t for further 260mm. Failure 0.4m from top.
7, 8, 9	2.44 X 0.15	None	67	28	Creaking at 50t, sudden failure 0.5m from top.
10, 11	2.44 X 0.15	51mm hardwood	42	22.5	Creaking at 40t, sudden failure 0.7m from top

TEST NO.	PROP SIZE LENGTH X DIAMETER	CAPS	MAX LOAD (TONNES)	CONVERGENCE (MM)	REMARKS
12	2.44 X 0.15	102mm cypress	39	57.5	Creaking at 20t, sudden failure 39t.
13, 14, 15	1.83 X 0.15	None	72	15	No warning, sudden failure 0.5m from top.
16, 17	1.83 X 0.15	51mm hardwood	59	23	No real warning, sudden failure 0.6m from top.
18	1.83 X 0.15	102mm cypress	44	45	Audible breaking of cap at 20t, cap fails at 43t, load held 25t for further 100mm.
19, 20, 21	1.83 X 0.20	None	78	22	Sudden failure.
22, 23	1.83 X 0.20	51mm hardwood	83	27.5	Sudden failure.
24	1.83 X 0.20	102mm cypress	72	50	Sudden failure, load held at 72t for further 70mm

Prop test results

The prop tests showed that cypress props used without a cap shorten, when under load, less than 25 millimetres at breaking point and would break suddenly, with little warning of failure.

The prop tests showed that cypress props used with a 51 millimetres thick hardwood cap shorten, when under load, slightly more than 25 millimetres at breaking point and would break suddenly with little warning of failure.

The prop tests showed that cypress props used with a 102 millimetres softwood cap shorten, when under load, by almost 51 millimetres at breaking point and give both visual and audible warning of impending failure. That was the best test result.

Generally speaking, the various size cypress pine props, with a 102 millimetres soft wood cap, will be able to support the following loads if installed correctly:

- 2.44m by 0.20m - 60 tonnes
- 2.44m by 0.15m - 40 tonnes
- 1.83m by 0.20m - 70 tonnes
- 1.83m by 0.15m - 40 tonnes

It is important to note that the amount of shortening in a prop is a function of time. The more the prop shortens without failure, the longer the time there is to take necessary action.

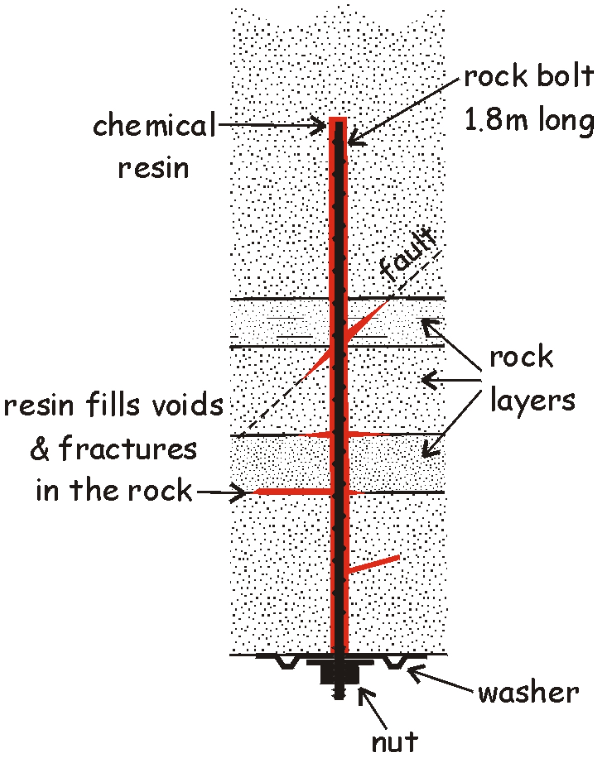
Props are commonly placed at one metre centres. Competent miners have been known to make variations above or below this figure after assessing rock strength, discontinuities, the effects of existing and neighbouring workings and the size of props being used.

Ground support with rock bolts

Rock bolts are frequently used to improve the stability of underground openings. Bolts are used to bind rock masses that are otherwise discontinuous, due to joints, faults or bedding. They can also be used for stabilising wedges or blocks of ground.

Figure 64 - Rock bolt in roof

Figure 65 - Cross section of rock bolt in roof



An adequate anchor, beyond the boundary of any geological discontinuities, is required when bolting wedges or blocks. A fall of rock into an excavation may occur through separation of the strata in combination with rock strength being unable to support its own weight.

Principles of rock bolting

Properly installed roof bolts aid roof control by:

- tying separate layers of strata together to form one effective beam, with greater strength than the unbolted strata
- fastening weaker roof beds to an overlying stronger bed
- applying a positive restraint to a movement of the strata at an early stage.

Figure 66 - Principles of rock bolting

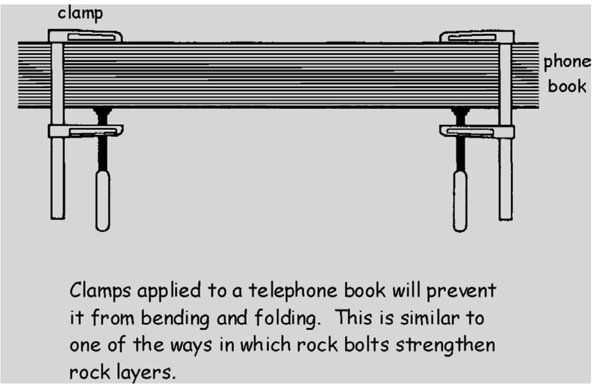
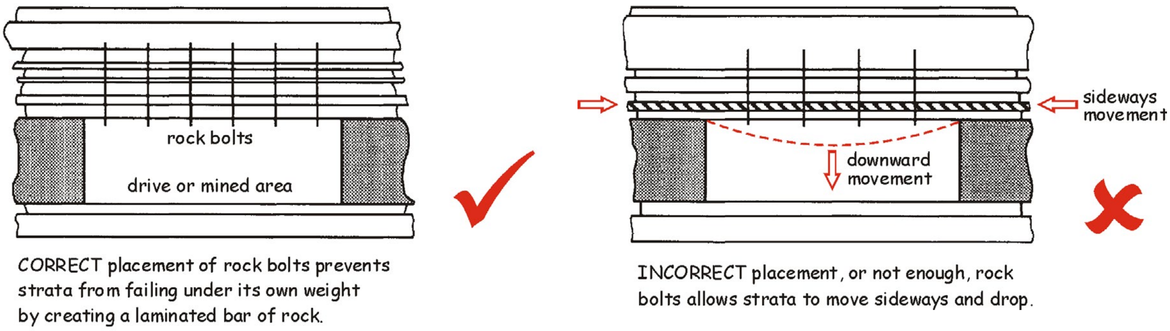


Figure 67 - Principles of rock bolting



Bolt Length

The optimum bolt length is determined by the measurement of the uppermost layer where failure is occurring.

Many secondary rock falls at Lightning Ridge appear to be one metre or less in thickness.

When it is not possible for the required length of bolt to be placed, a greater density of bolts should be used to stiffen the lower roof strata, minimising the load that the layer above the top has to carry.

Bolt size

Generally, bolts 24 millimetres in diameter by 1.8 metres long inserted into a 27 millimetres diameter hole and fully encapsulated with chemical grout have been used at Lightning Ridge.

Bolt density

Bolt density is determined by the density of reinforcement needed to give enough restraint to the deforming rock layers, without the bolts exceeding their yield capacity or pull out strength.

Figure 68 - Concentration of rock bolts above a drive intersection

Bolt spacing and pattern

Having the required number of bolts in the roof is not enough. They also must be placed in a pattern and spacing to provide the required density in the area where the rock layers are deforming and tie the rock layers together.

Timing of placement of support

Bolts should be placed as soon as the face has advanced enough to allow installation. The roof should not be given time to loosen and separate.

Advantages of rock bolts

Bolting is not necessarily cheaper than propping, but it has significant advantages including:

- reduced storage and handling
- improved ventilation due to removal of obstructions
- freedom of movement of loaders, without risk of dislodging supports
- minor maintenance.

Rock bolt tests

In 1992, a series of pull out tests using chemically anchored bolts were carried out at Lightning Ridge, specifically at Dead Bird Rush, Cheryl's Rush, Chinaman's Gully (Sheepyard) and Emu's Rush. Point anchor and fully encapsulated bolts were tested. All bolts were 1800 millimetres by 24 millimetres in diameter and installed in a 27 millimetres hole.

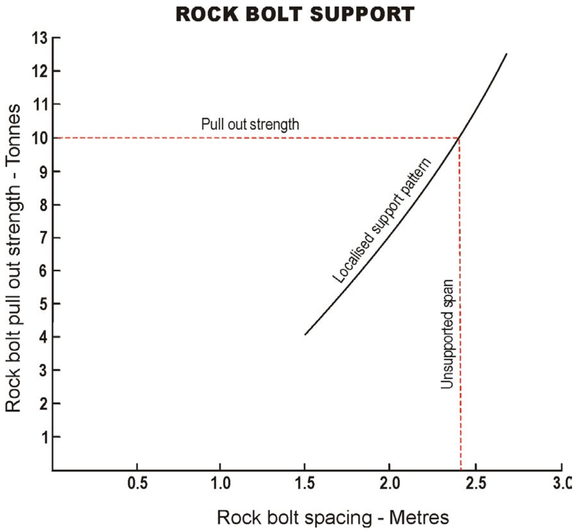
Table 5 - Average pull out in tonnes

FIELD	AVERAGE PULL OUT (TONNES)
Dead Bird, Coocoran	12
Cheryl's, Coocoran	12
Chinaman's Gully, Sheepyard	14
Emus, Coocoran	5

The tests concluded that:

- Rock bolts were not suitable for ground support at Emu's Rush
- Rock bolts were suitable for ground support at Dead Bird Rush, Cheryl's Rush and Chinaman's Gully
- Rock bolts with a pull-out strength of 10 tonnes or greater can generally support a span of 2.4 metres
- 2.4 metres should be the maximum distance between rock bolts, as the rock strength will not support greater spans
- A pull out strength of less than 10 tonnes may be used, provided the bolt spacing is no greater than the indicated pull out strength. (e.g. 7 tonnes pull out = 2.0 metres bolt spacing).

Figure 69 - Maximum rock bolt spacing for given pull out strengths



Pillar maintenance

Regularly inspect the condition of pillars and note any deterioration. Rock being shed from pillars, known as fretting, is a sign that the pillar is either taking weight or the claystone is drying out.

It is important to properly maintain pillars. A pillar's strength will rapidly reduce if its size diminishes due to fretting or over mining.

Figure 70 - Fretting pillar

With experience and careful observation, a distinction can be made between pillars fretting due to pressure and those that are drying out. If in doubt, regard the area as being under pressure until there is significant evidence to show otherwise. Obtain the opinions of more experienced miners.

The structure of the pillar can be confined by various means. Anything which prevents rock spalling off the pillar and reducing its dimensions is suitable. This includes straps, rock bolts, chicken wire, plastic mesh, wire rope or timber.

By containing loose rock fretting off the side of a pillar, the pillar's strength and integrity can be maintained.

Weight bearing down on a pillar can be relieved by the installation of timber props.

Netting

Plastic or wire mesh can be used to wrap and enclose a pillar, preventing drying rock from fretting. Rock that dries out is held against the pillar, providing insulation from further drying. Care needs to be taken to systematically pin and secure the mesh against the pillar or drive wall.

Figure 71 - Pillar support using wire netting is ineffective as the mesh is too large

Figure 72 - Pillar support using plastic netting and fibreglass rock bolts

Backfilling

Backfilling is used where a combination of pillar or wall support, and disposal of waste materials, is desirable. Backfilling has the disadvantage that it does not support the roof, only the sides.

Backfill cannot be packed close enough to the roof to provide total support, however it does assist in maintaining pillar strength.

Figure 73 - Backfill supporting pillars

REMEMBER

- Roof failures occur when the rock does not have the strength to support itself. Secondary support such as props and rock bolts can be used to prevent or delay roof failure.
- Support should be installed at the time of excavating an area, before the rock has had a chance to settle or move.
- It is better to have too many props rather than too few.

Room and pillar design

With most opal or gemstone mining fields, room and pillar mining is the most applicable method of mining. Pillars are planned to provide primary support of the ground, while props and rock bolts only provide secondary support.

The size of rooms, in relation to the pillar sizes, is critical from an economical and ground support point of view. The relationship determines the amount of ground that can be safely extracted and the amount of secondary support required.

HAZARDS - ROOM AND PILLAR MINING

- Rockfalls.
- Workings may become unstable and dangerous, as well your neighbours.
- A gemstone mine or several gemstone mines, may subside (collapse) through to the surface.

Room and pillar mining is accomplished by driving openings into the gemstone bearing layer to divide the mine into rectangular or square blocks. These blocks or pillars of ground that are left provide support for the overlying strata.

This support may be temporary, if selected pillars are recovered later, or permanent, where the pillars are left in place. The span that will stand unsupported depends primarily on the characteristics and properties of the roof. Even the most thorough design sometimes results in roof failure. Roof falls are the greatest health and safety hazard in underground mines.

Room size also determines what equipment may be used, as well as what extraction methods may be employed. Competent miners understand that it is desirable to maximise gemstone dirt extraction in productive ground. However, they also maintain enough primary support to prevent serious injuries or fatalities from roof failure.

The main advantages of the room and pillar mining method are:

- A highly flexible system, easily modified throughout the mine life to suit the conditions and equipment used
- New drives can be easily started or stopped without serious effect on mining methods or timing
- The development of rooms is a productive operation

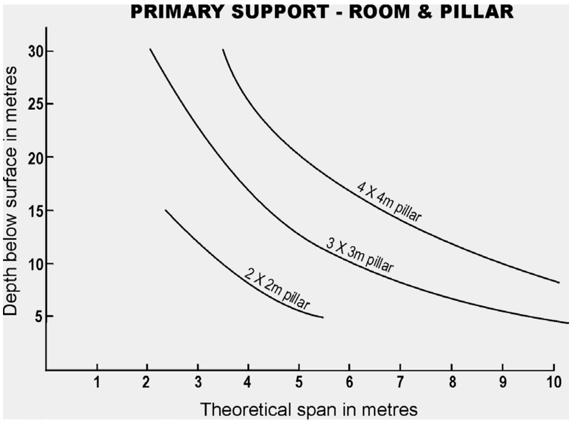
- Amenable to a high degree of mechanisation
- Adequate ventilation is relatively easy to achieve.

Figure 74 - Room and pillar mining

Design of pillar spacing

When designing the pillar layout, it is essential that the designed span between pillars should be no greater than 2.4 metres, unless secondary support is installed.

Figure 75 - Relationship between working depths, pillar sizes and maximum spans.



REMEMBER

As a general guide, drives greater than 1.8 metres wide (2.4metres maximum span at drive intersections) will require secondary support.

In some cases, secondary support will be essential in narrower drives, depending on rock strength, discontinuities in the rock and nearby workings.

It is reiterated that depending on ground conditions, the designed span may need to be considerably less than 2.4 metres. Pillar layout depends largely upon the safe spans determined for the immediate and main roof strata. The table below shows design examples.

Table 6 - Examples of room and pillar mining parameters

DEPTH BELOW SURFACE	PILLAR SIZE	THEORETICAL SPAN	ASSUMED DESIGN SPAN	DRIVE WIDTH	SECONDARY SUPPORT REQUIRED	% PRIMARY EXTRAC-TION
20m	2.5mX2.5m	2.4m	2.4m	1.8m	No	46
20m	4mX4m	4.8m	2.4m	3.5m	Yes	52
15m	2mX2m	2.4m	2.4m	1.8m	No	53
15m	3mX3m	4.2m	2.4m	3.0m	Yes	50

For example, if a claim is at a depth below the surface of 20 metres and a pillar size of 4 metres by 4 metres is chosen, the theoretical span is 4.8 metres. The theoretical span of 4.8 metres is the span from the corner of the pillar to the corner of the diagonally opposite pillar. As a result, the drive width is 3.5 metres. Because these spans exceed 2.4 metres, secondary support is required.

Points to note:

- The shaft(s) can be located anywhere within the claim area
- A shaft pillar must be left in all cases
- Unsupported design span must not exceed 2.4 metres
- Either props or rock bolts can be used for secondary support. Rock bolts can only be used if ground strata is suitable and testing has been done.

- There is a variation in the percentage primary extraction rate, depending on the design chosen.

Figure 76 - Example of room and pillar mining, 2.4 metres maximum span

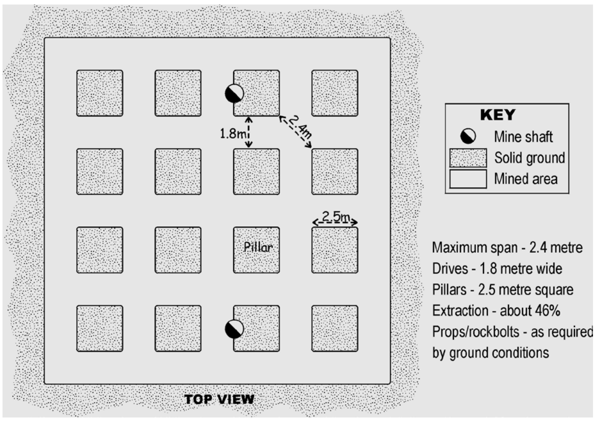
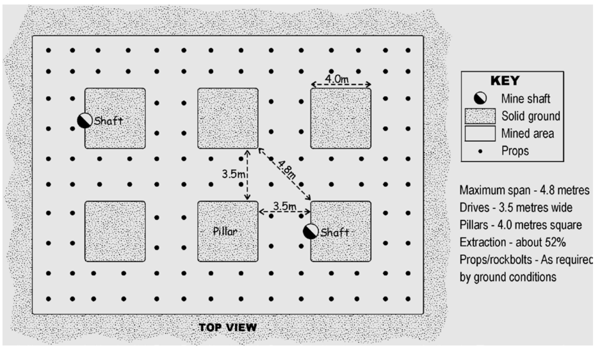


Figure 77 - Example of room and pillar mining, 4.8 metres maximum span.



Effect of adjacent mines

The layout and extent of mining within adjacent mines will have a significant effect on the potential design for your underground workings. The possibilities to consider are:

- Water in old or currently unworked mines could cause a water inrush, if a breakthrough occurs
- Stresses transferred through the rock due to the excavations made in the adjacent claims
- The requirement for boundary pillars to be left
- The presence of geological discontinuities and any falls that occur act as a warning

Mine operators must notify the adjoining mine operator if there is anything in the mine which may affect the safety of the adjacent workings.

Pillar extraction

The entire extraction of a gemstone bearing layer from a mine should not be considered under any circumstances due to the substantial risks involved.

Strategic pillars should always be left. No attempt should be made to recover them.

Pillars should only be removed if they can be replaced with appropriate ground support, such as props.

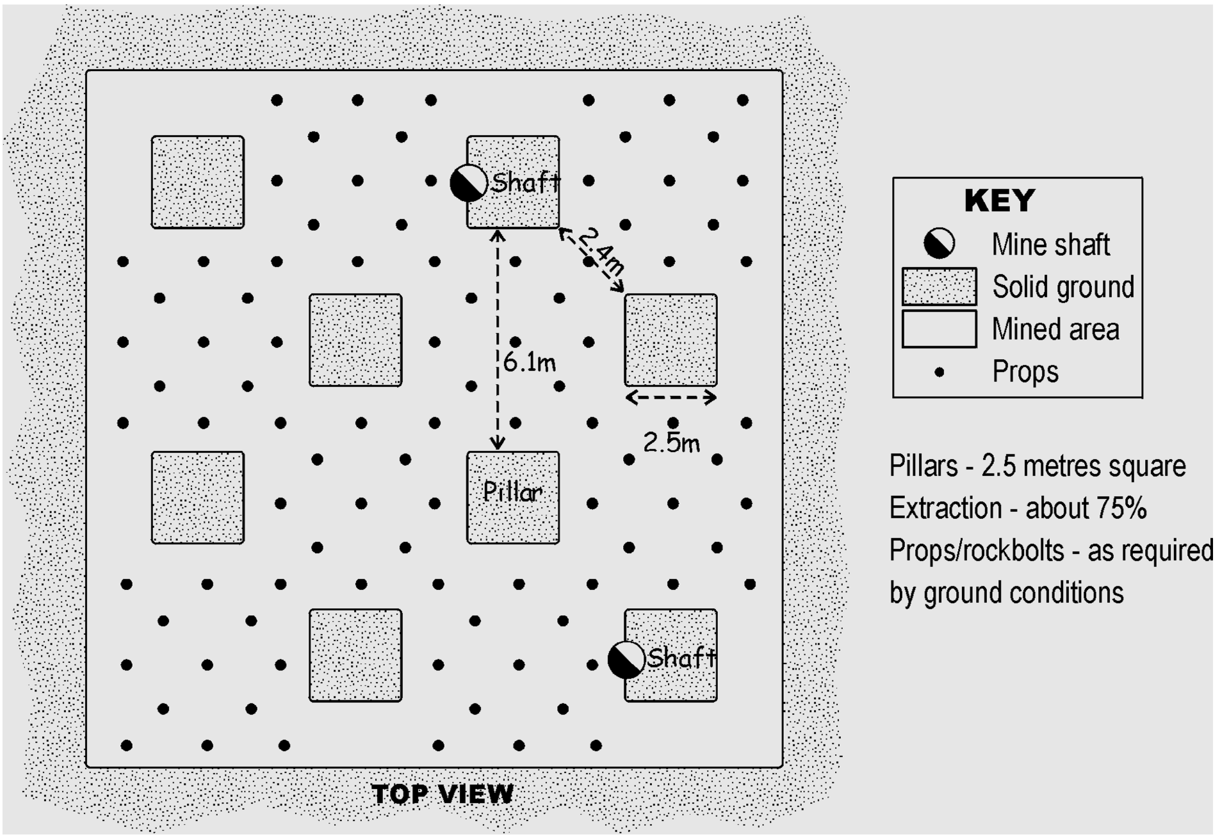
When removing pillars, a retreat system should be observed in case a rock fall occurs. Start by extracting pillars furthest from the shaft, moving towards the shaft in a systematic manner.

Fundamental principles of pillar removal include:

- Only take alternate pillars (every second pillar)
- Always prop the surrounding ground before removing a pillar
- Prop during pillar removal to support the ground area previously held by the pillar
- Constantly look for ground discontinuities and manage appropriately.

In the below figure, pillar extraction is being carried out using the room and pillar design. Props are installed at each corner of a pillar prior to removal, and in the centre, during extraction. Only alternate pillars have been extracted.

Figure 78 - Example of room and pillar mining after extraction of alternate pillars



Special cases

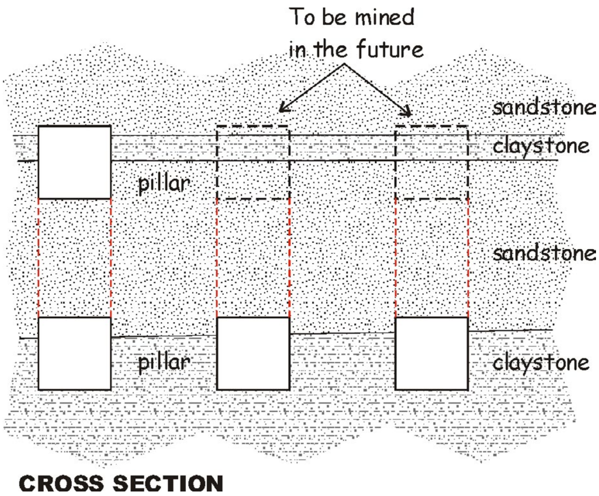
Multiple layer mining

Where two or more opal or gemstone levels are present, safe mining becomes more complicated. Advice should be sought from experienced miners and the NSW Resources Regulator. The major issue of concern is roof stability. Depending on the thickness and strength of the ground between the levels, several approaches are possible.

Generally, it is recommended that mining be undertaken on the bottom layer first, with a maximum extraction of 50% of the level, provided ground conditions are adequate. The upper level can then be mined, while taking special care to ensure that pillars are within a column and placed in line between the two levels.

The objective of mining the bottom level, followed by the upper level, is to work under the most stable roof possible.

Figure 79 - Multiple layer mining (claystone may be gemstone bearing rock)

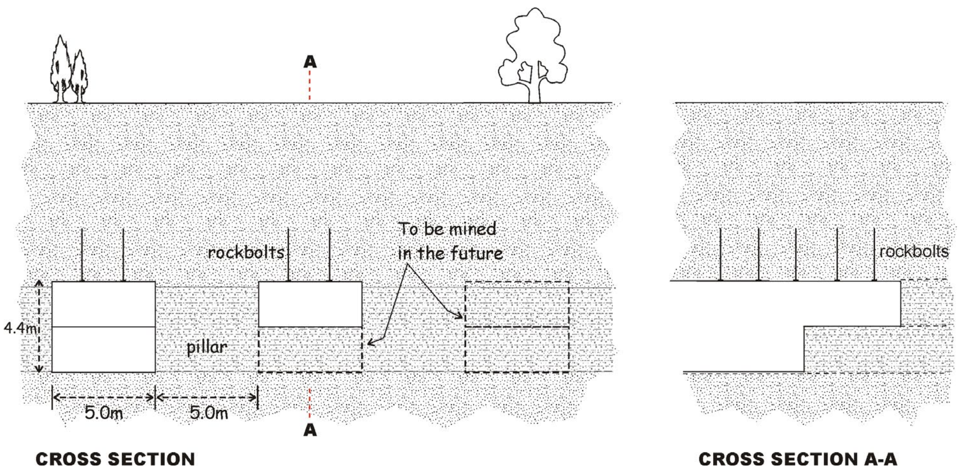


Thick level mining

Careful consideration and planning are required before mining a thick claystone level or layer, or gemstone layer. Advice should be sought from an experienced miner and the Regulator prior to mining any level greater than 3.5 metres thick. Above this height, roof control becomes difficult.

To maintain roof control in this situation, the level should be mined in two sequences. The top section should be mined first, installing rock bolts and leaving pillars as mining advances. The bottom section should lag the first. In this way, proper roof and wall support is maintained. Columnisation of pillars is essential.

Figure 80 - Thick level mining



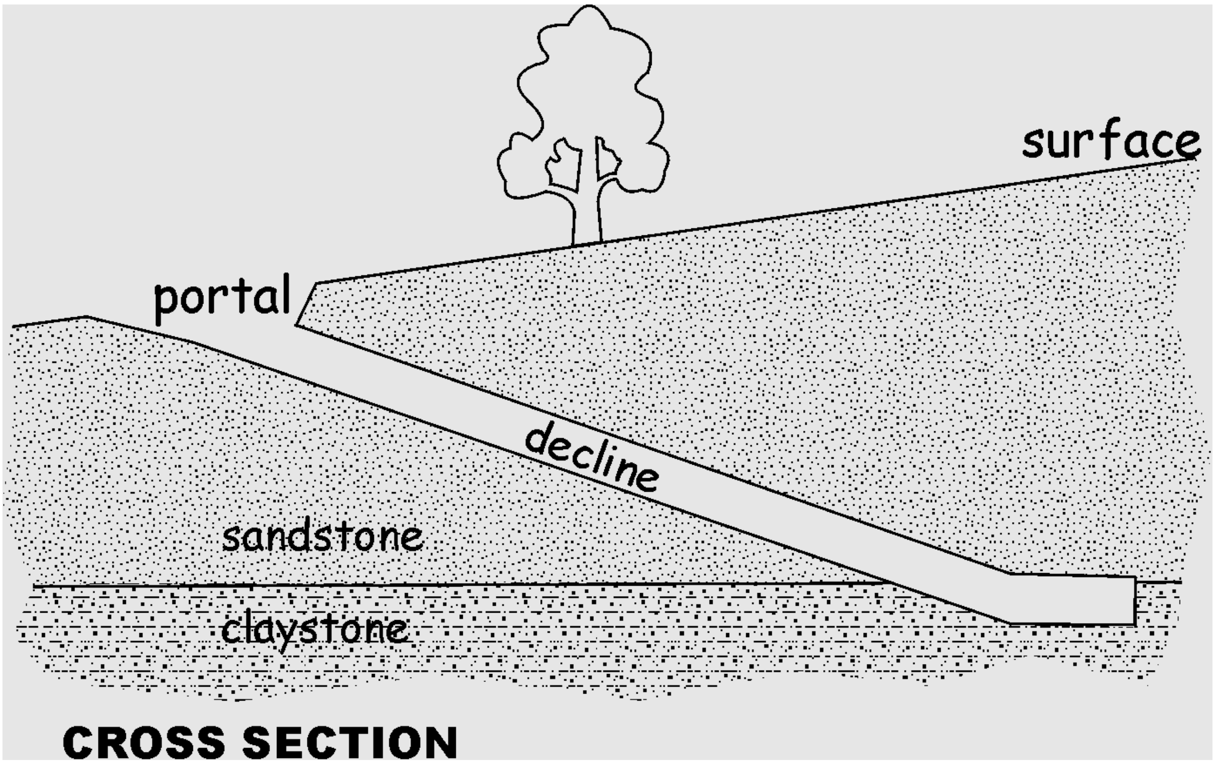
REMEMBER

Decline access mining requires a permit to be issued under the *Mining Act 1992* (section 175). Activities cannot begin until approval has been granted.

Declines can be used for access to gemstone levels and replace the conventional vertical shaft. With the shallow mining depths at some gemstone areas, this method is worth consideration. Haulage of material from the mine can be handled by either mobile equipment or conveyor belt. When using mobile equipment, grades could be between 1 in 5 to 1 in 10. When using a conveyor, the grade should be no less than 1 in 3.2.

Figure 81 - Underground access using a decline

Figure 82 - Example of decline layout.



The major advantages of decline mining are:

- Production rates can be increased without further major capital expenditure
- Mobile equipment can be moved easily between underground and surface without disassembling

REMEMBER

- Pillars provide primary support, essential to prevent subsidence.
- Depth of workings and opening sizes have a direct impact on the minimum pillars sizes that will be required.
- Workings in adjacent mines will have an impact on how and where the mine can be safely worked.

Ventilation

Ventilation of mine workings is necessary to ensure that the air breathed by workers is able to sustain life. It must contain an acceptable level of oxygen (at least 19.5% oxygen) and is free of impurities. An adequate air flow also removes excess heat from machinery and hot work places.

In order for air to move through a mine, and to maintain an adequate quantity and quality of mine air, it is necessary to have the workings connected to both an intake and an exhaust shaft.

To ensure that the quality of air is maintained in underground mines, the WHS laws stipulate requirements regarding ventilation.

HAZARDS - VENTILATION

- Death through asphyxiation
- Deterioration of health as a result of exposure to a range of gases and dust
- An uncomfortable working environment.

Methods of ventilating underground mines

Natural ventilation

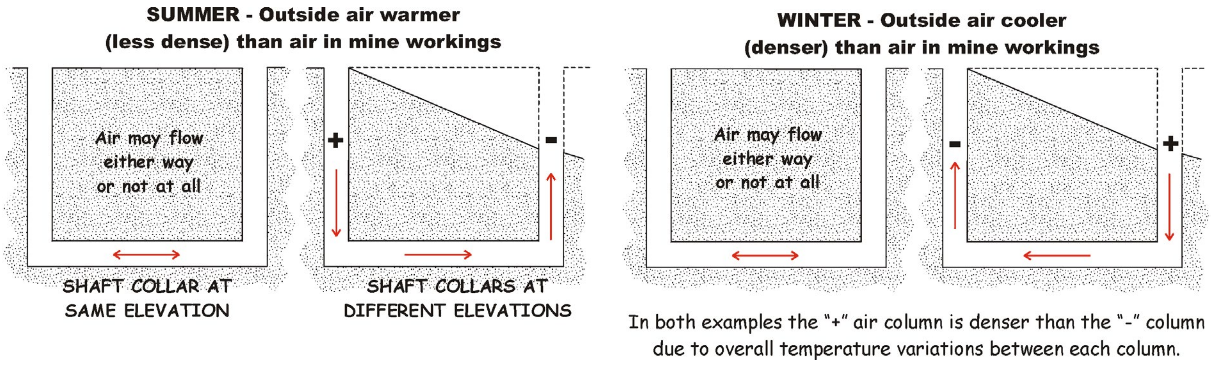
Natural ventilation is the mine airflow resulting from a difference in pressure between the intake and exhaust shafts. This depends on the differences in air temperature inside and outside the mine, and on the height difference between the surface and the mine workings.

The temperature of the air in underground workings remains constant throughout the year because of the consistency in rock temperature. However, the surface temperature will vary due to the time of day and the season. This variation in surface temperature will determine the flow and direction of natural ventilation.

When the temperature of air inside and outside the mine is the same, there will be minimal air flow through the workings. In the situations where there is minimal air flow, ventilation often needs to be improved with a fan or other mechanical means.

If there is a significant difference in air temperature inside and outside a mine, there will tend to be an air flow through one shaft and out another, especially where the shaft collars are at different elevations.

Figure 83 - Natural air flow as a result of seasonal temperature variations



Natural air flow in a mine can be enhanced by installing large diameter, black coloured pipes over the collars of ventilation shafts or auger holes. Air within the black pipes becomes heated by sunlight and rises, allowing cooler air to enter the mine through another opening. The quantity of air flow depends on obstructions, pipe sizes, directions and sizes of mine openings.

Figure 84 - Black pipe over an auger hole used to help natural ventilation

Air flow can also be increased by placing an industrial exhaust ventilator (powered by wind) on top of a large diameter pipe fitted to a borehole. As the ventilator rotates due to wind, air is exhausted from the mine. This energy saving device provides a greater flow of air regardless of the surface temperature.

Figure 85 - Ventilation fan over and auger hole

The amount of air flow caused by natural ventilation will vary with the length and size of the mine openings and may need to be supplemented by mechanical ventilation. Mechanical ventilation gives better control over air flow direction and volume.

Mechanical ventilation

Fans can be used to supply air to either the entire mine or, when used as auxiliary ventilation, to only part of the mine. They can be installed as either an intake (blowing) or exhaust ventilation system, preferably working with the direction of the natural ventilation.

Intake air (clean air) enters the mine through a shaft and is exhausted through an exhaust or ventilation shaft. The fan is commonly mounted over an upcast shaft. There are two main types of fans, axial flow and centrifugal (or radial) flow. Either can be fixed on the surface as a major ventilator or used underground as an auxiliary fan.

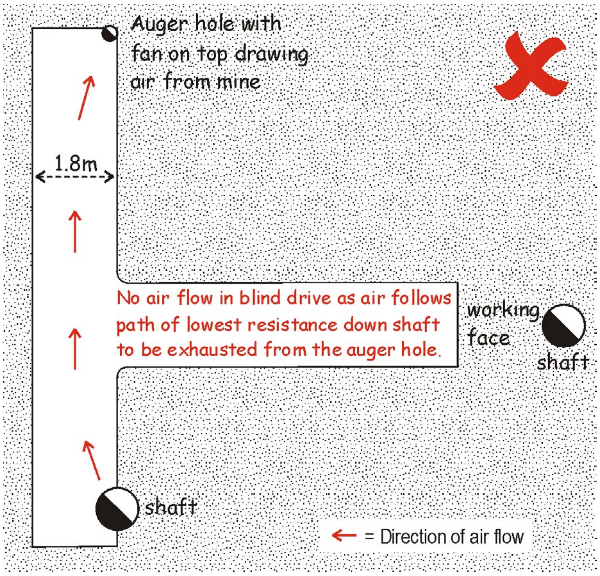
The simplest axial fan is the desk or ceiling fan used to put stagnant air in motion, with rotating blades working on the same principal as a propeller. Fans designed for use in mines work similarly, often designed to vary the required quantities of air flow.

Figure 86 - Electric ventilation fan over a mine shaft

Auxiliary ventilation

Where the main ventilating current is inadequate or cannot reach all working faces, reliance must be placed on supplementing the means of supplying air. The practice of augmenting the main ventilation system is called auxiliary ventilation, and is especially required for blind, or dead end headings where the air is not replenished by the main ventilation current.

Figure 87 - Blind drive without auxiliary ventilation



The common applications of auxiliary ventilation can be grouped into several categories:

- Supplying air to dead-end working places, both development and production. This is the most frequent and important application of auxiliary ventilation. Drives and shafts require auxiliary ventilation as they proceed beyond the main air stream.
- Supplying uncontaminated air to faces of working places in contaminated environments. Where contaminated air is thought to be present, auxiliary ventilation must be maintained until the contaminated air is entirely replaced with fresh air.
- Supplying cooler air to hot working places.

Supplying air to dead-end workings is a very important function of auxiliary ventilation.

Compressed air and injectors

Exhaust from compressed air equipment helps the environment in hot and/or dusty work places. However, compressed air exhausts should never be accepted as a substitute for ventilation, as these machines run for only part of a shift. Air quantity is insufficient to remove airborne contaminants. Ventilation from compressed air lines is expensive and is rarely necessary. However, it has been used to purge rises and winzes to clear smoke and fumes from the face after blasting.

The compressed air injector has the advantages of limited maintenance, ease of installation, and being able to operate under poor conditions. Such injectors are limited to a very small area of influence and require a constant supply of compressed air.

Fan and ventilation tubing

For development work, a single length of tubing is suspended in the working place from hangers in the backs or walls and attached to an auxiliary fan. Vent tubing is more suitable for longer distances than compressed air injectors, but has some shortcomings. These include vulnerability to damage and a decrease in air velocity beyond the vent tubing.

Figure 88 - Ventilation tubing hung from a walk of drive supplying fresh air to the working face

Auxiliary ventilation layout

There are two types of auxiliary ventilation:

- Exhaust and force
- Force only.

When using an exhaust and forcing system, the distances to the face should be decided individually for each ventilation system, the size of the fan and tubing having a great bearing on the effectiveness of the system.

The figure below illustrates a force system which is more efficient and delivers air to the face at a greater velocity.

Figure 89 - Auxiliary ventilation in blind drive - combined exhaust and force system. Distances are a guide only.

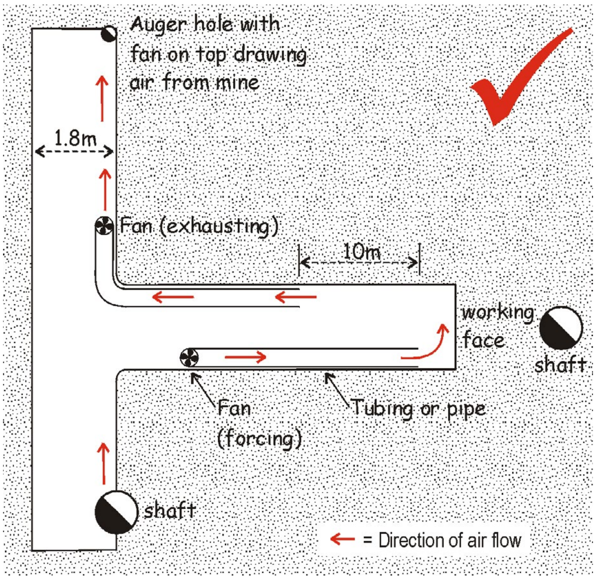
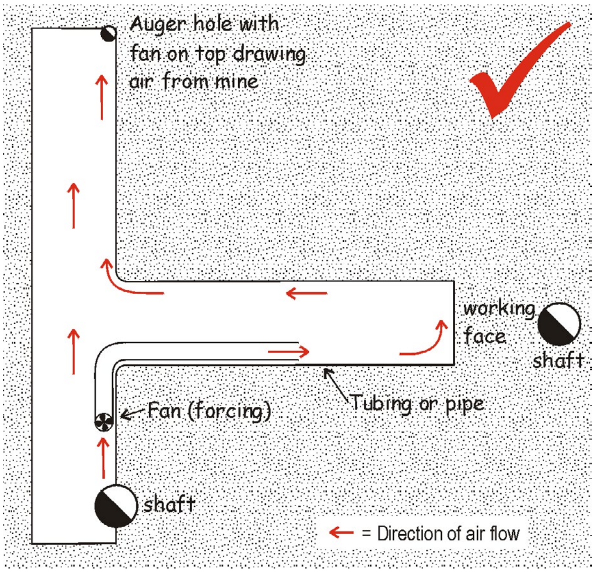
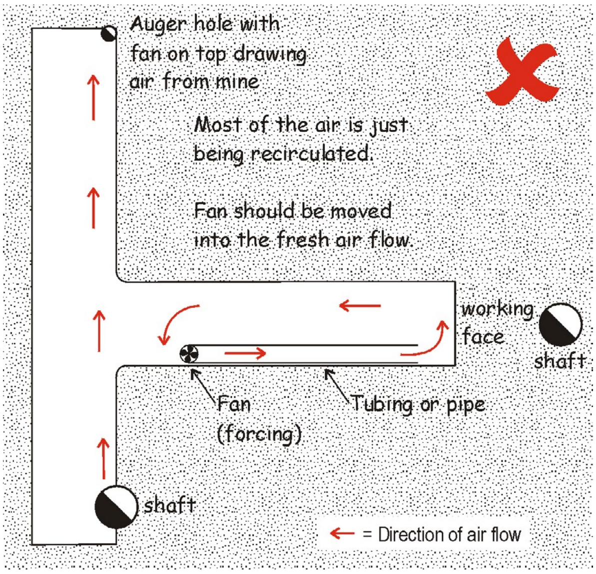


Figure 90 - Auxiliary ventilation in blind drive - force only system.



In both systems, care must be taken to prevent recirculation. Bad air may be recycled because of overlap and/or insufficient air velocity to ensure discharge of the contaminated air from the workplace.

Figure 91 - Auxiliary ventilation in blind drive - forcing fan recirculating air



In some mines it may be necessary to create barriers in previously worked areas to ensure that air will flow through the workings in the required direction. These barriers can be made from conveyor belt, plastic sheeting, timber or similar materials.

The below figure shows an example of a barrier that consists of plywood on a timber frame. Air leakage of air has been prevented by sealing the edge of the timber frame with expanding foam.

Figure 92 - Plywood ventilation barrier across an old drive

Fumes generated with expanding foam sealing chemical requires consideration of ventilation management during installation.

Detection and measurement of air flow

The movement of air (velocity) can be measured using a variety of instruments, including smoke tubes, vane anemometer, pitot tube or hot wire anemometer.

The simplest way of detecting the direction and flow of air is from a visible trail created from a puff of smoke, talcum powder or chalk dust. The velocity can be measured by painting two lines one metre apart on the wall of the desired measuring location and creating a puff of smoke or chalk dust trail at the upwind side, and using a watch, time the period it takes for the visible trail to travel one metre.

If the dust trail takes 10 seconds to travel one metre through a drive having a cross sectional area of 1.5m by 2.0m, the velocity can be calculated as follows:

VELOCITY	=	DISTANCE/TIME
	=	1/10
	=	0.1 metres/second

The quantity of air moving past that point can be calculated as follows:

QUANTITY OF AIR (Q)	=	VELOCITY X AREA OF THE DRIVE
	=	0.1 metres/second X 1.5m X 2.0m
	=	0.3 metres/second

The volume and velocity reflect the ability of the ventilating current or flow of air to remove dust particles, sustain life, and dilute gases and other contaminants present in the mine air.

Quality of mine air

Air is the mixture of gases comprising the natural atmosphere. The main constituents of air are:

Nitrogen	78%
Oxygen	21%
Carbon Dioxide	0.03%
Other gases	0.9%

Of these, the two main gases that have influence on human life are oxygen and carbon dioxide.

Oxygen (0^2)

Oxygen is an odourless, tasteless and colourless gas, essential for sustaining life. Mine air should contain no less than 19.5% by volume. An oxygen level of less than 17% is hazardous to life.

Depletion of oxygen may be caused by dilution from other gases, or by sulphide ores and carbonaceous shales that oxidise slowly. Timber decay and rusting iron also uses up oxygen and may result in a decrease in oxygen availability in the mine.

Carbon dioxide (CO^2)

Carbon dioxide gas is colourless and has a slight pungent smell in high concentrations. It is non-explosive in air. It can be found at floor level because it is denser than normal air. The maximum allowable concentration is 0.5%. Concentrations of carbon dioxide greater than 5% will cause loss of consciousness. The rate of breathing doubles at a concentration of 3%.

The proportion of carbon dioxide is increased by mine fires (e.g. slow combustion of timber in an abandoned mine), blasting, breathing, burning of flame lamps, breakdown of carbonate ores and diesel vehicles.

Impurities in mine air

Airborne dust can affect the health and safety of people working underground. Any dust, if present in excessive amounts for a length of time, can affect the health of workers. Consequently, it is very important to take every precaution to minimise the potential for dust to become airborne, particularly when using machinery and shot-firing underground.

When dust becomes airborne, the velocity of the ventilating current of air should be strong enough to dilute and remove the dust and fumes. The minimum velocity should be in the range between 6-9metres/minute, but higher velocities would have a more positive effect.

There are several recognised dust types that have different effects on the human body, including:

- Pulmonary dusts (harmful to respiratory system):
  - Silica (quartz, silcrete)
  - Silicates (asbestos, talc, mica and sillimanite)
  - Metal fumes (nearly all).
- Toxic dusts (poisonous to body organs, tissue, etc):
  - Ores of arsenic, lead, mercury, tungsten, nickel, silver (principally the oxides and carbonates).
- Explosive dusts (combustible when airborne):
  - Metallic dusts (magnesium, aluminium, zinc, tin and iron).

- Inert dusts (harmful effect)

Silica (quartz) dust is probably the most significant dust to threaten the health of miners on gemstone fields. It is produced as a result of drilling (especially hand drilling silcrete or other silica containing rock to place explosives charges), excavating rock with diggers and jackhammers, as well as from vehicle movements aboveground.

Silica dust can cause:

- Silicosis, an incurable disease of the lungs
- Fibrosis, the formation of scar tissue on the lungs which reduces their effectiveness
- Vulnerability to other health problems, such as tuberculosis and lung cancer
- Cancer.

Table 7 - Maximum allowable concentrations of various dust types

TYPE OF DUST	MAXIMUM ALLOWABLE CONCENTRATION
Respirable dust	5.0 milligrams per cubic metre
Quartz bearing dust	0.5 milligrams per cubic metre
Nuisance dust	10 milligrams per cubic metre of air

Dust should be minimised with good ventilation and wetting down any broken rock or material before moving it.

Impurities in mine air – gases

Workers should only be in well ventilated areas of an underground mine. If using equipment, welding or conducting oxy-acetylene work, it needs to be done only in a well-ventilated area of the underground mine.

The following gases may be found as impurities in the atmosphere of underground mines.

Carbon monoxide (CO)

Carbon monoxide is a colourless, tasteless and odourless gas that is lighter than air. The gas is easily absorbed into the blood stream and is very toxic at low concentrations. Consequently, the maximum allowable limit in mine air is 0.005%. It is explosive in air between concentrations of 12.5% and 74%.

The main sources of carbon monoxide are exhaust emissions, blasting operations and any incomplete combustion. Petrol engines are a source of carbon monoxide and should not be used underground or located next to intake airways.

Never operate petrol motors underground or on the surface close to mine shafts. Detection can be accomplished with a gas detector or with gas detector tubes and a hand pump.

Sulphur dioxide (SO2)

Sulphur dioxide is a toxic, colourless gas with a strong sulphurous suffocating odour. It is non-combustible and non-flammable. It is a very poisonous gas but, owing to the irritating effect on eyes and respiratory passage, sulphur dioxide is intolerable to breathe for any length of time in dangerous concentrations. The maximum allowable concentration is 0.001% (10 parts per million by volume).

Principal sources of sulphur dioxide are fires in sulphide ore bodies, diesel engines, blasting and burning rubber.

The gas may be detected by its smell at concentrations of 0.003%. Detection can also be accomplished with a modern gas detector or using gas detector tubes and a hand pump.

Fumes or oxides of nitrogen (NOX)

The term fumes refer to all oxides of nitrogen but particularly to nitrogen dioxide, nitric oxide and nitrogen peroxide. All are toxic, having a pungent smell and an irritating effect on the air passage. Any air with sufficient nitrous fumes to cause appreciable irritation of the air passage should be regarded as dangerous. Maximum allowable concentrations are 3 ppm (parts per million) and 25 ppm for nitrogen oxide and nitric oxide, respectively.

The main sources are exhaust emissions and partial detonation of explosives.

Detection is by odour and should be taken as a warning not to proceed. Gas detectors and gas detector tubes are also available.

Radon

Radon is natural radioactive gas that is present everywhere and it is produced as a result of the decay of naturally occurring uranium. Most soil and rock contain uranium, with a world average concentration of about 4 parts per million. Radon gas can accumulate in poorly ventilated spaces, like those found in some opal or gemstone mines.

Test results of radon in a gemstone field

A radon sampling program was completed in 1999 across the Lightning Ridge opal fields. The results showed that radon gas concentrations were highest in blind drives and in the lower levels of mines that have been worked on two levels. It is important to note that the highest results were substantially below the internationally accepted levels that would require immediate preventative action.

Although the levels of radon gas found did not warrant immediate concern, the Regulator has been advised that for opal or gemstone miners working underground for 2,000 hours per year or more, it is desirable that they have some form of mechanical ventilation. The appropriate use of such ventilation assists in dispersing and preventing the build-up of radon within an opal or gemstone mine. Options include a blower or exhaust fan with sufficient airflow to disperse any build-up of radon.

Radon cannot be detected by any convenient method as it requires specialist equipment.

Other gases

Other gases that may be present in mines include methane, aldehydes and hydrogen sulphide. These are not common in the gemstone fields. However, mine operators mining in proximity to a land fill site should be aware that gases may be produced by decomposition of the waste. Consult the Regulator if there is any doubt about the composition of the mine air.

Diesel exhaust fumes

This contaminant (soot) results from diesel exhausts and the quantity produced is related to the quality of diesel fuel and the type of engine. An allowable concentration of 2 milligrams/m3 of air is recommended.

The WHS laws require that the mine operator must ensure that pollutants from diesel plant underground be minimised as far as reasonably practicable. A guide *MDG 29 - Management of diesel engine pollutants in underground environments* has been compiled to assist in formulating a management system approach for the safe use of diesel engines underground. It provides guidance material in managing health risks from diesel engine pollutants, when diesel engines are operated in an underground environment

Table 8 - Maximum allowable concentrations for various gases in mine air

GAS	LIMIT
Carbon monoxide (CO)	30 ppm (0.003%)
Carbon dioxide (C02)	5000 ppm (0.5%)
Nitrous oxides (NO3)	25 ppm
Nitrogen dioxide (N02)	3 ppm
Sulphur dioxide (S02)	2 ppm

The number of engines that can be operated in a mine at any one time will be governed by the quantity of air available for ventilation.

Explosive atmospheres

In addition to the gases already mentioned (methane, carbon monoxide, hydrogen sulphide), other materials can create an explosive atmosphere within a mine. These are:

- acetylene, which is usually stored in cylinders for oxy-acetylene cutting. It is a colourless gas and explosive in air mixtures ranging from as low as 3% up to 82%
- oxygen stored in cylinders can cause rapid burning (oxidation) and should always be stored away from grease and electrical equipment
- fuel vapours can easily be ignited by any flame, if not properly flushed by a current of air
- vapours from fast drying agents and paints are potentially explosive. They should always be in well-ventilated areas within the mine. If possible, away from intake air used by workers, and not in dead ends.

Heat and humidity

Temperature and humidity control are part of the process of air conditioning used to maintain the quality of mine air, to provide a comfortable working environment and to reduce possible health hazards. Essentially, this involves removing heat emitted from different sources in the mine, along with water contained in the air.

Collectively these two factors can have severe physiological effects on mine workers.

In shallow mines, ventilation systems can cope with the heat and humidity in the mine air. This will control the physiological effects that heat and humidity can have on a human body. The human body has very efficient heat-regulating mechanisms, which strive to keep the body temperature at about 37 degrees Celsius.

A major factor in the production of heat from the body is the degree of physical exertion undertaken. This heat is mainly transferred to the surrounding air. If this transfer cannot be achieved because of the temperature and humidity of mine air, then workers experience undesirable physiological effects.

Problems with old mine workings

To protect workers from the adverse effects of working in a high humidity environment, the temperature in any working place should always be less than 27 degrees Celsius wet bulb.

Old and abandoned mine workings are potentially hazardous and should be treated with respect. While horizontal mine workings may be entered after taking appropriate safety measures, no person should attempt to enter vertical openings such as shafts, rises or winzes, unless adequately equipped under the supervision of an experienced underground miner or other qualified person. Hazards such as noxious gases may not be obvious or readily detected.

Underground workings should be checked for natural ventilation. Exhaust airways should be checked for the possible presence of noxious gases.

Where the mine atmosphere contains insufficient oxygen and/or high concentrations of dangerous gases, a system of forced ventilation must be installed and operated for a sufficient period before entry. This may require a small compressor, compressor air hoses, small compressed air fan and flexible ventilation tubing that will reach the work area.

Never enter abandoned workings alone. Ensure suitable ventilation. Always have another person situated in a safe place, in communicating range so that help can be provided if required.

REMEMBER

- Often there are high levels of carbon dioxide in blind shafts and drives. This must be dispersed from the mine with some form of mechanical ventilation.
- Silica dust is a major potential hazard that must be controlled with appropriate ventilation flows and/or personal protective equipment when it cannot be eliminated at the source.
- Petrol motors are not safe to use underground under any circumstances.

Open cut mining

Open cut mining is often seen as the final procedure in the recovery of opal or gemstone from a given location, after underground mining has been completed. It also allows the rehabilitation of the area to an acceptable standard for the landholder's continued use. The standards for rehabilitation vary between fields, depending upon the final use of that area and the environmental requirements of the Regulator. Open cut mining requires planning and can be very expensive.

In some circumstances, open cut mineral claims or titles can cover an area of up to two hectares, providing that any one side does not exceed 200 metres in length.

Open cut mining requires a permit to be issued under the *Mining Act 1992* (section 175). Activities cannot commence until approval has been granted.

Planning

When planning the mine's operation, consider the following checklist:

- How many cubic metres of overburden will have to be removed?
- Where will the topsoil be stockpiled?
- Where will the overburden be stockpiled?
- Will the cap rock need blasting?
- How many times will the pit need to be benched?
- Where will the ramp/haul road be positioned?
- What earthmoving equipment will be required?
- How many trucks will be needed?
- Is the stockpile area large enough?
- How will the gemstone dirt be processed?
- Would strip mining be the best option?
- What fencing and security will be needed?
- How will area be rehabilitate?
- Do you have the required financial resources?

Good planning can mean the difference between making a profit or a loss. Obviously, the biggest cost involved will be the removal and replacement of the overburden. The equipment used and the proximity of the stockpile area are major factors in whether the operation is cost effective. Most open cut mines are undertaken to recover gemstone left behind in pillars from underground mining that could not otherwise be extracted. There is no way of calculating which pillars will produce payable opal or gemstone and which pillars won't. Consequently, all of the gemstone dirt will need to be processed in order to average out the return.

During the removal of overburden, the gemstone level is often contaminated by rubble falling down the shafts. This adds to the volume of gemstone dirt needed to be processed and tailings to sort through at the processing stage. This can be partially overcome by backfilling the shafts with gemstone dirt or puddling silt before removing the overburden.

Processing costs can be reduced by screening the dirt before transporting it to the wash plant (agitator). This has added advantages of keeping more dirt on the site for the backfilling stage and reducing the volume of dirt that needs to be transported for processing.

Figure 93 - Benching in the Three Mile open cut at Lightning Ridge

The figure above shows the necessary benching in the background. A standard requires that for every 6-metre depth, a 3-metre bench should be left to stabilise the pit face. The left foreground in the figure shows evidence of undercutting or fretting. This pit has been open for a long time, so weather conditions may have been a contributing factor in the fretting. Evidence of cracking along benches of an open cut needs to be identified, as the ground below would then be unstable.

GUIDELINES - EQUIPMENT

Using the correct machinery can make a big difference to the cost effectiveness of the operation.

A dozer can be used to rip the overburden before pushing. It can also be an effective means of backfilling where the overburden is adjacent to the pit.

An excavator is an ideal machine for digging the softer level. It can also be used for trenching and is excellent for loading trucks in virtually any position.

Figure 94 - Removing the opal level using a 15-tonne excavator

Figure 95 - A 45-tonne excavator loading a 10 cubic metre tip truck. Standards require that there to be a bund wall around the excavation edge.

Figure 96 - A trommel used for reducing the amount of opal dirt to be processed

Figure 97 - Rehabilitated open cut at Three Mile Flat, Lightning Ridge

GUIDELINES - EFFICIENCY AND SAFETY

Large excavators are an efficient means of removing both the overburden and the gemstone dirt levels.

They have both the power and the weight to dig and load overburden but require enough trucks to keep pace with their output.

The lack of a berm (or windrow of material) on the upper bench would not be tolerated under the WHS Regulation.

Where the overburden is adjacent to the pit, they are an efficient means of backfilling the pit, provided they don't have to double handle the dirt. It may be more efficient to hire a large dozer for the final backfilling stage, leaving the mine in a safe condition and rehabilitated, as required by law.

Mechanical equipment and maintenance

Since the 1970s, there has been a widespread adoption of the use of mechanical equipment on the Lightning Ridge opal fields.

Every year, thousands of workers use machinery, plant or equipment. In recent years, there have been more than 160,000 injuries in NSW workplaces alone as a result of using plant incorrectly[1].

Energy sources associated with plant and structures

It is important for duty holders to identify hazards and potential consequences to assess and treat the risk. The table[2] below provides guidance on general hazards associated with mechanical plant. Further guidance can be found in AS 4024.1 series of Standards.

Table 9 - Mechanical hazards

ENERGY/HAZARD	MECHANISM/SCENARIO	POTENTIAL CONSEQUENCES
Chemicals	■ diesel particulate matters ■ dust ■ fluids ■ fumes ■ gases (toxic) ■ mists	■ asphyxiation ■ burn injuries - chemical ■ burn injuries – temperature ■ cancer ■ chronic respiratory disease ■ death - asphyxiation ■ dehydration ■ disturbed judgement ■ eye irritation ■ hypoxia ■ poisoning ■ lung damage ■ nausea ■ mood changes ■ throat and bronchial irritation

ENERGY/HAZARD	MECHANISM/SCENARIO	POTENTIAL CONSEQUENCES
Chemical reactions	■ fires ■ flammable gas explosion ■ self-heating ■ self-ignition ■ uncontrolled exothermic reaction	■ burn injuries ■ death – asphyxiation ■ impact injuries
Electrical energy	■ direct contact ■ fire ■ indirect contact ■ electrostatic phenomena ■ loss of control of plant ■ plasma	■ burn injuries ■ death - electrocution ■ electric shock
Static electricity	Discharge of energy causing ignition of explosive gas or stored fuel sources.	■ burns ■ asphyxiation
High pressure fluids	■ escape of fluids under pressure ■ component failure ■ loss of control of plant	■ burns ■ crush injuries ■ death ■ fluid injection injuries ■ impact injuries
Stored of trapped fluids	■ engulfment ■ head pressure ■ suction pressure	■ drowning ■ suction injuries
Kinetic energy ■ Moving parts ■ Moving plant ■ Vibration	■ collisions ■ crushing ■ drawing-in or trapping ■ entanglement ■ friction or abrasion ■ hazardous manual tasks (exertion,repetition, extended duration) ■ hand held plant vibrations ■ operation of moving plant	■ amputations ■ crush injuries ■ death ■ entanglement injuries ■ friction burns ■ impact injuries ■ strains ■ unhealthy posture ■ musculoskeletal disorders

ENERGY/HAZARD	MECHANISM/SCENARIO	POTENTIAL CONSEQUENCES
Noise	■ excessive/harmful noise levels	■ fatigue ■ hearing loss ■ stress
Stored energy ■ gravity ■ stored elastic energy	■ fall of people from heights ■ hazardous manual tasks ■ mass in elevated machine components ■ mass in raised material falling ■ slips, trips and falls – access ways ■ deflection of metallic materials ■ deflection of plastic materials e.g. pipe ■ tension in elastic materials, e.g. belts ■ strain in materials e.g. chains	■ bone breakages ■ crush injuries ■ death ■ fall injuries ■ impact injuries ■ shock ■ sprains and strains ■ unhealthy posture from muscular skeletal injuries
Radiation energy ■ non-ionising ■ ionising	■ welding arc flash ■ emitted radiation	■ burns ■ dehydration ■ loss of conscious ■ heat stroke ■ radiation sickness ■ cancer ■ death

Plant general requirements

PCBUs have an obligation under the Work Health and Safety Regulation to ensure that all mechanical equipment is, so far as reasonably practical, without risk to the health and safety of any person.

People with management control of mechanical plant have an obligation under law to ensure that the plant is only used for the purpose for which it was designed.

Suppliers of plant, including second-hand plant, also have a duty under the Work Health and Safety Regulation to supply plant that is without risk to health and safety and provide the following:

- condition of the plant to also include any defects
- information on use and maintenance requirements.

Purchasing or hiring plant

Many injuries and illnesses associated with plant occur due when the correct equipment for the job is not selected.

Before purchasing plant, conduct a check to ensure that it is suitable for its intended use and work environment. Also check if special skills are required to operate and maintain the equipment. Discuss your needs with the plant supplier. The supplier must provide information about:

- the purpose for which the plant was designed or manufactured
- the results of any calculations, analysis, testing or examination
- any conditions necessary for the safe use of the plant
- any alterations or modifications made to the plant.

Before purchasing, hiring or leasing plant, determine:

- the hazards and risks associated with installation, commissioning, operation, inspection, maintenance, repair, transport, storage and dismantling of the plant
- control measures needed to minimise these hazards and risks
- the manufacturer's recommendations in relation to the frequency and type of inspection and maintenance needed
- any special skills required for people who operate the plant or carry out inspections and maintenance
- any special conditions or equipment required to protect the health and safety of people carrying out activities such as installation, operation and maintenance
- any alterations or modifications required to be made to the plant.

Check the plant for the following characteristics:

- contact with or access to dangerous parts is prevented (i.e. by using guards and protective structures)
- sturdy construction with tamper-proof design
- no obstructions to the plant operator
- has fail safe operation
- easy to inspect and maintain
- does not introduce other hazards (i.e. manual handling problems or excessive noise) into the workplace
- incorporates measures to minimise risks during use (i.e. low noise).

Registering plant

Certain items of plant and types of plant designs must be registered. Registrable plant must be:

- design registered before it is supplied
- item registered before it is used.

Design registration

Design registration is the registering of a completed design, from which any number of individual items can be manufactured. The person applying for design registration may be either the original designer or a person with management or control of the item of plant.

Item registration

Plant item registration applies to a specific item of plant and each item requires registration. The purpose of registering an item of plant is to ensure that it is inspected by a competent person and is safe to operate. It is the responsibility of the person with management or control of the plant to ensure that all required plant items are registered.

Items of plant requiring registration of a design

- Pressure equipment, other than pressure piping, and categorised as hazard level A, B, C or D according to the criteria in Section 2.1 of AS 4343–2005 (Pressure equipment—hazard levels).
- Gas cylinders covered by Section 1.1 of AS 2030.1–2009 (Gas cylinders—General Requirements).
- Hoists with a platform movement exceeding 2.4 meters, designed to lift people.
- Work boxes designed to be suspended from cranes.
- Boom-type elevating work platforms.
- Mobile cranes with a rated capacity of greater than 10 tonnes.

Exceptions

The items of plant that are exempt from design registration:

- A heritage boiler.
- Any pressure equipment (other than a gas cylinder) excluded from the scope of AS/NZS 1200:2000 (pressure equipment). See section A1 of Appendix A to AS/NZS 1200:2000 (Pressure equipment).
- A crane or hoist that is manually powered.
- An elevating work platform that is a scissor lift or a vertically moving platform, or tow truck.

Plant requiring item registration

- Boilers categorised as hazard level A, B or C according to criteria in Section 2.1 of AS 4343–2005 (pressure equipment—hazard levels)
- Pressure vessels categorised as hazard level A, B or C according to the criteria in Section 2.1 of AS 4343–2005 (Pressure equipment—Hazard levels), except:
  - gas cylinders
  - LP gas fuel vessels for automotive use
  - serially produced vessels
  - mobile cranes with a rated capacity of greater than 10 tonnes.

Exceptions

The items of plant that are exempt from item registration:

- Any pressure equipment (other than a gas cylinder) excluded from the scope of AS/NZS 1200:2000 (pressure equipment). See section A1 of Appendix A to AS/NZS 1200:2000 (pressure equipment).
- A crane or hoist that is manually powered.

Inspection and maintenance of pressure equipment

Pressure equipment should be inspected by a competent person to assure it is in safe operation in accordance with the table[3] below.

Table 10 - Inspection intervals for pressure equipment

Legend: p = design pressure in megapascals, V = Maximum volume and liquid space in litres

pV VALUES OR CATEGORY	COMMISSIONING INSPECTION	FIRST ANNUAL INSPECTION	INSPECTION INTERVALS, YEARS		
			EXTERNAL INSPECTION	INTERNAL INSPECTION	
				NOMINAL INTERVAL	EXTENDED INTERVAL
Compressed air containing vessels					
pV ≤ 100 Mpa.L	No	No	2	4	12
100 < pV ≤ 150 Mpa.L	Yes	No	2	4	12
pV > 150 Mpa.L	Yes	No	2	4	12

pV VALUES OR CATEGORY	COMMISSIONING INSPECTION	FIRST ANNUAL INSPECTION	INSPECTION INTERVALS, YEARS		
			EXTERNAL INSPECTION	INTERNAL INSPECTION	
				NOMINAL INTERVAL	EXTENDED INTERVAL
Process vessels – Vessels which form part of a process train which are subjected to changes during its process cycle.					
Hazard level A	Yes	Yes	2	4	8
Hazard level B	Yes	Yes	2	4	12
Hazard level C	Yes	Yes	2	4	12
Hazard level D	Yes	No	4	-	-
Auxiliary vessels – Vessels which form part of a package or part of a subsystem (i.e. intercoolers and hydraulic accumulators) **Accumulators**					
pV ≤ 100 Mpa.L	No	No			
100 < pV ≤ 200 Mpa.L	Yes	No			
pV > 200 Mpa.L	Yes	Yes	2	12	12
Other auxiliary vessels containing corrosive, toxic or flammable contents					
	Yes	Yes	12	12	12
Refrigeration and air conditioning vessels **Group A1 refrigerants to AS/NZS 1677.1**					
pV ≤ 100 Mpa.L	No	No			
100 < pV ≤ 200 Mpa.L	Yes	No			
pV > 200 Mpa.L	Yes	Yes	2	12	12
Group A2, A3, B1 and B2 refrigerants to AS/NZS 1677.1					
	Yes	Yes	2	12	12

Plant inspection and maintenance

General requirements

Maintenance, inspection and testing of plant must be carried out by a competent person and, as a minimum, in accordance with the manufacturer's recommendations. Where no manufacturer's recommendations exists, maintenance requirements should be developed in consultation with a competent person. It should include, as a minimum, an annual inspection to ensure that the plant remains fit for purpose.

Reasonably practical control measures must be implemented to ensure the health and safety of people conducting inspections and maintenance on the plant (i.e. plant is switched off or isolated from the energy source).

Following inspections and maintenance, all guarding must be replaced before starting plant.

Inspecting plant

Inspections of plant should be conducted in accordance with regular maintenance to identify:

- defects with plant, leaks, missing components, wear and tear, corrosion and damage
- problems not considered in the design of the plant
- inadequate hazard control measures.

A pre-use inspection should be carried out before use to include the following:

- Inspect brake, coolant, engine, fuel, hydraulic and steering systems for damage, signs of leaks or pooling of oil.
- Inspect engine bays and exhaust systems for leaks and build-up of combustible materials such as oil, fuel, rubbish or rags.
- Inspect fire extinguisher to ensure it is charged, hoses are secured and free from damage or blocked nozzles.
- Inspect plant for damage or wear to include impact damage, cracked welds or metal, doors not opening or closing correctly, damaged hoses, piping or guarding, cracks or distortions in structures.
- Inspect plant for worn, missing or loose components to include belts, handrails, tracks, electrical enclosures, guarding, lights, exhaust system and wheel nuts.
- Inspect cabins to ensure doors open/ close and seats/ seat belts are operable.
- Inspect tyres and rims to ensure they are not flat, bald, damaged and all wheel nuts are secure.
- Inspect gas cylinders and ensure they are secured.

- Inspect fluids and top up as required.
- Function test plant to include brakes, steering, lights, hydraulics, emergency stop, seat belts, safety latches gauges, boom extensions and winches are all working correctly.

Maintaining plant

Maintenance of plant and the frequency should be identified by:

- tasks recommended by the designer or manufacturer
- systematic examination of failure modes
- as required by law
- as recommended by Australian or industry standard
- good engineering practice
- feedback from inspection or failure in service
- greater than expected deterioration of performance
- other innovative asset management means.

An up-to-date register of the items of plant requiring regular inspection and maintenance should be kept to include:

- the name of the person completing the inspections
- standards against which plant is inspected (e.g. AS1851 Routine service of fire protection systems and equipment for fire equipment, AS 3788 Pressure equipment – In service inspection)
- the frequency of inspections
- critical safety instructions to be followed during inspection (i.e. the isolation procedure)
- procedures for inspections, including:
  - periodic inspections
  - specific tests
  - repaired or modified plant.
- any variations from normal operation or dangerous occurrences and any trends that may be occurring.

Defects

Defects in plant and structures are normally found during operation, pre use inspection, testing and maintenance activities.

It is preferable to repair defects as soon as possible. Where it is not reasonably practical to repair the defect straight away, the plant may only be operated with defects once they have been evaluated and are not deemed safety critical to prevent harm to people.

This evaluation shall be made considering:

- the nature of the defect
- effectiveness of other layers of protection
- the effect of the prevailing conditions[4].

Hazardous atmosphere

Petroleum (diesel, petrol oils) tanks are areas where hazardous atmospheres, such as flammable gases and fumes, are likely to be present.

A hazardous atmosphere exists where:

- there is not a safe oxygen level
- the concentration of oxygen increases the risk of fire
- the concentration of flammable gases and/or fumes exceeds five per cent of their lower explosive limit (LEL)
- combustible dust is present in a quantity and form that would result in a hazardous area.

It is essential to manage the risks associated with the atmosphere in the workplace, including any ignition sources.

Confined spaces

Confined spaces pose dangers because they are usually not designed to be areas where people work. Confined spaces often have poor ventilation that allow a hazardous atmosphere to quickly develop, especially if the space is small. The hazards are not always obvious and may change from one entry into the confined space to the next.

The risks of working in confined spaces include:

- loss of consciousness, impairment, injury or death due to the immediate effects of airborne contaminants
- fire or explosion from the ignition of flammable contaminants
- difficulty rescuing and treating an injured or unconscious person
- asphyxiation resulting from oxygen deficiency or immersion in a free-flowing material (i.e. grain, sand, fertiliser, water or other liquids).

A confined space is determined by the hazards associated with a set of specific circumstances and not just because work is performed in a small space.

A confined space means an enclosed or partially enclosed space that:

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[4] *Source information Work Health and Safety Regulation Chapter 5 Part 5.1 Division 7 Subdivision 2 Clause 210 & 213 and Managing the risks of plant in the workplace code of practice.*

- is not designed or intended primarily to be occupied by a person
- is, or is designed or intended to be, at normal atmospheric pressure while any person is in the space
- is, or is likely to be, a risk to health and safety from an atmosphere that does not have a safe oxygen level
- contaminants, including airborne gases, vapours and dusts, that may cause injury from fire or explosion
- harmful concentrations of any airborne contaminants
- engulfment.

Confined spaces are commonly in vats, tanks, pits, pipes, ducts, flues, chimneys, silos, containers, pressure vessels, underground sewers, wet or dry wells, shafts, trenches, tunnels or other similar enclosed or partially enclosed structures, when they meet the definition of a confined space in the WHS Regulations.

A confined space does not include a mine shaft or the workings of a mine.

Entry and exit to a confined space

The follow shall be completed when entering and exiting a confined space:

- A safe level of oxygen is present (19.5% - 23.5%).
- Atmospheric testing is conducted prior to entry of the confined space and as required during the task, as per the outcomes of a risk assessment.
- A safe means of access is established into the confined space that is large enough to allow people wearing the necessary protective clothing and equipment to enter and exit.
- Concentrations of flammable contaminants are below 5% of its lower explosive limits.
- A confined space entry permit has been completed.

Figure 98 - How to determine a confined space

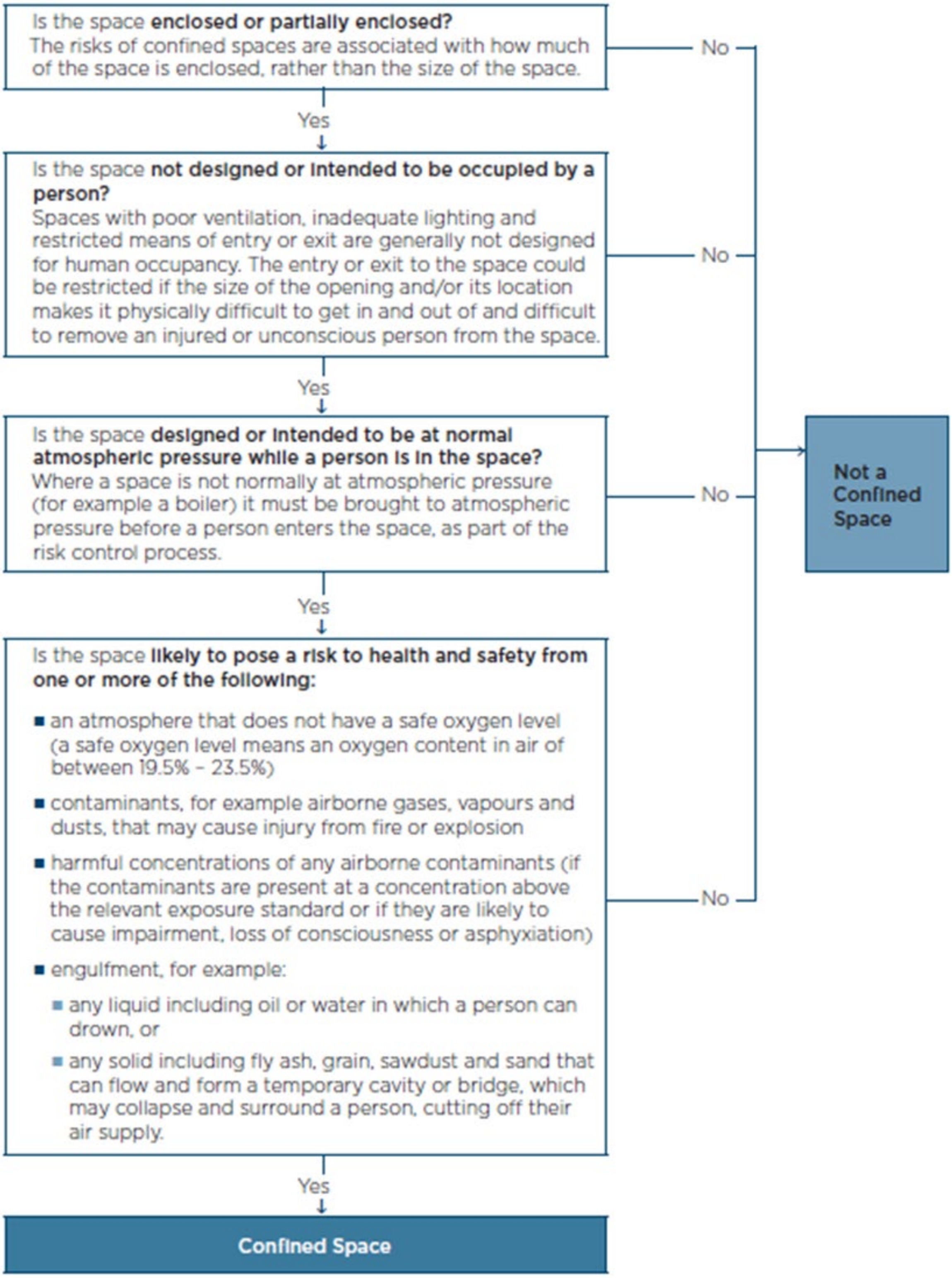


Table 11 - Atmospheric hazard management (source: Safe Work Australia)

CONTAMINANT	ABBREVIATION	ENTRY	WORK	ACTION
Lower Explosive Limit	LEL	<5%	<10% (With Continuous Monitoring)	Entry or work not permitted unless gas measurement is below the entry or work value (or within the specified range). Ventilation required before entry or during work where values are deemed unacceptable.
Oxygen	O^2	19.5 to 23.5%	19.5 to 23.5%	
Carbon Monoxide	CO	30 ppm	30 ppm	
Hydrogen Sulphide	H_2S	10 ppm	10 ppm	

Falling objects

Objects have the potential to fall on people or hit people in the work area if precautions are not put in place. Equipment, materials and items of plant that can fall or be released sideways or upwards are also considered falling objects.

Examples include:

- tools, rock, soil, plant components
- objects free-falling from lifting machinery, a vehicle or other plant equipment to include loads that are not secured or are unstable
- objects or materials ejected while using plant or hand tools
- collapse of unstable structures
- material falling from blowers.

PCBUs must manage the risks associated with an object falling on a person, if it is reasonably likely to injure the person. If elimination is not practicable, the risks must be minimised, so far as reasonably practical, and provide and maintain a safe system of work including:

- fall prevention such as moving items onto ground level, if not practical
- a system to arrest falling objects such as securing of loads, guarding, restraining bars, netting or evenly distributed loads, overhead protection on mobile plant and tethering or otherwise securing tools and materials.

Other control measures can include:

- using isolation or no-go zones where there is a risk of an object falling into an area
- training
- using personal protective equipment (PPE).

Falls

Falls from height are a major cause of serious injuries and fatalities in Australian workplaces. A review of recent incident data from the Lightning Ridge region has identified an unacceptable number of falls from height incidents.

In one of these incidents, a worker at an opal mine fell 20 metres from a shaft access ladder and landed in a hoist bucket. He suffered a compound fracture to his left femur and both tibias. It took nearly two hours to locate the worker.

In another incident, a worker fell 2.5 metres into a mine shaft in similar circumstances. He broke both ankles. In this instance, it took more than 10 hours to find him.

The Lightning Ridge area poses its own unique environment, with many miners working alone without fully appreciating the risks of falls from heights while accessing their mines from ladders.

A working at heights plan should be developed that considers self-rescue and emergency management.

DID YOU KNOW?

PCBUs and mine operators have specific obligations under the Work Health and Safety Regulations to manage the risk of a fall by a person from one level to another, including requirements to:

- ensure, so far as is reasonably practicable, that any work involving the risk of a fall is carried out on the ground or on a solid construction
- provide safe means of access to and from the workplace
- minimise the risk of falls, so far as is reasonably practicable, by providing a fall prevention device, work positioning system or a fall arrest system.

Workers also have a duty to take reasonable care for their own health and safety, as well as not adversely affect the health and safety of other people. Workers must comply with any reasonable instruction given by the person conducting the business or undertaking.

How do you manage the risk of falls?

Personal risk factors

- be aware
- take your time
- wear protective gear
- stay clean – muddy hands don't grip.

Environmental risk factors

- keep your work area clean and tidy
- identify hazards that get in the way of climbing (i.e. ropes, hoses, pipes)
- buckets are for material, not miners
- make your work area as safe as possible.

It states in chapter 3 Part 3.1 Clauses 34–38 of the Work Health and Safety (WHS) Regulation 2017 that a duty holder must:

- identify reasonably foreseeable hazards that could give rise to the risk to health and safety
- eliminate the risk, so far as is reasonably practicable
- if it is not reasonably practicable to eliminate the risk, minimise the risk, so far as is reasonably practicable, by implementing control measures in accordance with the hierarchy of control
- maintain the implemented control measure so that it remains effective
- review, and if necessary, revise the risk control measures to maintain, so far as is reasonably practicable, a work environment that is without risks to health and safety.

Control the risks

Falls are preventable. There are several ways to control the risks of falls. Some control measures are more effective than others. Control measures can be ranked from the highest level of protection and reliability, to the lowest. This is known as the hierarchy of control. The WHS Regulations require duty holders to choose the control that most effectively eliminates or minimises the risk in the circumstances. This may involve a single control measure, or a combination of two or more different controls.

In managing the risks of falls, the WHS Regulations require the following specific control measures to be implemented, where it is reasonably practicable to do so:

Can the need to work at height be avoided to eliminate the risk of a fall?

- Carry out any work that involves the risk of a fall, on the ground.

Can the fall be prevented by working on solid construction?

- A structure that is used for safe access and egress from which there is no risk of a fall from one level to another (i.e. a properly constructed cover over mine shafts or physical barrier around the edges).

Can the risk of a fall be minimised by providing and maintaining a safe system of work?

- Provide a fall prevention device (i.e. installing guard rails).
- Provide a work positioning system (i.e. an industrial rope access system) if it is not reasonably practicable to provide a fall prevention device.
- Provide a fall-arrest system, if it is not reasonably practicable to provide a fall prevention device or a work positioning system.

In some cases, a combination of control measures may be necessary (i.e. using a safety harness while working from an elevated work platform).

Control measures are needed where there is a risk of injury irrespective of fall height. For low falls, assess the risk and provide reasonably practicable measures that reflect the risk.

Ensure that the control measures selected do not create new hazards (i.e. electrical risks from contact with overhead power lines or crushing and entanglement from plant such as elevated work platforms).

Control measures

WHS Regulation 37 states that the control measures implemented must remain effective. This includes checking that the control measures are fit for purpose, suitable for the nature and duration of the work, installed and are used correctly.

To allow the chosen control measures to operate effectively:

- develop work procedures on how to correctly install, use and maintain the control measure to include details of:
  - the equipment to be inspected (including its unique identification)
  - the frequency and type of inspection (pre-use checks, detailed inspections)
  - action to be taken on finding defective equipment
  - means of recording the inspections
  - training users
  - the system of monitoring the inspection regime to verify that inspections are carried out appropriately.
- provide information, training and instruction to workers, including procedures for emergency and rescue covering:
  - the type of control measures used to prevent falls
  - procedures for reporting fall hazards and incidents
  - the correct selection, fitting, use, care, inspection, maintenance and

storage of fall-arrest and restraint equipment
– the correct use of tools and equipment used in the work (i.e. using a tool belt instead of carrying tools)
– control measures for other potential hazards.

Competency

The PCBU must ensure any person accessing the shaft is trained/ deemed competent in accessing and exiting a shaft on a ladder, fall arrest systems or operation of a man riding hoist.

People inspecting working at heights equipment must be competent to do so.

Protecting mine shafts and holes

Mine shafts, holes, penetrations and openings through which a person could fall should be made safe immediately after being formed.

There are two methods that can be used.

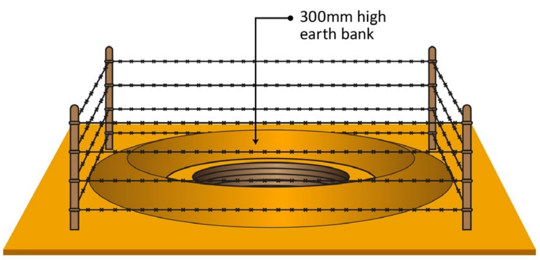
Install guard rails or fencing to prevent access.

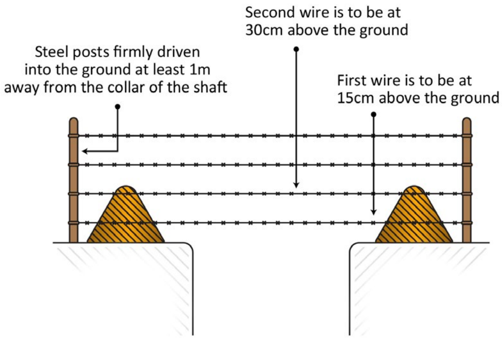
If preventing access to the shaft or hole by guard rails or fencing, it should be designed and constructed to withstand the force of someone falling against it. This can consist of guard rails, solid balustrades or other structural components.

As an example, wire mesh supported by posts with a reinforced top edge could be used. The top of the guard rail or component should be between 900 millimetres and 1100 millimetres above the working surface. If a guard rail system is used, it should also have mid-rails and toe boards or wire mesh infill panels.

If access is required, it should be protected with gates.

Figure 99 - Installing guard rails or fencing

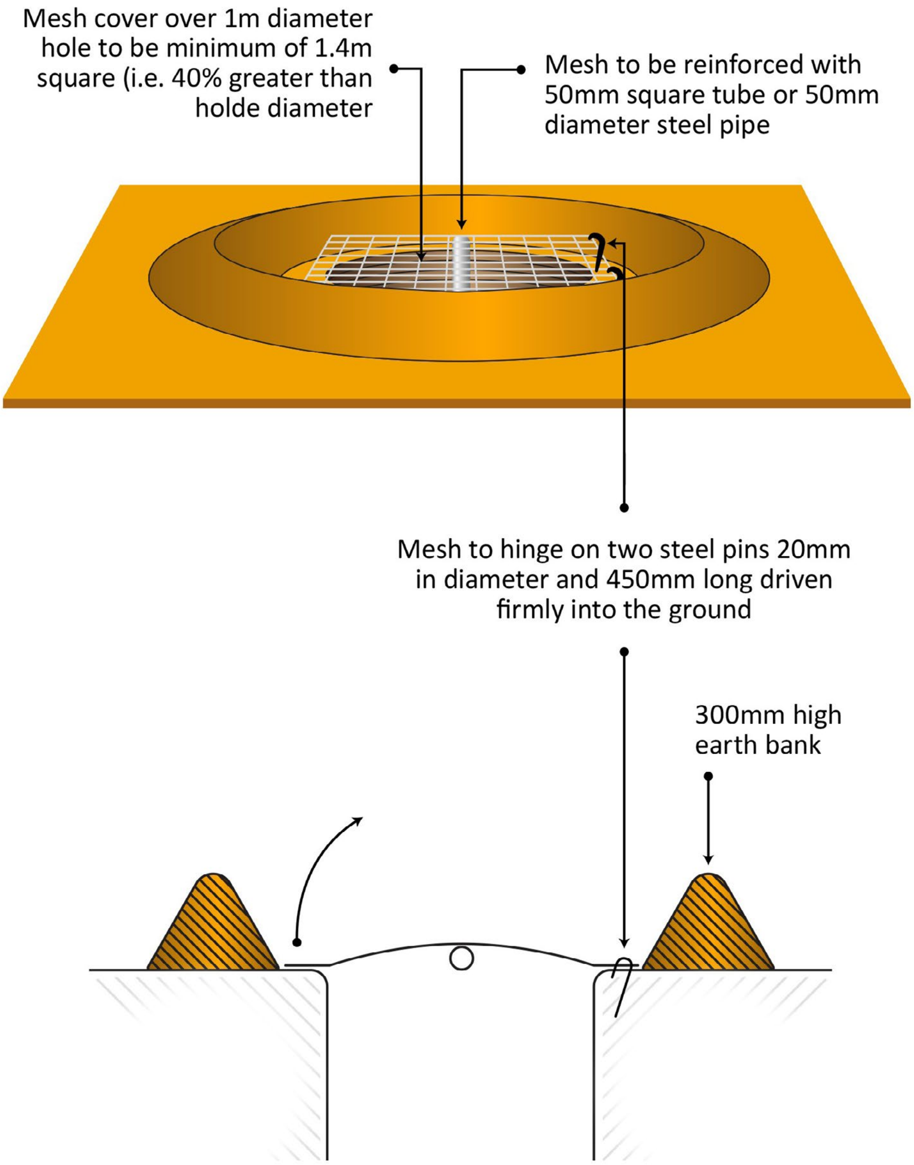




Cover the shaft or hole with a suitably rated cover.

If a cover is used to prevent access to the top of the mine shaft, it must be made of material strong enough to prevent people or objects falling through and must be securely fixed to prevent any dislodgement or accidental removal.

Figure 100 - Covering the mine shaft



Covers should:

- be secured to the ground to stop movement
- be able to withstand the force of 2kN or 200-kilogram of load. Under this load, it must not crack, tear or permanently deflect. One kilonewton (1 kN) is 102.0 kgf, or about 100-kilogram of load. (1 kN = 102 kg × 9.81 m/s2. 2kN is about 200 kg of load).
- prevent a person's foot from penetrating (i.e. a gap of no more than 35 millimetre).

Figure 101 - Opal shafts with both fencing and shaft cover.

Accessing mine shafts

Before accessing a mine shaft, all loose objects at the top of the shaft should be removed or secured to prevent trip hazards or objects falling below.

When using a ladder to access a shaft, three points of contact should be maintained at all times (i.e. one foot and two hands or, one hand and two feet.)

When climbing the ladder, workers should remain within the vertical supports of the ladder.

A ladder must rise to a height of at least one metre above the shaft. Refer to the fixed ladder section for more information.

Fixed ladder installations

Fixed installations shall be designed and constructed in accordance with the requirements of AS1657 - Fixed platforms, walkways, stairways and ladders - design, construction and installation.

A harness-based fall arrest system must be used if a fixed ladder is used and a risk of personal injury due to working at heights exists (i.e. no ladder cage or a fall greater than 6 metres could occur).

General design

General design inclusions:

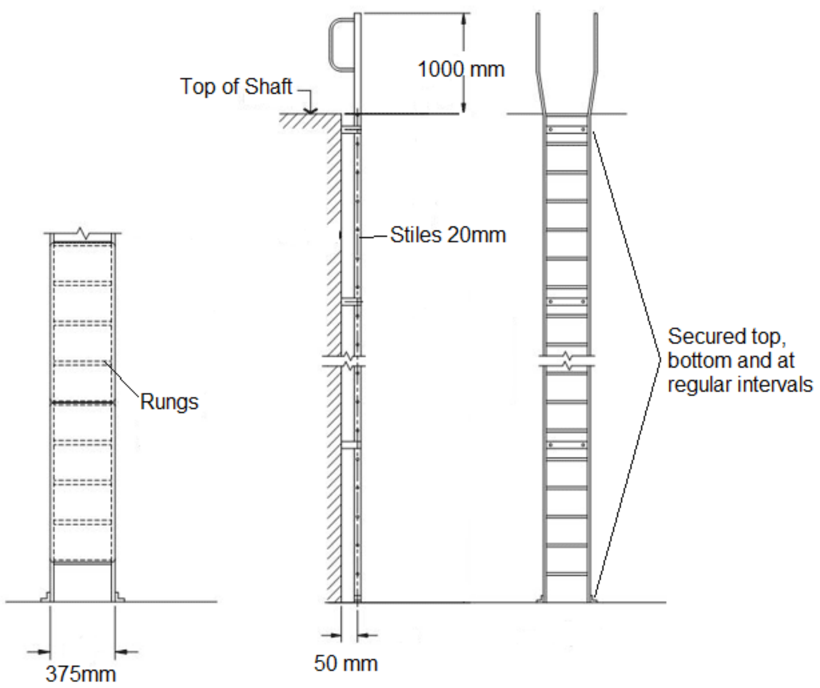
- the ladder, as a minimum, must extend 1,000 millimetres above the top of the shaft or landing
- no protrusion from hand rails to include welds dressed smooth
- system shall not move under load
- steps must be slip resistant
- rungs and stiles to be 20 millimetres in diameter as a minimum or be able to withstand a force of 3.0kN to allow easy hand grip
- spacing between rungs to be 250 millimetres to 300 millimetres, with all rungs of equal distance
- stiles width to be between 375 millimetres and 525 millimetres
- hand clearance around stiles to be 50 millimetres
- angle of install to be between 70° to 90°.

Fixing ladders

The ladder shall be secured in a manner that withstands the loads being applied. It includes:

- being attached top and bottom and at intervals to prevent lateral swaying
- a hand clearance to be not less than 50 millimetres on the ladder.

Figure 102 - Fixing ladders



Industrial fall-arrest systems and devices

A fall arrest system is intended to safely stop a worker from falling an uncontrolled distance and reducing the impact of the fall. This system must only be used if it is not reasonably practicable to use higher level controls, or if higher level controls might not be fully effective in preventing a fall on their own.

All equipment used for fall arrest should be designed, manufactured, selected and used in compliance with the AS1891 series of Standards.

Key safety considerations in using fall arrest systems are:

- ensuring the correct selection, installation and use of the equipment
- ensuring the equipment and anchorages are designed, manufactured and installed to withstand the force applied to them in the event a person falls
- ensuring the system is designed and installed so that the person travels the shortest possible distance before having their fall stopped
- ensuring workers using a fall arrest system also wear adequate head protection in the event of a fall
- ensuring that if the equipment has been used to arrest a fall, it is not used again until it has been inspected and certified by a competent person as safe to use.

Individual fall arrest systems

Individual fall arrest systems consist of some or all the following components:

- anchorages
- lifelines
- inertia reel
- lanyard of fixed length
- retractable lifelines
- rope grabs
- wire grabs
- rail system
- shock absorbers, both personal and industrial
- harness
- snap hooks (double or triple action to prevent rollout)
- karabiners (double or triple action to prevent rollout)
- rescue equipment.

Individual fall arrest systems rely on workers wearing and using them correctly. Workers who will use such a system must be trained in its safe use.

A rescue plan is required where a worker could sustain a fall from a height greater than 600 millimetres.

Anchorage points

Each anchorage point should comply with the requirements in AS/NZS 1891:4 Industrial fall arrest systems and devices – selection, use and maintenance.

All anchorages should be tested and approved by a competent person before use. A visual inspection may not reveal the structural integrity of the anchor point (i.e. the bolt may have failed below the concrete surface).

The following can be used as anchor points:

- Trees with the following:
  - no sharp objects that could cut the sling or static line
  - the sling or static line is barricaded to prevent damaged by people or vehicle movements
  - the tree base is a minimum of 150 millimetres in diameter
  - the tree is free from defects
  - the root system is substantial enough for the tree to be used as an anchor point for life support.
- Metal spikes ground anchors with the following:
  - at least three ground anchors driven in, at least one metre away from the shaft, at a 15 to 30-degree angle facing away from the shaft
  - linked together, unless manufacturer specifies differently in the technical installation information
  - the head will prevent the slings from easily sliding off, if the worker is standing directly above them
  - no sharp objects that could cut the sling or static line
  - the sling or static line is barricaded to prevent damaged by people or vehicle movements.
- Steel ladder mounting bars with the following:
  - be 50 millimetres or larger, with a wall thickness of 3 millimetres or greater
  - be twice the diameter of the shaft opening
  - be secured to the ground or structure so it cannot move in any direction
  - the ladder shall be secured to the bar with suitable U bolts /clamps.
- Frame based anchor points (i.e. auto bucket hauling frames, blower frames, vehicle) with the following:
  - the structure/ frame being used as the anchor point is not able to fit down the shaft
  - the structure/ frame being of a weight that prevents it from being pulled into the shaft, or is anchored to the ground to prevent it from moving
  - the structure/ frame is a sufficient size and thickness to handle the forces generated in a fall.
- Vehicle-based anchor with the following:
  - plant isolated

- hand brake applied
- wheels chocked.

Each anchorage point should be located so that a lanyard of the system can be attached to it before the person using the system moves into a position where they could fall.

Safe access options

Mine shafts

Before accessing a mine shaft, all loose objects at the top of the shaft should be removed or secured to prevent trip hazards or objects falling below.

Safe ladder access can be achieved by using one of the following methods:

- a temporary vertical static line (rope or flexible wire rope) with 5 kilograms of weight applied to the end
- an inertia reel with a tag line off set to one side
- body harness or waist belt.

When using a ladder to access a shaft, three points of contact should always be maintained (i.e. one foot and two hands or, one hand and two feet.)

When climbing the ladder, workers should remain within the vertical supports of the ladder.

A ladder must rise to a height of at least one metre above the shaft.

Blowers

Safe access can be achieved by using one of the following methods:

- Portable ladder with the following:
  - ladder secured top and bottom.
  - body harness with adjustable lanyard or temporary static line connected to blower structure.
- Parked vehicle with the following:
  - plant isolated
  - handbrake applied
  - wheels chocked
  - body harness with adjustable lanyard or temporary static line connected to blower structure.
- Climbing the blower itself with the following:
  - plant isolated
  - hand brake applied
  - wheels chocked
  - body harness with adjustable lanyard and short sling to progressively

climb.

Large washer plant

Safe access can be achieved by using the following method:

- horizontal static line
- body harness with adjustable energy absorbing lanyard.

Small washer plant

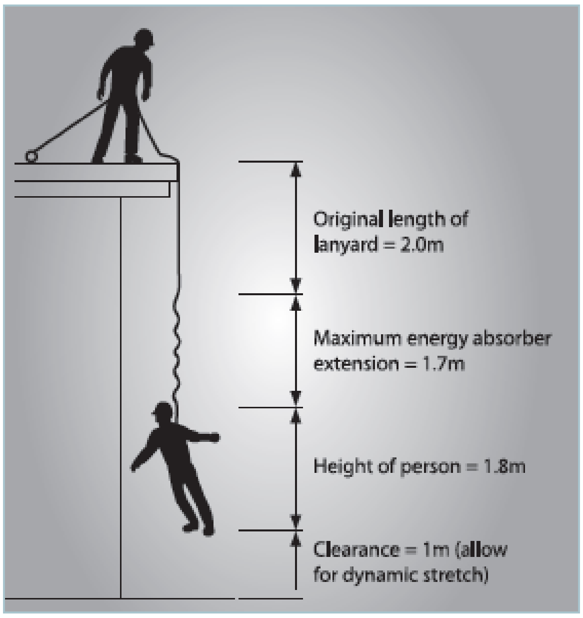
Safe access can be achieved by using one of the following methods:

- installing walkways with guard railings
- relocating plant to ground level, where practical.

Limit free fall distance

Fall arrest systems, incorporating a lanyard, should be installed so that the maximum distance a person would free fall before the system takes effect is two metres. There should be enough distance between the work surface and any surface below to enable the system, including the action of any shock absorber to fully deploy.

Figure 103 - Fall arrest system



Use suitable harness

A full body harness should be worn and correctly fitted. Workers should connect the fall arrest line to the attachment point on their harness that will provide the best protection in the situation it is being used. Consideration should be given to the potential fall distance, potential impact with the structure, body position after a fall and the need to interact with equipment such as rope-grabs.

Maintain minimum of slack in fall arrest lanyard

There should be a minimum of slack in the fall arrest lanyard between the user and the attachment. The anchorage point should be as high as the equipment permits. Avoid working above the anchor point, as this will increase the free fall distance in the event of a fall, resulting in higher forces on the body and greater likelihood of the lanyard snagging on obstructions. Use inertia reels correctly.

Inertia reels should not be used as working supports, by locking the system and allowing it to support the user during normal work. They are not designed for continuous support.

Vertical and self-retracting anchorage lines can be used as a risk control measure, in connection with work performed from ladders.

Anchorage lines or rails

Anchorage lines or rails are temporary or permanent fall arrest systems, which can be installed to provide continuous fall protection for workers using ladders.

When using anchorage lines or rails, consider the following safety measures:

- temporary systems comply with the AS/NZS 1891 series of Standards
- the locking device is attached to the frontal attachment point of the harness and the lanyard assembly is a maximum of 300 millimetres in length
- the point of connection onto the ladder by the climber is near the base of the ladder to allow the connection before ascending begins and to provide continuous connection to the disconnecting point when at a safe higher level
- free fall is limited to a maximum of 600 millimetres
- permanent systems are of wire or rail construction and are installed according to the manufacturer's instructions.

After a fall, remove the system from service and have it inspected by a competent person before it is used again.

Maintenance and inspection

All access systems should be inspected before use to ensure they are in serviceable condition. Checks should ensure:

- items are secure and free from defect
- ladder is not obstructed
- item is not damaged and is clean
- buckles and clips are correctly installed and free from damage
- harness webbing and lanyards are not frayed, cut or damaged
- harness and safety lanyard are within their 'remove from service date' –

which is 10 years from date of manufacture unless otherwise marked

- the equipment is fitted with a current periodic inspection tag or recorded on a register.

Table 12 - Requirements for recommended inspections of equipment

ITEM DESCRIPTION	INSPECTION FREQUENCY	COMPETENCY REQUIRED
Personal equipment including connectors, harnesses, lanyards, fall arrest devices	Before and after use	Height safety operator
Harnesses, lanyards, associated personal equipment Fall arrest devices (external inspection only) Ropes and slings	Every 6 months, unless recommended by manufacture (no greater than annually)	Height safety equipment inspector
Anchorages – drilled in type or attached to timber frames	Annually	Height safety equipment inspector
Anchorages – other types	Annually unless recommended by manufacturer – no greater than every 5 years	
Fall arrest devices – full service	Annually unless recommended by manufacturer – no greater than every 5 years	Height safety equipment inspector
Horizontal or vertical lifelines – steel rope or rail	Annually unless recommended by manufacturer – no greater than every 5 years	Height safety equipment inspector
Horizontal or vertical lifelines – fibre rope or webbing	Annually	Height safety equipment inspector
All items of personal and common use equipment	On entry or re-entry to service	Height safety equipment inspector
All items that have been stressed because of a fall	Inspected prior to further use	Height safety equipment inspector

Safe access option guidance

The basis of the safe access option guidance is shaped by the working systems as defined in AS / NZS 1891.

Table 13 - Safe access option guidance

MINE SHAFT ACCESS	
The ladder access can use either a temporary vertical static line (rope or flexible wire rope) or an inertia reel with a tag line position to one side of the ladder. The inertia reel option require an anchor point vertically above the shaft and cannot be connected to ground anchors due to dirt being dragged into the mechanism. The static line needs 5 kilograms of weight on the end so it is not dragged up behind the worker.	
EQUIPMENT	**EXAMPLE**
Temporary rope vertical static line fastened to anchor point directly or via a sling connection made up of: ■ 1-metre by 1-tonne round sling ■ 2 steel screw gate karabiner ■ One 11-millimetre static rope with knotted terminations conforming to AS/NZS4142.3 or EN1891 – length to suit shaft (10 to 25 metres in length) ■ One ASAP with energy absorber & connection hardware ■ One 500-millimetre by 7-millimetre prussic loop ■ Rated waist belt or lower body harness or full body harness ■ One storage bag	
Temporary flexible wire rope vertical static line, with swaged eye termination, fastened to anchor point directly or via a sling connection made up of: ■ 1-metre by 1-tonne round sling ■ Two steel screw gate karabiner ■ One 8-millimetre stainless steel flexible wire rope with swaged eye each end conforming to AS/NZS1891 – length to suit shaft (10 to 25 metres in length) ■ One Arresta wire rope grab with energy absorber & connection hardware ■ One 500-millimetre by 7-millimetre prussic loop ■ Rated waist belt or lower body harness or full body harness ■ One storage bag	

MINE SHAFT ACCESS	
EQUIPMENT	EXAMPLE
Fall arrest devices – full service Inertia reel fastened to anchor point directly or via a sling connection made up of: ■ 1-metre by 1-tonne round sling ■ One steel screw gate karabiner ■ One wire rope inertia reel conforming to AS/NZS1891 or EN – length to suit shaft (10 metres or 20 metres versions) ■ One 10 to 20 metre by 3-millimetre tag line tied to the inertia reel connection hardware. ■ One tag line to suit inertia reel length ■ Rated waist belt or lower body harness or full body harness ■ One storage bag	

BLOWER ACCESS

Accessing blowers can be done by either using the same rope or wire static line as detailed in the mine shaft access kits. If the blowers need to be accessed with the shaft system still in place, then the worker can choose to utilise a second static line or use a Grillon adjustable lanyard for attachment.

The worker, if using an extension ladder, will also need secure the ladder at the top and bottom to prevent it from slipping sideways.

EQUIPMENT	EXAMPLE
Temporary rope vertical static line made up of: ■ One 1-tonne by 1-metre round sling ■ Four connection hardware items to suit the setup ■ One ASAP work positioning device with energy absorber ■ One prussik loop (friction hitch knot) connected to the rope to secure a weight bag to the end of the rope ■ 10-metre to 11-millimetre hard wearing static rope with knotted thimble eye terminations. Rope can be reversed for even wear. Rope can be replaced if worn without replacing the ASAP. ■ Rope grab ■ Lower body harness or full body harness ■ One storage bag	
Grillon adjustable rope lanyard made up of: ■ One 1-tonne by 1-metre round sling ■ Three connection hardware items to suit the setup ■ One Grillon adjustable rope lanyard with energy absorber ■ Lower body harness or full body harness ■ One storage bag	

LARGE WASHER'S ACCESS

Accessing the larger washers with a longer elevated conveyor belt can be achieved by either using a vertical rope or wire static line.

The worker will connect to the static line using the ASAP work positioning device; or the Arresta wire rope grab with energy absorber.

If the static line installation has intermediate anchor points, then extra slings and karabiners may be required to minimise the sag in the static line, if someone falls on it.

Depending on the height above the conveyor belt that the static line is set up at, the worker may need to use a Grillon adjustable lanyard.

EQUIPMENT	EXAMPLE

Horizontal rope static line made up of:

- Two 1-tonne by 1-metre round sling
- Two 1-tonne by 2-metre round sling
- Four connection hardware items to suit the setup
- 20-metre to 11-millimetre Grillon adjustable working line with Sewn terminations. Rope can be reversed for even wear.
- Rope grab
- Full body harness
- One storage bag
- Labelling

Horizontal flexible wire rope static line:

- One Swaged termination
- One adjustable termination
- Two 1-tonne by 1-metre round sling
- Two 1-tonne by 2-metre round sling
- Four connection hardware items to suit the setup
- Rope grab
- Full body harness
- One storage bag
- Labelling

Grillion adjustable lanyard:

- Three connection hardware items to suit the setup.
- One Grillon adjustable rope lanyard with energy absorber
- Rope grab
- Full body harness
- One storage bag

Harness options

Table 14 - Harness options and advantages

DESCRIPTION	APPLICATION	ADVANTAGES	CAUTIONS
Rated waist belt with quick release buckle	■ Shaft access	■ Quick to put on ■ Light weight ■ Cheap ■ Two connection points ■ Padded	■ Not recommended for free falls 400 millimetres or more. ■ Not recommended for suspensions.
Lower body or sit harness	■ Shaft access ■ Blowers where a fall distance does not exceed 600 millimetres	■ Quick to put on ■ Light weight ■ One front connection point ■ Two side connection points ■ Padded waist belt and leg loops ■ Gear loops	■ Not recommended for free falls greater than 600 millimetres
Full body harness	■ All applications	■ Can be used for all situations ■ Gives the most protection in all situations ■ Easy to put on ■ Light weight ■ One front connection point ■ Four gear loops ■ Minimal parts that are affected by grit ■ Easy to clean	■ Not recommended for free falls greater than 4,000 millimetres

Guarding

Designer obligations (clause 189 Work Health and Safety Regulation)

Designers must ensure that guarding, when used as a control measure, will prevent access to the danger point or area of plant.

If there is a need to access the area of the plant during operation, maintenance and cleaning, the guard needs to be a permanently fixed, physical barrier which can only be altered or removed by tool.

If the plant to be guarded contains moving parts which may break, the guard must be suitably constructed to control the risk of the broken part.

Manufacture obligations

Manufactures of guarding must ensure that the guarding is manufactured in accordance with information provided by the designer and the Work Health and Safety Act and Regulation.

The guard must be of solid construction and securely mounted to resist impact or shock.

Persons with management or control of plant obligations

The person with management or control of plant must ensure:

- that guarding is a fixed solid barrier
- that it is securely mounted and can only be altered or removed by a tool
- that it does not create a risk in itself
- that it prevents by-passing or disabling of the guard
- that it prevents the ejection of broken parts
- that it be properly maintained
- that it allows for servicing, maintenance and repairs to be undertaken with relative ease.

General guarding requirements

Guards shall be designed to prevent:

- people reaching into the danger zone
- any body part coming into contact with the danger zone
- clothes and hair or other body parts becoming caught
- conveyed materials accidentally falling or being projected onto people
- the hazard from the failure of a component
- inadvertent contact with a danger point on the machine
- inadvertent contact with hot or hazardous fluids from fluid couplings or torque converters.

If any type of guarding is removed for the purposes of maintenance or cleaning, it must be replaced before the plant is put back into normal operation. The plant should not be able to restart unless the guarding is in place.

When removing guarding, eliminate the energy source by disconnecting the power supply or by locking out motive power sources.

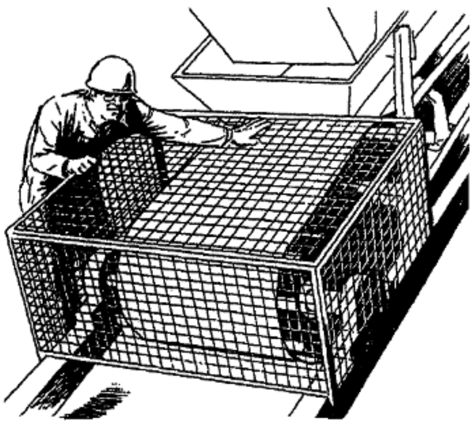
Heat or cold is to be guarded or insulated if a risk to health and safety exist (i.e. hot exhaust system adjacent to where workers are required to perform activities).

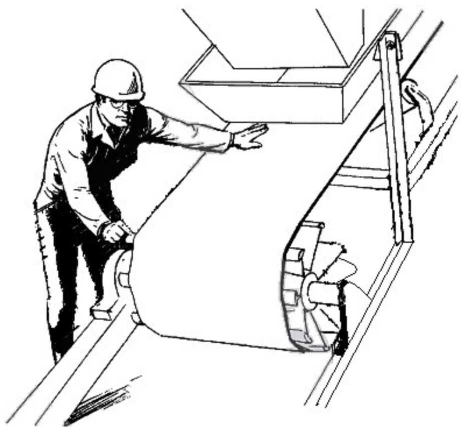
Guards should be fitted as a minimum to the following areas:

- belt drives
- conveyor belts
- couplings
- fans
- gears
- head pulleys
- loading points
- pulleys
- rack and pinions
- rotating shafts
- shafts
- take up pulleys.

Figure 104 - Examples of good (left) and bad (right) pulley guarding

Figure 105 - Other examples of good (left) and bad (right) guarding





Hot work

Many different energy sources can be used for welding, including gas flames, electric arcs, electric resistance, lasers, electron beams, friction, molten metal baths and ultrasound. Welding includes joining methods as diverse as fusion welding, forge welding, friction welding, braze welding, brazing, soldering and explosion welding. Welding is a potentially hazardous activity and precautions are required to avoid electrocution, fire and explosion, burns, electric shock, vision damage, inhalation of poisonous gases and fumes and exposure to intense ultraviolet radiation.

In managing risks associated with hot work activities, identify all the hazards that have the potential to cause harm and put in place suitable controls.

Hazards can include:

- electric shock – contact with electrically live components
- thermal burns – burns due to weld splatter or contact with hot molten materials
- respiratory problems – may result from inhalation of fumes from hot work activities
- asphyxiation – displacement of oxygen by non-toxic gases can be dangerous, particularly in unventilated environments
- hearing impairment – excessive noise should be avoided
- radiation burns – burns to eyes or body due to welding arc
- explosion of fuel or gases, flammable gases contained within or flammable gaseous mixtures created with containers during hot work ignited by arcs, flames sparks, hot metal, splatter or electrical faults
- eye injury – radiation – excessive visible IR or UV radiation, fumes and foreign matter
- fire in surrounding environment due to flammable materials, gasses or liquids and particles due to hot metal, arc flame, sparks, hot metal or splatter or electrical faults
- physical injuries – muscular skeletal injuries – slips and trips, struck by high velocity particles, pinch points, falling objects and falls
- stored energy from work piece – welded on wear plates which can spring up when being cut off
- poor equipment and maintenance.

Hot work activities and area preparation

The following should be considered prior to commencing hot work activities:

- Are there controls in place to prevent the work area, tradesmen and all welding equipment from becoming wet? (i.e. perspiration, liquids, mud)
- Has all equipment that could release water or moisture into the work area been adequately controlled?

- Will insulating materials to isolate the operator from the work be used? (i.e. insulating mat, cushions)
- Will a clamp or insulated tool be used to hold metal attachments when tacking?
- Will the welding machine be turned off before connecting, disconnecting or moving the electrode lead and work lead and clamp, or when relocating a suitcase lead clamp (where applicable)?
- Is there adequate ventilation in place to remove fumes?
- Is adequate fire protection equipment available, inspected and ready to use, located within 10 metres?
- Are all areas, within 15 metres, clean, and free of all combustible materials or materials are suitably covered, such as using fire/ heat blankets, screens, hard barriers? If using a fire blanket as a barrier for molten metal, it must be rated at 1500°C. A hard barrier should be used where practical.
- Have the opposite side of walls, above and below, and inside sections been checked and all combustibles removed or controlled?
- Will the work piece be secured before cutting (if applicable) and load, compression, tension and kickback been considered prior to cutting?
- Do workers have all necessary personal protective equipment in place to complete the work safely?
- Are all potential energy sources (i.e. electrical and mechanical), hydraulic hoses, pipelines (i.e. water, steam, gas) isolated or protected?
- Confirmation that stored energy has been controlled prior to the task, including off the work piece? Consideration of cutting off wear plates.
- Have the contents of all containers been determined?
- Is all hot work equipment inspected and fit for purpose?
- Is a fire watcher required?
- Have suitably rated fire blankets been placed to protect areas subject to damage from hot works?

Fire suppression and prevention

A fully charged fire extinguisher should be available, with the type of extinguisher to be determined by a risk assessment. The fire extinguisher must be located within 10 metres of the work area. If using a water supply, the hose should be run to the work area and charged with an adjustable nozzle.

Personal protective equipment (PPE)

The following PPE should be considered:

Table 15 - Hot work activity and minimum PPE to be considered

ACTIVITY	PERSONAL PROTECTION REQUIRED
Gas cutting and welding	■ Goggles or shields with appropriate filters. ■ Adequate clothing, welding gloves gauntlets and footwear. ■ Suitable head wear for overhead cutting. ■ Impact protection. ■ Suitable respirators (P2 minimum) /ventilation
Arc welding (manual)	■ Welding mask. ■ Adequate dry clothes, welding gloves, gauntlets and footwear. ■ Suitable respirators (P2 minimum) /ventilation
Grinding and chipping	■ Full face protection. High impact face shields and safety glasses. ■ Adequate clothing. ■ Hearing protection. ■ NOTE – Welding Helmets shall not be used for grinding and cutting applications unless the lens and face protection material is rated for high impact protection (Lens will be marked with the Letter 'V')
Plasma cutting	■ Goggles with appropriate light filters. ■ Adequate clothing, gauntlets and footwear. ■ Suitable head wear for overhead cutting. ■ Suitable respirators (P2 minimum) /ventilation
Cutting and welding (zinc or cadmium coated plate, fasteners etc.)	■ Suitable respirators. ■ Ventilation.
Oxy (thermal) lancing	■ Goggles or shields with appropriate light filters. ■ Welding jacket ■ Welding gloves ■ Double hearing protection ■ Adequate clothing gauntlets, fire resistant hood and footwear. ■ Impact protection. ■ Suitable respirators (P2 minimum) /ventilation

Prevention of electric shock

To prevent a welder being exposed to the electrical hazard of the secondary circuit involves a combination of three strategies: avoiding contact with the electrode, avoiding contact with the work piece and limiting the open circuit voltage. The most fundamental safety requirement is for the welder to always avoid bare skin contact with the electrode or live parts of the electrode holder or gun.

The following applies to reduce the risk of electrical shock:

- Ensure the welding machine is in good condition before use. Tag defective equipment so it cannot be used before it is repaired.
- Use only insulated cable for the welding and return leads. Avoid using bare metal straps as a work return. Never use gas or water pipes as part of the welding circuit. Connect the return as close as possible to the welding. Ensure the welding machine return is connected to only one workpiece.
- Connect all leads before turning on the power source.
- Keep welding leads as short as possible.
- Keep connection points (i.e. work return clamp, machine terminals) clear of flammable materials, particularly insulated electrical leads, compressed air, oxygen and flammable gas hoses.
- Do not drag live welding leads to the work area.
- Ensure the welder is properly insulated from the workpiece.
- Use heat resistant mats, insulated mats, rubber covers, welding blankets, wooden duckboards or other means to maintain effective isolation from metal surfaces.
- Use welding gloves on both hands when handling the electrode holder or gun, and when changing electrodes. Welding gloves need to be dry and free from holes.
- Do not hold electrodes under the arm pit while changing them.
- Do not wrap the electrode lead around yourself.
- Keep the welder and the work area dry.
- Do not use leaking water-cooled equipment.
- Dry up any condensation.
- Keep clothing and gloves dry.
- Do not work in rain or standing water.
- Do not cool the electrode holder with water.
- Remove power from the welder when changing electrodes or cleaning the tip.

Use of gas cutting welding and heating equipment

Safety considerations

When performing gas welding, cutting, heating and allied processes, the following safety considerations apply:

- Secure the work piece before cutting, with consideration to load, compression, tension and kickback.
- Confirm that stored energy has been controlled prior to the task, including off the workpiece. (i.e. burns from flames, hot objects, molten particles)
- Fuel gas leakage from cylinders, hoses and equipment connections to minimise explosion from mixed gas concentrations.
- Avoid ignition of flammable materials, leakage of fuel gases, and contact with hot slag to minimise fire.
- Ignition of materials not normally considered flammable due to oxygen enrichment.
- Asphyxiation due to displacement of atmospheric, breathable air by inert or toxic gases (i.e. leakages in confined spaces or lack of oxygen resulting from excessive rusting in confined spaces).
- Radiation damage, to eyes principally.
- Fumes originating from the particular materials being welded, cut or heated.
- Electric shock which could result from gas welding or cutting on cables or other conductors at high voltage.
- Influence on the workplace from the above hazards (i.e. containers, vessels, heights)
- Check for signs of distortion and consider warning signs on any of the identified enclosed spaces. If there are signs of steel plate distortion notify the OEM for possible causes.
- Knowing what is on the other side of a plate that is being cut, welded or vented, before any hot work commences.
- Considering the potential for organic material such as grease and oils to become flammable when heated.

Safe use of equipment

The operator should ensure the following:

- An adequate gas supply is available to safely complete the work. Cylinders are safety secured.
- Equipment is matched to the fuel gas to be used.
- Flashback arrestors are fitted for added protection.

- All parts of the system are in good working order. When in doubt, replace or repair before proceeding.
- Minimise the length of the welding hoses and use a larger bore size if required. Keep the hose free from kinks and tangles.
- Test the system for leaks before lighting up.
- Ensure that the correct procedures are followed during light-up and shutdown.
- All equipment items should be kept free from hydrocarbons (i.e. grease, oil, coal dust, silicon sealant).

For further information refer to AS4839-2001 the safe use of portable and mobile oxy-fuel gas systems for welding, cutting, heating and allied processes.

Leak test

A leak test should be conducted before every use of the equipment.

Lighting up

An ignition safety device (Flint Gun) for gas cutting and heating activities shall be used at all times. Matches, cigarette lighters, wicks, smouldering material and other similar devices shall not be used to ignite a gas.

Before opening the cylinder valve, stand to the side. Open each cylinder valve slowly. The fuel gas cylinder valve should only be opened about a quarter of a turn.

Ensure the pressures are set correctly, as per the manufacturer's recommended pressure settings for welding, cutting and heating.

When using cutting, heating or brazing equipment, the fuel gas is to be turned on first, then the oxygen. When the cutting, heating or brazing operation is complete, the fuel gas is to be turned off first, then the oxygen.

After the work is finished or before leaving the work site, the fuel gas and the oxygen need to be turned off at the cylinder, by use of the cylinder valve, then back off the pressure regulator valves and vent the lines.

Shut down

When shutting down the following should be conducted:

- Extinguish the blowpipe flame in compliance with the manufacturer's operating instructions.
- Extinguish any pilot lights.
- Close both cylinder valves.
- Open the blowpipe valves to vent hoses separately. Close blowpipe valves.
- Wind the regulator adjusting screws all the way out to zero pressure or zero delivery to remove pressure from the diaphragm.
- Check equipment for damage. Report any damage and tag defected

equipment.

- Return equipment and cylinders to a place of safe storage.
- Check to ensure that the cylinder valves are properly closed and that there is no gas leak.

Cutting and welding in a hazardous area

Reference should be made to AS1674.1 Safety in Welding and Allied Processes – Section 3 Hazardous Areas.

Hazardous areas may be found in the following locations:

- place where explosives are stored
- place where batteries are charged
- refuelling stations and oil dispensing stations
- bulk fuel and oil storage areas, as well as gas cylinder storage areas
- drums which have held fuels or chemicals as well as conveyor transfer chutes.
- fuel and hydraulic tanks
- confined spaces
- where an explosive gas atmosphere is present or is likely to occur
- counterweights
- pressure vessels.

Cutting and welding operations in areas where combustible dusts are visually present (i.e. coal bins and reclaim tunnels), should not be carried out unless the combustible dusts have been removed, the area is effectively ventilated, the area surrounding the work area effectively wetted and tests for the presence of methane gas carried out, using an approved and properly calibrated methane gas tester.

Cutting and welding operations, adjacent to diesel fuel and oil dispensing stations and diesel fuel and oil storage areas, should only be carried out after the area is cleaned of spilled diesel fuels and oils, and a check is made that diesel fuels and oils cannot be discharged during the cutting and welding operations. If the cutting and welding operation is in close proximity, then an effective shield must be placed around the operation to contain hot material.

For all cutting and welding operations in hazardous areas, the following should occur, where practicable:

- Adequate ventilation provided.
- The work area is isolated from entry by people not involved in the work.
- Welding equipment is located outside the hazardous area.
- A fire watcher is assigned and adequate fire suppression equipment available.
- Investigate all objects in the area where hot or molten metal or sparks could

possibly cause fire or explosion and ensure controls are in place.

- Remove all objects to be welded or cut to a safe location, if this is possible.
- Guards that are non-combustible should be used to confine flames, sparks and molten metal to the safe area.
- For outdoor work, grassed areas should be thoroughly soaked prior to starting any welding or cutting operation. A competent firewatcher should be on duty.
- When working outdoors, consider and risk assess high wind conditions as they can increase the size of the fire danger/hazard area.

Fluid power systems

The person with management or control of powered mobile plant at a workplace must, in accordance with WHS extract clause 214 Part 3.1, manage risks to health and safety associated with the mechanical failure of pressurised elements of plant that may release fluids that pose a risk to health and safety.

Personal protective equipment

Prior to working on fluid power systems, have all the correct personal protective equipment (PPE) required to do the task safely. This may include the following:

Remember, personnel protective equipment may not protect against fluid injection (i.e. high pressure (725 PSI – 50 Bar) will penetrate most gloves).

Oil temperature is normally in the vicinity of 600 degrees Celsius depending on the system design. Some applications often operate at temperatures much hotter than this, sometimes approaching the boiling point of water. Oil burns are painful, serious, and long lasting.

Personal safety

Before working on any hydraulic circuit, always assess the task for potential hazards and isolate all energy sources and bleed off any residual pressure that may be in the system. Never:

- use part of the hydraulic circuit for any task for which it was not intended
- vent hydraulic fluid to atmosphere, unless safely controlled
- disconnect any line that had not been de-energised and tested for de-energisation.

Hydraulic fluids such as oils, phosphate esters and other fluids can cause injuries to health. Reference should be made to the manufacturer's safety data sheet for the appropriate control measures when working with them.

Oils in a hydraulic system are often under high pressure and may also be hot. Be aware of leaking hoses and pipes. These should be reported/ repaired as soon as possible to prevent injury.

Fluid escaping from a small hole can be almost invisible to the eye. Searching for fluid leaks by feel is a dangerous practice and will eventually result in injury to fingers and hands. Instead, use a piece of cardboard, wood, paper or a mirror, instead of hands, to search for suspected leaks.

Fluid injection

A pin-hole in a hydraulic line operating at 137 bar (2000 psi) will create an oil exit velocity of approximately 1,500 kilometres per hour and can easily penetrate the skin and enter the blood stream. Exposure to pressurised hydraulic oil, under pressures as low as 50 bar (725 psi) and below, can result in fluid injection or other serious injuries to the eyes and other sensitive areas of the body.

Any person suffering, or suspected to have suffered, a pressurised fluid injection, no matter how small, should present to a medical facility for further examination and treatment. The person must not be left alone or allowed to drive themselves to the medical facility.

Medical considerations

High pressure injection of a fluid constitutes a medical and surgical emergency, even when the wound appears small. The following apply to all potential fluid injections:

- no consumption of food or drink
- methoxyflurane, if required
- superficial clean with saline
- lightly cover the wound without using compression bandages or pressure
- elevate and splint the affected limb
- ice pack may help reduce the pain.

Urgent surgical treatment is required to reduce the long-term implications of this type of injury. Hydraulic fluids trapped in the tissue cannot be easily removed and instances of gangrene have often occurred.

Figure 106 - Fluid injection injury to hand following surgery

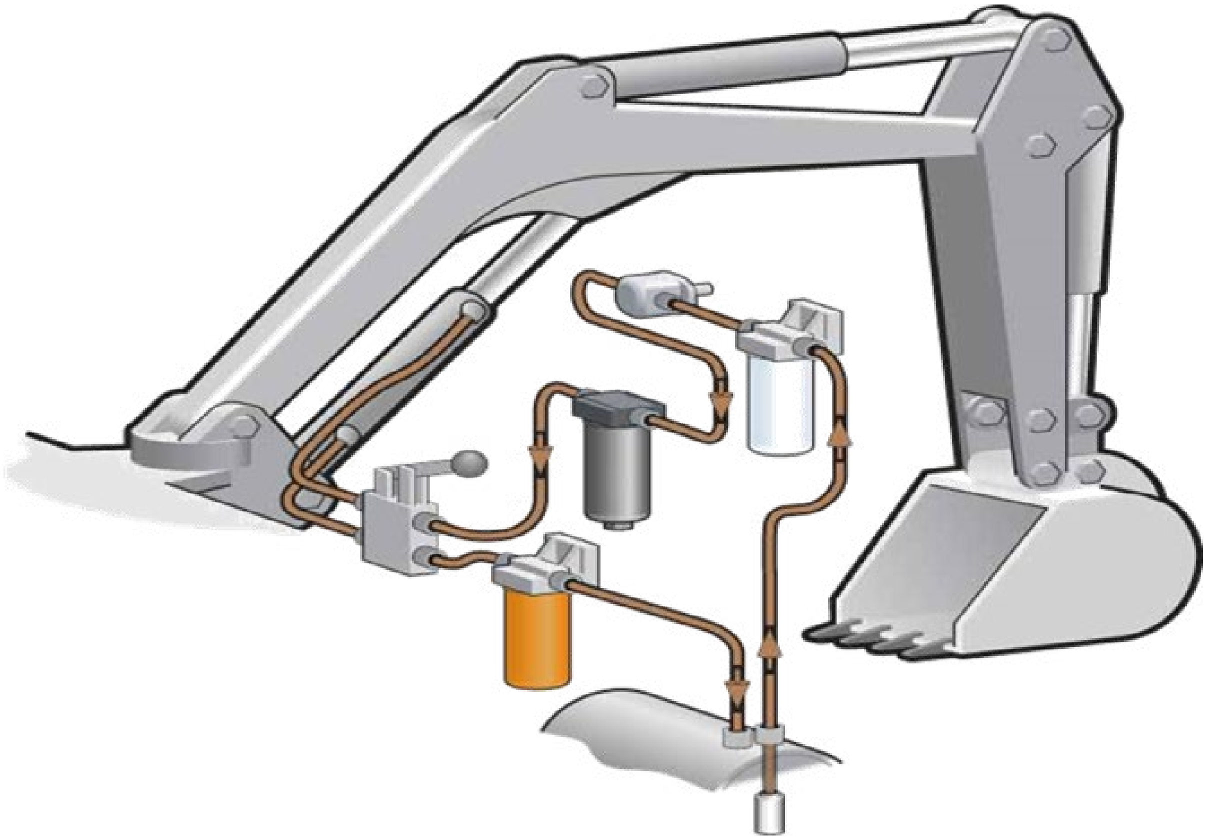
Fluid power systems design

GENERAL

HYDRAULIC SYSTEMS

A confined fluid is one of the most versatile means of controlling motion and transmitting power.

Figure 107 - Hydraulic hose diagram for boom lift cylinder - arrows show direction of flow



Fluid power, or specifically hydraulic systems, operate on the following basic principles:

- A hydraulic pump is used to create a flow of an incompressible fluid.
- A pressure can then be generated on a surface by restricting the flow of a fluid.
- If actuators (i.e. hydraulic cylinders) are placed in the flow of fluid, a pressure will be exerted on the piston of the cylinder, resulting in a mechanical movement of the piston.
- As a result, this mechanical movement causes the arm of the digger to extend or retract. A flow of fluid in the opposite direction will cause mechanical movement in the opposite direction.

Flow allows for movement. Pressure acting on the surface of the piston produces force. Force from the hydraulic cylinder produces work by causing the arm of the digger to move.

Hydraulic systems are used in many applications such as trucks, cranes, dumpers, bulldozers and excavators.

Fluid power systems should be designed, and components selected, to provide safe operation over the intended design lifecycle of the systems.

Seals and sealing devices should be compatible with the fluid used, adjacent materials, working conditions and environment.

Fluid systems should be designed to minimise excessive heat generation.

RATED WORKING PRESSURE

To avoid pressurised fluids escaping into the environment, fluid power system components should have appropriate factors of safety on the rated working pressure to bursting pressure.

Hose assemblies should have a factor of safety of at least 4:1.

Adaptor fittings should have a factor of safety of at least 4:1 on rated working pressure to catastrophic failure of the adaptor or fitting

Other fluid power components, such as cylinders, valves, actuators or similar should have a factor of safety of at least 2.5:1.

Where the above safety factors are reduced, appropriate engineering analysis and/or cycle and endurance testing should be carried out and documented. ISO 7751 provides guidance.

When considering a factor of safety for components for fluid power system, due consideration should be given to life cycle of the component.

EXCESSIVE PRESSURES

A means or device should be provided to protect the circuit against excessive pressures (i.e. a relief valve). Refer to ISO 4413, ISO 4414 and AS 4041 for further information, as appropriate.

The device should be:

- purpose designed to suit maximum flow rate and may include rare events, such as the impact of major roof falls on longwall hydraulics
- adequately supported and mechanically protected from damage in high wear or impact areas
- positioned for access for maintenance purposes
- positioned to reduce the ingress of contaminants from the environment.

PROTECTION FROM UNCONTROLLED ESCAPE OF PRESSURISED FLUIDS

The design should minimise the risk of injury to operators and maintenance personnel from the uncontrolled escape of pressurised fluids. Controls should be provided in accordance with the hierarchy of controls.

Consideration should be given to:

- routing hoses, pipes and pressurised components away from high risk areas, or otherwise as far away as possible
- using protective fixed guards to prevent escaped fluids entering work areas

- using devices to divert or disperse the escaped fluid
- providing means to detect a potential component failure before it occurs
- providing means for effective isolation, energy dissipation and verification (refer to Clause 3.6).

It is not considered acceptable to solely rely on PPE in high-risk areas.

UNINTENDED PRESSURE INTENSIFICATION

In order to prevent pressure intensification in a hydraulic system and failure of that system, a means should be provided to prevent unintended pressure intensification on all fluid power systems, in particular hydraulic cylinders (i.e. unloader valves, relief valves and burst discs).

Fluid power systems should be designed and manufactured using existing engineering standards and principles, so they are fit for the intended purpose and safe to use by a competent person.

FLUIDS

Fluids should be compatible with the system's components.

Manual controls

GENERAL

Hazardous conditions caused by inadvertent operation of the controls should be considered in the design, and be minimised.

Where the operation of the control may create a hazard, the system should be safe guarded in accordance with AS 4024.1.

All controls should be accessible for maintenance.

Direction of movement

The direction of movement for manually operated levers should be consistent with the direction of operation of the actuator (i.e. lever up raises actuator). Refer to AS/NZS 4024.1906 for guidance on general principles.

The direction of the manual control lever should not be confusing. Manual controls should be clearly and permanently identified.

Hose service life

Storage and age control can affect hose life. The following should be considered:

- Storage areas should be relatively cool and dark, as well as free of dust, dirt, dampness and mildew.
- Storage of tested hose assemblies should be limited to two years from inspection. Hose assembly stored for more than two years, should be visually inspected and proof tested or follow manufacturer's recommendations.
- Hoses older than eight years should be discarded unless otherwise recommended by the hose manufacturer.

Proper hose installation is essential for satisfactory performance. If the hose length is excessive, the appearance of the installation will be unsatisfactory and unnecessary cost of equipment will be involved. If hose assemblies are too short to permit adequate flexing and changes in length, due to expansion or contraction, hose service life will be reduced.

Premature failure of hose assemblies

Statistics on the failure of flexible hose assemblies in workplaces indicate that the major mechanism of hose failure is abrasion, followed by stresses inducing pin holing near the hose ends. Control measures for the risks presented by such failures include:

- route hose assemblies to avoid abrasive situations
- cover and protect hose assemblies to avoid abrasion from abrasive material (i.e. accumulation of debris on underground equipment).

Keep stress on hose assemblies to a minimum by:

- adhering to the manufacturer's minimum bend radius (MBR)
- using non-flexible length (NFL) adjacent hose ends
- clamping the hose and using directional hose ends to reduce torsional effects
- understanding the effects of pressure loading on the hose assembly.

Figure 108 - Prevention of external damage.

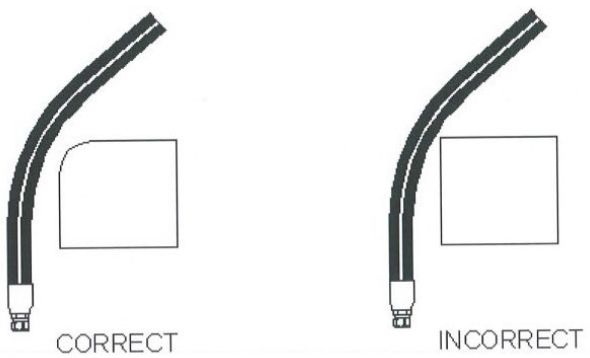
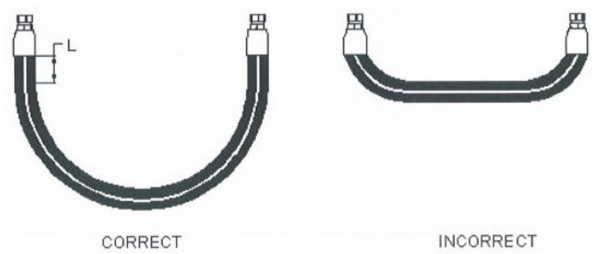
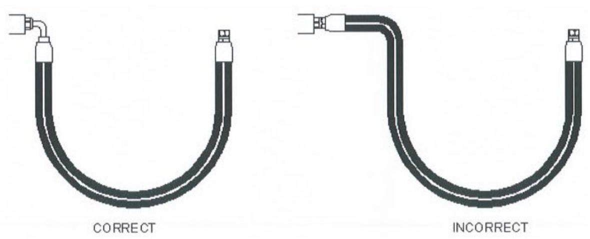


Figure 109 - Minimum bend radius



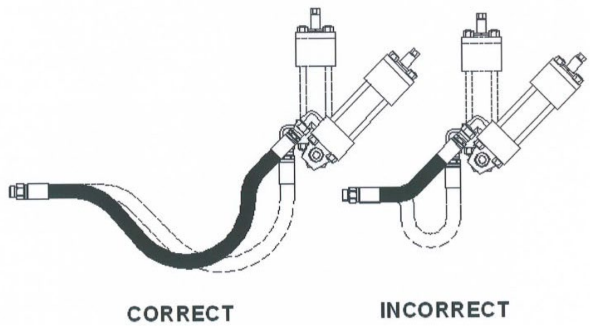
Correct routing and installation of the hose to its minimum bend radius will increase its service life.

Figure 110 - Elbows and adapters



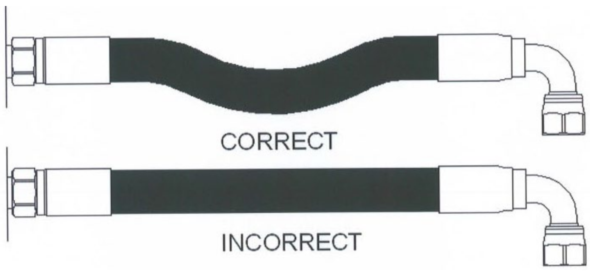
An unnecessarily long hose can increase pressure drop and affect system performance. When pressurised, a hose that is too short may pull loose from its fittings, or stress the hose fitting connections, causing premature metallic or seal failures.

Figure 111 - Motion absorption



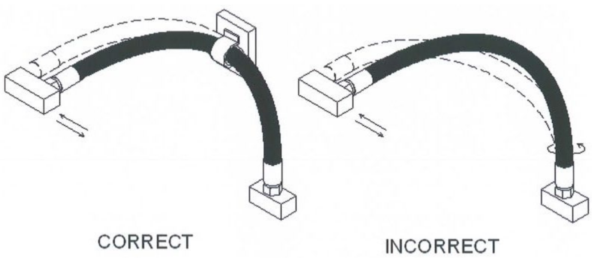
Design hoses to allow for changes in length due to machine motion and tolerances.

Figure 112 - Hose and machine tolerance



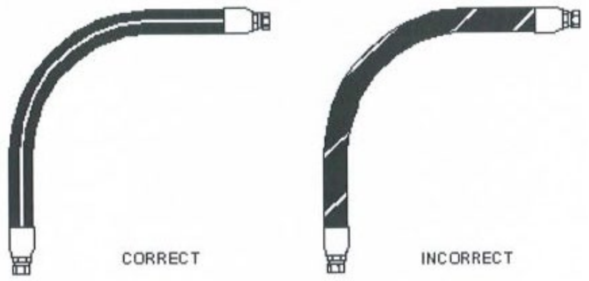
Design hoses to accommodate length changes from changing pressures. Do not cross or clamp together high- and low-pressure hoses. The difference in length changes could wear the hose covers

Figure 113 - Prevent hose bending in more than one plane



Pressure applied to a twisted hose may shorten the life of the hose or loosen the connections. To avoid twisting, the hose layline, or marking, can be used as a reference if the layline or marking is parallel to the axis of the hose. Twisting can also be avoided by using two wrenches during the installation of the swivel connectors.

Figure 114 - Twist angle and orientation



For additional guidance, refer to AS 2671 Hydraulic fluid power, MDG 41 Fluid Power and MDG 3007 Hydraulic safety.

Cranes

General requirements

There are specific requirements in the Work Health and Safety Regulations in relation to cranes and lifting activities, including:

- The person with management or control of plant at a workplace must ensure, so far as is reasonably practicable, that the plant used is specifically designed to lift or suspend the load.
- If it is not reasonably practicable to use plant that is specifically designed to lift or suspend the load, the person must ensure that:
  - the plant does not cause a greater risk to health and safety compared to a specifically designed plant
  - if the plant is lifting or suspending people, the use of the plant complies with Clause 220.
- The person must ensure that the lifting and suspending is carried out:
  - with lifting attachments, that are suitable for the load being lifted or suspended
  - within the safe working limits of the plant.
- The person must ensure, so far as is reasonably practicable, that no loads are suspended or travel over a person, unless the plant is specifically designed for that purpose.
- The person must ensure, so far as is reasonably practicable, that loads are lifted or suspended in a way that ensures that the load remains under control during the activity.
- The person must ensure, so far as is reasonably practicable, that no load is lifted simultaneously by more than 1 item of plant, unless the method of lifting ensures that the load placed on each item of plant does not exceed the design capacity of the plant.

Before carrying out lifting activities, a risk assessment should be conducted taking into consideration:

- the task to be carried out
- the type of plant or equipment that will be required or used
- competence of people operating the plant
- size and mass of the load
- position of people and visibility of the load
- adequacy and condition of lifting points
- stability of the load
- specific environmental conditions including, but not limited to:
  - grade
  - ground stability
  - proximity to hazards
  - night/day
  - weather conditions.
- the range of methods by which the task can be done
- the hazards involved and the associated risks
- the actual method and the other required plant and material
- adjacent work teams
- route of the load being transported.

All cranes and lifting equipment should be inspected before use.

For further information refer to Safe Work Australia – Guide to mobile cranes.

Mobile cranes

All mobile cranes shall be designed and maintained in accordance with the requirements of AS 1418.5.

All vehicle loading cranes (VLC) and alteration shall be designed in accordance with AS1418.1 and AS 1418.11.

The VLC shall be suitably mounted to the chassis of the vehicle in accordance with AS1418.11.

The installer of a loader crane shall adhere to any specific requirements issued by the crane manufacturer, the vehicle manufacturer, local regulations and site requirements.

The following should be considered:

- exposure to exhaust gases to operator
- exposure to hot surfaces, with surfaces over 55 degrees Celsius protected.
- crushing, striking or trapping the operator by the crane or stabiliser function movements.

Load charts, documentation and registration

Rated capacity and lift curve charts shall be included in the documentation and be situated in the vehicle cabin at all times for reference by the operator.

The equipment operation manual should be kept in the vehicle cabin for use by the operator.

Vehicle loading cranes, with a rated lift capacity greater than 10 tonnes, require both design registration and item registration, in accordance with the Work Health and Safety Regulation 2017 Part 5.3. Item registration is to be completed by the owner of the plant.

MAINTENANCE AND INSPECTION

PRE-USE INSPECTION

Before use, the crane should have a visual inspection and functional test. The inspection and testing should include the following:

- operating and emergency controls
- brakes
- safety switches and interlocks
- structure
- wire ropes to ensure they are on the drum and correctly reeved on the sheave.

REGULAR INSPECTIONS

Regular inspections must be carried out in accordance with the manufacturer's instructions or those of a competent person or, if this is not reasonably practicable, annually.

An annual inspection may be less comprehensive than a major inspection. It should include every item specified by the crane manufacturer for annual inspection and every item included in the routine inspection and maintenance programs.

Annual inspections should include a detailed check of:

- the functioning and calibration of limiting and indicating devices
- structural and wear components
- tolerances for wear limit
- evidence of corrosion
- critical areas for evidence of cracking.

MAJOR INSPECTIONS

A major inspection must be completed for registered mobile cranes and should be completed for non-registrable mobile cranes, so that they continue to operate safely.

Major inspections must be carried out at the end of the crane's design life, as determined by the manufacturer's instructions. If these are not available, a competent person is required to meet the same minimum requirements established by relevant technical standards.

If it is not reasonably practicable to inspect a crane, inspect the crane at least every 10 years from the date the crane was first commissioned or registered, whichever was first. This must include inspection of the structure, as well as mechanical components.

Major inspections must be carried out by, or under the supervision of, a competent person who:

- has acquired thorough training, qualifications or has the knowledge and skills to carry out a major inspection of the plant and is registered under a law that provides for the registration of professional engineers

  OR

- is determined by the Regulator to be a competent person.

Completion of a major inspection does not indicate that the components inspected will have a further 10 year life. It should not be assumed that the items included in the list only require inspection at 10 year intervals. Items will require some type of inspection and maintenance at more frequent intervals (i.e. annual and other inspection intervals) according to the crane manufacturer's instructions.

Mobile and transportable plant

Operating limits and capacities of mobile plant

Before procuring mobile plant, the conditions of where the plant is to be operating should be established, to ensure the selected plant is fit for its intended purpose.

The following plant limits will need to be considered, and selection made based on the below inputs, prior to procurement:

- working grade (%)
  - loaded at maximum gross vehicle mass (GVM or GCM as applicable). (As built)
  - unloaded
  - tipping
  - fully loaded with park brake applied
  - fully loaded with emergency brake applied
  - other variables, where applicable.
- cross grades
  - loaded at maximum GVM or GCM as applicable (as built)
  - unloaded
  - tipping
  - other variables, where applicable.
- maximum load (tonnes)
  - level conditions
  - on range of grades
  - maximum speed (km/h)

- on level conditions
- on range of grades
- other variables, where applicable.

- maximum speed (km/h)
  - on level conditions
  - on range of grades
  - other variables, where applicable.

Access to plant

To minimise the potential for accidents relating to mobile plant access, three points of contact should be provided on access systems. The access systems should be positioned to provide an ergonomically safe access, which is intuitive for a person to use.

To minimise the risk of falling, plant operators and maintenance personnel should be able to carry out normal duties without leaving a designated walkway, access platform, or the ground.

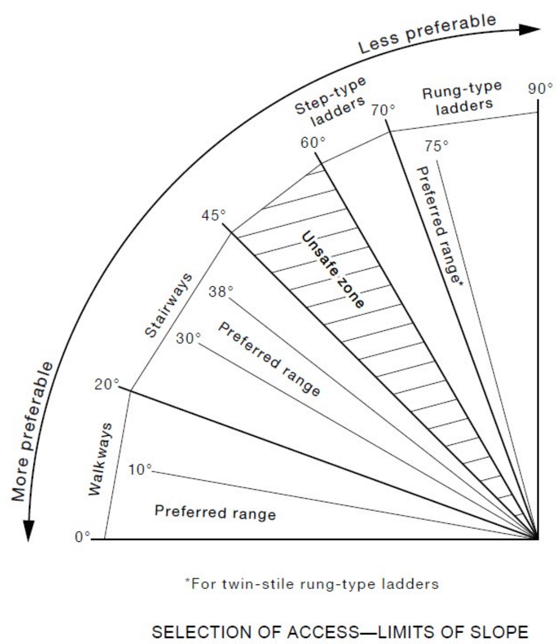
Where this is not reasonably practicable, and there is a potential that a person could fall, consideration should be given to the provision of harness points or other methods of safe access provided (i.e. mobile work platforms).

Ladders and stairs

To minimise the risk of falling:

- stairs should be provided wherever practical
- ladders should be installed in the preferred or recommended zone as shown in the figure
- the bottom step of the primary access should not be more than 400 millimetres from ground level, as measured on flat ground.

Figure 115 - Selection of access system



Where this is not reasonably practicable, then retractable stairs or ladders should be installed.

Flexible bottom steps should be avoided unless there is no reasonably practicable alternative.

A means of preventing retractable stairs from being damaged should be provided. Measures should be implemented to prevent the stairs or ladder from being in the lowered position while the vehicle is being moved.

Walkways and handrails

To minimise the risk of slips, trips and falls:

- handrails should be in a continuous length, without sudden changes of direction, to assist evacuation with minimal visibility
- walkway surfaces should be non-slip and self-cleaning
- openings in guardrails, for access to ladders, should be fitted with a hinged or sliding guardrail gate, where reasonably practicable, with chains avoided
- hinged gates should open onto the platform and should be self-closing.

Egress

Two means of egress should be provided from the operator's cabin to the ground including:

- at least one means of easy egress/normal access (i.e. cabin door)
- at least one means of emergency egress.

At least one means of egress should be useable in the event of a hazardous condition (i.e. mobile plant roll-over) or where the normal access is blocked due to a fire or other hazards.

The emergency egress should be suitably marked and could be achieved by a second door, a push-out window or other alternative.

At least one of these means of egress should not be near a potential source of fuel that can be ignited and sustain a fire.

All means of egress should have a provision for three points of contact (i.e. handrails on both sides of escape ladders).

Brakes

Adequate means of braking should be available to safely bring mobile plant to rest, under all conditions of operation, and hold the mobile plant stationary. This includes adequate braking measures in the event of the failure of the primary braking system.

Brake system periodic verification

Information on brakes should be provided in manuals to enable periodic verification tests for brake systems. This information should include:

- the means for the operator and maintenance worker to check the brakes, including a method of verifying the functionality of the service, secondary and park brakes
- the means to check brake performance following brake maintenance which includes:
  - acceptance criteria and test methods for verifying the functionality and performance of the service, secondary and park brakes
  - deceleration limits and stopping distances for the service and secondary braking systems
  - holding limits for park brakes.

Park brake system

All mobile plant should be equipped with a park brake system capable of being applied and released from the operator's position. The park brake system should have the capability of holding the mobile plant stationary, at its gross vehicle mass in both forward and reverse directions, on the greater of:

- the maximum grade as specified by the mine or petroleum site

  OR
- a 15% grade in both forward and reverse directions.

Safety chocks or other positive means to prevent movement should be provided, in the event of the mobile plant being immobilised.

Once applied, the park brake system should not rely on any exhaustible energy source.

Whenever the operator leaves the cab, a means of verifying that the park brake has been applied should be in operation, where reasonably practicable.

Brake testing

To verify the condition of braking systems, end users will need to undertake testing as per the manufactures recommendations, or if there are no manufacturer's recommendations, in accordance with the recommendations of a competent person. This should be undertaken every year as a minimum.

Emergency stop

Emergency stop devices should be provided to enable the emergency shutdown of a machine. These devices should be in accordance with AS 4024.1604 or ISO 13850. The emergency stop function should operate in all operating modes.

The emergency stop function should be designed so that the operation of the mobile or transportable plant is stopped in an appropriate manner, according to the risk assessment and without creating additional hazards.

Emergency stops should be located to enable the plant engine to be stopped and brakes applied, in the event it is necessary to minimise a hazard.

Suggestions for a typical location for an emergency stop include:

- at the operating station
- in the vicinity of the normal boarding point onto the plant, to allow a person to reach the device from a position on the ground at the boarding point
- locations away from the front of outblowing fans or airflows, as these may direct fire to the control point
- locations that avoid inadvertent operation of the emergency stop.

Engine compartment

To minimise the potential for serious fires, loss of control, serious bodily injuries including burns relating to plant, the following should apply:

- the surface temperature of the engine system should be controlled to eliminate hot surface ignition of fuels (i.e. escaped hydraulic oil, diesel fuel and engine coolant)
- the location of services, including fuel, hydraulic oil and electric power within the engine compartment, should be avoided wherever possible
- any services required to be in the engine compartment should be effectively shielded from exposure to heat sources and protected from forces which cause wear and tear
- the potential for physical damage to services during maintenance work should be considered and managed
- hydraulic components should not be located where main ventilating air will cause leaking oil to be spread over the engine compartment
- all pipes/ hoses should be constructed of fire-resistant material, routed away from hot engine surfaces
- an effective shielding should be considered between the pipe/ hose and any adjacent components which have operating surface temperatures in excess of 150 degrees Celsius
- all pipes/ hoses should be routed to give maximum mechanical protection against wear and damage.

Radiator caps

Radiator caps for cooling systems should not be able to be opened while there is pressure in the cooling system. Cooling systems should be fitted with a means of safely relieving pressure to prevent burning personnel. Cooling systems should be able to be accessed safely.

Fire control

Fires may result in injury to workers and loss of control of plant. Fires may also be the cause of asphyxiation, tyre explosion, fuel tank explosions and other unwanted events.

Fire extinguisher(s)

Due to the high number of fires on mobile plant at mines, it is very important that all mobile plant with an onboard operator is fitted with a portable fire extinguisher (more than one may be required). An assessment should determine the type(s), numbers and location(s).

Portable fire extinguisher should be located:

- in a readily accessible location where access would not present a hazard to the user
- in an area that is least likely to be affected by fire.

Fire extinguishers should:

- be easily detached from their mountings
- have gauges that are easily readable
- be of a size suitable for the purpose (i.e. appropriate for the type and extent of fire that might occur on the plant).

Refer to AS 5062 'Fire Extinguishers', AS 2444 and AS 1850 for further guidance.

Operator's cabin and protection

Specific duties apply in relation to operator protection under clauses 214 – 218 inclusive of the WHS Regulation 2017.

So far as is reasonably practicable, a suitable combination of operator protective devices must be provided, used and maintained where there is a risk of:

- mobile plant overturning
- things falling on or against the operator of the mobile plant
- an operator being ejected from the mobile plant
- the plant colliding with any person or thing.

All passengers must be provided with the same level of protection equivalent to that provided to the operator.

All equipment fitted with legislated operator protection systems must include seat and personal restraint as part of those systems.

Roll over protection

Roll over protection (ROPS) is mandatory on tractors and should be fitted to the following mobile plant, due to the risks of roll over:

- wheeled off-highway dump trucks
- wheel and track dozers
- scrapers
- graders
- rollers
- loaders

- excavators
- water trucks operating on haul roads
- fuel and lubrication trucks intended to be operating on haul roads (not road registered delivery trucks).

Falling object protection

It is mandatory for earthmoving machinery to be fitted with securely fitted protective structures. Falling object protection (FOPS) should be fitted to the following plant:

- loaders
- graders
- dump trucks
- rollers
- dozers
- drilling rigs – wheel or track mounted at the operators control station
- fuel and lube trucks, which may operate near high walls
- trucks underneath loading bins.

The falling object protection used should be designed and manufactured to provide suitable protection for the operator under all conditions in which it may be used.

Wheels, rims and tyres

Fatalities have resulted from issues relating to wheels, rims and tyres. This section provides guidance to designers, manufacturers, importers and suppliers to assist in minimising the potential for unwanted events over life cycle activities.

Wheels, rims and tyres on mobile plant should be capable of withstanding designed wheel loads and intended mobile plant duty. The type and size of wheel/rim/tyre should be stated. Principles in this section should also be considered for transportable plant.

Split wheel rims should not be used, unless there is an effective means to prevent disassembly when the rim/tyre is attached to the mobile plant. Appropriately documented procedures with fit-for-purpose equipment should be used when carrying out maintenance or service activities. Fatalities have occurred while carrying out maintenance and service activities involving split rims. Split wheel rims include multi-piece rims, multi-piece wheels and divided wheels, where two sections of the wheel are bolted together.

The manufacturer of wheels, rims and tyres should recommend:

- the maximum permissible duty cycle (TKPH) and tyre pressure
- procedures for servicing wheel rims and tyres, including multi-piece wheel rims (Refer to AS 4457.1 & AS 4457.2. Although AS 4457 applies to wheels and rims with a diameter of 600 millimetres (24 inches) or more, the

principles should be applied to all wheel assembles).

Tyres and rims should be inspected on a regular basis checking for:

- inflation pressure
- wear
- damage
- separation
- fatigue
- valve assembly
- lock ring for wear, corrosion and deformation
- bead seat band for cracks, wear and corrosion
- flanges for wear, cracking, fretting, corrosion or damage
- rim base for wear, cracking, fretting, corrosion or damage.

Tyres that have been operated at less than 75% of normal cold operating inflation pressure or overloaded, should be removed and check for internal damage, due to the risk of zipper ruptures in the sidewalls.

For further information refer to SafeWork Australia document Guide for split rims.

Fuel delivery hoses

All rubber-type fuel delivery hose should comply with the following:

- AS/NZS 1020 The control of undesirable static electricity
- AS1940 The storage and handling of flammable and combustible liquids
- AS 2683 Hose and hose assemblies for distribution of petroleum and petroleum products (excepting LPG).

As a minimum, the hose will be a type-3 anti-static in accordance with AS 2683 and tested in accordance with AS 1180.13A. The resistance of the hose should not be less than 1.0 kWm nor greater than 1.0 MW/m.

Hoists and winches

All hoists must be designed by a competent person.

People riding hoists are required, under the Work Health and Safety (Mines and Petroleum Sites) Regulation, to be designed registered and item registered.

The designer of the hoist should consider:

- risks to health and safety of workers that may be affected by its use
- the intended purpose of the hoist (i.e. maximum working load, operating environment as the weight must be used for all calculations and testing)
- rope, brake, sheaves and drive system selection based on calculations
- failure modes of components (i.e. broken winch rope, failed drive motor,

broken drive belts, failed limit switches)

- guarding of all moving components
- control system
- inadvertent activation
- hoist stopping mid shaft
- installation of overrun protection.

Specific hazards associated with hoist should also be considered such as:

- gravity, including:
  - the conveyance falling out of control
  - objects or persons falling down the shaft.
- stability of the plant
- mechanical energy, including:
  - rotating and percussion machinery
  - entanglement, entrapment, include people being caught between the cage / material hoist and shaft/shaft gates.
- electrical energy
- hydraulic energy
- human error.

Hoist selection

A hoist should be selected based on its intended use, considering:

- maximum working load to be carried
- operating environment
- depth of the shaft
- time of haulage
- type of power, such as:
  - manual
  - air
  - electric
  - hydraulic
  - diesel / petrol
  - a combination of the above.
- maintenance requirements
- any special training requirements.

Winch assembly

The winch drive system must be capable of lifting and lowering the end of rope load. All drive components must be rated for this load.

All driving mechanisms used between the drive drum and the device that holds the winch stationary (i.e. brakes or appropriate worm type gearbox that exhibits properties of static and total dynamic irreversibility) must be positive type driving mechanisms.

Clutches, vee belts or fluid couplings are not positive type driving mechanisms and should not be used between the drive drum and braking device. However, they may be used between the drive motor and the means, to hold the winch stationary (i.e. brake) provided the winch remains stationary when the drive motor is stopped or if failure of the power transmission was to occur.

The operating speed must be sufficiently slow to allow an operator to recognise and avoid a potential hazard, by stopping the winch in time to avoid the potential danger.

The drive system must not be capable of breaking the rope under any condition.

Brakes

The hoist should have the means to bring the conveyance to rest and hold it stationary. The means must be based on a fail-to-safety principle (i.e. spring-applied or gravity-applied).

Brakes must be fitted to prevent a freefall event such as a rope failure, drum coupling failure, motor failure and hydraulic hose failure.

Where a worm-type gearbox is used, it must exhibit properties of static and total dynamic irreversibility throughout its lifecycle.

The motor fitted gearbox must be capable of holding and driving down the work platform.

Brakes should comply with the following requirements:

- In the static condition hold a minimum of 1.6 times the rated capacity.
- From the dynamic condition, arrest a minimum of 1.2 times the hoist rated capacity from the maximum lowering speed, without a damaging snatch effect and without unacceptable overheating within an acceptable braking distance for the winch.

Dynamic irreversibility occurs when the output shaft of the worm type gearbox stops as soon as the driving force applied to the input shaft is stopped. Static irreversibility occurs when the output shaft of a worm type gearbox remains stationary after the application of a load.

The stopping or holding means must be capable of holding two times the end of rope load stationary when stopped.

Emergency load lowering

When emergency load-lowering is required, the hoist brake should be capable of being released manually. The mechanism should be arranged to ensure that:

- the load is under control during lowering
- the lowering rate is limited, to be compatible with the brake heat dissipation characteristics

- the brake is able to be released and reset without the requirement for tools
- the brake will reset automatically upon release of the manual override mechanism.

Instructions for the operation of the manual release mechanism should be provided on the hoist and in the operating manual.

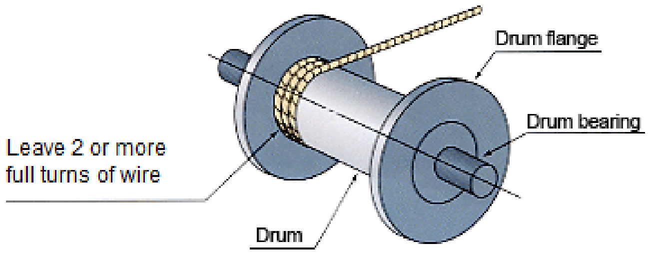
Hoist drums

There are two types of drums. They are grooved and ungrooved. Regardless of the type, hoist drums should be designed for the total load to be hoisted with a factor of safety of 10.

The minimum diameter of a hoist drum to enable the lifting of material should be 18 times the nominated rope diameter.

There should be a minimum of two turns of wire rope left on the drum at all times.

Figure 116 - Hoist drum



Grooved drums

Grooved drums shall be designed to have no less than two occupied grooves, when the rope for each connected rope end is fully paid out.

The drum should be flanged at both ends, for a radial distance of no less than a 1.5 rope diameter.

Where the rope is in more than one layer, a rope guide should be made for the rope to guide it from one layer to the next.

The groove should be an arc having a minimum radius of 0.535 times the nominal diameter of the rope and subtending an included angle no less than 130°.

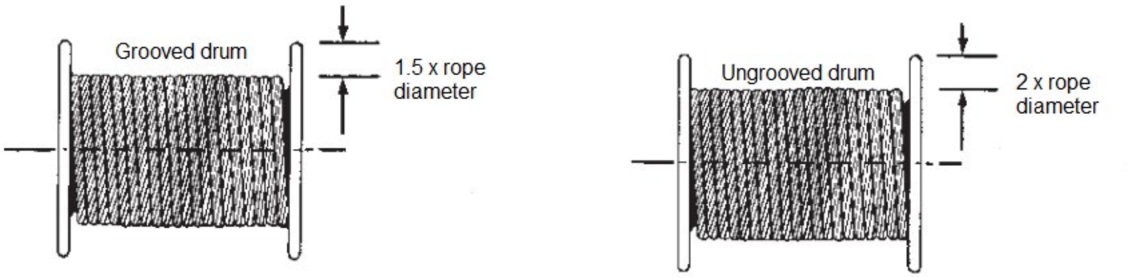
The groove should be smoothly finished and free from surface defects to avoid damage to the rope. The edge between grooves should be rounded.

Ungrooved drums

Ungrooved drums should be flanged at both ends, for a radial distance of no less than 2 rope diameters beyond the rope in the outer layer, when the rope is fully wound on the drum.

The face of a brake, gear or other component mounted at the end of the drum, may be considered as being a flange, provided it is a flat face and of the correct outside diameter.

Figure 117 - Grooved and ungrooved drums



Rope anchorage

All drum ropes should be mechanically anchored. Where the anchorage relies on a clamping action, it should consist of two or more clamps.

The rope anchorage without any turns on the drum, must be capable of withstanding twice the load due to nominal force on the rope.

Figure 118 - Rope anchorage on drum

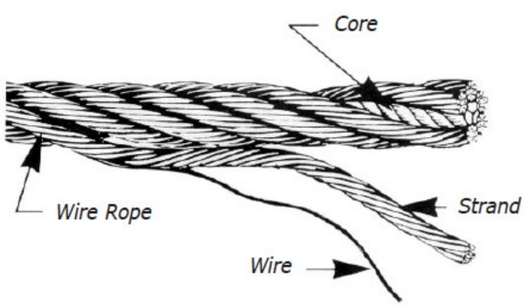
Ropes

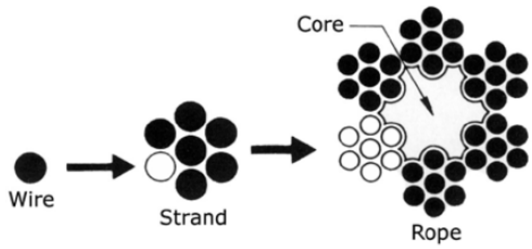
The main components of a wire rope are the wire, strand and core.

The size and number of strands in a rope greatly affect the characteristics of the rope. In general, a large number of small-sized wires and strands produce a flexible rope with good resistance to bending fatigue. The rope construction is also important for tensile loading (static, live or shock), abrasive wear, crushing, corrosion and rotation.

The properties of a wire rope are derived from its size, construction, quality, lay and type of core.

Figure 119 - Wire rope composition





SELECTION

The selection of rope should be made in consultation with a competent person taking into consideration:

- load to be carried
- length required
- dimensions of drum and sheave(s)
- environmental conditions (i.e. corrosive conditions).

The working load limit (WLL) should be based on the minimum breaking force (MBF) required, not the actual breaking force. MBF is measured in kN, with 1kN of force equal to 101.97 kilograms.

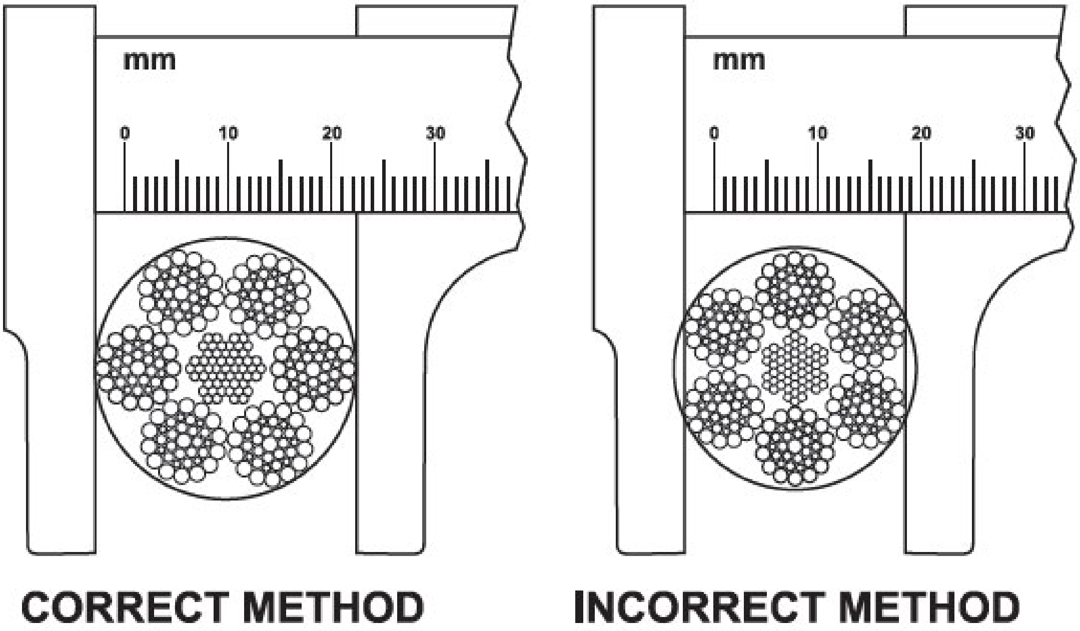
All ropes, as a minimum, should comply with the relevant Australian Standards.

Given the corrosive conditions and that regulator maintenance may be difficult, galvanised wire ropes should be used in opal mines.

As a guide, the following safety factors apply:

- Person-riding hoist ropes must have a minimum factor of safety of 10.
- Material hoist ropes should have a minimum factor of safety of 5.

Figure 120 - Size measurement



Care and maintenance

A wire rope should be broken in as soon as it is installed, by loading it very lightly for a few cycles and then gradually stepping up the load, to enable both wires and strands to 'bed down' into the working positions, with the load distributed as uniformly as possible.

A used rope must not be reinstalled unless it can be proven to be safe to use.

A spliced connection must not be used to join two or more ropes together.

All wire ropes should be inspected regularly for defects.

Lubrication impregnated into the rope during manufacture is not sufficient to last the life of the rope. Additional lubrication should be done during the service, as determined by the operating conditions. For corrosive conditions, a high penetrating, water repellent rush-inhibiting oil should be used.

Broken wires

General purpose ropes, crane ropes and hoist ropes should be discarded whenever any types of degradation exceed the limits provided below. However, the rope life may be at an end before these limits are reached.

Table 16 - Limits of degradation for discard of general lifting purpose ropes, crane ropes and hoist ropes.

TYPE OF DEGRADATION	CONSTRUCTION	LIMIT OF DEGRADATION FOR DISCARD	
		MAXIMUM ALLOWABLE NUMBER OF BROKEN WIRES OVER A LENGTH OF SIX TIMES THE ROPE'S DIAMETER.	MAXIMUM ALLOWABLE NUMBER OF BROKEN WIRES OVER A LENGTH OF 30 TIMES THE ROPE'S DIAMETER.
	6 × 19 (12/6/1)	5	10
	6 × 19 S (9/9/1)	3	6
	6 × 26 SW (10/5 and 5/5/1)	5	10
	6 × 25 FW (12/6 and 6/1)	5	10
	6 × 29 FW (14/7/7/1)	7	14
	6 × 24 (15/9/F)	5	10
	8 × 19 S (9/9/1)	5	10
	8 × 25 FW (12/6 and 6/1)	6	13
	6 × 36 SW (14/7 and 7/7/1)	7	14
	6 × 37 (18/12/6/1)	10	19
	6 × 41 SW (16/8 and 8/8/1)	9	18
	18 × 7 NR	1	2
	34 × 7 NR	2	4
	4 × 48	2	4
Wear	All types	Outer wires are worn more than one-third of their diameter.	
Loss of area	All types	The loss of metallic area due to a combined wire wear and broken or cracked wires exceeding 10%.	
Corrosion	All types	Corrosion is marked by noticeable pitting or loosening of outer wires.	

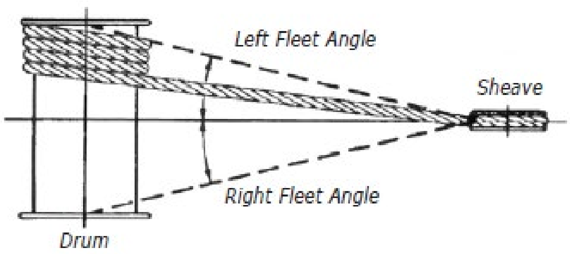
Fleet angle

The fleet angle has an important bearing on the winding of a rope from sheave to drum. If winding is to take place smoothly, the fleet angles on both sides of the drum will have to be kept within acceptable limits.

Excessive fleet angles can result in considerable abrasive damage to both sheave flanges and rope, considerably reducing the life of the rope and the equipment.

Fleet angles range from a maximum of 1.5° for plain drums, to a maximum of 2.5° for grooved drums. Unless the head or guide sheave is centred with respect to the drum, there will different values for the left and right fleet angles.

Figure 121 - Fleet angle



Sheaves

Sheaves should be designed so the component loadings are not exceeded while a load equal to the working load limit (WLL) of the winch is applied to the sheave block. Consider the following:

- rated for the load to be lifted and the power developed by the winch
- a method of retention to prevent the rope from leaving the sheave groove
- the depth of the groves is no less than 0.585 times the diameter of the rope, except where the rope is less than 7 millimetres, then the depth of the groves is no less than 0.615 times the diameter of the rope
- grooves shall be tangential to the bottom arc and flared with an included angle of no less than 30°, symmetrical to the centre line of the groove.

The diameter of each sheave should be measured at the pitch diameter of the grove.

Each sheave block should be capable of supporting a test load of five times its working load limit and be able to rotate while loaded to 1.25 times the working load limit.

All sheaves should be suitably secured by components that meet the design loads.

Figure 122 - Sheave fitment guide

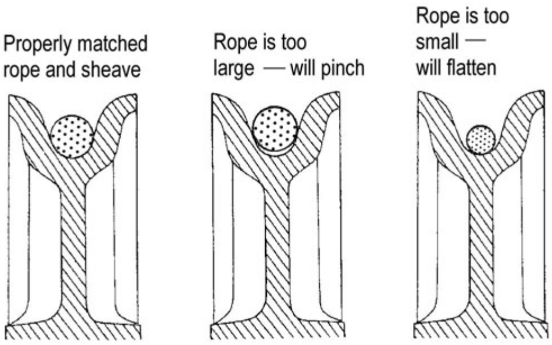
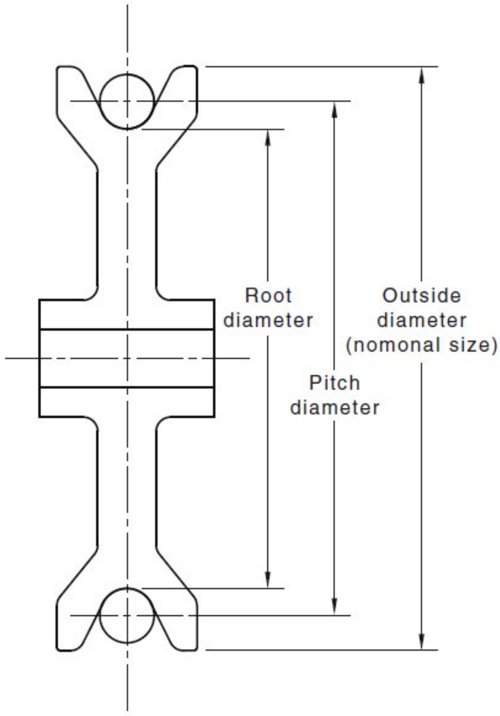


Figure 123 - sheave



Rope attachment

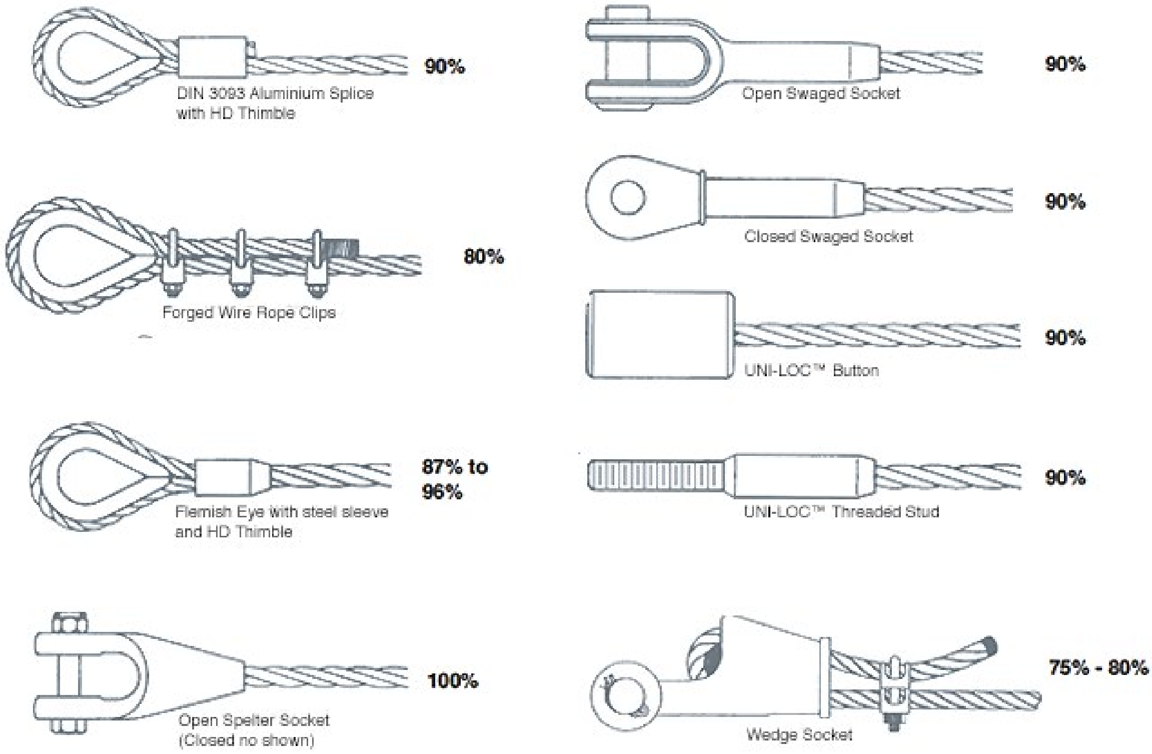
The rope fitting should be properly designed for the service expected. The fitting of the end attachments to ropes should be carried out with the necessary care and skill to ensure that the load can be effectively transferred from the rope to the attachment.

There are several types of rope fitting and end attachments to include:

- ferrule-secured rope attachment
- swaged end fittings
- poured sockets
- wedge grip capels
- wedge type sockets
- wire rope clips.

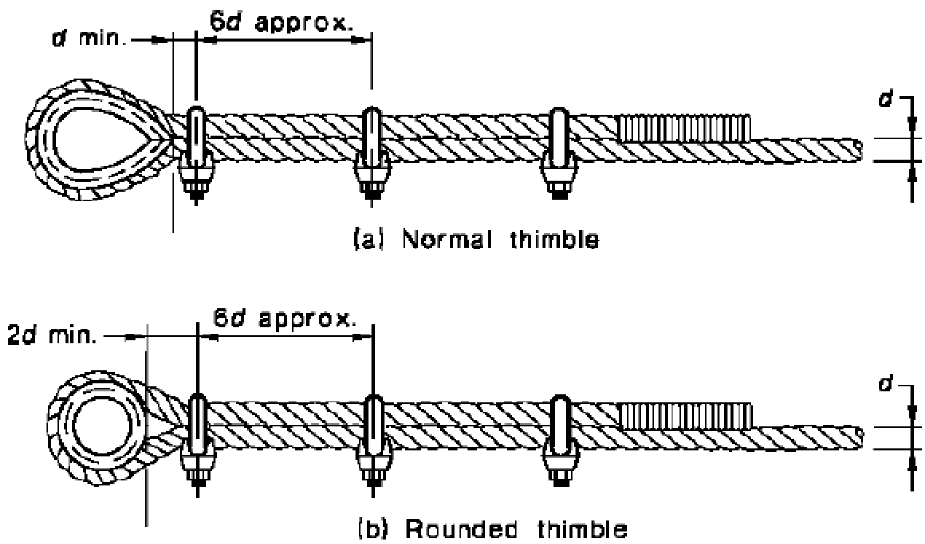
The end fitting impacts the efficiency rating of the rope and needs to be considered when selecting for it a particular application.

Figure 124 - Rope end fitting and efficiency ratings



When wire is being secured using wire ropes clips, ensure a thimble is fitted and clips are installed properly so that the rope is not damaged.

Figure 125 - Wire rope clips and thimble and spacing



Motor control

Person riding hoist must:

- be able to be controlled from the cage/platform while a person is riding on it
- incorporate an automatic means of stopping the cage/ platform at both the top and bottom of the shaft
- have a risk assessment carried out that assesses the control circuit failure modes on all control circuits
- provide palm or hand-operated mechanically latched emergency stop switches, accessible from within the cage/ platform and accessible to a person at the shaft entrance (near the person-riding hoist motor) and any other location identified in the design risk assessment
- must not be able to be started until the emergency stop switch, that stopped the person-riding hoist, is released.

Hoist general

Where a motion can be controlled from more than one control point or mode, the controls should be interlocked to enable operation from only one point.

The control system should provide a fail-safe operation at all times.

All types should be hold on to run type.

Cage/ platform

A cage/ platform must:

- be designed for the application and load conditions
- have a design with a suitable means to prevent a person from falling out of the cage and prevent entanglement between the cage and shaft while the person is being transported
- have an 'emergency arresting device' fitted to the cage/ platform so that in the event of a rope failure, the cage/ platform with its maximum rated load, will be automatically brought to rest safely
- have a 'manually activated emergency arresting device' fitted to the cage/ platform so that in the event of winch holding failure, the cage/ platform with its maximum rated load, may be brought to rest through manual deployment of this device
- allow the manually activated emergency arresting device to be a manual activation of the automatic emergency arresting device
- have a suitable means to prevent the cage/ platform from moving away from the shaft guide (ladder)
- allow the spacing of guide devices, that connect the cage/ platform to the guide rails, to be of a suitable distance, to ensure stability of the cage/ platform at all loads and speeds.

Headframe and shaft guides

The headframe must:

- be designed for the application and the load conditions
- be securely anchored to prevent dangerous movement, such as overturning or slipping into the shaft.

The shaft guides must:

- be designed to withstand and control the forces applied from a loaded cage/ platform, moving as it operates up and down in the shaft
- have guide joints designed to minimise the potential for jamming of the cage/ platform during operation
- be designed to hold the full load under dynamic conditions with the application of the emergency arresting device at any point in the shaft.

Limit switches

A limit switch is required to effectively interrupt an electrical circuit to fulfil one of the following:

- limit range of distance of motion
- limit speed of motion
- perform interlocking function
- send mechanical or operational malfunctions of the winch by rope slackness, rope out of position (i.e. bunched on drum, overspeed operation or other means).

Where limit switches are installed, the failure of those switches should not present a risk to the health and safety of people.

Emergency stops

Emergency stops should be fitted on all hoists. The emergency stop should be a 'stop and lock-off' type so that the plant cannot be restarted after an emergency stop control has been used, unless that emergency stop control is reset.

The stop control must:

- be prominent, clearly and durably marked and immediately accessible to each operator of the plant
- have any handle, bar or push button red in colour which is associated with the stop control
- not be adversely affected by electrical or electronic circuit malfunction.

Hoists inspections

Hoist should be inspected before use. Maintenance should be completed in accordance with the manufacturer's recommendations or minimally, on an annual basis.

Figure 126 - Hoist pre use inspection template

Date:	
Name:	
Hoist/Claim No.	

Indicate condition of hoist by marking: Pass, Fail or N/A for checks that are not applicable.

Component Check	Checks to perform	Pass	Fail	N/A
Shaft	Check that the shaft is suitably covered to prevent unauthorised access. This includes fencing, gate or grates in place over the shaft.			
Hoist frame	Check hoist frame is secured to prevent tipping and is free from damage or cracking of frame or welds.			
Rope sheaves	Check rope sheaves are secured, free from damage and move freely. Grease as required.			
Winch rope and drum	Check that the winch rope is not frayed and is secured at both ends, either by a swagged splice, thimble and three clamps, wedge and socket or clamped to drum with either two clamps or clamp plate. Check that the winch rope is evenly distributed on the drum. Check two turns of rope are left on drum when fully paid out.			
Guarding	Check that guarding is in place and secured around rotating equipment to include belts and pulleys.			
Belts and couplings	Check belts and couplings are secure, correctly tensioned and in good condition, free from excessive cracking or fraying.			
Pumps / motors	Check pumps and motors are secured, free from damage and leaks.			
Hoist return mechanism	Check that the hoist bucket return mechanism is in place and operates freely to allow auto return of the bucket.			
Hydraulic hoses	Check hydraulic hoses are free from damage, wear and tear and are routed correctly.			

Shaft access ladder	Check that the shaft access ladder is secured top and bottom to prevent movement and is adequately stood off from shaft to enable three points of contact. Check ladder rungs for cracks and that all joints are secured.
Oil and grease	Check fluid levels are correct and components greased. Top up and grease as required.
Cables	Check electrical cables are free from damage and run in a way to prevent cable damage.
Material bucket / platform	Check that the bucket is secured. Check that guide rollers and guide plates are secured, free from damage and move freely.
Control system	Check that the control system is secured and operates as intended.
Brake holding and lowering device	Check that the brake holding device operates.
Emergency stop	Check that the emergency stops work and that the plant does not restart unless the emergency stop is reset.
Limit switches	Check that the limit switches are adjusted correctly and operate as intended.

Electricity

Electricity is the most efficient form of energy to generate, transmit and use on a mine. Determining the electrical needs of a mine can be achieved by simple calculations, verified by a licensed electrician. Such calculations are very useful when purchasing electrical equipment.

This chapter discusses power requirements, means of transmitting electricity, consumption considerations and protection of systems and identification of hazards.

For detailed information relating to electrical work in your workplace review both clause 146 of the Work Health and Safety Regulation and Work Health and Safety (M&PS) Regulation clause 32.

Managing electrical hazards

Common hazards with electricity are:

- death by electrocution
- injury from electric shock, arc blast and burns
- injury sustained through unintended operation of equipment
- fire from short circuits, overloaded cables or equipment burning out.

If properly controlled, it is also the safest and healthiest form of energy to use in opal mines compared to a diesel engine and associated transmission shafts and belts.

Working with electricity is not for the inexperienced or untrained, because it can be lethal. It is very important to seek assistance from a qualified electrical tradesperson where necessary.

For electricity to be useful as a source of energy, it is necessary to create a circuit within which the electricity can flow. Electrical energy is constantly seeking the path of least resistance and it is this phenomenon which makes the use of electricity hazardous unless proper precautions are taken.

When using electrical power, the primary safety concern is to ensure that the design, installation, commissioning, operation, modification, decommissioning and maintenance of the circuits does not allow electricity to flow through the operator.

Avoid working in moist conditions. Do not stand in wet or damp areas when operating 240 or 415 volt electrical equipment. If working at the mine surface, stop work if it starts to rain and ensure that fittings and connections are kept dry. The resistance of the human body is much lower when in contact with water. Lower resistance provides an easier path for the flow of electricity.

Constantly check for frayed or damaged cables, particularly on handheld tools and portable pumps or machines. Where possible, use battery powered tools to eliminate such hazards.

Determining the electrical needs of a mine can be achieved by simple calculations from a licensed electrician. Such calculations are also useful when purchasing electrical equipment.

In short, all electrical systems must be of such construction as to prevent danger, so far as is reasonably practicable. These will usually include incorporation of suitable protective equipment and will always be supported by safe working procedures.

Figure 127 - Electrical cable burnt out after contact with condensation moisture in a mine shaft.

Make sure that circuit components:

- are designed for the duty intended
- have cables which are correctly sized to avoid overheating and insulation deterioration, as well as voltage drop over long runs
- use the recommended plugs and sockets for the type of cable used
- use equipment with the correct weather ratings.

Have the circuit design checked by a qualified electrical tradesperson.

To further reduce the likelihood of electric shock, wear protective clothing such as rubber-soled boots and gloves when using electrical tools and equipment. Where possible, use battery powered tools. Keep the work area around switchboards and power boards in a tidy condition to enable unobstructed access. Take steps to lock or protect these items and install them away from dust and moisture. Don’t compromise the weather protection seals on plugs, enclosures or doors.

Typical physiological effects of electric shock include tingling (an electric current at 1mA is equal to 1/1000th of an Ampere), involuntary muscular contraction (i.e. a ‘can’t let go’ response at 10mA), respiratory paralysis at 20mA and ventricular fibrillation (i.e. heart muscles quiver with erratic useless impulses instead of steadily pumping blood at pressure at 100mA). People can be killed by relatively low values of current associated with lower voltages (most typically 240V or 415V). The likelihood of a shock is increased when electricity is used near water or where moisture from rain or condensation is present. These levels of electric current are extremely small, especially when compared to a hoist motor that may use 8 to 10 Amps.

The risk of electrocution can be effectively reduced if an 'earth leakage protection' device is fitted and known to be working efficiently. The device is also known as a residual current device (RCD) and as a safety switch. On 240 volt circuits, the maximum sensitivity rating to be used should be 30 mA to protect people. An RCD, however, must be tested daily, because the internal electrical circuit that senses a fault and automatically switches the power off before anyone gets a shock, is delicate and prone to failure if exposed to dust and moisture.

Australian Standards make provision for various configurations of the output circuits of generators that may or may not include earth leakage devices. However the legislation covering mining requires earth fault protection to be fitted to all distribution and control circuits, and earth leakage to be fitted to all sub-circuits . The advice of the equipment supplier or a qualified electrical tradesperson should be sought to determine what type and level of protection will be the safest for your mine. In all cases, this will require the fitting of 30mA earth leakage (RCDs) to all circuits.

The mine operator must ensure that all circuits that are equipped with earth leakage protection are tested regularly using the use of the test button on the device. Additionally, a periodic test looking at the time it takes for the device to operate, must be done by a competent person using a test instrument. If the device fails to operate or is slow to operate when tested, it must be replaced.

For testing and tagging, a competent person refers to a qualified electrical tradesperson or a person with a recognised competency for testing and tagging. Always seek the assistance of a qualified electrical tradesperson.

Power sources

Electricity can be obtained from several sources.

Portable battery power

Battery-powered portable tools may enable work to be done safely in a damp environment, where the use of 240 volt tools would be hazardous. Adaptors are available to recharge some batteries from a 12 volt vehicle. Larger tools require a 240 volt charger and care must be taken to ensure that the battery charger is not exposed to moisture.

Direct current (DC)

Direct current is usually obtained from a series of batteries providing 12 or 24 volts DC. This is most suitable for lighting and operating 12 volt refrigerators. It is a relatively safe form of power, however, care must be taken not to short circuit the battery terminals, as high currents will flow. This can cause severe burns and the battery may explode. Twelve and 24 volt DC power circuits suffer severe drops in voltage if transmitted over long distances. As a rule, the longer the distance, the thicker the cable required. A range of 12 volt lights, switches, fittings and other domestic electrical appliances are available. Battery terminals should be fully insulated and guarded . Care should be taken to keep batteries in a well-ventilated space to dissipate any hydrogen gas that batteries create when charging. Hydrogen gas is very explosive.

It is generally accepted that a diesel engine generator is more expensive to buy initially than a petrol driven generator but is cheaper to operate and maintain.

Diesel fuel is less volatile than petrol, with less risk of fire.

Generating plants must not be installed within the mine, or near the intake airway as they emit toxic fumes.

Alternating current (AC) – 240 volt, single phase

A 240 volt AC single phase is generally produced by a generating plant driven by a petrol or diesel motor. When a generator on a mining claim has been fitted with an RCD, it should be fitted with industrial weatherproof switched socket outlets rated at IP56, instead of domestic type socket outlets. RCDs and weatherproof socket outlets should be fitted and tested for correct operation by a qualified electrical tradesperson.

Figure 128 - 240v generator

Earth stakes are optional for free standing generators, however the earth conductors in the supply cables and flexible cables must be electrically continuous. This is to ensure that any faults will be detected and not flow through the operator.

Small generators designed for camping do not supply sufficient power to operate power tools used in an underground mine. Some generators are supplied with an in-built RCD, however the majority do not have earth leakage protection fitted. Any generator that has a socket outlet fitted must have an RCD fitted.

Advice should be sought on whether overload protection is correctly set for a generator. Some small generators rely on a thermal cut-out to automatically disconnect power and prevent damage to the alternator. These overload protective devices (i.e. circuit breakers) should be sized to protect the generator. A circuit breaker will take time to operate depending on the size of overload it is detecting (i.e. a 10 Amp circuit breaker with 11 Amps flowing may take a few minutes to operate, whereas if 15 Amps is flowing, it may take a few seconds to operate). The time to trip is inversely proportional to the size of the overload current.

Circuit breakers are also designed to detect and operate quickly when a short circuit occurs. Potentially high electric current can flow during a short circuit, and high levels of arc fault energy can be generated at the location of the short circuit. A circuit breaker in this situation will trip in very quickly, in a matter of milliseconds to clear the fault.

The length of cable installed will affect the performance of circuit breakers. If the length is too long, the circuit breaker may not detect the fault, electric current will continue to flow and equipment may catch on fire.

Alternating current (AC) – 415 volt, three phase power is produced from large diesel generating plants. These are generally used to provide power for larger electrical equipment underground and on the mine surface. Three phase generators must be designed, installed and maintained by qualified electrical engineers and/or qualified electrical tradespersons.

Three phase generators must be fitted with earth leakage (or RCD Residual Current Device) protection and circuit breakers, to protect against overloads and short circuits and be installed by a qualified electrical tradesperson. Earth fault limitation must be installed on power supplies going underground so as to control step and touch potentials.

Power supplies for mobile equipment supplied by a flexible or trailing cable must have protection installed so that power cannot be turned on to the equipment if there is an earth fault on the cable, and the power is automatically disconnected if the earth connection to the equipment is interrupted.

Three phase electrical systems have complexity and hazards that are beyond the scope of this publication. For further electrical guidance in this area see EES013: Electrical Engineering Safety – Guide and EES014 Technical Principles for the Use of Stand Alone Generators.

The figure below shows a well-guarded generator with RCD and weatherproof socket outlets. The installation can be improved by taking more care to avoid strain on cables. The installation of an earth stake is optional, provided the installed earthing connections remain in good condition.

Figure 129 - 415 volt (3 phase) generator

All mining generators should produce alternating current (AC) at a frequency of 50 Hertz (HZ) and a voltage of 240 volts (V) (single phase) or 415/240 volts (V) (three phase).

Selecting a single-phase generating plant

Go to a reputable supplier who employs technical people capable of assisting with the selection of a suitable generating plant. A generator marketed as being compliant to the state's requirements (in some states it is a WorkCover Authority specification), will have one or more vibration isolated, individually switched weatherproof power outlets installed. The power outlets must be protected by a combination earth leakage/overload circuit breaker. This breaker should be sized to the generator capacity or the rating of the power outlet, whichever is the lower. The weatherproofing rating of IP66 or IP56 has a very high resistance to moisture and dust, however the generator itself is generally not as highly rated and should be protected with a suitable protective covers.

The following features should be considered:

- the maximum electrical load that may be required by the mine at any time, calculated in kVA or kW
- requirement that the generator start with a load
- the load-starting demands of motors, welders and other equipment (i.e. generally 5 to 8 times the rating of those motors, welders)
- having earth leakage protection fitted to the generator
- having overload and short circuit protection fitted to the generator
- the battery having a lockable isolation switch
- the power outlets needing to be locked in the off position
- fitted covers to live electrical parts
- the need for the main earth bar, generator frame and alternator winding star point (i.e. earthable point) to be connected
- the MEN Link connected and clearly labelled
- all outlets labelled, warning signs and a resuscitation sign needed to be fitted
- fuel sources and fuel lines securely routed, clear of hot surfaces
- length of the warranty for industrial uses, including parts and labour
- the machine's weight
- the generator is diesel or petrol driven
- the maintenance recommendations
- power needed above the total demand to overcome inefficiencies
- a fault causes the generator to stop or automatically switch off the output power.

To calculate the sizing of a generator, the operator needs to know what electrical load intend to connect to the generator. This is called the maximum demand (power requirements).

Ohm's Law relates potential difference (Volts) to resistance (Ohms) and current (Amperes) by the following equation.

POTENTIAL DIFFERENCE (Volts) = CURRENT (Amps) X RESISTANCE (Ohms)

The other most important calculation is power. All equipment is rated in units of power consumption or power generation and will be expressed as Watts (W) or volt-amps (VA).

Power is calculated as follows:

Power (VA)	= Potential Difference (Volts) x Current (Amps) at unity power factor
Power (Watts)	= Potential Difference (Volts) x Current (Amps) x power factor (pf)
Power	= Power is expressed in Watts (W) or Kilowatts (kW), where 1kW = 1000W

When calculating power requirements kW = kVA multiplied by the power factor. Power factor is the ratio of true power (power available) to the apparent power (theoretical power obtained from the product of volts and amperes). The difference occurs due to the time lag that happens between voltage and current, depending on the circuit configuration. When they are in time with each other, the power factor is 1.0. Usually electric motors have a power factor of 0.8. This is a typical power factor that can be used in calculations.

Table 17 - Power requirements and generator size

POWER REQUIREMENTS FOR 240V ELECTRIC MOTORS					
	RUNNING		STARTING		GENERATOR REQUIRED
ELECTRIC MOTOR SIZE	POWER NEEDED	RUN AMPS	POWER NEEDED	RUN AMPS	NOMINAL NAMEPLATE POWER RATING
1 hp	0.75 kW	4 A	3.8 kW	20 A	5 kVA
1.5 hp	1.1 kW	5 9A	5.7 kW	30 A	7 kVA
1.75 hp	1.3 kW	6 9A	6.6 kW	35 A	8 kVA
2 hp	1.5 kW	7.9A	7.6kW	40 A	9 to 10 kVA

POWER REQUIREMENTS FOR 240V ELECTRIC MOTORS					
	RUNNING		STARTING		GENERATOR REQUIRED
ELECTRIC MOTOR SIZE	POWER NEEDED	RUN AMPS	POWER NEEDED	RUN AMPS	NOMINAL NAMEPLATE POWER RATING
2.5 hp	1.9 kW	9 8A	9.4 kW	50 A	12 kVA
3 hp	2 25kW	11 8A	11.3kW	60 A	15 kVA

POWER REQUIREMENTS FOR 415V ELECTRIC MOTORS					
	RUNNING		STARTING		GENERATOR REQUIRED
ELECTRIC MOTOR SIZE	POWER NEEDED	RUN AMPS	POWER NEEDED	RUN AMPS	NOMINAL NAMEPLATE POWER RATING
1 hp	0.75 kW	1.8 A	5.2 kW	9 A	6 to 7 kVA
1.5 hp	1.1 kW	2 6 A	7.5 kW	13 A	10 kVA
3 hp	2.2 kW	5.0 A	14.4 kW	25 A	18 -20 kVA
4 hp	3.0 kW	6.2 A	17.9 kW	31 A	22 - 25 kVA
5 hp	4.0 kW	7.5 A	21.6 kW	38 A	25 - 30 kVA
7.5 hp	5.5kW	11 A	31.6 kW	55 A	40 kVA

Typical capabilities for generators are illustrated in the tables above. For example, a 240-volt generator rated at 5 kVA and operating at a power factor of 0.8 will produce 4 kW of power. This generator will comfortably start and run a 1.0 hp (0.75 kw) electric motor. A 415-volt generator rated at 40kVA will comfortably start and run a 5.5kW 3 phase motor.

This is the most fundamental calculation in estimating power requirements. When making such calculations, ensure the numbers used are in the correct units. Such calculations will provide answers to the following:

- size generator needed to operate all electrical equipment in the mine and on the surface (i.e. equipment such as the caravan fridge) efficiently
- size cable needed in the mine.

MAXIMUM DEMAND CALCULATION - CALCULATING THE ELECTRICAL LOAD OF A GENERATOR

Suppose a 240V single phase generator is required to supply power for:

- one 1hp (0.75kW) electric motor
- two 120W lights
- one 1.05kW electric jackhammer

For the purposes of this example, the electric motor full load current is 4 amps, with a starting current of 20 amps (5 times full load current). The power consumption calculation for continuous load is:

	KW
0.75 kW electric motor	**0.75**
1.05 kW electric jackhammer	**1.05**
2 X 120 w lights	**0.24**
TOTAL	**2.04**

Therefore, the generator will be running with continuous load of 2.04 kW. However, the generator must also be capable of supplying the starting current of the electric motor for a short time until the motor reaches full speed. If the motor is fully loaded, that high current can be drawn for up to one second.

Most industrial generators can withstand a reasonable period of overload during the starting of motors, however the number of starts per hour should be considered when calculating the optimal power output rating. Too many starts per hour may overheat the windings in the alternator, causing premature aging and failure. If the generator is too small, the inertia of the generator is insufficient to maintain full speed when the starting current is drawn, and the generator will slow down and may stall.

Therefore, the initial starting current of 20 amps for the electric motor will require a generator with the capability to produce a peak or short time power rating as follows:

VA	=	VOLTS X AMPS
	=	240 x 20
	=	4800 volt amperes
	=	4.8 kVA

To meet this short time power requirement for a self tipping hoist with a 1.0hp (0.75kW) motor, a 5 or 6 kVA generator will be a minimum requirement.

However, an operator can be underground, using the jackhammer (1.05kW) and the lights (0.24kW). The generator will be supplying 1.29 kW of power starting the motor. In this case, when the hoist motor is switched on, the demand on the generator will be as follows:

Exiting load base	=	1.29 kW	=	1.61 KVA
Add motor starting	=	3.8 kW	=	4.74 KVA
TOTAL LOAD	=	5.09 kW	=	6.36 KVA

To meet the needs in this scenario, a generator rating should be at least 7.5KVA. It is important to actually look at how the electrical power will be used to properly assess what size of generator needed.

Working further through this example, consider the surface power needs in calculations. The following table gives some approximate loads of typical equipment found on the surface of mines.

Table 18 - Approximate load of electrical appliances and equipment.

APPROXIMATE POWER REQUIREMENTS		
APPLIANCE	AMPS	WATTS
Refrigerator	0.5 to 2	100 to 400 *(running)
Kettle or electric jug	6 to 8	1500 to 2000
One stove element	6	1500

APPROXIMATE POWER REQUIREMENTS		
APPLIANCE	AMPS	WATTS
Frypan	6	1500
Microwave oven	3 to 6	1000 to 1300
Toaster	4 to 5.5	1000 to 1300
Iron	4	1000
TV set	0.5 to 1	100 to 200
Kango (small)	4	900 *(running)
Kango (large)	4.5	1100 *(running)
Jack hammer	7.5	1650 *(running)
Circular saw	7.5	1800 *(running)
Drill	8	1920 *(running)
Compressor 1.5 HP	9	2160 *(running)
Welder	12.5	3000

With a combination of 415v loads and 240v loads, there will be a need to get assistance from an electrical tradesperson or engineer, as the loads will need balancing to optimise the sizing of the generator.

Using a generator at less than its capacity will cause damage to the motor driving it. As a rule:

- diesel generators should operate at no less than 2/3 (66%) of their full load
- petrol generators should operate at no less than 1/2 (50%) of their full load.

Consider generator fuel consumption:

- generators up to 4 kVA consume 1.5 to 3 litres of fuel per hour
- generators up to 10 kVA consume 3.5 to 4.5 litres of fuel per hour.

Protection systems

Generators are usually fitted with an earthing stud, fitted to the carrying frame of the plant. It is not essential that this stud be connected to an earth stake. However, it can improve safety to run earthing cables from this lug to nearby metal structures, particularly those on which electrical equipment is mounted. This is called equipotential bonding. The size of the equipotential bond should match or be larger than the power cable conductor size of the generator

Gemstone mines that use a 240-volt generator, an earth stake is considered impractical and optional. It is however essential to ensure that power cables and extension leads have an earth conductor and that the earth connection on metal cased equipment is connected to the earth in its supply cable and effective.

Regular testing and tagging of electrical equipment must also include checks that the earth conductor in all cables (i.e. shaft cables and extension cables) are continuous and effectively connected to the main earth at the generator.

Earthing of supply authority power supplies

Power supplies from supply authorities generally have a better earthing system supporting their power supply system than a generator. It is imperative that the earthing system at the mine is electrically continuous to the main earth point at the supply main switchboard.

Regular testing and tagging of electrical equipment must also include checks that the earth conductor in all cables (i.e. shaft cables, extension cables) are continuous and effectively connected to the main earth, at the source of power supply, usually the main metering switchboard.

Over-current protection

Over-current protection is installed to protect a circuit or part of a circuit from being overloaded. A generator should have a protective device fitted to protect the generator from being overloaded, and to protect the cables connected to the generator. To protect the generator when multiple power socket outlets are used, suitable overload and short circuit protection, such as a fuse or circuit breaker, is necessary. On very small generators with a single power socket outlet, a self-resetting thermal cut out is usually incorporated.

Current operated protection devices require careful selection to ensure that the device will operate properly when a severe fault occurs and the output voltage drops.

Circuit breakers and fuses primarily provide protection for cables. Motors generally come with thermal overload devices.

Residual Current Device (RCD) or earth leakage protection

A residual current device (RCD) is an electric switch designed to disconnect the power when current finds an alternate path through ground or through the earth conductor (earth leakage) back to the generator. An RCD will also operate where equipment has developed some types of fault. A good earth system must be in place for an RCD to operate. All metal objects that could be in contact with power must be effectively earthed. This is normally achieved by the earth wires and connections in leads being present and correct. Additional equi-potential bonding earths will give added safety.

These connections should be periodically tested by a qualified electrical tradesperson.

Installation of RCD

Portable generators are available with an RCD fitted and permanently installed at the generator. These are often marketed as specified generators within the state. When an RCD is installed, it will detect any current flow to earth from a damaged or wet electrical lead or tool and cause the power to be automatically disconnected.

A qualified electrical tradesperson must be consulted to have an existing generator fitted with an RCD. In most cases, the RCD must be installed at the generator. Alternatively, a switchboard placed nearby may contain the RCD. The down side of fitting the RCD in a switchboard is that the switchboard and the cable from the generator to the switchboard will not be protected against an earth fault occurring (i.e. the operator coming into contact with live wires in the switchboard). However, it will still provide protection on cables and equipment connected to the switchboard.

Where long operating periods exist, mounting the RCD off the generator may provide a longer operating life for the RCD. For further electrical guidance review EES014 Stand Alone Generators under Electrical Guidelines in References.

The RCD needs to be of sufficient rating to match the starting and continuous current demands. Also, check that it is rated for generator use, as fluctuating voltages occur and these will damage some units.

Where a person makes contact with a live conductor, the RCD will cut off the power . However, in the case of a direct contact between active to neutral, an electric shock is likely. An electric shock should be medically treated as the resulting damage is not always visible and may be life threatening.

When a circuit breaker or an RCD has been tripped

There are various situations when a circuit breaker or an RCD will trip to the off position. Circuits can be protected by a circuit breaker against overload and short circuits. A separate RCD protects against a fault to earth. Typically, a single device with a circuit breaker and RCD are used, as these are easier to use and only one device needs to be installed.

There are a number of scenarios that can result in a CB/RCD to trip, and each requires a different approach to find out it tripped.

Firstly, determine if there is any damage done to the electrical equipment, or if anyone has suffered an electric shock, by:

- Checking with workers to determine if they are okay and safe and have not had an electric shock (if they have, take action).

- Switching all circuits off and unplugging all leads.
- Visually inspecting leads and appliances for signs of damage (i.e. molten plastic), a burnt smell or evidence of fire.
- Removing damaged equipment or leads from the mine to be repaired by a qualified electrical tradesperson.
- With no electric shock and no damaged equipment, reconnecting the equipment and cables, leaving everything switched in the off position.
- Starting at the generator (or main switchboard), switching the main circuit breaker on. If this trips off, the fault is in the section between the generator and the next switch. Turning off the power supply and reinspecting the cables and equipment in that section. If it is not visible, an electrician will need to find the fault.
- If the power remains on, going to the next switch in line and repeating the process.

If the power remains on at the end of repowering the system, there may have been an overload trip. This will happen if too many loads are connected and operating at the same time. Actions to be followed:

- Do all the checks as above first.
- Progressively turn on equipment. If it was an overload trip, then the same will occur when running all equipment. In this case, stop some equipment to allow the load to drop and the power supply to be better able to supply electricity to the mine.

If the problem cannot be found, and the power supply keeps tripping off, shut the system down and get help from a qualified electrical tradesperson. The source of the problem must be identified and removed from the circuit. Repeatedly resetting an CB/RCD against a fault is dangerous and may result in the CB/RCD exploding.

Cables

Electrical cables are rated for the continuous flow of current and for the dissipation of heat. If excessive current is drawn through a cable, it will begin to overheat and the insulation will burn, causing a fire which produces toxic fumes and short circuit.

It is therefore essential to calculate the current requirements of the mine, the length of cable required and purchase the appropriate cable size and insulation rating.

Do not hang cables directly on pins or brackets made from exposed metal. They can become live if the cable is damaged.

Cable selection

The selection, use and installation of electric cables at a mine should be based on anticipated current demands and the location of this equipment with respect to the generating plant.

Cables of a large cross-sectional area have lower resistances and therefore are capable of conducting higher current loads, with small drops in voltage and reduced heating. A cable with a resistance of 1 ohm per 100-metre length will give a smaller voltage drop than a cable with a resistance of 3 ohms per 100 metre length.

If cable sizes are too small and the voltage drop is too great, power tools will fail to perform and subsequently burn out.

Cables should be chosen to match the required current carrying capacity and the duty to which they are to be used and not selected merely on the basis of cost. This should be done in consultation with the electrical supplier.

Cable Installation – in shafts

Electrical cable has considerable weight when large lengths are involved. Therefore, the cable should always be supported at regular intervals. In shafts, the following points should be considered:

- Support electrical cable every 0.3 metres on a separate support catenary wire or rope attaching it to the support at regular intervals (approximately every 5 metres).
- Install the cable away from the shaft conveyance or brackets.
- Do not attach the cable to the ladder.
- Design the electrical circuit so that there are no electrical connections in the shaft.
- Avoid kinking.
- At both the collar and the bottom of the shaft, ensure that the cable is held clear of equipment movement and work areas.
- Keep the cable off the ground in drives by attaching it to the roof or walls.
- Inspect the cable regularly for damage caused by falling material.

Cable Installation – along drives

Plan to have the cable off the ground and securely supported along the drive at regular intervals. Where the cable is unlikely to be disturbed, fix it to the catenary at no more than 2-metre intervals with insulated attachments.

Installing cables on the wall or roof of a drive reduces the risk of damage from equipment and keeps them out of the way. They should be protected and insulated at each support point with a sleeve of plastic tubing or similar, to avoid abrasions against the fastening arrangement.

Where excess cable is available, looping it back along the drive is preferable to having it rolled up at the end. This reduces the heating effect, maintains the current carrying capacity and extends the life of the cable.

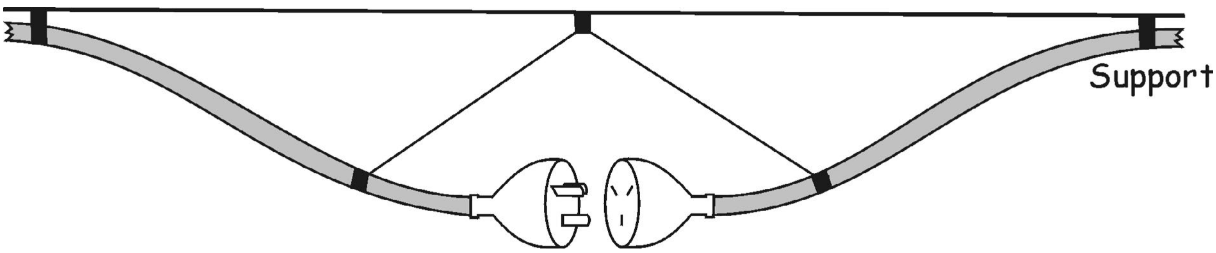
Figure 143 - Electrical cable secured to drive roof with rubber and a steel pin.

Cables supported by means of a catenary wire must be stranded flexible cables having double insulation. If the cable is installed outdoors, ensure it is suitable for exposure to sunlight.

Connectors

Avoid bends in the cable of less than 10 times the diameter of the cable.

Figure 144 - Electrical cable supported to reduce tension



Do not use double adaptors, as they are very dangerous. Use individual sockets for each plug and place the main power board on the mine surface in a dry environment.

Ensure that where plug and sockets are used for cable connections, the connections are supported to avoid tension. In damp conditions, use weatherproof plugs to provide protection from moisture. Remember moisture and electricity are a deadly combination.

Voltage drop

A drop in voltage occurs along a length of electrical cable when an electrical current is transmitted. This means that the voltage at the end of a cable will be less than at the beginning or power supply input. The amount of drop is dependent on the size of cable used and the amount of current being transmitted. The effect is similar to the drop in pressure experienced in a long length of water hose.

When designing an electrical circuit, care should be taken to consider the drop in voltage that will occur to ensure maximum efficiency of the system. As a rule, large current causes large voltage drops, and small current gives only small voltage drops. The problem of voltage drop can be reduced by using larger diameter cables or shorter lengths of cable. The table below provides general guides to the voltage drops on various flexible cable sizes.

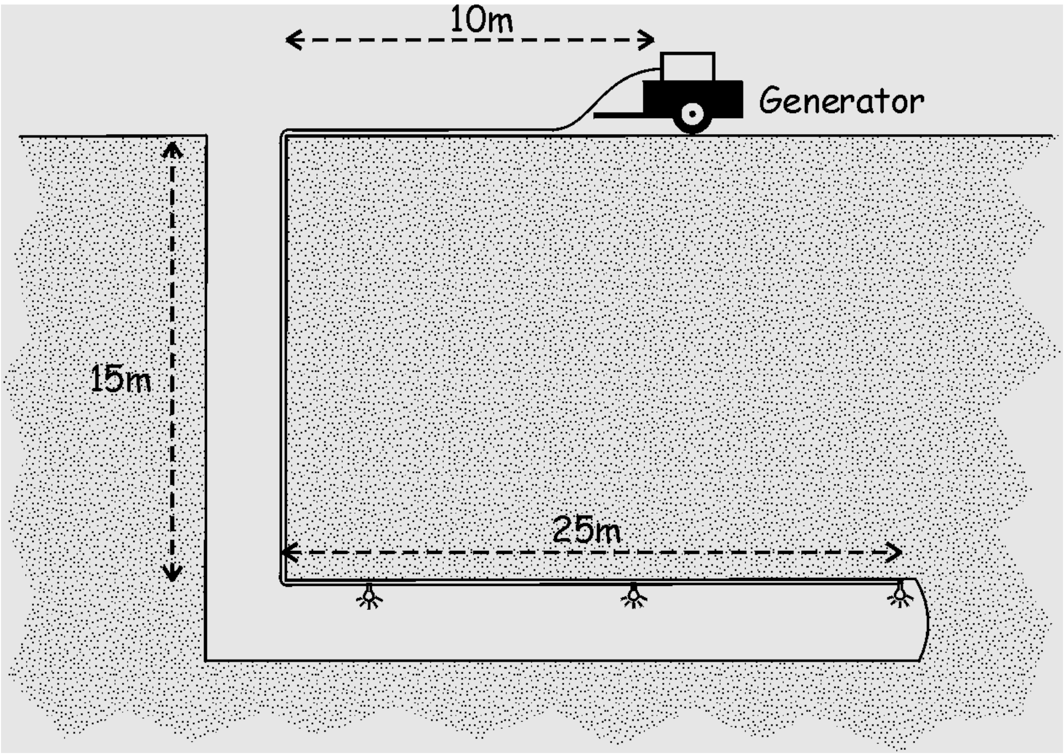
The voltage drop in a 240 volt circuit can be measured by a qualified electrical tradesperson using a measuring instrument at connections at various points on the circuit. It will indicate the adequacy of the electrical system.

The voltage drop in a 12 volt circuit can be measured by a competent person using a meter that is rated for the purpose.

EXAMPLE

The operator is planning to install a 12-volt lighting system underground. To calculate the voltage drop, consider the length of cable required to reach the furthest point underground and establish what size cable is required.

Figure 145 - Cable lengths in an electrical circuit



Total length of cable to last light.

- 10m + 15m + 25m = 50 metres

The current required at the light is 2.5 amps.

The table below shows the flexible cord milli-volt voltage drop for each ampere of current for each metre of cable (mV/Am). Voltage Drop = mV/Am x A x m

Consider using a flexible cord rated at 10 amp.

It is being assumed that all the current is used at the last light bulb (to make it easier to calculate).

Voltage drop/Am on 10 amp cord	=	45 mV/amp.metre
VDrop = 45mV x 2.5 amps x 50m	=	5.63V
	=	Say 5.6 volts

The voltage drop of 5.6 volts on a 12-volt system is too great. Consider a flexible cord rated at 20-amp cable.

Voltage drop/Am on 20 amp cord	=	18 mV/amp.metre
VDrop = 18 mV x 2.5 amps x 50m	=	2.25 V

The voltage drop is acceptable. Therefore, use the 20-amp cord which has a cross section of 2.5 mm^2.

Table 19 - Current carrying capacity and volt drop – flexible cord

1	2	3	4
Nominal area of conductor	Number & diameter of wire strands	Current carrying capacity [a,b,d]	Single phase voltage drop
mm^2		A	mV/A.m
0.5	16/0.2	3 c	-
0.75	24/0.2	7.5	60
1.0	32/0.2	10	45
1.5	30/0.25	15	31
2.5	50/0.25	20	18
4.0	56/0.30	25	12

The above table displays the current carrying capacities of flexible cords 0.5 to 4.0mm^2 cross sectional area. It also reveals the following:

- The stranding given in column 2 represent the minimum number of strands and the nominal size of each strand. The values in column 3 also apply to conductors having a large number of smaller strands than specified in column 2.

- The values in column 3 are based on an ambient temperature of 25C and a maximum operating temperature of 60°C.
- Not recommended to be used are cords with tinsel conductors rated at 5 amps.
- Where a flexible cord is wound on a drum, multiply the values in column 3 by the following factor:

NUMBER OF LAYERS	1	2	3	4
DERATING FACTOR	0.76	0.58	0.47	0.40

Table 20 - Voltage drop values - single and three-phase flexible cables

1	2	3	4	5	6	7	8
		CURRENT CARRYING CAPACITY, A[b]					
CABLE SIZE Mm2	NUMBER AND DIAMETER OF WIRES No/mm	SINGLE & TWO CORE R75, R90 V75, V90		THREE & FOUR CORE R75, R90 V75, V90		Three-phase voltage drop mV/A.m	
						Single ph 2 core	Three ph 4 core
1.5							
2.5							
4							
6	84/0.30	40	44	35	41	7.0	7.3
10	77/0.40	57	61	45	56	4.0	4.3
16	26/0.40	77	82	61	75	2.6	2.7

1	2	3	4	5	6	7	8
CURRENT CARRYING CAPACITY, A[b]							
CABLE SIZE Mm2	NUMBER AND DIAMETER OF WIRES No/mm	SINGLE & TWO CORE R75, R90 V75, V90		THREE & FOUR CORE R75, R90 V75, V90		Three-phase voltage drop mV/A.m	
						Single ph 2 core	Three ph 4 core
25	209/0.40	96	110	80	98	1.7	1.7
35	285/0.40	120	135	96	115	1.1	1.2
50	380/0.40	140	170	125	150	0.84	0.87

The above table displays the current carrying capacities of 0.6/1 kV flexible cables. It also reveals the following:

- The stranding given in column 2 represent the minimum number of strands and the nominal size of each strand. The values in column 3 to 8 also apply to conductors having a larger number of smaller strands than specified in column 2. The stranding in column 2 represent the minimum number of strands and the nominal size of each strand. The values in column 3 to 8 also apply to conductors having a larger number of smaller strands than specified in column 2.
- Where a flexible cable is wound on a drum, multiply the values in columns 3 to 6 by the following factor:

NUMBER OF LAYERS	1	2	3	4
DERATING FACTOR	0.76	0.58	0.47	0.40

- For single-phase voltage drop, multiply the three-phase value by 1.155.
- Single-core, two-core and three-core only.
- Single-core only.

Flexible cords vs flexible cables

There are different ratings for flexible cords and flexible cables. Flexible cords have a lower current carrying capacity and are calculated to operate at a conductor temperature of 60 degrees celcius. Flexible cables, which are more common, are more suitable for operating in a mining environment. Both cables usually have a maximum conductor operating temperature of 75 degrees celcius.

Cable temperature

It is the ability of a cable or cord to disperse the heat it generates, while conducting electricity that gives the cable or cord its current carrying rating. The hotter a cable operates at, the lower the current carrying capacity it will have. Therefore, on the surface of the mine, shade the cables. They can be buried but the hot soil will further reduce the cable's capacity. If a cable is going to operate in a hot environment, such as direct sun, go to a cable with a larger conductor size than what was initially calculated. A larger cable can carry more current, but when de-rated for the effects of direct sunlight, will end up as a properly sized cable.

Switching gear

Reference should be made to the WHS Regulation. All switchgear should be:

- Of an adequate rating for the intended duty, equal to or greater then the current and voltage it is switching. The ingress protection is suitable (i.e. IP56 minimum, no domestic fittings underground).
- Kept dry, securely fixed to a box or board and provided with adequate security provisions to prevent accidental contact.
- Used with only the correct fittings for each circuit.
- Fitted with RCD (safety switch) with a sensitivity maximum of 30mA.
- Provided with overload and short circuit protection.
- Able to be locked in the off position.
- Clearly labelled what it supplies, and where the on and off positions are.

Lighting circuits

Underground lighting is a necessary part of equipping any mine. Illumination should be sufficient to provide good visibility both at the working face and those parts of the mine used for travelling and access.

The 12-volt lighting system is preferred. The advantages are:

- It can be operated from a generator or a 12-volt car battery.
- When supplied from a battery, if the main generator stops, the lights keep working.
- Is safe with personal contact not posing as an electric shock hazard.

- Fittings and globes are readily available.
- LED fittings are easily available and use less current than an incandescent bulb.
- Standard power cable can be used.
- It is easy to maintain.
- Less likely to cause hazards in wet or damp conditions.
- Fittings are small and lightweight and readily transportable.

For either 12-volt or 240-volt lighting systems, only use lights with ‘protected’ bulbs such as cage lights and enclosed flood lights. This reduces the risks associated with a broken bulb short circuiting, causing a fire, or having personal contact with live connections resulting in burning skin (12v & 240v) or electric shock (240v).

Always have a torch available for backup in case the lighting circuit fails.

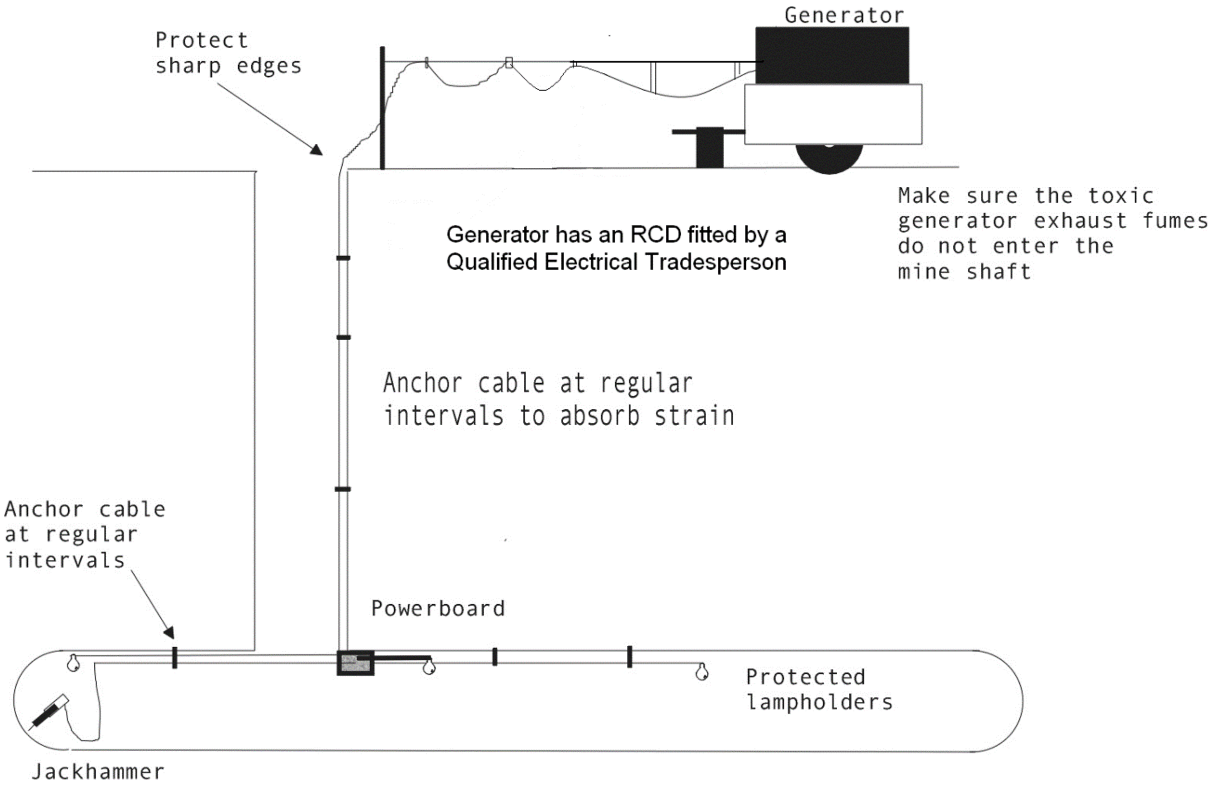
Figure 146 - Protected light fitting, household globe.

Figure 147 - Protected light fitting, floodlight.

Party or festoon type lights do not provide any protection from contact with live connections if they are broken and should not be used underground.

Figure 148 - Party or festoon light – DO NOT use.

Figure 149 - Arrangement of power cables - example of a 240-volt AC circuit



General precautions

General precautions to follow:

- Use 12-volt power.
- Anchor cable in shaft, roof or walls.
- Use low wattage halogen bulb for best results (i.e. 20-watt in drives and 50-watt at face).
- Consider using LED lights as they use less current and will be a lesser drain on the battery.
- There must be a lockable isolation switch at the battery
- There must be circuit protection, such as a circuit breaker, to protect the cabling network.

Using 240-volt power

With a 240-volt installation, always use an RCD at or near the generator and test regularly.

All RCD's are to be push button tested regularly before use or every six months. They should be tested by a qualified electrical tradesperson for time / current trip testing annually.

Do not use double adaptors, light duty figure eight flex cable or single insulated cable. They are all prone to fire and a source of electric shock.

Use heavy duty red or orange cable. Cable down the shaft should be sized for the total load underground and prospective volt drop and be medium to heavy duty. Earth screened cable is also available and provides added protection against electric shock from nicks or cuts in the cable sheath. Light duty figure eight flex should never be used.

Double adaptors should not be used. Instead, use an industrial power board and medium duty flex underground.

Use protected light fittings.

When installing a self-tipping hoist with a stop/start control, make sure that the control wiring is 24-volts or less and fail safe (i.e. it stops when there is a fault in the circuit).

Keep machinery and lighting electrical circuits separate to ensure that any failure of the machinery circuit leaves the operator with adequate lighting.

Only use power tools in a good to excellent state of repair. Use only double insulated tools, or preferably battery powered tools.

All metal framed electrical plant must be connected to the protective earth circuit. Additional equi-potential bonding earths add to the safety of the system. It is essential that all earth connections throughout the mine are maintained and tested for continuity periodically.

Use individual cable from power board to each lighting power circuit.

Use individual cable from power board to each jackhammer.

Secure all cables to shaft, roof or walls.

Select electrical plant with appropriate weatherproofing.

Locate the generator well away from the shaft to:

- avoid exhaust fumes entering the mine
- provide a safe area away from the shaft for maintenance.

When using portable or mobile equipment at 415 volts or greater, operators should, in the first instance, seek advice from an Electrical Inspector of Mines with the regulator for the state.

Install equipment that complies with the WHS Regulation. These requirements are further described in other publications on the Regulator’s website.

Hand held power tools - installation

Do not use double adaptors. Each circuit should originate from a switched outlet.

Buy extension leads which are already assembled. They are generally cheaper than homemade ones, which can be dangerous if incorrectly wired. Yellow or orange heavy duty leads are preferred.

Plugs and sockets should preferably be of the moulded type or clear plastic type.

In shafts, support cables on rope so that the weight is supported and the plug terminals are not being strained. This should only be a temporary installation. For a more permanent installation review the section on cable installation in shafts .

In drives, support cables above the floor, preferably with catenary wire.

Replace all power points, switches, cords, plugs and appliances which are broken, damaged, or badly worn. Keep them in good repair. Regularly inspect them before use.

Hand-held tools – operation

Do not pull on the cord to unplug equipment. Instead, switch off the power and pull out the cord by holding the plug.

Do not use plug and sockets for switching, instead use switches.

Most equipment comes with instructions for safe use. Please follow them.

Extension cords which are on reels should be unreeled before being used to prevent overheating, cables melting and fires.

Take care while using portable equipment. Be aware of where the cord is in relation to work being done so that cords are not damaged. A jackhammer can cut cables.

Do not use electrical equipment in wet conditions, particularly where the operator might be partly immersed. Dampness increases the damage that electricity can cause to the human body.

Do not leave cords and appliances out in the weather.

Treat any 'tingle' from a lead, an appliance or a tool as a warning. Refer to the electric shock procedure. Do not use the equipment until it has been checked and repaired. All electric shocks need to be reported to the Regulator and treated by doctor, as residual effects of an electric shock can cause heart failure days after the initial shock.

Do not use 240 or 415 volt power tools and appliances in wet conditions.

Check the operation of the earth leakage protection system or RCD regularly.

Have repairs carried out by a qualified electrical tradesperson.

Use battery powered hand tools in preference to 240-volt power tools.

Clothing

Wear rubber soled shoes when using portable equipment.

Wear dry clothing that covers at least the trunk of the body.

Care for your hoist motors

If an electric motor on a self-tipping hoist is stopped when it is bringing mullock to the surface, it can be forced to spin at high speed in reverse. In the process, the motor can disintegrate, as well as destroying the bucket and hoist ladders.

Some work practices to avoid

- Do not allow the generator to run out of fuel.
- Do not use a generator that is too small for the job.
- Do not keep increasing the load on a generator until it is too small for the job (i.e. putting a new larger bucket on the hoist, without determining whether the hoist motor and generator are adequate or by adding extra jackhammers, lights or fans).
- Disconnecting the power.
- If a generator is too small, then one solution is to get another generator with adequate output. Alternatively, a petrol motor could be fitted to the hoist and used to drive (i.e. 6 to 1 reduction, 7hp Honda) freeing the generator for powering the other equipment. The use of petrol instead of diesel introduces a lot of hazards. Fire, fumes and refuelling hot engines can be very dangerous. The preference is to use adequately rated diesel-driven equipment.

REMEMBER

- RCDs fitted to electrical circuits will decrease the risk of electrocution.
- The earth wire in cables is essential for ensuring that an RCD can operate safely.
- RCDs do not work if a neutral connected to earth is not made.
- Use protected lights to minimise the risk of exposure to live connections.
- Use cables of adequate capacity for the current involved, to eliminate damaging voltage drop and the risk of fire.
- Always use a qualified electrical tradesperson to repair and periodically test electrical equipmennt.

Maintenance, inspection and testing

Electrical equipment (240-volt and above) used at an opal or gemstone mine must be visually inspected, physically checked and tested at regular intervals, as well as after being repaired, to ensure that the equipment is safe to use. The mine operator with the advice of a qualified electrical tradesperson should decide the frequency of the inspections, checks and tests depending on the type of equipment, the working environment and the frequency of use. Reference to manufacturers' manuals is essential.

Testing of RCDs must be carried out on a regular basis. This includes both push button testing by the user, and inspection testing for operation by a qualified electrical tradesperson.

Unless operated from time to time, an RCD may mechanically freeze and not trip when required.

Push-button testing by the user only confirms satisfactory mechanical performance of the tripping mechanism of the RCD. It does not replace inspection testing for operation by a qualified electrical tradesperson using an instrument that measures tripping current and tripping time.

Guidelines for inspection and testing of electrical equipment and RCDs are provided in Australian Standard AS 3760 In-Service Safety Inspection and Testing of Electrical Equipment. It is recommended that a qualified person be consulted. A thorough knowledge of the entire standard and of the intended environment is needed before a person can competently recommend test intervals.

The testing of RCDs and electrical equipment plugged into a socket outlet is mandatory under the Work Health and Safety Regulation.

Welding electrical safety

A 415-volt or 240-volt welder is a transformer. The welding handpiece, the electrode, the work clamp and the return conductor are on the secondary side of the transformer. Safe welders have an extra low output voltage of less than 50 volts. RCDs do not provide electric shock protection from the output circuit of welding equipment. Both welding terminals should be insulated from the frame of the welder. Always firmly attach the return conductor directly to the work being welded, otherwise the large current may travel through electrical wiring and cause damage.

The primary winding of the power source supplying the welding plant will require RCD protection if the welding plant is portable equipment and intended to be moved while in use.

Portable RCD protection should also be provided to any portable or hand-held electrical equipment which is supplied with electricity from an auxiliary power outlet on welding equipment, unless the power outlet has in-built RCD protection.

Welding safety starts with regular inspection and maintenance of the equipment. To prevent electric shock, discard broken hand pieces and replace damaged leads. Secondly, do not weld in wet areas. A large proportion of electric shocks have occurred due to the presence of moisture. This includes people who are wearing wet clothing due to rain, humidity and sweat.

All parts of welding circuits, including output leads and work return paths, should be considered electrically alive. Consequently, people welding should ensure that no part of their body is placed in such a position so as to create a conductive path or part of a conductive path for the passage of electric current

It is recommended that a safety assessment be carried out before welding. Some points to consider are:

- DC welding sets in preference to AC welding sets.
- Hazard Reduction Devices must be used.
- Avoid wet conditions.
- Minimise perspiration and change clothes and gloves if they are damp.
- Use mats to insulate the welder from the work.
- Appoint an observer in case of an emergency.

The operation of electric arc welding and allied process equipment has caused fatalities. Fortunately, the majority of electric shocks are not fatal. However, any electric shock from a source above 90 volts DC or 50 volts AC; or if wet, 25 volts AC or DC, has the potential to cause a fatal injury. There are a number of electrical hazards that may cause electric shock and fire. These hazards should be recognised by welders, to ensure safe operation.

Electric shock procedure

This section details the action to be followed when a person receives any electric shock from an electricity source above extra low voltage (50 volts AC or 120VDC). This is the minimum level of treatment for any person who has been in contact with a 'live' electric current. This includes anyone who has received an electric shock regardless of how minor the contact may appear. All events must be reported to the mine operator who must then contact the Regulator.

People must be aware that delayed effects can occur, in some cases several hours, days or months after a severe electric shock.

What to do

If the person is unconscious or disabled, approach with caution. Switch off power to prevent other people from also receiving an electric shock. If capable, the person should make the area safe and the person or witness must immediately report the occurrence to the mine operator. The operator should arrange for a first aider or other person to remain with the injured person who may be suffering the effects of shock and may collapse.

The mine operator or another person should phone the medical facility to advise that a person has sustained an electric shock and will be arriving for medical treatment. The facility should be informed of the person's name and their state of consciousness, burns or other injury.

The injured person must not be left alone or allowed to drive themselves to the medical facility. Heart problems can occur for up to several hours following an electric shock. The first aider/carer will accompany the person to the medical facility and wait until they have completed the tests.

Upon arriving at a medical facility, a medical check and ECG tests will be performed. If considered necessary, the doctor may require the person to stay for a few hours or overnight for observation. The carer should clarify whether the hospital or the carer will advise the injured person's family and the mine operator of the situation.

Following the medical examination and tests, if the person is not required to remain at the medical facility, they should be taken home or back to work by the carer.

Upon arrival back at work, notify the mine operator of the outcome, and the operator is to provide an update to the Regulator.

Personal safety equipment and welfare

Personal protective equipment will protect workers from some hazards. Protection from a problem is not as good as getting rid of the problem, but it is better than nothing. Fitting a dust extraction system is preferable to wearing a dust mask. Personal protective clothing and equipment (PPE) is often treated as the only control measure needed to prevent occupational injury and disease. However, there are far more effective ways to manage hazards in a mine.

Using PPE limits a hazard, but does not eliminate or fully control it. The first preference for managing a hazard is to eliminate it. If this is not possible, then a range of other options can be considered through to PPE, which is the least effective.

The mine operator is required by the WHS Regulation to supply PPE when people work at the mine, to minimise risk. In situations where PPE is the only way to manage a risk from a hazard, workers using it must understand its proper use. A miner must make it their business to read and understand the instructions supplied with the equipment. If they cannot understand them, or none were provided, they should seek assistance from the supplier and/or manufacturer.

Where people are visiting a mine, they need to be made aware of the mine site's safety rules. It is the responsibility of the mine operator to supply any PPE required and instruct visitors in its appropriate use. The visitors must understand when the equipment is to be worn and the level of protection that it provides.

At all opal and gemstone mines, no matter how big or small, certain items of PPE are essential. Professional, as well as amateur miners, benefit from the protection provided by PPE.

All mine operators have a duty of care to remove hazards from their mines. Where hazards cannot be removed, the risk must be managed. The least effective method of controlling hazards is using PPE because the hazard remains.

Hazards encounter every day that can be managed with PPE include:

- Being hit on the head by falling rock.
- Excessive noise from blowers, jackhammers, hydraulic diggers.
- Objects striking sensitive body parts such as eyes.
- Dust from operating mining machinery.

Personal protective equipment

The owner of a mine is required to provide personal protection to all workers where there is no practical means of removing a hazard associated with any activity on a mine. Other control measures should also be in place to reduce risks.

Personal safety equipment is designed to be worn by a person to protect parts of the body from injury such as burns, blindness, loss of hearing and other impairments. This equipment must be manufactured to a standard, to ensure it is robust and capable of providing the required protection within specified limits from hazards associated with any mining or industrial activity. To ensure quality, it is recommended that personal safety equipment is purchased from reputable manufacturers and complies with Australian Standards. The item will be marked with an AS number for Australian Standards.

Good quality safety equipment can be expensive. Careful selection will ensure the appropriate equipment is purchased and, if maintained as recommended by the manufacturer, will give reliable service. The following procedure may assist in selecting safety equipment for a particular activity:

- Identify the hazard and identify what is needed to manage the risk.
- Implement procedures to remove the hazard where practical, to eliminate the risk.
- Obtain appropriate safety equipment for personal protection from the risk.
- Ensure safe work procedures (SWP) are decided on when doing an activity involving that risk.
- Document the SWP and ensure every person at the mine knows and understands the SWP. The PPE should be included in the SWP.

Head protection

Every person working in a mine should wear a safety helmet of a type complying with the Australian Standards, to reduce the risk of injury from striking objects or falling material.

Safety helmets should not fall off when a miner is bent over.

The safety helmet harness inside the safety helmet should be maintained in good order to absorb shock and every safety helmet should be replaced if damaged or affected by heat. Otherwise, it may not protect the person. Be aware that safety helmets should be regularly replaced in any circumstances. Use the issue date label inside the helmet and abide by manufacturer's recommendations.

Eye protection

Appropriate eye protection should be worn when grinding materials, using arc welding and oxy gas equipment, handling chemicals, striking rock or other materials with a hammer.

Eye protection should also be worn when barring down or using hand held rock excavating equipment. Keep eye protection clean and replace broken or cracked lenses.

Hand protection

Where there is risk of injury to hands from abrasion, hot materials, corroded metals, splinters from wire ropes and timber, suitable gloves should be worn to protect the skin. Gloves are available in rubber, cotton, heavy leather and heat resistant materials.

If it is necessary to handle liquids or chemicals, wear gauntlets suitable for the substances being handled. Be sure that gauntlets cannot become entangled in moving machinery.

Standard gloves will not protect the hand from impact injuries. When working near moving machinery, gloves may be a hazard.

Respiratory protection

Air for breathing should be free of contaminants. However, in surface and underground mines, air contains dust particles, gases, fumes, and vapours due to excavating activities, handling of fuels, paints and arc welding. Such contaminants should be exhausted or diluted by fresh air, to comply with recommended health limits. Where the concentration of airborne contaminants becomes a problem because of inadequate ventilation, work should stop until the problem is rectified.

Ensure that workers are properly instructed in the wearing and maintaining of respirators and filters. These should be changed on a regular basis. For hygiene purposes, using disposable respirators or individual units for each person is recommended.

Respirators should be used as short-term protection, with the idea of improving the ventilation.

Protective clothing

When working with or around moving machinery, wear close-fitting and close-fastened garments and ensure personal ornaments cannot readily be caught up by or become entangled in such machinery.

When handling explosives, it is recommended to wear cotton clothing to avoid the build-up of static electricity.

It is a requirement that all people working at a mine should wear safety footwear which will protect the foot from being crushed by machinery, sharp rocks, penetration from spikes, chemical spills, hot slag and falling objects, such as rocks. Footwear which gives ankle support is generally required by miners and operators working on broken ground.

Consideration should also be given to provision for shin guards and ankle protection, as well as reinforced toe caps for underground safety boots.

The type of footwear must be appropriate to the task.

Protection of long hair

Where a person has long hair or hair styled in such a manner that it may be caught in moving machinery, ensure that a close fitting hair net is worn when using or working on or near machinery.

Controlling heat exposure

When working in hot environments or in direct sunlight, reasonable measures should be taken to prevent heat stroke or heat strain caused by the loss of body fluid.

Body protection from direct sunlight includes wearing long sleeved shirts, long pants, sun screen and a wide brim hat. Regular rest periods and the consumption of cool water is recommended. Take a break where the temperature is excessive.

Protection from vibration

The exposure of people to continuous vibration, either for the whole body or at the hands and fingers, should be avoided.

When driving vehicles, proper seating, designed to absorb shock and dampen vibration, should be used by operators to reduce the exposure to high vibration levels.

Hand held excavating equipment should be fitted with vibration reduction handles. Vibration reducing gloves should also be worn to prevent injury to hands and fingers.

Mine lighting

All lighting and associated apparatus, provided at a mine for producing artificial lighting, must be securely installed, adequately protected against contact by people and mechanical damage, and be properly maintained.

If fixed mine lighting is not installed, the operator should possess a cap lamp or torch, with sufficient power to illuminate the immediate work area for a given period of time.

Protection from noise

Hearing protection, such as ear muffs and ear plugs, may be used to reduce noise exposure to an acceptable level. The current limit for noise exposure is 85 dB(A) for an 8 hour shift.

Hygiene

Always ensure that an adequate supply of cool potable water for drinking washing purposes.

Water should not be allowed to stagnate in work places, nor should waste/wash water or sewerage be dumped into old mine workings.

First aid facilities

A first aid kit is required in all work places. For a work place with less than 10 people, an approved industrial class C first aid kit is required. The first aid kit supplier should be able to provide this type of kit.

NOTES

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