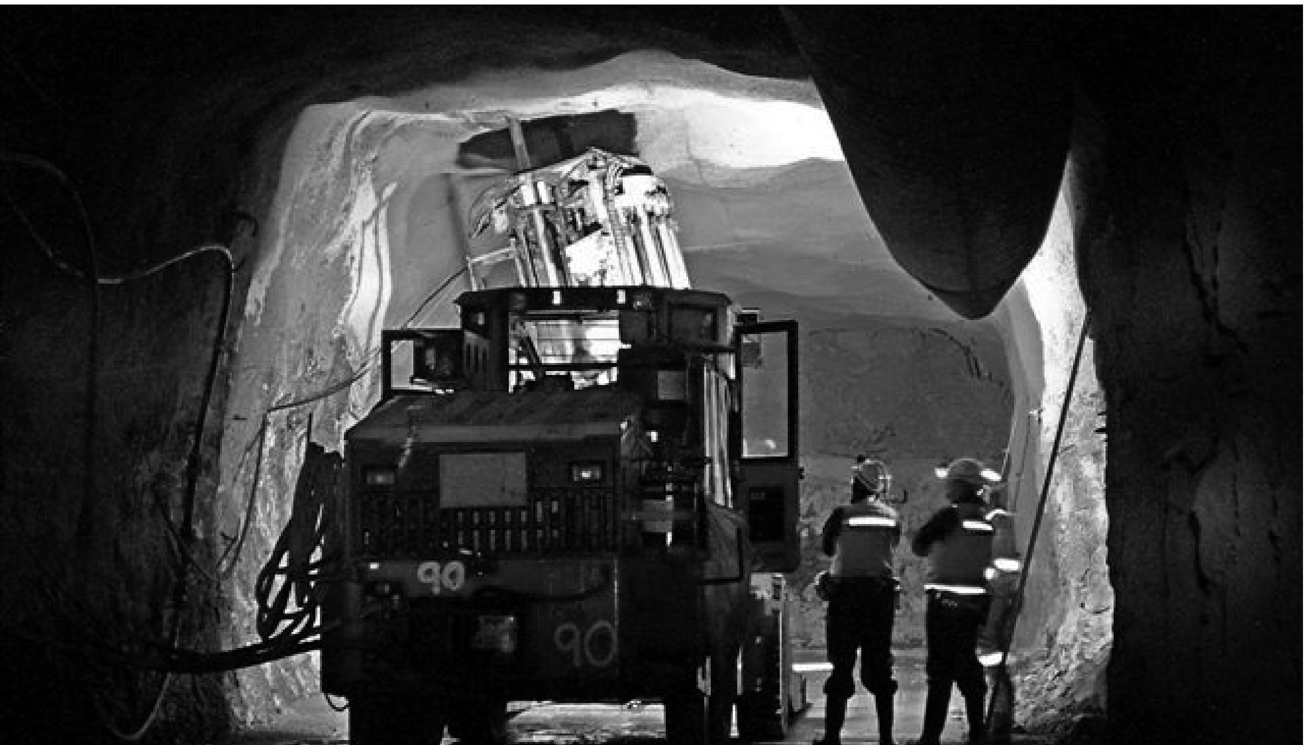
DRAFT

Code of Practice

VENTILATION OF UNDERGROUND MINES



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FOREWORD

This Code of Practice (this Code) on ventilation of underground mines is an approved code of practice under section 274 of the *Work Health and Safety Act* (the WHS Act).

An approved code of practice is a practical guide to achieving the standards of health, safety and welfare required under the WHS Act and the Work Health and Safety Regulations (the WHS Regulations).

A code of practice applies to anyone who has a duty of care in the circumstances described in the code. In most cases, following an approved code of practice would achieve compliance with the health and safety duties in the WHS Act, in relation to the subject matter of the code. Like regulations, codes of practice deal with particular issues and do not cover all hazards or risks which may arise. The health and safety duties require duty holders to consider all risks associated with work, not only those for which regulations and codes of practice exist.

Codes of practice are admissible in court proceedings under the WHS Act and Regulations. Courts may regard a code of practice as evidence of what is known about a hazard, risk or control and may rely on the code in determining what is reasonably practicable in the circumstances to which the code relates.

Compliance with the WHS Act and Regulations may be achieved by following another method, such as a technical or an industry standard, if it provides an equivalent or higher standard of work health and safety than the code.

An inspector may refer to an approved code of practice when issuing an improvement or prohibition notice.

This Code has been developed by Safe Work Australia in conjunction with the National Mine Safety Framework Steering Group as a model code of practice under the Council of Australian Governments' *Inter-Governmental Agreement for Regulatory and Operational Reform in Occupational Health and Safety* for adoption by the Commonwealth, state and territory governments.

A draft of this Code was released for public consultation on 29 July 2011 and was endorsed by the Select Council on Workplace Relations on [*to be completed*].

SCOPE AND APPLICATION

This Code provides practical guidance for persons who have duties under the *Work Health and Safety Act* and Regulations on to provide adequate ventilation for the health, safety and welfare of workers while they are at work.

Given that the nature of work and the mines in which that work is carried out vary significantly, this Code provides advice on determining what is reasonably practicable in relation to providing adequate ventilation in particular circumstances.

What mines are covered?
This Code applies to all underground mines covered by the WHS Act and will apply to all operating metalliferous and coal mines. Operating includes activities during the life of the mine, such as exploration; construction; operation; decommissioning and final mine closure.

Surface mines, quarries and exploration sites are not within the scope of this code. This code does not cover the treatment or prevention of dust, spontaneous combustion or fires, although the effects on ventilation are included.

Who should use this Code?

You should use this Code if you are a person operating or working in an underground mine.

If you have management or control of a mine this Code will help you assess whether the existing ventilation provided for the welfare of workers is adequate and effective.

If you are planning a new mine, you should use this Code to determine what standard of ventilation needs to be provided. The extent of expertise required will depend on the nature and complexity of the ventilation system. Expert advice could be provided by ventilation engineers, hygienists, or related professionals.

This Code can also be used by managers, workers and health and safety representatives who need to know about the standard of ventilation.

How to use this Code

In providing guidance, the word ‘should’ is used in this Code to indicate a recommended course of action, while ‘may’ is used to indicate an optional course of action.

This Code also includes various references to provisions of the WHS Act and Regulations to provide context with legal requirements. These references are not exhaustive.

The words ‘must’, ‘requires’ or ‘mandatory’ indicate that these legal requirements exist, which must be complied with.

1 INTRODUCTION

1.1. What is ventilation?

Ventilation refers to the movement of air around the mine to provide suitable quality and quantity of air to maintain a safe and healthy environment in which workers may work.

A mine ventilation system includes fans, airways, control devices to direct or restrict air flow, cooling and filtering air and systems for monitoring air quality and quantity.

1.2. Duties

This Code will help the mine operator identify and assess the requirements of workers in respect of ventilation and to decide what is reasonably practicable in particular situations.

> The WHS Act requires a person conducting a business or undertaking to ensure, so far as is reasonably practicable, that workers and other persons are not put at risk from work carried out as part of the business or undertaking.
>
> This duty includes ensuring, so far as is reasonably practicable, the provision of adequate ventilation facilities for the welfare of workers who carry out work for the business or undertaking.

Managing risks

> Regulation 9.2.18 of the WHS Regulations requires the mine operator of an underground mine to ensure that a ventilation control plan is prepared to provide for the management of all aspects of ventilation at the mine.
>
> Regulation 9.2.20 requires the mine operator to implement measures that effectively reduce, dilute or extract the concentration of any airborne contaminants or asphyxiant or explosive gases to meet air quality and safety standards as set out in the WHS Regulations.

To effectively control the risks at a mine, requires the mine operator to follow a *risk management process*. This Code provides practical guidance on how a Ventilation Control Plan can assist in managing and controlling the risks associated with ventilation.

The hazards which are controlled by ventilation include:

- oxygen content
- toxic and asphyxiant gases
- flammable gases
- airborne dust
- fumes
- products of combustion
- humidity
- temperature, and
- naturally occurring radioactive materials (NORMs).

These hazards may occur naturally or as a result of mining operations.

The Ventilation Control Plan minimises the risk of these hazards by providing for the systems, processes and procedures to establish and maintain a safe level of air in an underground mine. It sets out requirements for

- roles, responsibilities and competencies
- design and planning
- inspection, measuring and monitoring
- fans
- ventilation control devices
- auditing and review, and
- reference to standards.

General guidance on the risk management process is available in the *Code of Practice: How to Manage Work Health and Safety Risks.*

Air monitoring

Regulation 9.2.26 of the WHS Regulations requires the mine operator to ensure that air monitoring is conducted at the mine in accordance with any risk assessment.

If a mine operator uses air monitoring devices, the devices must:

- be suitable and have regard to the nature of the monitoring being conducted and the gas or airborne contaminant being monitored, and
- be positioned to ensure they will work to best effect.

The must keep records of the air monitoring for at least 7 years and make it accessible to workers and other person and for inspection under the WHS Act. The records must include:

- the results of the monitoring
- details of the location and frequency of the monitoring and
- the sampling method used.

Consultation

Throughout the development and implementation of a Ventilation Control Plan, the mine operator must consult with their workers and other persons at the mine including other persons conducting a business or undertaking at the workplace. Further guidance on consultation, cooperation and coordination can be found in the *Code of Practice: Work Health and Safety Consultation, Co-operation and Co-ordination.*

2 QUALITY OF AIR AND SAFETY

Regulation 9.2.22 of the WHS Regulations requires that a mine operator of an underground mine must ensure that the ventilation system of the mine provides air that is of sufficient volume, velocity and quality to ensure, so far as is reasonably practicable, the health and safety of workers and other persons in the mine having regard to all relevant factors including:

- concentration of oxygen, carbon dioxide, airborne contaminants and flammable or explosive gases, and
- likely changes to these concentrations at different stages of mining operations in the mine.

The ventilation system for the mine is designed, implemented and monitored to ensure the atmosphere in each part of the mine that is a workplace has a general body concentration:

- for oxygen – at least 19.5 per cent under normal atmospheric pressure, and
- [to be determined for other gases and airborne contaminants.

2.1 Safe oxygen level

The mine ventilation system must provide air at sufficient volume and velocity to all places where people travel or work to maintain a safe level of Oxygen, between 19.5% and 23.5% by volume.

The Ventilation Control Plan provides for the management and control of hazards which can deplete the oxygen levels in underground mines, such as:

- Displacement by naturally occurring gases such as Methane or Carbon Dioxide
- Oxidation of reactive sulphide ores, coal, timber and iron
- Internal combustion process of diesel engines
- Fumes from blasting
- Products of combustion (fires)

Generally, there is no warning via the senses of insufficient oxygen levels.

The risk of low oxygen levels in a mine is controlled by

- Identification of likely causes of depletion
- Adequate ventilation flow to areas where people travel or work
  - Minimum velocity for roadways – 0.3 m/sec
  - 0.06 m^3/sec per kW of maximum output capability of the engine or a minimum quantity of 3.5 m^3/sec
- Design and documentation of ventilation flowpaths
- Prevention of unplanned recirculation
- Inspections and monitoring
- Restriction of access to
  - unventilated areas
  - chutes, bins and sumps
  - areas around seals which have intentionally been inertised (coal mines)
- Reporting of ventilation system defects
- Procedures for

- re-entry after blasting
- restricting access to sumps, bins or chutes
- starting and stopping fans
- restoration of ventilation after a disruption
- restoration of ventilation to unventilated areas
- action to be taken when ventilation fails

2.2 Gaseous contaminants

Gases in mines may be naturally occurring, the products of combustion or fumes from vehicle exhaust emissions or activities such as blasting.

The gases may be toxic, asphyxiant or flammable. They include methane and other hydrocarbons, carbon dioxide, carbon monoxide, oxides of nitrogen, sulphur dioxide, hydrogen sulphide hydrogen, ammonia and radon.

As well as creating hazards through toxicity, asphyxiation or flammability the gases displace oxygen.

The Ventilation Control Plan should provide for:

- an assessment to determine the likelihood of a gas occurring at a mine.
- a sampling program, and
- detectors and personal monitors.

If a gas may occur, there is a need for:

- Inspections of workplaces where gas may be encountered;
- Monitoring at points such as on the return side of activities where the gas may be produced, released or accumulate
- Self rescue equipment to allow escape, and
- Oxygen therapy equipment to deal with exposures.

Trigger levels should be set at which:

- people must be withdrawn in the case of toxic or asphyxiant gases or oxygen depletion, and
- energy sources such as electricity, internal combustion engines and explosives are removed when explosive gases are found.

The *Exposure Standards for Atmospheric Contaminants in the Occupational Environment* set out:

- **Time-Weighted Average (TWA)**' - meaning the average airborne concentration of a particular substance when calculated over a normal eight-hour working day, for a five-day working week.
- **Short Term Exposure Limits** (STEL) - meaning a 15 minute TWA exposure which should not be exceeded at any time during a working day even if the eight-hour TWA average is within the TWA exposure standard. Exposures at the STEL should not be longer than 15 minutes and should not be repeated more than four times per day. There should be at least 60 minutes between successive exposures at the STEL.

Carbon Dioxide (CO_2)

Carbon Dioxide is a colourless and odourless gas, with a soda water taste. It is denser than air – Specific Gravity 1.53. It accumulates towards the floor and in low lying areas. A person standing in an accumulation of CO_2 will feel a warm sensation on their legs. The CO_2 content of air is nominally 0.03%.

CO_2 is an asphyxiant, as it displaces the oxygen in the air. CO_2 occurs naturally in many coal seams. It is released as the coal is mined. It may release under pressure as an outburst.
Increased levels of CO_2 can occur from:

- seam gas
- mine fires
- blasting operations
- diesel emissions
- oxidation of coal and timber
- action of acid waters on carbonate rocks, and
- planned inertisation (coal mines).

The risk of CO_2 in a mine is controlled by

- identification of likely sources
- drainage of the area before mining
- adequate ventilation flow to areas where people travel or work
    - minimum velocity for roadways – 0.3 m/sec, and
    - 0.06 m^3/sec per kW of maximum output capability of the engine or a minimum quantity of 3.5 m^3/sec
- design and documentation of ventilation flowpaths
- prevention of unplanned recirculation
- inspections and monitoring
- restriction of access to
    - unventilated areas, particularly low lying areas
    - chutes, bins and sumps, and
    - areas around seals which have intentionally been inertised (coal mines)
- reporting of ventilation system defects, and
- procedures for
    - re-entry after blasting
    - restricting access to sumps, bins or chutes
    - starting and stopping fans
    - restoration of ventilation after a disruption
    - restoration of ventilation to unventilated areas, and
    - action to be taken when ventilation fails.

CO_2 can be detected by readily available portable gas detectors or chemical detector tubes.

The exposure standards for CO_2 in general workplaces are:

- TWA: 5,000 ppm; STEL 30,000 ppm.

The exposure standards for CO_2 in coal mines are:

- TWA: 12,500 ppm; STEL 30,000 ppm.

Further information about these values is in the exposure standards and should be consulted when setting trigger levels.

Carbon Monoxide (CO)

Carbon Monoxide is colourless, odourless and tasteless. It has approximately the same density as air – Specific Gravity 0.97. It is toxic at low concentrations and accumulates in the blood stream. It is explosive in air between the range of 12.5% and 74%.

Increased levels of CO can occur from

- diesel emissions
- blasting operations
- spontaneous combustion (coal mines)
- incomplete combustion of carbonaceous materials, and
- fires.

The risk of Carbon Monoxide in a mine is controlled by

- identification of likely sources
- adequate ventilation flow to areas where people travel or work
  - Minimum velocity for roadways – 0.3 m/sec
  - 0.06 m^3/sec per kW of maximum output capability of the engine or a minimum quantity of 3.5 m^3/sec
- design and documentation of ventilation flowpaths
- reduced ventilation flow to areas where spontaneous combustion is likely (coal mines)
- Prevention of unplanned recirculation
- inspections and monitoring
- restriction of access to
  - areas around seals which have intentionally been inertised (coal mines)
- reporting of ventilation system defects
- procedures for
  - re-entry after blasting
  - starting and stopping fans
  - restoration of ventilation after a disruption
  - restoration of ventilation to unventilated areas, and
  - action to be taken when ventilation fails.

CO can be detected by readily available portable gas detectors or chemical detector tubes.

The exposure standards for CO in general workplaces are:

- TWA: 30 ppm.

Further information about these values is in the exposure standards and should be consulted when setting trigger levels.

Methane (CH_4)

If there is a risk arising from the presence of methane, Regulation 9.2.23 requires the mine operator to ensure the concentration of methane in intake air does not exceed 0.25%.

The mine operator must ensure that arrangements are in place:

- that trip the supply of electricity to a production area in which the concentration of methane exceeds 1.25%.
- to ensure that person in a work area are evacuated if the concentration of methane in the return air for the work area exceeds 2.0%.

The mine operator must monitor the level of methane at the mine by installing air monitoring devices that produce a visible or audio warning if:

- the concentration of methane in intake air is 0.25% or more
- the concentration of methane in a production area is 1.25% or more, or
- the concentration of methane in return air is 2.0% or more.

Regulation 9.2.24 requires the mine operator to notify affected workers or other persons at the mine if the results of air monitoring indicate these levels exist.

Methane is colourless, odourless, and tasteless. It is lighter than air – Specific Gravity 0.55. It will migrate towards the roof and may accumulate in cavities or form layers. It is explosive in air in the range 5% to 15%. It is also an asphyxiant as it displaces oxygen.

Methane occurs naturally and is present in most coal seams. It is released as the coal is mined and also when coal is heated. It may release under pressure as an outburst.

The risk of methane in a mine is controlled by

- Identification of likely sources
- Separating the mine into explosion risk zones
- Drainage of the area before mining
- Removal of energy sources such as electricity, internal combustion engines and blasting
- Adequate ventilation flow to areas where people travel or work
  - Minimum velocity for roadways – 0.3 m/sec
- Design and documentation of ventilation flowpaths
- Prevention of unplanned recirculation
- Inspections and monitoring
- Restriction of access to areas around seals which have intentionally been inertised (coal mines)
- Reporting of ventilation system defects
- Procedures for
  - starting and stopping fans
  - restoration of ventilation after a disruption
  - restoration of ventilation to unventilated areas
  - action to be taken when ventilation fails
  - assessing the location of explosive risk zones

CH_4 can be detected by readily available portable gas detectors.

Methane is described in the exposure standard as an asphyxiant. Further information about these values is in the exposure standards and should be consulted when setting trigger levels.

Hydrogen Sulphide (H_2S)

Hydrogen Sulphide is colourless and tasteless and has a powerful odour of rotten eggs at low concentrations. It will disable the sense of smell after continued exposure and at high concentrations. It is a toxic gas, irritates the lungs and respiratory tract. It has a narcotic effect on the nervous system. Symptoms may be delayed. Bronchitis and conjunctivitis may occur after exposure.

It is heavier than air – Specific Gravity 1.19. It is explosive in air in the range 4.5% to 45%.

Hydrogen Sulphide occurs naturally in coal seams with high sulphur content. It also accumulates around stagnant water. It may be released as the coal is mined and also when coal is heated and by the action of acid waters on easily decomposed sulphide ores. It may be present in explosive fumes.

The risk of Hydrogen Sulphide in a mine is controlled by

- Identification of likely sources
- Adequate ventilation flow to areas where people travel or work
    - Minimum velocity for roadways – 0.3 m/sec
- Design and documentation of ventilation flowpaths, avoiding stagnant water
- Prevention of unplanned recirculation
- Inspections and monitoring
- Reporting of ventilation system defects
- Procedures for
    - starting and stopping fans
    - restoration of ventilation after a disruption
    - restoration of ventilation to unventilated areas
    - action to be taken when ventilation fails.

H_2S can be detected by readily available portable gas detectors.

The exposure standards for H_2S in general workplaces are:

- TWA: 10 ppm; STEL 15 ppm.

Further information about these values is in the exposure standards and should be consulted when setting trigger levels.

Nitrous Fumes (NOx)

Nitrous fumes refer to the Oxides of Nitrogen which are found in diesel exhaust and explosive fumes. It is made up of Nitric Oxide (NO), Nitrogen Dioxide (NO_2) and Nitrogen Peroxide N_2O_4. Nitrous Oxide (N_2O) is not included in this group. It is an analgesic gas, which when mixed with Oxygen is used for pain control. It is called Entonox.

Nitric Oxide (NO) is oxidised to NO_2 in the presence of Air, and makes up the majority of Nitrous fumes found in mines.

NO_2 is reddish brown in colour, has an acid taste and acrid smell. The Specific Gravity of NO_2 is 1.6, but this can be affected by the presence of other gases in the mix.

It is a toxic gas. It may cause coughing, can seriously affect the respiratory passages and may cause acute bronchitis and pneumonia. The onset of symptoms may be delayed and a person exposed to these fumes should be referred for medical observation overnight.

Increased levels of Nitrous fumes can occur when explosives are not completely detonated.

The risk of exposure to Nitrous fumes in a mine is controlled by

- Identification of likely sources
- Selection of blasting product
- Restriction of access
    - Through exclusion zones around blasting locations
    - By delaying re-entry until the fumes have dispersed
- Actively dispersing fumes by forced ventilation
- Adequate ventilation flow to areas where people travel or work
    - Minimum velocity for roadways – 0.3 m/sec
    - 0.06 m^3/sec per kW of maximum output capability of the engine or a minimum quantity of 3.5 m^3/sec
- Selection of diesel fuel
- Inspections and measurement of diesel emissions
- Maintenance of diesel equipment
- Limits on the number and total power of diesel engines in a ventilation circuit
- Design and documentation of ventilation flowpaths
- Prevention of unplanned recirculation
- Monitoring
- Reporting of ventilation system defects
- Procedures for:
    - blasting
    - re-entry after blasting
    - starting and stopping fans
    - restoration of ventilation after a disruption
    - action to be taken when ventilation fails.

NOx can be detected by readily available portable gas detectors or chemical detector tubes.

The exposure standards for NO_2 in general workplaces are:

- TWA: 3 ppm; STEL 5 ppm.

Further information about these values is in the exposure standards and should be consulted when setting trigger levels.

Hydrogen (H_2)

Hydrogen is colourless, odourless and tasteless. It is very light – Specific Gravity 0.08. It is flammable. It is explosive in air between the range of 4% and 74%.

Very low levels of Hydrogen may occur naturally as a coal seam gas.

Increased levels of Hydrogen can occur from

- Distillation of coal
- Spontaneous combustion (coal mines)
- Battery charging

The risk of exposure to Hydrogen in a mine is controlled by

- Identification of likely sources
- Design and documentation of ventilation flowpaths
- Sealing goaf areas (coal mines)
- Sampling
- Venting of battery compartments on battery powered traction equipment
- Ventilation of battery charging stations
- Control of electrical energy in the vicinity of battery charging operations

H_2 can be analysed on a gas chromatograph.

An increase in the presence of Hydrogen is an indicator of spontaneous combustion in coal.

H_2 is described in the exposure standard as an asphyxiant. Further information about these values is in the exposure standards and should be consulted when setting trigger levels

Ammonia (NH_3)

Ammonia is a colourless, strongly alkaline gas with a characteristic pungent odour. As the concentration increases the odour becomes more irritating. It can be extremely irritating in minute concentrations and highly toxic at moderate concentrations, possibly leading to pulmonary edema.

It is lighter than air – Specific Gravity 0.59.

NH_3 is toxic. The most likely source of ammonia in underground mines is from Ammonium Nitrate (ANFO) explosive reacting with cement in the presence of water. This can become a problem if ANFO is spilled during charging operations, and cement is present. It is also present in significant quantities in refrigeration plants, such as those used for cooling air.

The risk of Ammonia in a mine is controlled by

- Identification of likely sources
- Adequate ventilation flow to areas where people travel or work
- Minimum velocity for roadways – 0.3 m/sec
- Inspections and monitoring
- Restriction of access
- Through exclusion zones around blasting locations
- By delaying re-entry until the fumes have dispersed
- Actively dispersing fumes by forced ventilation
- Procedures for
- Handling and storing explosives
- Re-entry after blasting
- Applying shotcrete

- Handling cement

NH_3 can be detected by portable gas detectors or chemical detector tubes.

The exposure standards for NH_3 in general workplaces are:
- TWA: 25 ppm; STEL 35 ppm.

Further information about these values is in the exposure standards and should be consulted when setting trigger levels.

Radon (Rn)

Radon is a colourless, odourless and tasteless gas. It is produced during the decay of Uranium. It is a health hazard due to its radioactivity.

On entering the mine atmosphere, Radon continues to decay to form airborne Radon progeny, positively charged, atomic sized particles, which tend to attach to respirable dust and other free surfaces in the mine atmosphere.

Sources of radon are:
- Wall rock
- Broken ore
- Material handling
- Tailings back fill
- Ground water

The risk of Radon in a mine is controlled by
- Identification of likely sources
- Adequate ventilation flow to areas where Radon is produced

Limit Radon residency time to a maximum of 15 minutes
- Removing broken ore
- Sealing old workings and other sources of Radon
- Controlling water in the mine
- Inspections and monitoring

Rn can be detected by radiation gas monitors.

2.3 Non-gaseous contaminants

Airborne dust

Regulation 9.2.21 requires the mine operator to eliminate the exposure of any person at the mine to any airborne contaminant including respirable dust and inhalable dust, so far as is reasonably practicable. If this cannot occur, the risk must be minimised so far as is reasonably practicable.

No person at the mine must be exposed to:
- a harmful level of any airborne contaminant and
- time-weighted average atmospheric concentrations of airborne dust that exceed 3.0mg per cubic metres of air for respirable dust or 10.0mg per cubic metre of air for inhalable dust.

Personal protective equipment (PPE) should not be used to control this risk, however, if it is the only means of ensuring the risk is eliminated or minimised, any person who may be exposed must:

- be given suitable PPE
- instructed in the use of the PPE, and
- use the PPE where there is any possibility of exposure.

The risks associated with airborne dust that are controlled by ventilation are

- The effect on workers' health
- Reduced visibility

Possible explosions of coal and sulphide dusts are dealt with in another Code of Practice.

There are two dust fractions that can be inhaled through the nose and mouth:

- Inspirable dust, which does not enter the lungs
- Respirable dust, which can reach the deepest part of the lung (alveoli) where lung damage can occur.

The major hazardous dusts are those containing

- Crystalline silica, which can cause silicosis
- Coal, which can cause pneumoconiosis
- Lead Dust which may be inhaled, but also may be ingested, which is a toxin
- Naturally Occurring Asbestos, which can cause Mesothelioma

The main sources of dust are:

- Cutting
- Drilling
- Blasting
- Transport
- Crushing

The risk of exposure to airborne dust in a mine is controlled by

- Identification of likely sources
- Reduction at the source
    - Sharp cutting picks and drill bits
    - Dust extraction and containment and redirection into return airways
    - Scrubber fans
    - Stopes, draw points exhaust to return
    - Wetting of dust as it is generated
- Adequate ventilation flow through areas where dust is generated
    - Minimum velocity for roadways – 0.3 m/sec
    - Very high velocities can raise dust into an airway
- Design and documentation of ventilation flowpaths
- Working on the intake side of dust generating activity
    - Remote operation of equipment
- Homotropal ventilation of conveyor roadways
- Prevention of unplanned recirculation
- Inspections and monitoring
- Reporting of ventilation system defects

- Personal Protective Equipment
- Air conditioned operator cabs
- Procedures for
    - re-entry after blasting
    - starting and stopping fans
    - restoration of ventilation after a disruption
    - roadway maintenance, including watering
    - action to be taken when ventilation fails.

Airborne dust can be measured through static and personal samplers.

Diesel Particulate Matter (DPM)
The exhaust from diesel engines includes Carbon Monoxide and Nitrous fumes, which are dealt with above and Diesel Particulate Matter.

Diesel particulate matter is the term applied to the particulate component of diesel exhaust, which contains soot and aerosols. The particles may not be visible or otherwise detected by the senses.

It may be carcinogenic, and can cause heart and lung damage. Long term exposure may lead to cardiovascular disease, cardiopulmonary disease and lung cancer.

The level of DPM can be affected by
- The quality of the diesel fuel
- The type of engine
- The engine and fuel system tuning and maintenance
- Fuel pump settings
- The workload demand on the engine
- Engine temperature

The risk of DPM in a mine is controlled by
- Identification of likely sources
- Adequate ventilation flow to areas where diesel engines operate
    - 0.06 m^3/sec per kW of maximum output capability of each engine or a minimum quantity of 3.5 m^3/sec
- Design and documentation of ventilation flowpaths
- Maintenance and testing of diesel engines
- Inspections and monitoring
- A system to record the number and location of diesel vehicles
- Reporting of ventilation system defects
- Procedures for
    - testing vehicle emissions
    - limiting access of diesel vehicles
    - action to be taken when ventilation fails.

DPM can be measured using laboratory analysis equipment

2.4 Temperature, humidity and velocity

Regulation 9.2.19 of the WHS Regulations requires the mine operator of an underground mine to ensure that:

- the atmosphere in the mine is subject to controls that prevent heat stress, and
- the moisture content of the atmosphere in the mine is maintained at a safe level.

Ventilation reduces the hazards of thermal stress which is affected by air temperature humidity and velocity. Inadequate ventilation may lead to heat illness.
Factors that may affect the underground environment include

- temperature and humidity (moisture content) of the intake ventilating air from surface
- temperature rise due to auto compression in adiabatic conditions (approx. 1°C and 0.4°C per 100m of depth increase for dry bulb and wet bulb temperatures respectively)
- temperature rise of in situ rock due to depth
- heat exchange with strata and groundwater
- heat exchange with casual water, sumps drains etc
- radiant heat emitted from equipment & machinery
- radiant heat from waste areas (seals, open goaf), and
- radiant heat from oxidation of coal or ore.

Personal factors that may increase the risk of thermal stress include

- dehydration
- lack of acclimatisation
- poor physical fitness
- overweight or obesity
- fatigue
- sleep deprivation
- skin disease
- illness and medical conditions
- metabolic work rate
- clothing

The risk of exposure to heat in a mine is controlled by

- Identification of likely sources
- Adequate ventilation flow through areas where heat is generated
  - Minimum velocity for roadways – 0.3 m/sec
- Design and documentation of ventilation flowpaths
- Homotropal ventilation of conveyor roadways
- Prevention of unplanned recirculation
- Inspections and monitoring
- Reporting of ventilation system defects
- Personal Protective Equipment that is suitable for hot environments
- Air conditioned operator cabs
- Air cooling plants
- Procedures for
  - working in hot and humid conditions
  - trigger levels for reduction of shift or withdrawal, and
  - action to be taken when ventilation fails.

Where there is a risk that wet bulb temperatures may exceed 27 degrees Celsius, a Working in Heat Management Plan must be established.

Where there is a risk that wet bulb temperature may exceed 27 degrees Celsius, a working in heat management plan must be established. Where the wet bulb temperature exceeds 34 degrees Celsius work must be stopped, other than work to reduce the temperature.

Thermal stress can be affected by

- air temperature (wet and dry bulb)
- radiant heat exchange
- humidity
- air movement
- the level of physical work
- the amount and type of clothing being worn.

2.4 Spontaneous Combustion

Spontaneous combustion occurs when the amount of heat generated by an exothermic reaction, such as oxidation, exceeds the heat removed by air movement. The most common mining occurrences of spontaneous combustion are in coal. It may also occur in reactive sulphide ores or explosives. This topic deals with spontaneous combustion in coal. The principles may apply in varying degrees to other minerals where spontaneous combustion occurs.

Oxygen in air oxidises coal. This generates heat which promotes further oxidation. Spontaneous combustion in a mine occurs when the amount of heat generated by oxidation exceeds the cooling effect of the ventilation circuit.

Normally a fire requires oxygen, heat and fuel. This is known as the fire triangle. Sometimes it is described as the fire tetrahedron, adding chemical reaction as a fourth requirement. Any fire requires all four ingredients and a fire can be extinguished by removing one of the sides of the tetrahedron. Exclude oxygen, and the fire is extinguished. Remove the fuel and the fire is extinguished.

The heat source in a spontaneous combustion reaction is generated by the exothermic (heat generating) chemical reaction when coal is oxidised. Almost any coal can be made to combust spontaneously in a laboratory. One measure of likelihood of a coal to spontaneously combust is known as the R70 value.

The effect of spontaneous combustion in underground coal mines includes

- Accumulations of coal catching fire
- Coal pillars catching fire
- Coal left in a goaf catching fire
- The coal fire causing a gas explosion.

Spontaneous combustion of coal occurs when ventilation pressure draws air through broken coal. This can happen when

- Ventilation pressure is applied across inadequate pillars
- Air leaks through broken ground around ventilation control devices such as overcasts, regulators and stoppings
- Stowed coal oxidises
- Coal is left in goaf areas.

The risk of spontaneous combustion in a mine is controlled by

- Identification of likely sources
- Sealing worked out areas of the mine
- Design and documentation of ventilation flowpaths
    - Reducing the number of stoppings and overcasts through adjacent intakes and returns
- Locating regulators to reduce ventilating pressure
- Increasing the number of headings to reduce resistance
- Increasing leakage resistance for seals
- Reducing the amount of coal left in the goaf
    - Adopting longwall mining systems
    - Mining the full seam height
- Inspections and monitoring
- Reporting of ventilation system defects
- Sealing of worked out areas
- Inertisation of worked out areas

Active spontaneous combustion can be dealt with by:

- Sealing the affected areas
- Inertisation
- Loading out affected coal
- Fire fighting techniques

Spontaneous combustion can be detected by:

- An increase in CO Make
- A change in the $CO/O_{2\ def}$ ratio
- An increase in CO, Hydrogen or Ethane
- The presence of Ethylene

3 VENTILATION CONTROL PLAN

Regulation 9.2.18 requires the mine operator to ensure a ventilation control plan is prepared. It must describe all control measure implemented in relation to ventilation at the mine, including by cross referencing relevant sections of the WHS management system for the mine. Regulation 9.2.28 requires the mine operator to ensure the following: • ventilation circuits at the mine do not allow uncontrolled airflows to recirculate • plant and structures that regulate airflow are maintained in good working order • dead-end openings are not worked unless adequate auxiliary ventilation is provided, and • no work area at the mine is ventilated with contaminated air. The air supplied to the ventilation system must be obtained from the purest source available.

The Ventilation Control Plan provides for the systems, processes and procedures to establish and maintain a safe level of air in an underground mine. The plan sets out

- roles, responsibilities and competencies
- design and planning
- inspection, measuring and monitoring
- ventilation control devices
- auditing and review, and
- reference to standards.

The Ventilation Control Plan is established using risk management principles. It must be developed in conjunction with other management plans that rely on ventilation as a control, for example, the Gas Management Plan, the Spontaneous Combustion Management Plan and the Working in Heat Management Plan.

3.1 Roles, responsibilities and competencies

Depending on the nature and complexity of the operation, the Ventilation Control Plan should specify one or more competent persons to have the responsibility to

- ensure adequate ventilation of the mine
- ensure the quality of the mine air is measured and recorded
- ensure that any defects are investigated and rectified
- manage any change to the ventilation system
- ensure all ventilation control devices at the mine are properly constructed and maintained
- maintain a record of the current status of the mine ventilation system, and
- audit the operation and effectiveness of the ventilation system at intervals not exceeding two years.

3.2 Design and Planning

The mine's ventilation system must be designed so that it is possible to maintain healthy and safe atmosphere at all times. Ventilation will provide adequate quantities of fresh air to the miners and render harmless toxic, asphyxiant and flammable gases and dusts and carry them out of the mine through dilution by fresh air.

The design should take into account the physical parameters of the airways, the layout of the mine, and the hazards that are likely to be encountered.

The mine ventilation is planned using risk management principles.
Depending on the nature and complexity of the operation, a computer model may be required to design the ventilation system and assess potential changes.

Ventilation planning should include the possible effect on the ventilation system of

- Fires in the underground workings, including:
- the effect on ventilation pressure
- response from a fresh air side
- the need for separated escape ways
- The effect of seasonal changes on
- Temperature and humidity, and
- Barometric pressure.

3.3 Inspection, measuring, monitoring and reporting

Regulation 9.2.28 requires the mine operator to ensure the direction, course, volume and velocity of air current at the mine is regularly measured. There must be a record of the measurements and all other monitoring and testing ventilation at the mine.

The record must be kept for at least 7 years, be readily accessible to workers and other persons at the mine and be available for inspection under the WHS Act.

A system of inspections and monitoring should be established to determine that the air quality and quantity is adequate

- before work commences
- at suitable intervals while work is in progress
- after activities such as blasting
- after a disruption to the ventilation system
- after a change that may have affected the ventilation system, such as
  - discontinuing use of a part of the mine
  - re-entering disused workings
  - when a new process or substance is introduced
  - stope extraction and filling

The system will include arrangements for measuring

- Air quality, including
  - gases
  - contaminants
  - temperature and humidity
- Air quantity at critical points
- Vehicle emissions

Monitoring arrangements may include

- Continuous monitoring at critical locations
- Periodic sampling
- Personal exposure levels

Records, including data and plans, shall be kept of

- Ventilation circuits and fans
- Sealed, disused and unventilated areas of the mine
- Location of ventilation control devices
- Inspection, monitoring and testing results

Records must be controlled, secure and readily available.

3.4 Fans

The ventilating air current is drawn around a mine through pressure created by a fan. Fans include:

- Main fans, which are located on the surface, create the ventilating pressure that generates the ventilation circuit around the mine.
- Booster fans, which are located underground and reduce the pressure that must be generated by the main fans
- Auxiliary fans which generate an air flow beyond the circuit created by the main and booster fans.
- Scrubber fans, which remove dust by passing air through a filter.

Fans must be designed, constructed and installed to

- Suit the duty, including the effect on other fan installations
- Minimise the risk of ignition of an explosive mixture of gases passing through the fan (coal mines)
- Prevent access during operation, and
- Prevent unauthorised starting and stopping.

Main fans should have arrangements to

- Monitor air quantity and pressure
- Monitor any gases that are likely to pass through the fan (coal mines)
- Prevent damage in the event of an explosion
- Have an auxiliary power supply in case of mains supply failure
- Cut the power supply to booster and auxiliary fans in the ventilation circuit supplied by the main fan
- Monitor vibration and bearing temperature, and
- Use non incendive materials, such as brass or copper, in the rotor of the housing (coal mines).

Booster fans should have arrangements to

- Monitor the operating status of the fan
- Monitor air quantity and pressure
- Prevent recirculation
- Monitor general body levels of methane around the fan motors (coal mines)
- Cut the power supply to auxiliary fans in the ventilation circuit supplied by the booster fan, and
- Allow for the fan to be bypassed in case of failure.

Auxiliary fans should have arrangements to

- Prevent recirculation
- Cut the power supply to electrical equipment operating in the ventilation circuit supplied by the fan (coal mines)
- Only be started after an inspection has been carried out in the affected roadways (coal mines), and

- Mix discharged coal dust with stonedust (coal mines).

Scrubber fans may have arrangements where the capacity of the fan is greater than the volume available in the workplace. This is planned recirculation, which removes dust through filtration.

3.5 Ventilation Control Devices (VCD)

Ventilation Control Devices are structures which control the direction and quantity of airflow around the mine. They include

- Ducts or line brattice to allow a single roadway to be divided so that fresh air can be brought to the face
- Stoppings to separate the intake and return air streams in adjacent airways
- Doors to allow people or vehicles to travel between an intake and return airway
- Seals (coal mines) or ventilation bulkheads (metal mines) to provide a long term substantial seal
- Coffin seals to allow a conveyor belt to pass from an intake to a return airway
- Overcasts to allow the crossing of intake and return air streams without mixing
- Regulators to regulate the flow of air through various airways when the quantity has to be split between the various airways

VCDs need to be constructed to a suitable standard which will vary according to

- The required duty
- The ventilation pressure
- The likelihood of an explosion
- Whether they are temporary, short term or nominally permanent

Specifications may stipulate requirements for

- Fire resistance
- Anti static properties
- Over pressure
- Leakage

Regulators should

- Include signs which state
  - that they must not be adjusted without authority, and
  - the area of the opening.

Doors should

- be positively secured in an open position when they are not normally closed
- doubled up to provide an airlock where
  - short circuiting may lead to a hazard
  - a high pressure exists across the doors and opening or closing may lead to a hazard.

3.6 Auditing and review

An audit of the effectiveness of the ventilation arrangements should be conducted at regular intervals, not exceeding two years. The audit should be carried out a suitably qualified person.

The Ventilation Control Plan should be reviewed

- After each audit, if any non conformances are identified
- Following an incident where ventilation has been identified as a contributing factor
- When the ventilation system has been found to be inadequate
- Following changes to the mine operating system which may affect the ventilation system.

3.7 Reference to standards

The Ventilation Control Plan shall include a reference to standards and management plans that were referred to or consulted during the development.

4 VENTILATION SYSTEM PLAN

Regulation 9.2.29 requires the mine operator of an underground mine to ensure that a plan of the ventilation system for the mine is prepared.

The ventilation plan must show:

- the direction, course and volume of air currents, and
- the position of all air doors, stoppings, fans regulators and other ventilating plant and structures at the mine,

A copy of the ventilation plan must be available for inspection under the WHS Act.

APPENDIX A – MEANING OF KEY TERMS

Airlock	An arrangement of doors between an intake and return airway that allows people or a vehicle to pass through without creating a short circuit.
Antitropal ventilation	The direction of travel of coal is opposite to the direction of air flow. (see Homotropal)
Blasting	Planned use of explosives
Brattice	A fire resistant, anti static fabric used in coal mines to make temporary ventilation controls
Bulkheads	In metal mines, bulkhead refers to substantial, permanent constructions erected for the purpose of controlling ventilation. In coal mines bulkhead refers to a seal constructed to withstand a head of water pressure as well as providing ventilation control.
Detector tubes	A tool for the rapid detection and measurement of contaminants in air. There are about 160 chemical detector tubes available for determining and measuring more than 350 different gases, vapours and aerosols with a hand held aspirator. The length of colour change is usually measured on a scale, indicating the amount of gas present.
CO make	A measure of the rate of production of Carbon Monoxide
$CO/O_{2\ def}$ ratio	Graham's ratio. A measure of the progress of spontaneous combustion
Coffin seal	A stopping constructed to allow a conveyor belt to pass from an intake to a return airway through a stopping. The name refers to the resemblance to a crematorium. It enable a change from antitropal to homotropal ventilation
Diesel emissions	The fumes and particles from a diesel engine exhaust
Displacement	The amount of Oxygen available in the air is reduced by the presence of other cases, most often Carbon Dioxide and Methane
Dry bulb temperature	The temperature registered on a normal thermometer. In conjunction with a wet bulb thermometer, humidity and effective working temperature. See definition of wet bulb temperature.
Entonox	A mixture of 50% Oxygen and 50% Nitrous Oxide used as an analgesic.
Explosive	In reference to a gas - a gas that undergoes a chemical change leading to a rapid increase in volume when ignited
Explosives	Chemical substances that undergo a rapid chemical change producing large volumes of gas when ignited
Explosion risk zone	An underground coal mine, or any part of it, where the general body concentration of methane is known to be, or is identified by a risk assessment as likely to be, greater than 0.5%.
Exposure standards	Refers to Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment [NOHSC:1003(1995)], and Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment NOHSC 3008(1995) 3rd

Edition

Available for download at http://hsis.ascc.gov.au

Flammable	A gas which burns, and explodes within a certain range.
Flanking returns	Return airways on each side of a set of main development headings so that gas emissions from in situ coal are carried out of the mine.
Gas drainage	Removal of gas from an area that has not yet been mined.
Gas management plan	A plan required under another code of practice.
Heat illness	A combination of symptoms associated with a person's prolonged exposure to heat and humidity. Heat illnesses include • Heatstroke • Heat exhaustion • Heat cramps • Heat rash
Heat stroke	A severe condition caused by impairment of the body's temperature-regulating abilities, resulting from prolonged exposure to excessive heat and characterized by cessation of sweating, severe headache, high fever, hot dry skin, and in serious cases collapse and coma.
Homotropal ventilation	The direction of travel of a conveyor belt is the same as the direction of air flow. The conveyor is in a return airway. This prevents dust and heat generated during conveying and transfer reaching the working faces.
Hot work	Refers to welding, soldering, heating, cutting, grinding or vulcanising in which the surface temperature of the work or a tool for the work is likely to exceed 150°C.
Inbye	Towards the working face (coal mines)
Inertised	The oxygen content of the atmosphere in a sealed area has been reduced either by introduction of nitrogen or carbon dioxide or by allowing displacement of oxygen through the natural accumulation of seam gases.
Line brattice	A fire resistant, anti static fabric used in coal mines to separate intake and return air in a single roadway
Non conformance	An auditing reference to a requirement of a standard not being met
Outburst	The sudden discharge of a large volume of gas and strata during mining operations
Outbye	In a direction away from the face workings
R70 test	The [R70] testing procedure essentially involves drying a 150 g sample of <212 mm crushed coal at 110°C under nitrogen for approximately 16 hours. Whilst still under nitrogen, the coal is cooled to 40°C before being transferred to an adiabatic oven.

	Once the coal temperature has equilibrated at 40°C under a nitrogen flow in the adiabatic oven, oxygen is passed through the sample at 50 ml/min. A data logger records the temperature rise due to the self-heating of the coal. The average rate that the coal temperature rises between 40°C and 70°C is the self-heating rate index (R70), which is in units of °C/h and is a good indicator of the intrinsic coal reactivity towards oxygen. From: R70 Relationships and Their Interpretation at a Mine Site, Beamish, B.B., Blazak, D.G. Hogarth L.C.S. and Jabouri, I – Underground Coal Operators Conference, University of Wollongong, 2005.
Recirculation	A condition where the capacity of a fan is greater than the amount of air that is available. This leads to contaminated air from the exhaust being introduced into the intake of the fan.
Regulators	A ventilation control device
Spontaneous combustion management plan	A plan required under another code of practice.
Thermal stress	The physical and psychological reactions of a worker to temperatures that fall outside the worker's normal comfort zone.
Velocity	The rate of change of position and direction of motion of air, usually expressed in metres per second (m/s).
Ventilation control plan	A management plan required under this code of practice.
Wet bulb temperature	The wet-bulb temperature is the temperature measurement of a mixture of air and water vapour. Wet bulb temperature is the lowest temperature that can be reached by the evaporation of water only. It is the temperature felt when wet skin is exposed to moving air. The difference between wet and dry bulb temperatures is used to calculate humidity. Effective working temperature is calculated using wet bulb and dry bulb temperatures and air velocity.
Working in heat management plan	A management plan required under another code of practice.

APPENDIX B – OTHER RELEVANT MATERIAL

- Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment [NOHSC:1003(1995)]
- Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment NOHSC 3008(1995) 3rd Edition
- Code of Practice: Work Health and Safety Management Systems