UNDERGROUND VENTILATION (METALLIFERROUS MINES)

GUIDELINE

Department of Industry and Resources

MOSHAB Approved

December 1997

Document No: ZED569LF

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FOREWORD

This Department of Industry and Resources (DoIR) guideline is issued to assist in the understanding of underground ventilation in metalliferrous mines, and to provide guidance, at the practical level, on essential design aspects and operating practice.

It is not a comprehensive technical document and does not deal in detail with ventilation practice for specific tasks or operating procedures.

The procedures outlined in the body of this guideline are not regulations, and compliance with them is not mandatory. However, adherence to the procedures indicated should ensure a high level of worker health protection. Procedures different from those set out in the guideline may also be acceptable.

Comments on, and suggestions for, improvements to the guideline are encouraged. The guideline will be revised as appropriate, to accommodate comments and to take account of new information on improvements in technology and operational experience.

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1.0 INTRODUCTION

Ventilation in an underground mine is of critical importance to the occupational health and safety of underground employees.

The atmosphere underground is limited and confined, and is thus readily reduced to a sub-standard (or even dangerous) condition if contaminants produced in the course of operations are not controlled, or safely extracted or diluted to harmless levels.

The contaminants may include dust, aerosols, diesel fumes and particulates and fumes from blasting, as well as gases released from the rock strata. Reduction of oxygen may result from oxidation of reactive sulphides under some circumstances.

Oxygen reduction may also take place due to recirculation of ventilating air where diesel engines are operating, and in unventilated areas where "standing" water is present.

It is essential to maintain levels of temperature, humidity and air velocity in the workplace such that employees do not suffer detriment to health from exposure to extremes of heat, humidity or cold.

Of equal importance to the maintenance of a healthy working environment underground is the need to protect employees against the risk and the consequences of underground fires and unplanned explosions, including sulphide dust ignitions.

Correct design, implementation and maintenance of mine ventilation is therefore of fundamental importance.

In present day mining, ventilation systems designed and operated to maintain efficient operations will normally enable a high standard of occupational health and safety to be achieved.

2.0 LEGISLATIVE REQUIREMENTS (WA)

The Mines Safety and Inspection Regulations 1995 has many requirements that apply to issues referenced in this guideline. Listed below are the regulation numbers and the short reference labels, the full text should be read in order to fully comprehend the scope of the legislation.

Regulation	**7.29**	**Workplace atmospheric contaminant monitoring to be provided**
	9.4	**Qualifications of ventilation officer**
	9.5	**Duties of ventilation officer - underground**
	9.7	**Ventilation log book**
	9.8	**Ventilation system defects to be rectified**
	9.11	**Exposure standards**
	9.12	**Control of atmospheric contaminants**
	9.14	**Air in underground workplaces**
	9.15	**Air temperature**
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	9.21	**Control of air distribution underground**
	9.22	**Fumes from blasting**
	9.26	**Tailings filled stopes - atmospheric contaminants**
	9.27	**Ventilation system may be cut off in disused areas**
	9.28	**Ventilation plans for underground mines**
	9.29	**Monitoring of toxic, asphyxiant and explosive gases**

3.0 DESIGN CONSIDERATIONS

3.1 Primary Ventilation

The basis of effective ventilation of underground mines is the adequacy of the primary ventilation system, that is the total volume flow through the mine which is conducted through the major underground workings, normally involving splits into parallel circuits.

Factors which determine total primary volume capacity (and pressure) requirements for a mine include the extent and depth of the mine, the complexity, and the stoping and extraction systems, together with the size of development openings and the equipment used.

One of the major constraints on primary ventilation volume which is sometimes not adequately provided for at the design stage, is intake air capacity.

Whereas high air velocities may be tolerable in return airways and exhaust rises and shafts, (where no personnel are exposed), there is a practical limit to tolerable air velocity in main intakes (shafts and declines) and main development openings where persons travel and work. Dust generation is one problem deriving from intake velocities in excess of 6m/sec.

Moreover, high velocities require high pressure gradients and very high power costs to maintain them.

A further major consideration with deep and extensive underground mines is the tendency to lean towards series ventilation circuits.

The main problem with series, or parallel-series circuits is progressive contamination of the air by recirculation from secondary ventilation system returns, and the increased fire risk, in that the fumes and smoke from any fire in the intake or any upstream section of the mine will be carried into working sections downstream.

In most cases, the system should be designed and scheduled to provide parallel paths from the primary fresh air intakes through operating areas to return airways connecting to exhaust rises and shafts.

In general terms the shorter and more direct the ventilation circuit through each working area, the better the system.

Maximum use of parallel paths will reduce the overall mine resistance for a given air flow, which in turn greatly reduces the power required and the operating cost. The essential proviso to this is that adequate volume flow through each working area is maintained to dilute dust and contaminants and ensure operator comfort.

Many mines rely on exhaust fans to provide the ventilation as it is relatively simple and easier to regulate than a combined pressure/exhaust system. However, the latter offers greater flexibility, at the expense of requiring more complex control systems.

The control of primary ventilation flows or circuits in a mine requires careful planning from the design stage and thereafter throughout the operating life of the mine. It is strongly recommended that as part of the initial design of any mine or a planned upgrade that computer simulation of the ventilation network be done to assist in:

- Fan selection based on fan curves.
- The effect of ventilation changes over the life of the mine. This should include start up and completion of mining and any interim times of significance, for example at time of maximum production.
- Selection of locations for doors, booster fans and regulators.
- Location of the second means of egress and its effect on ventilation eg. ladderways in shafts.

As the mine develops and new stoping areas are opened up, the total system alters continuously. In any given system, primary air flows can be controlled by regulating, (closure or restriction of some paths), or by boosting flow through designated circuits by the use of circuit fans, usually installed on the exhaust side.

Regulating flows is simpler to do and less costly, but increases the mine resistance and reduces total primary flow. Local circuit (booster) fans increase the total primary flow, and generally operate at high volume and low pressure, with a correspondingly lower power demand.

3.2 Primary Intake

It is axiomatic that close attention is paid to the location of intake airways to ensure that the potential for contamination of air drawn into the mine is minimised.

No activities generating dust and fumes should be allowed in the vicinity of the intake and all installations built of combustible materials or containing combustibles or inflammable materials must be located at a safe distance.

On the same principle, care must be taken that no unprotected fire hazards are created by installations in or near primary intake airways underground.

Workshops in intake areas should have sprinkler type fire protection.

An important aspect of primary ventilation is the need to minimise the presence of water in the intake airways, (shafts, adits, declines etc.), and in the main primary airways. This is particularly important in areas having high ambient surface temperatures, and even more so when combined with high humidity.

Where the intake air is relatively dry and of a moderate to high temperature, water pick up is rapid. The dry-bulb temperature decreases and the wet-bulb increases. Operator discomfort does not become a problem with increased humidity at moderate temperatures, provided that humidity does not become excessive.

To counter increasing temperature and humidity, it is necessary to increase air circulation, or introduce chilled service water.
Both of these measures are much more costly than maintaining an efficient drainage system.

Where extremes of temperature and humidity are experienced it may be necessary to introduce refrigerative cooling, on a "spot cooling" basis, or by large scale treatment of the primary air flow.

In general, moisture pick up in intake air should be limited by as many specific means as can be devised.

These include the use of water rings in shafts, covering drains, and piping drainage water to sumps.

Excess water running uncontrolled in trackless mines is very damaging to roadways and hence to mobile equipment.

Heat is added to intake air by conduction and radiation from the rock strata, by auto-compression in down cast shafts, and by diesel vehicle operation.

The potential for heat pick up by these means requires adequate assessment at the design stage, to ensure that the necessary volumes (and velocities) of ventilating air are maintained when the mine is fully operational.

3.3 Secondary Ventilation

Secondary ventilation refers to the provision of ventilation to development ends, stopes and services facilities which constitute secondary circuits tapped off the primary circuit or main through flow of air. These may be “dead end” in configuration, or be “parallel or “series in parallel” circuits. The use of secondary ventilation fans and ducting is normally required, most commonly in a "forced air" configuration, but pressure/exhaust overlap or total exhaust may also be used.

Total exhaust is used to extract contaminated air and conduct it directly to a return airway, and for long secondary circuits. Solid formed ducting is usually necessary for this purpose.

Effective secondary ventilation can be established only if the primary ventilation system itself is adequately designed and operated. The two systems are in fact an integrated whole. An unbalanced primary and secondary combination can cause re-circulation, which is inefficient and potentially hazardous.

Correct selection of fans for secondary ventilation on the basis of performance characteristics and ducting types used is critical to both the maintenance of health and safety and of efficiency of operation. The following should be considered:

- Proper selection of fan based on duct diameter, length and type and fan duty. Fan curves must be used to enable correct selection of the fan.
- Location of fan to prevent recirculation and damage from equipment.
- Availablity of sufficient power to start and run the fan.

Noise generation, this may require the use of attenuators or a slower speed fan.

Fume clearance capacity in the primary circuit is not normally a problem, but careful attention to secondary systems is essential, particularly on extended secondary circuits in development, and where secondary fans have to be turned off for blasting. This practice should be avoided if at all possible.

Air volumes which are adequate for operator health and comfort in the workplace may have to be further increased to reduce fume clearance time, or to remove heat from the workplace. Where development headings exceed 500 m in length, an exhaust overlap configuration may be required.

Attention to the correct design of fan/duct combinations is essential where large volumes are required over extended distances to cater for large scale diesel equipment.

It is cost effective to provide twin ducts and two fans in such situations, rather than to increase fan power to force larger volumes through a single duct at the much higher pressures required. The power cost can be reduced by 50% and the reduced pressure on the ducting greatly reduces leakage at joints and seams. The power cost saved rapidly offsets the cost of a second fan and the additional ducting, particularly when the system is to be split to service two or three workplaces.

The optimal layout of secondary ventilation systems to eliminate or minimise recirculation is of fundamental importance.

The application of properly engineered design to both primary and secondary systems will enable safe and healthy conditions to be maintained, and contamination reduced to levels which are as low as reasonably achievable. Commensurate operational efficiencies will be maintained.

3.4 General Planning and Operating Practice

In order to establish and maintain safe, healthy and efficient ventilation conditions in a mine, which is an integral component of effective production management, adequate plans and controls are essential.

Plans must be maintained for primary and secondary systems and all essential ventilation controls.

Regular monitoring and recording of the primary system performance is essential and regular checks should be made of the condition of the ambient air in workplaces.

Adequate plans and controls for underground ventilation are critical factors in the event of fire or gas emergency. These must be updated at regular intervals; (say every 2 weeks). The plans should be prepared as detailed in Australian Standard AS4368-1996 "Mine plans - Preparation and symbols".

The early establishment of through flow (primary) ventilation circuits as a mine is developed and deepened is essential.

4.0 SPECIFIC HAZARDS

A range of unusual hazards are evident from time to time in undergound mines, and awareness of some of the more serious risks that arise must be maintained and strategies put in place to eliminate or minimise those risks.

4.1 Gas Emissions

Although the release of hydrocarbon gases (such as methane) is not commonly experienced in metalliferrous mines, it can and does arise, and vigilance is essential to ensure early detection and control.

A range of gases may be emitted from the ground as a result of chemical reactions in the strata. This includes leaching by acid ground water of susceptible host rocks (such as carbonates) and their contained minerals, producing CO_2, SO_2, H_2S and other gases. These reactions are exothermic (heat producing) and may become self-sustaining, as the gases react with groundwater to produce more acid. Quite high ground temperatures may result from the exothermic reactions in large masses of material of this type.

When gas release from the strata is sustained at a substantial level, rather than minor and transient, effective control measures are required.

Measures may include:

- sealing of the strata

- closure and sealing of the problem area of the mine
- draining off the gases to exhaust
- pressurising the area to contain gases in the strata
- dilution of gases to harmless levels by increased ventilation volumes
- absorption by water percolation and spraying
- monitoring systems with appropriate alarm

It should be noted that under some circumstances, changes in barometric pressure will affect the release of gas from the strata.

In any mine where gas release from strata is likely to occur, vigilance must be exercised in monitoring, and all underground employees must be made fully aware of what to look for, the need to report, and what remedial strategies are available. Remedial strategies may include personal respiratory protection or self contained self rescuers where warranted, and training in the use of underground fire refuges, in the event of gas release. Gases may be toxic, asphyxiant or explosive, and some have both toxic and explosive properties, and the risks must be fully understood to be effectively managed.

Release of gases may be experienced from other sources, including generation from stagnant pools of water or from decaying organic material, including timber.

Spontaneous combustion from reactive sulphide ores or from accumulations of organic material and timber has resulted in fires under adverse circumstances. Extreme care must be exercised with spillages of ammonium nitrate explosive (ANFO) in the prilled form in particular. This material is a very powerful oxidising agent and may promote fire in contact with combustibles.

A hazard which is not uncommon arises when ammonium nitrate explosive is spilled from holes during charging on to floors of drives or stopes where cement is in use for grouting rock bolts or in strengthening stope filling.

In the presence of moisture the reaction of ammonium nitrate (ANFO) and cement produces ammonia which is extremely irritating in minute concentrations and highly toxic at moderate concentrations.

Vigilance must be exercised in preventing this interaction as far as practicable, and all persons must be advised of the hazard and instructed in prevention or remedial action.

4.2 Oxygen Depletion

Oxygen depletion in mines normally results from dilution (displacement) due to the presence of asphyxiant gases such as carbon dioxide (CO_2), or from actual depletion of oxygen in the atmosphere due to interaction with reactive sulphides, or from the internal combustion process of diesel engines.

Carbon dioxide is sometimes described as an inert gas, but it does have an adverse physiological reaction at even moderate concentrations which help persons trained to do so to detect its presence without instruments.

No warning is generally had of oxygen depletion, which may result not only from oxidation of reactive sulphides, but oxidation of timber or solution and entrainment in stagnant or flowing water.

The effect is most dangerous in a static, although not necessarily closed atmosphere. In sustained airflows of reasonable volume, oxygen depletion is much less likely to present a serious risk.

However, oxygen depletion has proved to be lethal in dead ends which are not sealed off, but where no convective overturn and circulation of air can take place.

4.3 Blasting Fumes

The release of fumes after blasting poses an obvious risk and by following correct operating procedures and relevant regulations, the risk is effectively managed.

It is, however, essential that all underground personnel are fully instructed in the nature of blasting fumes, methods of detection and correct procedures to avoid risks.

In particular the insidious danger of delayed adverse reaction from inhalation of oxides of nitrogen must be fully understood.

Clearance of fumes from rises, shafts and winzes requires particular attention.

4.4 Summary

The safety of persons employed underground depends in part on the provision of an adequate ventilation system. Hazards may be present during normal operations and can arise as a consequence of equipment malfunction or during an emergency situation.

It is essential that all persons who are employed underground are trained and experienced enough to satisfy themselves that there is an adequate supply of air. The training program should include information on hazards arising from the presence of flammable and toxic gases and fumes. Use of all appropriate safety equipment, as well as detailed information on emergency procedures, should also be included in the training program.

Basic information about the design and workings of the ventilation system should be provided to all persons employed underground. In particular the hazards associated with disused workings should be recognised. Restoration of the ventilation system is essential before any person commences work in, or passes through, the affected area.

Regular monitoring of air purity and air movement is essential. Monitoring programs should include regular measurement and recording of:

- air quality and where appropriate, temperature;
- volume distribution of air in the workings; and
- compliance with volume standards.

Personal respiratory protection, clothing and equipment should be readily available to all employees where it may be required and the employees should be trained in the care and use of equipment appropriate to the work being performed.

(The hazard potential in underground coal mining ventilation is much greater than that in metalliferrous mining and these aspects of coal mining therefore require to be considered specifically and in greater depth.)