Guideline for the management of diesel engine pollutants in underground environments

MDG 29

Produced by Mine Safety Operations Division, New South Wales Department of Primary Industries

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PRIMARY INDUSTRIES

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Foreword

The use of diesel engines in an underground environment is considered a hazardous activity potentially associated with short and long term adverse health effects.

All diesel engines need to be designed and item registered when used in underground parts of a coal operation.

This guideline, *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 in underground mines. It can be considered good industry practice for mitigating the risks associated with the pollutants emitted by the use of diesel engines in underground environments at this time.

This is a ‘Published Guideline’.

The principles stated in this document are intended as general guidance only assisting in the setting of safety standards. Owners, operators and managers should rely upon their own advice, skills and experience in applying safety standards to be observed in individual workplaces. Adherence to the guidelines does not itself assure compliance with the general duty of care.

This Guideline was distributed to industry for consultation and comment through the Coal Safety Advisory Committee, Metalliferous Safety Advisory Committee, Extractive Industries Safety Advisory Committee and on the Departments website.

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SECTION 1 PURPOSE AND SCOPE

1.1 TITLE

This is the guideline for *'The Management of Diesel Engine Pollutants in Underground Environments'*.

1.2 PURPOSE

The objective of the guideline is to minimise risks to health and safety of people from diesel engine pollutants when being used in an underground environment.

1.3 SCOPE

The guideline extends to all mines in New South Wales where diesel engines are being used in underground environments.

The guideline provides guidance material in managing health risks from diesel engine pollutants when diesel engines are operated in an underground environment.

Note:

1. The guideline is based on a management system approach for the control of diesel engine pollutants.
2. The guideline is intended to assist in the evaluation of risk and may not comprehensively cover all safety-related aspects of diesel engine pollutants that may give rise to other hazards.

This guideline covers the lifecycle of diesel engines and includes:

a) Systems for the management of pollutants generated from diesel engines.

b) The lifecycle of diesel engine pollutant including creation, monitoring, testing and analysis, auditing and review.

c) Actions to reduce risk to the health and safety of people in relation to pollutants from diesel engines.

d) Data retrieval for industry and safety requirements. Data required for health and safety management of diesel engine pollutants.

e) Protocols for the measurement and evaluation of particulates including raw exhaust and environmental particulates.

f) Protocols for the measurement and evaluation of gases including raw exhaust and environmental gases.

g) Protocols for the measurement and evaluation of noise.

h) Protocols for the type and accuracy of testing equipment.

i) Competencies of people associated with diesel pollutant testing and analysis.

1.4 APPLICATION

The guideline should be used throughout the lifecycle of diesel engine systems. It should be considered when;

a) type testing and evaluating a new diesel engine,

b) conducting routine testing and assessment of a new diesel engine,

c) conducting regular testing of in-service diesel engines in the underground environment,

d) conducting routine testing and assessment of old diesel engines, and

e) Discarding diesel engines.

1.5 ALTERNATIVES

Alternative methods of providing safety based on risk assessment may be used provided that the level of safety offered by alternatives is equal to or better than that provided by the methods given in this guideline.

1.6 REFERENCES

A partial list of references and associated documents is included in Appendix A for reference.

1.6.1 Abbreviations

AS	Australian Standard
AS/NZS	Australian / New Zealand Standard
ASCC	Australian Safety and Compensation Council
CO_2	Carbon Dioxide
CO	Carbon Monoxide
DP	Diesel Particulate
DTS	Diesel Test Station
EC	Elemental Carbon
EPA	Environment Protection Authority
HSMS	Health And Safety Management System
ISA	International Standard Atmosphere
JSA	Job Safety Analysis
LBP	Lower Back Pain
MSDS	Material Safety Data Sheet
MSTC	Mine Safety Technology Centre
nm	nanometres or (10^{-9} metres)
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
OC	Organic Carbon
ppm	Parts Per Million By Volume
PAHs	Polynuclear or Polycyclic Aromatic Hydrocarbons
SO_2	Sulphur Dioxide
STEL	Short Term Exposure Limit
STP	Standard Temperature and Pressure
SWP	Safe Work Practices
TC	Total Carbon
TWA	Time Weighted Average
WBV	Whole Body Vibration

1.7 DEFINITIONS

For the purpose of this document the definitions below apply:

1.7.1 'As New'

Means an engine which is brand new or an engine which has been reconditioned.

1.7.2 Competent Person

A person who has acquired through training, qualifications or experience, or a combination of them, the knowledge and skills to carry out that task.

1.7.3 Diesel Particulate (DP)

The particulate phase (diesel particulate matter) in the exhaust of a diesel engine usually consisting of:

- elemental carbon (EC),
- organic carbon (OC), and
- other trace materials including metals, sulphates, minerals, nitrates, etc.

Note: DP = OC + EC + other trace materials

1.7.4 Diesel Particulate Signature ($Q_{DP(min)}$)

The minimum ventilation quantity measured in cubic meters per second (m^3/s) to dilute diesel particulate exhaust emissions to meet a workplace particulate exposure of 0.1 mg/m^3 EC.

1.7.5 Department

Refers to the 'Department of Primary Industries'.

1.7.6 Diesel Pollutants

Substances or energy emitted from the diesel engine that can contaminate the environment including:

a) Gaseous emissions.
b) Diesel particulate matter (DPM).
c) Heat.
d) Noise.
e) Vibration.

1.7.7 Diesel Test Station (DTS)

A purpose built facility in which the ambient levels of gaseous emissions emanating from a diesel engine can be measured under controlled conditions which mirror or exceed operational use.

1.7.8 Direct sampling technique

A procedure whereby a sample of the exhaust stream is introduced directly to an analysis system without the intermediate step of collection into a vessel for subsequent analysis.

1.7.9 Elemental Carbon (EC)

Spherical particles (typically 15-30 nm in diameter) in the exhaust of a diesel engine which have been shown to have a graphitic structure.

1.7.10 Gaseous Emissions

Gaseous emissions include:

- Carbon Monoxide (CO).
- Carbon Dioxide (CO_2).
- Nitric Oxide (NO).
- Nitrogen Dioxide (NO_2).
- Sulphur Dioxide (SO_2).
- Methane (CH_4).

1.7.11 Heavy Duty Torque Converter

Means a torque converter that has the capability to withstand a torque stall test for at least 20 seconds without damage or excessive heating.

1.7.12 Licensed laboratory

Means a laboratory licensed by the Department of Primary Industries for sampling and analysis of diesel engine exhaust.

1.7.13 Load

The operation of a diesel engine to achieve maximum fuel input. This may be achieved using an engine or wheel dynamometer or:

*For **gaseous emissions testing -*** this is normally achieved by operating the diesel engine at full throttle and placing the engine under sufficient load to reduce the engine speed from its maximum by 200-300 rpm or other equipment manufacturers' recommendation.

Note:

1. The procedure should be documented for each diesel engine by the equipment manufacturer.
2. This is not the same as full throttle, no load or maximum engine speed.
3. The above rpm range may be altered to that specified by the equipment manufacturer, where documentary evidence is provided that maximum fuel input is achieved.
4. For all engines the equipment manufacturer must provide a method for loading the engine to maximum load so this test can be carried out. Alternatively testing as described in b) below may be carried out for gaseous emissions testing.

*For **particulate emissions testing*** **-** this is achieved:

a) Preferably by a single acceleration – load – deceleration sequence, as described in clause 6.3.2.1 *Standard Method*, or

b) For engines which cannot hold load for a 20 second period, by a series of quick accelerations – decelerations, as described in clause 6.3.2.2 *Alternative Method*.

1.7.14 Organic Carbon

Means all organic compounds including polynuclear or polycyclic aromatic hydrocarbons (PAHs) which can be absorbed by the elemental carbon in the exhaust of a diesel engine.

1.7.15 Raw Exhaust

For ***gaseous emissions testing*** - refers to diesel exhaust emissions (or fumes) that have not been affected by an exhaust conditioning system or catalytic converter and have not been diluted as part of a pollution control system.

For ***particulate emissions testing*** **-** refers to diesel exhaust emissions (or fumes) that have not been affected by a particulate filter or other particulate curtailment device and have not been diluted as part of a pollution control system.

Note: This may be downstream of a gaseous treatment device and/or a water type exhaust conditioner as these devices are not considered a particulate filter/curtailment device.

1.7.16 Shall

Indicates a statement is 'strongly recommended'.

1.7.17 Should

Indicates a statement is 'recommended'.

1.7.18 Total Carbon

Means the total summation of elemental and organic carbon, i.e. TC = EC + OC.

1.7.19 'Type' Testing

Mean testing a new type or model of diesel engine.

1.7.20 Undiluted Exhaust

Exhaust which may have been treated or filtered but has not been diluted by the atmosphere or by air introduced into the exhaust system.

1.7.21 Underground Environment

Includes;

a) Underground parts of the mine or mining operation, and

b) Areas on the surface of mines where the environment is enclosed and confined with minimum natural ventilation such as a reclaim tunnel or above ground workshops where DP may pose a risk.

SECTION 2 GENERAL HEALTH RISKS

2.1 GENERAL

2.1.1 The Underground Environment

Diesel engines emit pollutants into the environment. Underground environments are confined and have restricted ventilation and enclosed areas such that the pollutants cannot readily escape as the pollutants would if the diesel engine were operating in an open atmosphere.

Thus, health risks to people from excessive exposure to the diesel engine pollutants are increased when a diesel engine is operating in an underground environment. Additional controls should be implemented.

2.1.2 Constituents of Diesel Pollutants

Pollutants which emit into the underground environment from a diesel engine include:

a) Exhaust emissions – gaseous and particulate matter.

b) Heat.

c) Noise.

d) Vibration.

Note: Vibration and noise may be worse when the engine is installed in the machine. Further analysis should be undertaken. Refer MDG 1.

Excessive exposure to any of these pollutants may create a risk to the health and safety of people.

2.1.3 Composition of Diesel Exhaust Emissions

Diesel exhaust contains numerous gaseous and particulate substances some of which are known or suspected of giving rise to adverse health effects in humans.

The gaseous fraction contains the major gaseous components found in air (nitrogen, oxygen, argon, carbon dioxide and water vapour) and much smaller quantities of the pollutant gases carbon monoxide, nitrogen dioxide, nitric oxide, and sulphur dioxide.

The particulate fraction is a complex mixture of chemical compounds such as non-volatile carbon, condensed hydrocarbons, sulphates and trace levels of metallic compounds. The non-volatile central carbon core of diesel particulate is known as "Elemental Carbon" (EC) and it is this component that is generally linked to adverse health effects.

2.2 EXPOSURE TO GASEOUS EMISSIONS

2.2.1 General Health Effects

The adverse health effects of the gaseous pollutants generally found in the exhaust of diesel engines have been recognised for many years. Such knowledge has resulted in the implementation of appropriate control technologies which if applied adequately reduce workplace exposure levels below recognised exposure standards.

A full list of national exposure limits is available from the Australian Safety and Compensation Council (ASCC) via searching the exposure standard database at the following websites:

- www.ascc.gov.au/
- www.nohsc.gov.au/applications/hsis

2.2.2 Carbon Monoxide (CO)

Carbon monoxide is absorbed readily through the lungs and in the bloodstream it combines reversibly with haemoglobin to form carboxyhaemoglobin thus reducing the capacity of the blood to carry oxygen to critical organs. Depending on the level of exposure this can result in health effects ranging from slight headache to death as the level of carboxyhaemoglobin in the blood increases. Persons with heart disease are at greater risk due to reduced oxygen supply.

The current Australian Safety & Compensation Council (ASCC) 8-hour time weighted exposure standard for CO of 30 ppm is believed to be bioequivalent to 5% carboxyhaemoglobin (in the bloodstream) under normal temperatures, pressures and workloads. Compliance with such an exposure standard should minimise the risk to most persons.

2.2.3 Carbon Dioxide (CO_2)

Carbon dioxide when inhaled in elevated concentrations may act to produce mild narcotic effects, stimulation of the respiratory system and asphyxiation depending on the concentration present and the duration of exposure. Other effects known to occur in humans at high exposures of carbon dioxide include changes in sensory perceptions, disturbed judgement and mood changes.

The current ASCC 8-hour time weighted average exposure standard for coal mines is 12,500 ppm. It should be noted that this exposure standard is based on both health and practicability considerations and thus should be administered cautiously. For non coal mines an exposure standard of 5,000ppm has been adopted.

2.2.4 Nitric Oxide (NO)

The prevalence of adverse health effects reported in the scientific literature arising from exposure to nitric oxide alone is limited. There is some evidence to suggest that nitric oxide can react with haemoglobin in the blood to form nitrosylhaemoglobin, a compound that is incapable of oxygen transport. What is suspected is that humans exposed simultaneously to carbon monoxide and nitric oxide may experience a greater level of hypoxia than from carbon monoxide poisoning.

The current ASCC 8-hour time weighted average of 25 ppm NO has been established to limit potential potentiation effects from mixed NO and CO exposures.

2.2.5 Nitrogen Dioxide (NO_2)

Nitrogen dioxide is a severe respiratory irritant with excessive exposure having the potential for the development of adverse health effects such as emphysema and chronic bronchitis either immediately or after a delay of several days to a fortnight.

The literature also suggests that there have been many deaths from pulmonary oedema induced by the inhalation of high concentrations of NO_2.

The current ASCC 8-hour time weighted average of 3 ppm NO_2 is considered sufficiently low to reduce the potential for immediate injury or adverse physiologic effects from prolonged daily exposures.

2.2.6 Sulphur Dioxide (SO_2)

Exposure to elevated levels of sulphur dioxide causes irritation of the mucous membranes and bronchoconstriction with the inhalation of 5 ppm SO_2 or above.

The current ASCC 8-hour time weighted average exposure standard of 2 ppm SO_2 is considered appropriate to minimise respiratory irritation effects.

2.2.7 Aldehydes

Small amounts of aldehydes occur in diesel exhaust emissions and can give rise to bronchial constriction and lachrymation of the eyes. Recent research has indicated that the specific aldehyde “Acrolein” may be one of the contributing causes of eye irritation.

The current ASCC 8-hour time weighted average exposure for Acrolein of 0.1 ppm should minimise but not entirely prevent irritation effects.

2.2.8 Hydrocarbons

The presence of unburnt fuel and partial combustion products in diesel emissions gives rise to numerous aliphatic and aromatic hydrocarbons in the exhaust. As the level of hydrocarbons present is dependent on engine tune and the completeness of combustion it is not possible to state with certainty which hydrocarbons will be present.

It is known that some high molecular weight aromatic hydrocarbons (polynuclear or polycyclic aromatic hydrocarbons or PAHs) give rise to potentially serious adverse health effects however specific exposure standards for individual compounds have not been established. In this circumstance it is prudent to minimise employee exposures.

2.2.9 Summary of Workplace Exposure Limits

The maximum permissible workplace exposure limits for common diesel engine gaseous emissions are summarised in ***Table 1*** below.

Contaminant[1]	**TWA**		**STEL**	
	ppm	**(%)**	**ppm**	**(%)**
Carbon Monoxide (CO)	30	(0.003)	See note (2)	
Carbon Dioxide (CO_2) – for Coal Mines See note (3)	12,500	(1.25)	30,000	(3)
Carbon Dioxide (CO_2) – for Other Places	5,000	(0.5)	30,000	(3)
Nitric Oxide (NO)	25	(0.0025)	-	-
Nitrogen Dioxide (NO_2)	3	(0.0003)	5	(0.0005)
Sulphur Dioxide (SO_2)	2	(0.0002)	5	(0.0005)

Table 1 – Workplace exposure limits for common gaseous emissions

Notes:

1. For a full list of national exposure limits refer to the Australian Safety and Compensation Council (ASCC) hazardous substance information (HSIS) website at www.ascc.gov.au/ or www.nohsc.gov.au/applications/hsis and search the exposure standard database.
2. Refer to the HSIS website for guidance material in regards to short term carbon monoxide exposure.
3. The clause 21(b)(i) of the *Coal Mines Health and Safety Regulation 2006* imposes a 1.25% STEL limit for CO_2. This is less than the specified national exposure limit.

2.3 EXPOSURE TO DIESEL PARTICULATE

2.3.1 General Health Effects

The potential for adverse health effects in humans arising from excessive exposure to diesel particulate has been the subject of intense scientific debate for many years and due to areas of uncertainty may well be for many more. Notwithstanding this debate there is sufficient evidence to suggest diesel particulate is a potential carcinogen and thus various regulatory authorities around the world are moving to control employee exposure to this contaminant.

2.3.2 Malignant Health Effects

Between 1957 and 1999, 47 epidemiological studies have been reported in the literature where the prevalence of lung cancer in workers has been evaluated in respect to exposure to diesel particulate matter (MSHA 2001). Many of these studies have been discounted due to issues with study design but in 1995 the US based Health Effects Institute (an industry-government funded organisation) reviewed

30 such studies and concluded that the data was consistent in showing weak associations between exposure to diesel exhaust and lung cancer.

A statistical analysis of all epidemiological data reported in the literature was undertaken by two independent researchers in 1998 and 1999 with both groups reporting a causal association between increased risk of lung cancer and exposure to diesel exhaust.

MSHA (2001) in their review of the data suggested that at a mean concentration of 0.64 mg/m^3 DP (approximately 0.32mg/m^3 EC) for a period of 45 years occupational exposure would result in a doubling of the risk of cancer compared to that of unexposed miners.

In May 2002 the US Environmental Protection Agency (EPA) concluded that lung cancer was evident in occupationally exposed groups but was unable to determine a degree of potency.

At this point in time most overseas regulators are focusing on EC as the measure of workplace exposure to diesel particulate. Research is ongoing with respect to particle size and total surface area.

2.3.3 Non Malignant Health Effects

In recent years greater focus has been placed upon the non malignant health effects associated with exposure to diesel particulate. Perhaps the most definitive statement on this aspect was made in 2002 when the US EPA concluded that:

(i) Exposure to diesel emissions (including particulate) may give rise to eye, throat and bronchial irritation, light headedness, nausea, cough and phlegm.

(ii) Based on animal evidence the potential existed for chronic respiratory disease.

Other research has suggested that the irritant effect of exposure to diesel emissions which has traditionally been attributed to aldehydes in fact arises from the fine diesel particulate which impacts the mucus membranes causing a local irritant effect and at high concentrations a stinging sensation and lachrymation (AIOH 2004).

2.3.4 Summary of Health Effects

Based on the totality of the scientific literature most informed professionals would recognise that diesel particulate is a potential carcinogen.

As a well defined dose response relationship between exposure and health outcome currently does not exist there is little doubt that this area will be the subject of further research and debate.

Given the current state of knowledge there is sufficient evidence to indicate that an 8-hour time weighted average exposure standard of 0.1 mg/m^3 (measured as elemental carbon) should provide adequate protection against irritant effects and also minimise any risk of lung cancer.

2.3.5 Workplace Exposure

The recommended maximum workplace exposure (mine atmosphere) for diesel particulate in the elemental carbon (EC) fraction when expelled from a diesel engine is 0.1 mg/m^3.

Notes:

1. In the absence of a defined dose response relationship diesel particulate should be minimised to a level as low as reasonably practicable.
2. As measured in the sub-micrometre aerosol fraction using NIOSH Method 5040 (NIOSH 2003).
3. 0.1 mg/m^3 EC is approximately equal to 0.16 mg/m^3 Total Carbon (TC) or 0.2 mg/m^3 Diesel Particulate (DP).
4. Research in Australia (Rogers 1993) and the USA (Noll & Birch 2004, Birch & Noll 2004, Noll et al 2005) has demonstrated that there is minimal interference from coal dust or other carbonaceous material in the EC analysis using NIOSH Method 5040 (NIOSH 2003).

2.4 EXPOSURE TO NOISE

2.4.1 General Health Effects

Too much noise for too long can cause permanent hearing loss as well as health problems such as tinnitus (ringing in the ears).

Noise can also be a safety hazard, distracting people or hiding an alarm or warning signal. It can make communication difficult, interfere with concentration and cause fatigue and stress.

The risk of hearing loss depends on exposure. Exposure means *how loud* the sound is *and how long* a person is exposed to it. The risk continues to increase, the louder the sound and the longer the exposure.

The best way to find out whether a noise exposure is likely to be harmful is to have it assessed (the *National Code of Practice for Noise Management and Protection of Hearing at Work - 3rd Edition [NOHSC:2009(2004)]* describes a framework for managing exposure to noise at work and sets out procedures for noise assessments).

The best way of controlling exposure to noise is by reducing the *amount* of noise (making the source quieter, or stopping the noise from reaching people).

Another risk factor is the frequency of noise. People are particularly susceptible between 2,000-4,000 Hz.

2.4.2 Workplace Exposure Limits for Noise

The *National Standard for Occupational Noise [NOHSC:1007(2000)]* sets the maximum acceptable level of exposure to noise in the workplace, refer www.ascc.gov.au.

The maximum workplace exposure to noise being emitted from a diesel engine is:

a) An eight-hour equivalent continuous sound pressure level, $L_{Aeq,8h}$, of 85 dB(A), or

b) Peak levels of 140 dB(C) weighted.

Notes:

1. The measurement is to be made in accordance with AS/NZS 1269.1
2. Exposure is to be taken at the position of the ears of an operator or passenger.
3. The measurement is to be made on the assumption that the person is not wearing any device to protect from noise.

2.5 EXPOSURE TO VIBRATION

2.5.1 General Health Effects

The two main types of vibration exposure are hand-transmitted vibration and whole-body vibration (WBV). Much is known about the effects on humans of hand-arm vibration but there has been less research into the long-term effects of WBV.

2.5.2 Hand-arm vibration

Hand-arm vibration usually arises from the use of hand held motorised power tools commonly with a frequency between 25 and 150 Hz e.g. chain saws. The consequences for some people are disorders of the circulation of the fingers aggravated by cold (vibration white finger); tingling, numbness and/or reduced sensitivity and dexterity of the fingers; and muscle, joint and bone disorders. Once the conditions have become established they are not reversible so prevention through reduction of exposure duration and intensity is extremely important.

2.5.3 Whole-body vibration

Whole-body vibration (WBV) can be transmitted through the feet in standing work or more likely through the seat in seated work especially when operating machinery or driving vehicles.

The effects on humans of exposure to vibration generally at best may be discomfort and interference with activities and at worst may be injury or disease. These include:

a) Disorders of the joints and muscles and especially the spine (WBV).

b) Disorders of the circulation, bones and joints (hand-arm vibration).

c) Cardiovascular, respiratory, endocrine and metabolic changes (WBV).

d) Problems in the digestive system (WBV).

e) Reproductive damage in females (WBV).

f) Impairment of vision and/or balance (WBV).

g) Interference with activities.

h) Discomfort.

Lower back pain (LBP) is the most common complaint associated with WBV and there appears to be three different scenarios where symptoms of LBP may arise. The first is prolonged sitting; the second is where injuries result from a one-off severe jolt in an otherwise reasonable ride; and the third situation is where the onset of pain occurs after an extended period of moderate to severe jolts and jars [McPhee et al 2001].

2.6 EXPOSURE TO HEAT

2.6.1 General Health Effects

Heat (thermal) *stress* on the body is the combined effect of the external thermal environment and internal metabolic heat production by the individual. The body's response to the thermal stress by the cardiovascular, thermoregulatory, respiratory, renal and endocrine systems constitutes thermal *strain* [Di Corletto et al 2003].

There are large variations in individual responses to heat and these will vary with the type of work being performed and the acclimatisation of the individual. Mild heat strain resulting in discomfort and listlessness may subtly reduce an individual's work performance and their ability to concentrate. Moderate heat strain may manifest itself as cramps, prickly heat or fainting and will affect a worker's responses and their ability to perform work. Serious heat stress can lead to heat exhaustion or heat stroke and possibly death.

Physical work raises the body's temperature and the increased heat is transferred to the atmosphere. If conditions impede transfer of this heat the body's temperature will start to rise. Such conditions occur with higher air temperatures (>30^{o} C) especially in combination with higher humidity and little airflow. If the worker is wearing heavy protective clothing and there is radiant heat from the sun or other sources the heat load on the body can be even greater.

The body cools itself mainly through evaporation of sweat. However this fluid needs to be replaced by higher levels of water intake otherwise dehydration will occur. In high humidity the effectiveness of sweating is reduced. The body temperature may then start to rise and heat exhaustion and heat stroke can set in. Heat stroke can be fatal.

Heat disorders can occur for any of the following reasons:

a) Individual factors such as dehydration or lack of acclimatisation.

b) Inadequate appreciation of the dangers of heat by supervisors or individuals at risk.

c) Accidental or unforeseeable circumstances leading to very high heat stress conditions.

In neutral and cold climates the average resting body will lose about one litre of fluid per day while in warm environments about two litres. In very hot environments this can be as high as one litre per hour or more which may be greater than the body’s ability to absorb fluid [Di Corletto et al 2003].

2.6.2 Workplace Exposure Limits

There are six fundamental factors that define human thermal environments. The first four are air temperature; radiant temperature; humidity; and air movement and these basic environmental variables affect human response to heat. Human activity and clothing also change an individual’s response to thermal environments. All six need to be taken into account when designing work especially in extreme conditions. Temperature is important but should not be used as the sole indicator for action [McPhee 2005].

Other factors may also need to be taken into account e.g. behavioural factors that include:

a) *Clothing* - people may take off or put on clothes as their comfort dictates

b) *Work postures* - especially those dictated by restricted spaces

c) *Acclimatisation* - may influence the effects of heat and cold on individuals.

Any exact measure of heat and its effects on an employee must take into account air temperature, radiant temperature, air velocity, humidity and the intensity of the work being performed. While there is no entirely satisfactory single measure of heat and cold stress various predetermined limits are available for different ambient temperatures and working conditions. Essentially all exposure limits are sliding scales taking all these and other factors into account [Di Corletto et al 2003]. Acclimatization is the process of ensuring a worker’s body systems are compatible to the area and conditions that they are expected to work within.

2.7 ADJUSTING EXPOSURE STANDARDS FOR ALTERED WORK SHIFTS

The TWA exposure standards noted above are based on conventional work schedules (i.e. an 8-hour working day and five day working week).

Where extended shifts or non-standard rosters are worked these exposure standards should be adjusted in accordance with the following:

a) Pursue the “as low as reasonably practicable” (ALARP) principle below occupational exposure standards

b) No adjustments to PEAK or STEL exposure limits are required where extended shifts are used

c) TWA exposure adjustments should be based on *Table 2* below

d) Use the Brief and Scala models for substances with medium term effects or where there is uncertainty about the nature of the health effects

Notes:

1. This table is a partial extract on the model developed by the West Australian Department of Minerals and Energy in March 1999. Refer to their guideline ‘*Adjustment of exposure standards for extended work shifts*’.
2. This process has been in operation for an extended period and appears to offer a fair assessment of the process of exposure standard reduction for extended work periods.

Timeframe for Action	Health Effect	Typical Substances	Shift Roster	Exposure Reduction Factor
Medium – within shift or over a few shifts	Respiratory irritation, narcosis	Nitrogen dioxide Sulphur dioxide Hydrogen sulphide Carbon monoxide	≅ 10 hrs/day	0.7
			≅ 12 hrs/day	0.5
Long – over many shifts or years	Cumulative poisoning respiratory disease (silicosis, cancer)	Diesel fume	< 170 hrs/mth	1
			> 170 hrs/mth	170/*x*

Table 2 – Exposure reduction factors for extended shifts

where *x* = Average number of hours worked in the month. 170 is the typical hours worked in a month for a normal 8 hours/day, 5 day/week work cycle

For example;

If a mine were to operate a longwall change-out on a 12 hours shift basis then the carbon monoxide workplace exposure would be 30ppm * 0.5 (exposure reduction factor) = 15ppm.

Thus the maximum TWA exposure over the 12 hours shift would be 15ppm.

Note: While the above approach is appropriate for substances such as carbon monoxide and nitrogen dioxide there is little data at this point in time to apply a similar process to diesel particulate. Until such time as data linking health outcomes to workplace exposures over extended shifts becomes available, it is recommended that no alteration be made to the exposure standard for diesel particulate for extended working hours.

SECTION 3 MANAGEMENT OF DIESEL POLLUTANTS

3.1 OCCUPATIONAL HEALTH AND SAFETY

3.1.1 Legislative Framework

The Occupational Health and Safety legislative framework for mechanical engineering safety on mine sites is represented by the diagram in Appendix 9.2.

This diagram highlights the hierarchy of legislation and the legislative considerations when managing mechanical engineering safety on a mine.

3.1.2 OHS Act 2000 and OHS Regulation 2001

The OHS Act 2000 and the OHS Regulation 2001 requires:

⇒ Designers, manufacturers and suppliers of plant must ensure plant is safe and without risk to health or safety when properly used and must provide adequate information for its safe use.

This requires designers to identify any foreseeable hazards that have potential to harm health or safety, assess the risks and take action to eliminate or control the risks

⇒ Employers need to ensure the health and safety of their employees by addressing workplace health and safety through a process of risk management and consultation.

To effectively implement this guideline designers, manufacturers, suppliers of plant and employers need to be aware of these requirements and have systems and procedures in place to apply them.

Designers, manufacturers and suppliers of plant and employers are advised to consult the OHS Act 2000 and the OHS Regulation 2001, particularly Chapter 5 ‘Plant’, for details of these requirements.

This guideline provides guidance on how these requirements can be met.

3.1.3 Control of Risk

The OHS regulation requires risks (that cannot be reasonably eliminated) to be controlled in the following order:

a) Substitute the hazard for a hazard of lesser risk

b) Isolate the hazard from people

c) Minimise the risk by the use of engineering measures

d) Minimise the risk by the administrative means, eg SWP

e) Use of PPE

3.1.4 Consultation

Employers are required by the OHS Act 2000 to consult with employees when taking steps to assess and control workplace risks.

Further guidance can be obtained in the ‘OHS Consultation’ Code of Practice 2001 by WorkCover NSW

3.2 MANAGEMENT OF DIESEL POLLUTANTS

3.2.1 General

The management of diesel engine pollutants should be an integral part of the mine’s Health and Safety Management System (HSMS) which should be consistent with AS 4801.

The mine HSMS should identify how the mine complies with the exposure limits for each pollutant for various activities and locations throughout the mine and should address each of the following:

a) Hazard identification for each pollutant constituent.

b) Consultation with all stakeholders

c) Risk assessment.

d) Risk management procedures (eg JSA, SWP).

e) Information to be collated (eg manufacturers instructions, MSDS).

f) Instruction and training.

g) Supervision.

h) Monitoring.

i) Review.

j) Revision.

NOTE: Further guidance can be found in the document MES001 Mechanical Engineering Management at Mines, Part 1 - Mechanical Engineering Management Plans (MEMP).

3.2.2 Hazard Identification

All hazards must be identified and dealt with so that they are eliminated or controls established to minimise the risk. This guideline assists in identifying pollutant hazards for diesel engines operating in underground environments.

3.2.3 Consultation

The development of systems and procedures should be in consultation with mine employees and their representatives where appropriate and equipment manufacturers.

3.2.4 Risk Assessment

Legislation is quite specific in regards to the management of risks to health and safety in particular the hierarchy of controls.

In the context of diesel engine pollutants it is preferable to;

a) reduce pollutant generation (typically with better engine designs, lower sulphur fuels and good maintenance practices),

b) install systems/components on the diesel engine to capture and/or convert diesel engine pollutants,

c) increase ventilation quantities to reduce people’s exposure,

d) implement safe systems of work to maintain the diesel engine,

e) implement systems to monitor and review risk control methods, and

f) use personal protective equipment (PPE).

Clause 3.4 of this guideline lists the key system component outcomes, associated risks and main risk considerations which should be considered in the risk assessment.

3.2.5 Instruction, Training and Competencies

All persons involved with diesel engines pollutant management should be trained and assessed as to their competence for the task at hand.

3.2.5.1 Operators

Operators of diesel engines in the underground environment should be trained to recognise;

a) the potential long and short term health effects from exposure to diesel pollutants,

b) risk control measures adopted by the mine,

c) the systems/components incorporated into the diesel engine for the purpose of diesel pollutant reduction,

d) systems and procedures for monitoring and review of pollutant control measures, and

e) how poor/good driving habits can vary diesel pollutant generation.

3.2.6 Audit, Monitor & Review

The management of diesel engine pollutants should be audited, monitored and reviewed at appropriate periodic intervals.

3.3 DOCUMENTATION

Accurate records should be kept in a plant safety file for all stages throughout the lifecycle of the diesel engine, particularly:

a) The pollutant generation signature levels for each type of diesel engine.

b) Emissions characteristics prior to entry into the underground environment.

c) Systems/components incorporated into the diesel engine for the purpose of diesel pollutant reduction.

d) Trending of pollutant generation levels on a periodic basis over the life of each diesel engine.

e) Ventilation quantities to meet exposure limits.

f) Underground environment plan which shows required minimum ventilation quantities and diesel engine quantities/sizes for each activity being carried out to meet exposure limits.

g) Maintenance records and test reports on the diesel engine which affect or alter the generation of diesel pollutants.

h) Analysis of fuel and lubrication oils used on the diesel engine.

i) Engine operating hours.

j) System audit and review reports.

3.4 DIESEL ENGINE POLLUTANTS - RISK ELEMENTS AND CONSIDERATIONS

3.4.1 People Exposure to Diesel Engine Pollutants

3.4.1.1 Required Outcome

a) Develop and implement a mine strategy and policy to minimise exposure of people to diesel engine pollutants.

b) Minimise, control and monitor the exposure of people to diesel pollutants in the underground environment.

c) Identify areas of the mine where the risk to people exposure is increased e.g. poor ventilation, multiple diesel engines being used, etc.

d) Identify activities in the mine where the risk to people exposure is increased e.g. longwall change-out, single entry drivage, etc.

3.4.1.2 Main Risks

Short and long term exposure to diesel pollutants from:

a) Undetected changes to the normal operating environment.

b) Increase in the number of diesel engines in the same operating environment.

c) An undetected increase in quantum of pollutants being generated from each diesel engine.

d) Areas of poor ventilation.

e) Activities requiring a high use of diesel engines.

f) Excessive engine size (kW) for mine ventilation.

3.4.1.3 Main Risk Control Considerations

a) Identification of safe exposure limits applicable to the mine but not greater than those listed in Section 2.

b) Limiting diesel pollutants being generated in the underground environment.

c) Systems to reduce diesel pollutants being emitted into the underground environment.

d) Systems to monitor pollutant generation and pollutants being emitted into the underground environment.

e) Underground diesel pollutant test stations.

f) Minimum ventilation rates for the;

- number and size (kW) of diesel engine to be used in a particular area,
- quantity of pollutant generation from the diesel engines being used, and
- activities being undertaken and the duration of exposure where ventilation may be limited.

g) Systems to monitor and verify ventilation rates and the numbers and sizes of engines.

h) Systems to monitor pollutants in the underground environment and monitor short and long term exposure levels to people.

i) The MSMP to identify and document the maximum engine size that can be used in each heading and the minimum corresponding ventilation rate.

3.4.2 Gaseous and Particulate Pollutant Generation

3.4.2.1 Required Outcome

The pollutant quantities generated from each diesel engines system are monitored throughout the duty and lifecycle of the diesel engine.

Pollutants generated from diesel engines are minimised by good maintenance practices.

3.4.2.2 Main Risks

Increase in gaseous and particulate pollutants being generated from the diesel engine will increase people exposure and increase the risk to the health and safety of people.

Gaseous and particulate emissions generated from a DIESEL ENGINE may increase due to:

a) Changes in fuel quality.

b) Damage to the air intake system so that the air intake filter or flame trap is blocked.

c) Changes to the fuel injection system on the diesel engine such as;

- air/fuel ratio,
- fuel timing,
- fuel rate, and
- condition of injectors, pumps and valves

d) Change in engine operating temperature and cooling systems.

e) Increased exhaust backpressure.

f) Change in operating elevation of the diesel engine.

g) Wear and tear on the engine e.g. crankcase oil consumption.

h) Mismatch of operating duty cycle on the diesel engine allowing it to operate inefficiently.

i) Poor driving habits.

3.4.2.3 Main Risk Control Considerations

a) Use diesel engines that meet current European or current American environmental protection agency tier requirements for non-road diesel engine.

b) Benchmark the generation of each pollutant over the full operating range of the engine for each type of diesel engine when the engine is new and in good condition.

c) Benchmark the generation of each pollutant for each diesel engine in use in the underground environment.

d) Periodically monitor and review trends in pollutants generated from the diesel engine over its lifecycle.

e) Use fuels that comply with the Fuel Quality Standards Act 2000 (see Section 4.5).

f) Establish maintenance systems to ensure the diesel engine is in a fit for purpose condition.

g) Develop systems to monitor and evaluate the condition of the engine.

h) Use electronic controlled diesel engines and electronic controlled drive transmissions.

i) Optimise drive transmissions for the duty cycle required to allow the engine to operate more efficiently.

j) De-rate the diesel engine.

k) Train operators to reduce pollutant generation with good driving habits.

l) Use higher quality lubricating oils and oil/fuel filtration systems so the engine is not burning dirty oils.

3.4.3 Gaseous and Particulate Pollutant Curtailment

3.4.3.1 Required Outcome

The installation of curtailment systems or components on the diesel engine that either reduce, capture or convert generated gaseous and particulate pollutants and prevent the pollutants from being discharged into the underground environment.

Note: The extent of curtailment required will vary depending on the age, condition and design of the diesel engine. Engines which meet American and European Tier emission requirements for non-road DIESEL ENGINES generate less pollutants.

Monitoring the condition and effectiveness of pollutant curtailment systems.

3.4.3.2 Main Risks

a) Failure of the pollutant curtailment system to reduce pollutants results in increased people exposure to diesel pollutants and increases the risk to the health and safety of people if undetected.

b) The pollutant curtailment system reduces one type of pollutant but increases other pollutants e.g. a heavy coated platinum catalyst may increase NO_2.

c) Failure of the maintenance system to maintain the pollutant curtailment system in a fit-for-purpose condition.

d) Temperature fluctuations of the engine exhaust affect the performance of catalytic converter type systems.

e) Temperature of the exhaust system may be insufficient for regeneration to occur particularly for engines used in underground coal mines.

f) Fire on diesel engine exhaust due to containment of diesel particulate matter in the filter.

3.4.3.3 Main Risk Control Considerations

a) Use particulate filters to capture particulate matter.

b) Use of catalytic oxidiser to reduce smaller fractions of particulate diesel.

c) Use catalytic converter type systems to convert gaseous emissions and the organic fraction of particulate emissions.

d) Monitor the gaseous and particulate emissions generated from each diesel engine prior to using the diesel engine in the underground environment.

e) Monitor the effectiveness and condition of the gaseous and particulate pollutant curtailment systems.

f) Monitor the engine exhaust temperature.

g) Periodically inspect, test and clean the pollutant curtailment systems.

h) Monitor engine exhaust backpressure.

3.4.4 Excessive Noise

3.4.4.1 Required Outcome

Identify people’s exposure to noise generated by each diesel engine by carrying out a noise assessment of the diesel engine across its operating cycle prior to the diesel engine use in an underground environment.

Implement systems to control and monitor sounds pressure levels generated from diesel engines on a periodic basis.

Verify that noise is reduced by carrying out personal sound exposure monitoring.

3.4.4.2 Main Risks

a) Noise exposure affects the health and safety of people.

b) Failure of a person to wear and properly fit hearing protection.

c) The integrity of noise attenuation systems becoming damaged.

d) Failure of a component and/or wear and tear on the engine increasing noise levels.

e) Poor driving habits.

f) Noise exposure to people in the vicinity of the diesel engine.

3.4.4.3 Main Risk Control Considerations

a) Change the process so the noise is eliminated.

b) Noise exposure limits as outlined in *National Standard for Occupational Noise [NOHSC:1007(2000)]*.

c) Management and protection of hearing at work in accordance with *National Code of Practice for Noise Management and Protection of Hearing at Work - 3rd Edition [NOHSC:2009(2004)]*.

d) Compliance with AS/NZS 1269 for noise management.

e) Carrying out noise assessments prior to implementing the diesel engine in the underground environment.

f) When replacing equipment purchase quieter machines or replace the noisy process with a quieter one.

g) Carrying out periodic noise assessments as conditions change.

h) Implementing maintenance practices to check and inspect the condition of noise attenuation devices.

i) Train operators in good driving practices.

j) Use of diesel engines with lower emitted noise levels.

k) Use of physical barriers as a means to reduce noise pressure levels rather than rely on hearing protection where practicable.

l) Limit people entry to confined areas and rooms where noise is excessive due to the diesel engine operating cycle.

m) Reduce the time people are exposed to the noise.

n) Use modern engines which meet American and European EPA tiered requirements.

o) As a last resort individual protection like earmuffs or earplugs should be worn. If they *are* used it's very important to make sure they're the right sort and that they're fitted and maintained correctly. Earplugs must be inserted into the ear canal for at least ¾ of their length to be effective.

3.4.5 Maintenance

3.4.5.1 Required Outcome

A fit for purpose examination, inspection, testing and maintenance system be developed and implemented to ensure the diesel engine and pollutant curtailment systems/components are kept in an optimum condition without increased risk to the health and safety of people.

3.4.5.2 Main Risks

a) Inadequate maintenance which results in increase of people's exposure to diesel pollutants.

b) Pollutant curtailment systems/components become inactive due to lack of maintenance.

c) Pollutant curtailment systems/components become an increased hazard due to large accumulations of particulate and organic matter.

d) Dirty fuel and oils being burnt in the combustion process.

e) High oil consumption from wear and tear of the engine.

3.4.5.3 Main Risk Control Considerations

a) A testing program to monitor gaseous and particulate (EC) pollutants being emitted into the underground environment. The use of underground emission test stations (Diesel Test Stations) is preferred.

b) Procedures for maintenance activities to be developed.

c) Monitor the trend of the condition and pollutant levels of each diesel engine.

d) Change disposable exhaust filters on a regular basis.

e) Periodically clean catalytic converter and ceramic type particulate filters.

f) Test and monitor engine air intake pressures.

g) Test and monitor engine exhaust backpressures.

h) Test and monitor the fuel injection system including timing, rate, etc.

i) Use good quality fuels, oils and fuel/oil filters.

j) Training and competency of people carrying out maintenance activities.

k) Compliance with MDG 32 or AS 3584.3.

3.4.6 Monitoring Pollutant Generation

3.4.6.1 Required Outcome

A system for the testing, monitoring and evaluation of diesel engine pollutant generation and pollutant discharge into the underground environment is implemented and applied to all diesel engines.

Atmospheric ventilating air quantities, as required to control diesel pollutant exposure, are verified for each diesel engine operating in the underground environment.

3.4.6.2 Main Risks

a) The pollutant monitoring system does not accurately record pollutants being generated by the diesel engine.

b) The pollutant monitoring system does not accurately record pollutants being discharged into the underground environment by the diesel engine.

c) Errors in the type, setup and calibration of the analysis equipment which results in false pollutant readings.

d) Period between pollutant testing is too great allowing excessive people exposure to pollutants

e) Pollutant analysis data is not trended and interpreted incorrectly.

3.4.6.3 Main Risk Control Considerations

a) Implement sampling procedures, sampling periods and sampling equipment.

b) Calibrate equipment periodically.

c) Use dedicated underground pollutant testing stations.

d) Training and competency of people carrying out sampling and analysis of pollutant data.

e) Trend pollutant results for each diesel engine.

3.4.7 Monitoring People Exposure to Pollutants

3.4.7.1 Required Outcome

A system for the testing, monitoring and evaluation of people's exposure to diesel engine pollutants in the underground environment is implemented and applied throughout all areas in the underground environment where diesel engines are used.

Mine ventilating air quantities are confirmed and checked for compliance in all areas in the underground environment where diesel engines are used.

3.4.7.2 Main Risks

a) The pollutant monitoring system does not accurately record pollutant exposure in the underground environment.

b) Errors in the type, setup and calibration of the analysis equipment which results in false pollutant readings.

c) Period between pollutant testing is too great allowing excessive people exposure to pollutants.

d) Pollutant analysis data is not trended and interpreted incorrectly.

3.4.7.3 Main Risk Control Considerations

a) Implement sampling procedures, sampling periods and sampling equipment as detailed in this guideline.

b) Calibrate equipment periodically as detailed in this guideline.

c) Training and competency of people carrying out sampling and analysis of pollutant data.

d) Trend and monitor diesel engine pollutant generation results for each diesel engine to evaluate the engines condition.

e) Measure and record mine ventilation air qualities periodically where diesel engines are operating.

3.4.8 Fuels

3.4.8.1 Required outcome

Use of good quality low emission fuels in diesel engines.

3.4.8.2 Main Risks

a) Use of poor quality fuels increases the gaseous and particulate pollutants emitted from the diesel engine.

b) Use of non EPA approved diesel fuel additives may have other unknown health effects.

c) Use of higher density fuels increases gaseous and particulate pollutant generation.

d) Use of fuels with too low a flash point may cause fire and explosion risks.

3.4.8.3 Main Risk Control Considerations

a) Use ultra low sulphur contact fuels ($S<50ppm$).

b) Use fuels which comply with the National fuel standard (Automotive Diesel) Determination 2001 as amended.

c) Use fuels with a density of 0.85kg/l or less.

d) Carry out periodic testing and trending of the diesel fuel properties and compare with recorded pollutant emission levels.

e) For underground coal mines use fuels with a flash point greater than 61.5^0C.

f) Filter fuels to remove solid particles.

g) Use fuels with lower aromatics.

3.4.9 Heat Stress

3.4.9.1 Required outcome

People working in the underground environment do not suffer adverse health effects from exposure to excessive heat.

3.4.9.2 Main Risks

a) Environmental considerations – e.g. air temperature, radiant heat, humidity, air movement.

b) Physical work – strenuous or light.

c) Work organisation – e.g. its duration, exposure to heat.

d) Diesel engines – e.g. the amount of heat being transmitted and radiated into the environment from the size and quantum of diesel engines in a particular ventilation area.

e) Clothing – e.g. heavy protective clothing.

f) Work posture – e.g. restrictions of space when working.

g) Acclimatisation – effects heat on individuals.

h) Consider pre-disposing factors; medication, age.

3.4.9.3 Main Risk Control Considerations

a) Undertaking a risk assessment and determining a monitoring regime.

b) *Eliminating or substitution* such as using lower temperature processes, relocating to cooler areas or rescheduling work to cooler times.

- Reducing the quantum of heat-producing diesel engines in underground environments

c) *Engineering controls* such as;

- the provision of cool rest areas, cool drinking water, cooling down the work area, equipment for air movement and chilled air, insulation or shielding for plant causing radiant heat, and mechanical aids to reduce the need for heavy physical work,
- providing adequate ventilation,
- regulating air flow or modifying ventilation to provide adequate cooling in specific areas,
- refrigerating the air supply into the mine in extreme conditions,
- providing loose clothing and cool vests, and,
- providing cool drinking water (workers' typically drink half a litre of water each hour when hot environments cause excessive sweating).

d) *Administrative controls* include;

- documented procedures for inspection, assessment and maintenance of engineering controls to ensure the equipment continues to operate to its design specifications; appropriate clothing; encouragement of workers to replace fluids; work/rest regimes based on the measured levels of heat effects; and job rotation,
- rotating personnel in hot areas, and
- providing rest breaks in cool areas.

e) *Personal Protective Equipment* should only be used in situations where the use of higher level controls is not appropriate for the level of risk for short periods, while higher level controls are being implemented, or for short duration tasks.

f) *Self assessment* should be used as the highest priority system during exposures to heat stress. As individuals' ability to cope with heat stress varies from day to day this allows adequately trained individuals to use their discretion to reduce the likelihood of excessive exposure.

- Educating personnel to recognise symptoms of heat stress.

g) *Training* is a key component necessary to any health management plan for people involved in work in: hot environments, physically demanding work at higher temperatures, or environments that require them to wear impermeable protective clothing.

h) Predisposed conditions, medication, age and other factors must be considered in pre-employment and ongoing health surveillance.

i) Monitoring air velocity and wet-bulb temperature regularly, determining cooling effect, assessing and recording results.

3.4.10 Control of vibration exposure

Ways of reducing the impact of both hand-arm and whole-body vibration include regular monitoring of vibration levels and workers' reports of numbness in the fingers, back pain, headaches, nausea ; and operator training.

The design of equipment can significantly reduce vibration at source. Therefore the careful selection of tools, seats and machinery is important in controlling vibration exposure.

For whole-body vibration, controls include appropriate design of vehicles such as the isolation of the vehicle cab where vibration is excessive, effective maintenance of vehicles; limiting speed, prompt communication and correction of road problems, effective road maintenance programs, task variation and regular breaks out of the seat.

Reduce or eliminate aggravating factors such as cold and humidity when using hand tools.

SECTION 4 TESTING LIMITS OF POLLUTANTS

4.1 GASEOUS EXHAUST EMISSIONS

When tested in accordance with SECTION 5 *Monitoring of Diesel Engine Pollutants* the raw exhaust gas of the diesel engine shall;

a) not exceed the limits specified in *Table 3* below, and

b) be compared against the baseline limits as specified in *Table 4* below.

Description	**CO (ppm)**	**NO (ppm)**	**NO_2 (ppm)**	**NO_x (ppm)**
Type testing of new engines for underground coal mines without methane injection[2]	1,100 (0.11%)	900 (0.09%)	100 (0.01%)	-
Type testing of new engines for underground coal mines with methane injection[2]	2,000 (0.2%)	900	100	1,000
In-service engines in underground coal mines[1]	1,100	-	100	750 (0.075%)
Engines in other underground environment	1,100	900	100	1,000

Table 3 – Raw exhaust gas limits for diesel engines operating in underground environments

Notes:

1. Based on the coal legislation
2. Refer AS 3584.1 and AS 3584.2
3. NO_2 is far more hazardous that NO or NO_x. NO_2 is difficult to measure in the raw exhaust unless the engine is under steady state conditions such as on a dynamometer
4. Refer Appendix 9.3 for commonly asked questions.

Any engine which fails to meet the specified limits above must have the licensed laboratory report stamped with a 'FAIL' and must be withdrawn from use in the underground environment.

Baseline Test Results (refer clause 5.3)	**Recommended Maximum Variance (%)**
CO and NO_X is less than 500ppm	25% but not less than 75ppm
CO or NO_X is greater than 500ppm	15%
Diesel particulate (cleaner engines)	30%
Diesel particulate (dirtier engines)	15%

Table 4 – Recommended Baseline Variances

Note: The baseline limits are set to promote monitoring and trending of an engines condition. They are not applicable for diesel engines currently in-service which do not have a valid baseline test.

Any engine which exceeds the recommended maximum variance must have the licensed laboratory report stamped with an 'EXCEED'. The engine should be checked at the next maintenance opportunity and brought back to the baseline condition.

4.2 PARTICULATE EXHAUST EMISSIONS

At this point in time it is not possible to provide one absolute value for the level of diesel particulate in the raw exhaust of a diesel engine. This is due to the wide variety of engine types currently in service all of which produce varying levels of diesel particulate.

The health studies indicate there is no definitive level that will have 'no-effect' to the health of people exposed to diesel particulate. Therefore it is prudent to adopt the policy that the lower the level of emissions the safer even though some overseas regulator authorities have adopted a minimum workplace exposure level of 0.1 mg/m^3 when measured in the EC fraction.

Meeting this exposure standard will demonstrate that the mine has good practices and in light of current knowledge, maintaining the level within this limit, will mean that the risk is being reduced to a level as low as reasonably achievable (ALARA).

What is clear is that any diesel engine no matter what its design will degrade with a resultant increase in particulate emissions if appropriate maintenance is not performed.

One way to demonstrate that a mine is maintaining a diesel engine to an appropriate level is to:

a) Conduct a diesel particulate baseline test prior to the diesel engine commencing operation, refer 5.3 *Baseline Testing For Each 'As New' Diesel Engine.*

b) Regularly monitor the raw exhaust levels of the diesel engine over its operational life cycle and monitor changes. For diagnostic purposes this is best undertaken at the same time as a raw exhaust gas test.

c) For diesel engines that meet or exceed American EPA Tier II or European EPA Stage 2 emission standards the results should not deviate from the baseline test by more than 30%.

d) For diesel engines that do not meet American EPA Tier II or European EPA Stage 2 emission standards the results should not deviate from the baseline test by more than 15%.

e) The reasons for such a change from the baseline shall be investigated and recorded and appropriate action taken to return the engine emission levels to their baseline status.

4.3 MINIMUM VENTILATION QUANTITY

The minium ventilation quantity in the heading where the diesel engine is operating shall be the maximum of the ventilation quantity required for;

- gaseous emissions,
- particulate emissions, and
- heat stress.

The minimum ventilation quantity should also consider the total number and power of diesel engines operating in the same ventilation current at any one same time. For a newly developing mine, good practice is to provide 0.1 $m^3/s/kW$ of diesel engine power to overcome, diesel emissions (gaseous, particulate) and heat stress.

4.3.1 Gaseous Emissions

For gaseous emissions the minimum ventilation quantity (volume of air) in each place where a diesel engine operates shall be such that a ventilation current of not less than;

a) 0.06 $m^3/s/kW$ of maximum capacity of the engine, or

b) 3.5 m^3/s,

which ever is the greater is directed along the airway in which the engine is operating.

If more than one diesel engine is being operated in the same ventilating current the diesel engine rated kW shall be added.

Note:

a) Where the exhaust of one diesel engine feeds the intake of another diesel engine down stream, the increase in emission cannot be assumed to be linear.

b) Minimum ventilation rates as specified by the manufacturer should also be considered.

4.3.2 Particulate Emissions

For particulate emissions the minimum ventilation quantity (volume of air) in each place where a diesel engine operates should not be less than those quantities specified by the diesel engines particulate signature. Refer 5.2.3.2 *Diesel Particulate Signature (QDP(min))*.

Note: If a particulate filter is not being used by the mine the minimum ventilation quantity to control diesel particulate emissions (diesel particulate signature) is greater. Minimum ventilation quantity should be determined both with and without the filter installed.

4.4 WORKPLACE EXPOSURE

Workplace exposure limits shall not be greater than those specified in Section 2 *GENERAL HEALTH RISKS*.

4.5 DIESEL FUEL

Diesel fuel used in underground coal mines must comply with the requirements specified by gazettal.

Diesel fuel in underground environments, other than coal mines, should comply with points 1, 3 & 5 below.

These gazettal requirements are summarised as:

1. All diesel fuel must comply with the Fuel Quality Standards Act 2000, the Fuel Quality Standards Regulations 2001 and the National Fuel Standard (Automotive Diesel) Determination 2001, as amended, unless an approved variation has been permitted at the time of supply.
2. The flash point must not be less than 61.5°C when tested in accordance with either:
   (i) Australian Standard *AS 2106.2-2005*: Methods for the determination of the flash point of flammable liquids (closed cup) - Determination of flash point - Pensky-Martens closed cup method, or

   (ii) Australian Standard *AS 3570-1998* : Automotive diesel fuel, or

   (iii) American Society for Testing and Materials *ASTM D93-02a* : Standard Test Methods for Flash-Point by Pensky-Martens Closed Cup Tester.
3. Only diesel fuel additives that have been registered by the Environmental Protection Agency of the United States of America may be used.
4. Flammable liquids must not be added to diesel fuel.
5. The mine mechanical engineering manager must ensure that sufficient testing of the diesel fuel is carried out so as to ensure compliance with this notice. Records of such tests and records as required by the Fuel Quality Standards Act 2000 and must be retained at the mine for a minimum of 2 years.

SECTION 5 MONITORING OF DIESEL ENGINE POLLUTANTS

5.1 GENERAL

5.1.1 Pollutant Monitoring

Pollutant generation from diesel engines shall be monitored, trended and documented over the engine's lifecycle in accordance with the this section.

Notes:

1. A change in engine condition may unknowingly increase workplace exposure levels.
2. Regular monitoring and trending of gaseous and particulate emissions identifies potential maintenance concerns with the engine.

5.1.2 Documentation

In addition to clause 3.3 *Documentation* the following records shall be maintained in a plant safety file by the user for each diesel engine:

a) Certificates showing compliance with type testing criteria. Refer 5.2 *'Type' Testing of New Diesel Engines.*

b) Certificates showing compliance with base line testing criteria. Refer 5.3 *Baseline Testing For Each 'As New' Diesel Engine.*

c) The commencement or discontinuance of use of the diesel engine in the underground environment.

d) Any test report obtained before the engine was put into use in each mine (underground environment).

e) Any occasion when a diesel engine is withdrawn from service as a result of a failure of the exhaust gas or particulate analysis.

f) Any actions taken to repair a diesel engine following a failure of the exhaust gas or particulate analysis.

g) Trending and monitoring records over the engines lifecycle.

h) Minimum ventilation quantities as specified in clause 4.3 *Minimum Ventilation Quantity*.

i) Fuel documentation as required by clause 4.5 *Diesel Fuel.*

5.2 'TYPE' TESTING OF NEW DIESEL ENGINES

5.2.1 General

Any new diesel engines designed for and being introduced into the underground environment shall be designed to minimise diesel pollutants as far as reasonably practicable.

Notes:

1. For particulate emissions a definitive 'no-effect' level has not been established thus it is prudent to adopt the policy that the lower the level of emissions the safer. Refer 2.3 *Exposure to Diesel Particulate.*
2. New engines should meet current American or European EPA Stage/Tier standard for emission at the time type testing is being carried out.
3. Clause 5.2 only applies to diesel engines designed and intended for use in the underground environment.
4. Roads and traffic authority registered vehicles in metalliferous mines need not comply with this clause.

5.2.2 Gaseous Emissions

All new diesel engines being introduced into the underground environment shall be type tested on an engine dynamometer in accordance with the procedures outlined in Appendix D of AS 3584.2:2003, or Appendix D of AS 3584.1:2005 unless excluded by clause 5.2.4 below.

The undiluted raw exhaust gas emissions shall meet the levels specified in clause 4.1 *Gaseous Exhaust Emissions*.

Exhaust emissions testing shall be carried out by a licensed laboratory unrelated to the diesel engine or plant designer and/or manufacturer.

5.2.3 Diesel Particulate

5.2.3.1 Smoke

All new diesel engines being introduced into the underground environment shall be type tested on an engine dynamometer in accordance with the procedures outlined in Appendix C of AS 3584.2:2003, or Appendix C of AS 3584.1:2005 unless excluded by clause 5.2.4 below.

Exhaust emissions testing shall be carried out by a licensed laboratory unrelated to the diesel engine or plant designer and/or manufacturer.

5.2.3.2 Diesel Particulate Signature ($Q_{DP(min)}$)

The minimum ventilation quantity ($Q_{DP(min)}$) to dilute diesel particulate exhaust emissions to 0.1 mg/m^3 EC shall be:

a) Calculated in accordance with the procedures specified in clause 6.3.1 *Diesel Particulate Signature* for all new diesel engines being introduced into the underground environment.

b) Calculated ***with*** and ***without*** other system(s) or device which reduce diesel particulate being installed e.g. before and after a removable type particulate filter element.

c) Calculated on undiluted exhaust entering the mine atmosphere.

d) Provided to the end user of the diesel engine system and kept in the plant safety file.

Diesel particulate emissions testing shall be carried out by a licensed laboratory using one of the instruments listed in clause 8.2 *Diesel Particulate Monitoring Equipment*.

5.2.4 Engine Dynamometer Testing

Engine dynamometer testing as specified in clause 5.2.2 and clause 5.2.3.1 above is not required if the diesel engine complies with the American EPA Tier II or European EPA Stage 2 emission standards or greater and the following requirements are met:

a) The original diesel engine manufacturer provides certification stating the EPA compliance and this certificate identifies;

   i) the exhaust emission levels obtained over the test cycle, and

   ii) the conditions and parameter under which the diesel engine must be operated for this certification to remain valid.

b) The diesel engine is installed in the plant in accordance with the EPA certification conditions and parameters.

c) A copy of the EPA certification is maintained in the diesel engine plant safety file.

d) A licensed laboratory confirms that results obtained during baseline testing concur with the EPA certification.

Note: The diesel particulate signature of the diesel engine is still required to be calculated, refer 5.2.3.2

5.2.5 Noise

A noise survey as outlined in Appendix 9.5 should be carried out.

5.2.6 Heat Output

The diesel engine manufacture should specify the maximum heat output which the engine system puts into the underground environment. This should be based on the cooling capacity of all heat exchanges, radiators or the like or the heat being expelled from the exhaust.

This information should be provided to the end user and kept in the plant safety file.

5.3 BASELINE TESTING FOR EACH 'AS NEW' DIESEL ENGINE

5.3.1 General

Each diesel engine shall have a baseline exhaust emission test carried out in accordance with the test procedure specified in clauses 6.2.1 *Licensed Laboratory Raw Exhaust Gas Analysis* and 6.3.2 *Procedures for Monitoring Raw Diesel Particulate Emissions* when the diesel engine is;

a) installed in plant or a machine, and

b) in an 'as new' condition.

This baseline test shall be carried out by a licensed laboratory using equipment from SECTION 8 *Testing Equipment and Standards*.

For underground coal mines a report from the licensed laboratory must be provided before an item registration number is issued for that particular diesel engine.

This baseline test shall be documented, kept in the plant safety file and used for trending and maintenance purposes over the lifecycle of the diesel engine.

The undiluted raw exhaust emissions shall meet the levels specified in SECTION 4 *Testing Limits.*

When compared under similar conditions the CO_2 concentration shall not exceed that obtained during type testing by more than 8% (relative). Other gaseous concentrations are not to exceed those obtained during type testing or those obtained from baseline testing of other similar diesel engines by more than 15%, , refer AS 3584.2 and AS 3584.1.

The licensed laboratory shall confirm in writing that the baseline results are within these parameters.

Note:

1. This clause only applies to diesel engines designed and intended for use in the underground environment.
2. Roads and traffic authority (RTA) registered vehicles in metalliferous mines need not comply with this clause.

5.4 IN-SERVICE DIESEL ENGINE TESTING OF POLLUTANTS

5.4.1 General

5.4.1.1 New Engines Arriving Upon the Mine Site

An emissions test should be carried out by a licensed laboratory prior to the engine being put to work in the underground environment.

This test shall be compared against the original baseline test and the specified exhaust limits in SECTION 4 *Testing Limits*.

5.4.1.2 Failure to Comply with Limits Specified

5.4.1.2.1 Raw exhaust

Where emissions tests reveal that raw undiluted exhaust components from a diesel engine in use underground exceed the limits specified in ***Table 3*** then;

a) a FAIL must be stamped on the report and the result must be made known to the mine mechanical engineer or other competent person, and

b) the equipment in which the diesel engine is operating must not be used in the underground environment until the concentration of those emissions does not exceed those specified concentrations unless the equipment is being run to permit its transit by running in an unladen condition to a place for repairs, and

c) the failure and all repairs undertaken shall be recorded.

Where emissions tests reveal that raw undiluted exhaust components from a diesel engine in use underground exceed the recommended maximum baseline variance, as specified in ***Table 4***, then the engine should be checked at the next maintenance opportunity and brought back to the baseline condition. An EXCEED should be stamped on the report.

5.4.1.2.2 Mine Atmosphere

Where mine atmosphere testing reveals that the diluted constituents of diesel engine exhaust in the mine atmosphere exceed the limits specified in SECTION 2 *GENERAL HEALTH RISKS* the diesel engine must immediately be stopped and not operated until the constituents have dispersed unless;

a) the total air quantity in the roadway is increased to the extent that gases produced are diluted to not more than the above mentioned concentrations, or

b) the diesel engine is operated only to the extent necessary to remove the vehicle to a place for remedial maintenance.

The failure and all repairs undertaken shall be recorded.

5.4.2 Exhaust Emissions (Gaseous and Particulate)

5.4.2.1 Monthly Testing

At least once every 28 days the undiluted exhaust of each diesel engine in use in underground environments shall be sampled and analysed in accordance with the procedures for;

a) *Mine Site Raw Exhaust Gas Analysis,* refer clause 6.2.2, and

b) *Procedures for Monitoring Raw Diesel Particulate Emissions*, refer clause 6.3.2

The undiluted raw exhaust gaseous emissions shall meet the levels specified in clause 4.1 *Gaseous Exhaust Emissions*.

The results of this testing must be supplied to the mine mechanical engineer.

Monthly testing need not be carried out where the diesel engine is subject to a test of the type referred to below as a six-monthly test in accordance with clause 5.4.2.2 below at least every three months.

5.4.2.2 Six Monthly Testing

At least once every six months the undiluted exhaust of each diesel engine in use underground at a mine must be sampled and analysed by a licensed laboratory in accordance with the procedures for;

a) *Licensed Laboratory Raw Exhaust Gas Analysis*, refer clause 6.2.1, and

b) *Procedures for Monitoring Raw Diesel Particulate Emissions,* refer clause 6.3.2.

The undiluted raw exhaust gaseous and particulate emissions shall meet the levels specified in SECTION 4 *Testing Limits.*

5.5 WORKPLACE ATMOSPHERIC MONITORING OF DIESEL ENGINE POLLUTANTS

5.5.1 Gaseous Emissions

5.5.1.1 Mine Atmosphere Testing

At least once every week each diesel engine shall be tested to ascertain whether the limits specified in SECTION 2 *GENERAL HEALTH RISKS* are exceeded in the mine atmosphere. This provision does not apply where a diesel test station in used in accordance with clause 5.5.1.2 below.

The testing shall be carried out in a roadway in which the diesel engine normally operates in accordance with the procedure in clause 6.2.3.1 *Mine Roadway Testing*.

5.5.1.2 Diesel Test Station

As an alternative to clause 5.5.1.1 above at least once every month the atmosphere in the vicinity of the diesel engine exhaust may be tested in a Diesel Test Station (DTS).

Where a diesel test station is used testing shall be carried out in accordance with the procedure outlined in clause 6.2.3.2 *Diesel Test Station*.

Note: Atmospheric measurement of diesel gaseous emissions at a Diesel Test Station is preferred as the more repeatable results allow trends of engine condition to be monitored.

5.5.2 Diesel Particulate Emissions

The mine's diesel management plan should identify if and when workplace atmospheric monitoring of diesel particulates is required to be carried out.

Consideration should be given to the time when the health risk to people in the vicinity of the diesel engine is greatest such as:

a) Periods of high usage of and/or large diesel engines.

b) Areas that are poorly ventilated.

c) Areas where older engines operate.

d) Areas where complaints are being made by employees underground.

When environmental monitoring is required it should be carried out in accordance with the procedure in clause 6.3.3 *Atmospheric Workplace Diesel Particulate Sampling*.

5.5.3 Measuring Heat Stress Levels

In the first instance tolerable climatic conditions can be assessed by using employee's opinions as well as observing their physiological responses (flushing, sweating, body temperature, skin temperature and heart rate) and changes in work performance. Decreased urine output, changes in behaviour and flushed and/or dry skin may indicate dehydration and heat strain [McPhee 2005].

Any exact measure of heat and its effects on an individual must take into account air temperature, radiant temperature, air velocity, humidity and the intensity of the work being performed. While there is no entirely satisfactory single measure of heat and cold stress various predetermined measures are available for different ambient and working conditions.

There are a range of assessment techniques that can be used to determine heat loads and human responses. Some like the Wet Bulb Globe Temperature (WBGT) index are simple first order indicators of environmental heat stress. However the use of a heat stress index alone is not recommended where there is evidence of some level of heat stress. The Australian Institute of Occupational Hygienists [AIOH] proposes that where the heat stress index values exceed that allowable for continuous work with a specified workload then a second order assessment should be undertaken. These are thermal risk assessments and examples and checklists are available in the AIOH publication [Di Corletto et al 2003].

SECTION 6 TEST PROCEDURES

6.1 GENERAL

6.1.1 Records

The results of all tests carried out must be durably recorded without delay and the record retained in the plant safety file for the diesel engine.

6.1.2 Testing Results

6.1.2.1 Licensed Laboratories

The results of all diesel engine testing by licensed laboratories shall be supplied to the mine mechanical engineer and the Department of Primary Industries. Refer 7.1 *Diesel Emission Database*.

The licensed laboratory's test report shall be a NATA certificate in accordance with the terms of accreditation with NATA and must include all the following information:

a) Date of test, identification of licensed laboratory and test report number.

b) Identification of licensed laboratory and their current license number.

c) Machine type/model and serial/plant number.

d) Identification of engine including manufacturer, type, serial number, plant number, and registration number (underground coal mines).

e) The name of the person who sampled and analysed the exhaust.

f) Location test carried out.

g) Name of owner of diesel engine system.

h) The date of the previous test on the engine.

i) Method of loading the engine and engine RPM for each test conducted.

j) Whether sampled directly or by use of gas sample bags.

k) Where an hour meter is fitted, the hour meter reading on the engine.

l) Concentrations, (ppm) except CO_2(%), of each raw exhaust gas measured for each test condition.

m) Concentrations (mg/m^3) for the measured particulate (EC) in the raw exhaust.

n) Results of the previous measurements.

o) Baseline results for the particular diesel engine including pass/failure criteria.

p) Where exhaust results exceed limits specified in *Table 3* then a '***FAIL***' shall be stamped on the test report.

q) When the engine is re-tested then the test report shall be stamped with the word '***RE-TEST***'.

r) Where exhaust results exceed recommended maximum baseline variances as specified in *Table 4* then '***EXCEED***' shall be stamped on the test report.

s) Any action taken as a result of the test.

An example for a typical sheet is included in 9.4 *Appendix D – Elements for Licensed Exhaust Emissions Report.*

6.1.2.2 Mine Site Testing

The results of all tests carried out at the mine site must show:

a) Date of test.

b) Machine and engine type.

c) Identification of engine including serial number, plant number, and registration number (underground coal mines).

d) The name of the person who sampled and analysed the exhaust.

e) Method of loading the engine and engine RPM for each test conducted.

f) Where an hour meter is fitted, the hour meter reading on the engine.

t) Concentrations (ppm) of each raw exhaust gas measured for each test condition.

u) Concentrations (mg/m^3) for the measured particulate in the raw exhaust (EC).

g) Quantity of air passing the diesel engine.

h) Any action taken as a result of the test.

6.2 PROCEDURES FOR GASEOUS EMISSIONS

6.2.1 Licensed Laboratory Raw Exhaust Gas Analysis

Licensed laboratory testing of the undiluted and untreated raw exhaust of the diesel engine shall be carried out as follows:

a) Testing equipment shall comply with clause 8.1 *Exhaust Gas Test Equipment Specifications.*

b) NATA certified gas mixtures must be used to calibrate gas analysers.

c) The engine shall be operated until the engine temperature stabilises. Exhaust gas sampling shall be taken when the diesel engine is at normal operating temperature.

d) The raw exhaust of the diesel engine shall be sampled and analysed under the condition of maximum load or maximum fuel input (i.e. typically maximum power output), refer clause 1.7.13 *Load.*

e) In addition to d) above where a baseline test is being carried out (refer 5.3 *Baseline Testing For Each 'As New' Diesel Engine*) the raw exhaust of diesel engines shall be tested at;

   (i) half blocked intake at maximum load (power), and

   (ii) at normal idle speed under conditions of no load.

f) Exhaust analysis conditions will be satisfactory only if the test results at maximum power output for undiluted samples indicate that the CO_2 content by volume is not less than 6%.

   Note: The intent is to achieve maximum fuel input to the diesel engine with consideration to machine loading constraints.

v) The raw exhaust concentration (by volume) for each test condition shall be recorded for;

   (i) Carbon monoxide (CO),

   (ii) Carbon dioxide (CO_2),

   (iii) Oxides of nitrogen (NO_x), and

   (iv) Nitric oxide (NO) and nitrogen dioxide (NO_2) (direct sampling and dynamometer testing only).

g) The raw exhaust shall be analysed using a direct sampling technique where practicable.

h) Where direct sampling cannot be used samples shall be collected using a gas sample bag which shall meet the requirements of clause 8.1.3 *Gas Sampling Bags.*

i) Where there is a delay of ten minutes or greater after collecting bag samples for oxides of nitrogen (NO_x) the following procedure shall be used:

(i) A sample is to be collected in two bags with the engine operating under test conditions: one empty and the other already about half-filled with dry nitrogen.

Note: It may be found convenient to collect sample in the empty bag and then transfer part of this into the nitrogen bag.

(ii) Both bag samples shall be analysed.

(iii) The carbon monoxide results from both bags are used to calculate the dilution factor in the nitrogen bag. This factor is used to calculate a NO_x result from the diluted sample with the formula:

$$NO_x = (NO_x \ in \ diluted \ sample) \times \frac{(CO \ in \ undiluted \ sample)}{(CO \ in \ diluted \ sample)}.$$

j) Where the diesel engine is fitted with a catalytic oxidiser (purifier) then the specified limits (refer SECTION 4 *Testing Limits*) shall be applied to exhaust gas results obtained from samples taken prior to the exhaust gases reaching the oxidiser (raw exhaust).

Note: Good practice is to measure both before and after the purifier periodically to verify the purifier's functionality.

6.2.2 Mine Site Raw Exhaust Gas Analysis

Mine site testing of the undiluted and untreated raw exhaust of the diesel engine shall be carried out as follows:

a) Exhaust sampling and analysis shall be carried out by a person competent to the satisfaction of the mine mechanical engineer to carry out such test or by a licensed laboratory.

b) The diesel engine shall be operated until the engine temperature stabilises. Exhaust gas samples shall be taken when the diesel engine is at normal operating temperature.

c) The exhaust of the diesel engine shall be sampled and analysed under the following conditions:

(i) At normal idle speed under conditions of no load.

(ii) At maximum load or maximum fuel input (i.e. typically maximum power output), refer clause 1.7.13 *Load.*

d) The raw exhaust concentration (by volume) for each test condition shall be recorded for;

(i) Carbon monoxide (CO), and

(ii) Oxides of nitrogen (NO_x)

e) Gases shall be analysed by means of an appropriately calibrated portable digital or analogue gas detector but *not* a tube type gas detector.

The manufacturer's instructions relevant to the use and calibration of the detector must be followed.

Note: Tube type gas detectors do not provide sufficient accuracy for accurate trending of the engine condition.

f) The raw exhaust gas sample shall be taken before the gas is passed through any form of diluter, conditioner or purifier.

Note: Good practice is to measure both before and after the purifier periodically to verify the purifier's functionality.

6.2.3 Mine Atmosphere Exhaust Gas Analysis

6.2.3.1 Mine Roadway Testing

Mine atmospheric testing of gaseous exhaust emissions from the diesel engine shall be carried out as follows:

a) Exhaust sampling and analysis shall be carried out by a person competent to the satisfaction of the mine mechanical engineer to carry out such test.

b) The diesel engine shall be operated until the engine temperature stabilises. Exhaust gas sampling shall be taken when the diesel engine is at normal operating temperature.

c) The exhaust of the diesel engine shall be sampled and analysed at maximum load or maximum fuel input (i.e. typically maximum power output), refer clause 1.7.13 *Load.*

d) The mine atmosphere shall be recorded at approximately 20 metres away from the diesel engine on the return side and at a level approximately 1.5 metres above the floor for;

   (i) Carbon monoxide (CO),

   (ii) Nitric oxide (NO),

   (iii) Nitrogen dioxide (NO_2), and

   (iv) Airflow.

e) Gases shall be analysed by means of an appropriately calibrated portable digital or analogue gas detector but *not* a tube type gas detector.

   The manufacturer's instructions relevant to the use and calibration of the detector must be followed.

   Note: Tube type gas detectors do not provide sufficient accuracy for accurate trending of the engine condition.

6.2.3.2 Diesel Test Station (DTS)

Atmospheric testing of gaseous exhaust emissions in a diesel test station shall be carried out as follows:

Note: The test does not directly measure workplace (people) exposure levels. It does provide an indication of whether there is potential for workplace exposure limits to be exceeded.

a) Exhaust sampling and analysis shall be carried out by a person competent to the satisfaction of the mine mechanical engineer to carry out such test.

b) The test procedure shall be documented and standard for all diesel engines using the DTS.

c) The diesel engine shall be operated until the engine temperature stabilises. Exhaust gas sampling shall be taken when the diesel engine is at normal operating temperature.

d) The air flow over the diesel engine shall be set to the minimum specified air flow as required by clause 4.3 *Minimum Ventilation Quantity.*

e) Over the last 30 seconds of a 60 second test cycle the exhaust components of the diesel engine in the atmosphere shall be sampled and analysed at maximum load or maximum fuel input (i.e. typically maximum power output), refer clause 1.7.13 *Load.*

f) The atmosphere shall be recorded at approximately 20 metres away from the diesel engine on the return side and at a level approximately 1.5 metres above the floor for;

   (i) Carbon monoxide (CO),

   (ii) Nitric oxide (NO),

   (iii) Nitrogen dioxide (NO_2), and

   (iv) Airflow.

   Note: The 20m may be reduced if it can be verified there is complete mixing and no layering of the exhaust gas.

g) Gases shall be analysed by means of appropriately calibrated gas and airflow sensors and analysers. These analysers should meet the requirements of clause 8.1 *Exhaust Gas Test*

Equipment Specifications.

The manufacturer's instructions relevant to the use and calibration of the detector must be followed.

Note: Tube type gas detectors do not provide sufficient accuracy for accurate trending of the engine condition.

6.3 PROCEDURES FOR DIESEL PARTICULATE

6.3.1 Diesel Particulate Signature

The minimum ventilation quantity ($Q_{DP(min)}$) to dilute diesel particulate exhaust emissions to 0.1 mg/m^3 EC shall be calculated when the engine is loaded in accordance with the ISO 8178 duty cycle using the engine loadings and weighting factors as specified in *Table 5* below.

The diesel particulate signature shall be calculated using the following equation:

$$Q_{DP(\min)} = \frac{EC_{kW}}{3600 DP_{(Exposure\ Limit)}} P_{WA}$$

Where

$Q_{DP(min)}$	=	minimum mine ventilation quantity (m^3/s)
$DP_{(Exposure\ Limit)}$	=	0.1 EC (mg/m^3)
EC_{kW}	=	sum of weighted average diesel particulate (EC) per hour emitted from the diesel engine exhaust over the specified duty cycle (mg/hr)
P_{WA}	=	sum of weighted average power for the diesel engine over the duty cycle (kW)

Table 5 below provides requirements and a procedure for this calculation.

Elemental carbon (EC) concentration shall be measured in gravimetric units (mg/m^3) by a licensed laboratory using equipment specified in clause 8.2 *Diesel Particulate Monitoring Equipment*.

An example of how to do this calculation is provided in clause 9.7 *Appendix G – Example of Particulate Signature Calculation.*

Speed	Units	Low idle	Rated Torque speed			Rated power speed			
Test number		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Torque %		**0%**	**100%**	**75%**	**50%**	**100%**	**75%**	**50%**	**10%**
Torque (per test number), (T)	Nm	measured values from dynamometer testing							
Speed (per test number), (n)	rpm	measured values from dynamometer testing							
Power (per test number), (P_{test})	kW	= torque x rpm x 2π / 60,000							
Exhaust Volumes									
Engine nominal intake air flow (per test No.) (q_1)	l/s	as calculated[1], or measured at testing. Include turbo boost.							
Engine nominal intake air flow (per test No.) (Q_1)	m^3/hr	= l/s x 3.6							
Engine nominal flow rate adjusted to ISA[2] (Q_2)	m^3/hr	using Gas equation[3] $Q_2 = Q_1 x(P_1/T_1)x(T_2/P_2)$							
Particulate Concentration (as EC)									
EC concentration (per test No.) (EC_{Vtest})	mg/m^3	using measured EC from licensed laboratory							
Total EC per hour (per test No.) (EC_{Qtest})	mg/hr	= nominal adjusted flow rate (Q_2) x EC concentration above (EC_{Vtest})							
Weighted Results									
Weighting factor		0.15	0.1	0.1	0.1	0.15	0.15	0.15	0.1
Weighted EC per hour (per test No.) ($EC_{Qtestweight}$)	mg/hr	= using results above (EC_{Qtest}) x weighting factor							
Weighted power (per test No) ($P_{testweight}$)	kW	= using results above (P_{test}) x weighting factor							
Sum of Weighted Results									
Sum of weighted EC per hour (EC_{kW})	mg/hr	= sum of weighted EC results above $\Sigma(EC_{Qtestweight})$							
Sum of weighted power (P_{WA})	kW	= sum of weighted power results above $\Sigma(P_{testweight})$							
Average EC per kW per hour (EC_{KWH})	mg/kW/hr	= sum of weighted average EC (EC_{kW}) / sum of weighted average power (P_{WA})							
Minimum mine ventilation per kW (Q_{VentKW})	m^3/s/kW	$= EC_{KWH} /(3600 x DP_{ExposureLimi})$							
Minimum mine ventilation quantity $Q_{DP(min)}$	m^3/s	= minimum mine ventilation per kW (Q_{VentKW}) x (P_{WA})							
Note: These calculations should be carried out before and after the particulate reduction device									

Table 5 – Procedure for calculating the diesel particulate index

Notes:

1. Formulae for swept volumes can be found in AS 3584.
2. ISA = international standard atmosphere (15°C or 288.2K and 101.3kPa).
3. Absolute pressure and temperature in Kelvin to be used.

6.3.2 Procedures for Monitoring Raw Diesel Particulate Emissions

6.3.2.1 Standard Method

All diesel particulate testing shall be carried out using the following method unless the diesel engine cannot be held in the load condition for 20 seconds in which case testing shall be carried out in accordance with clause 6.3.2.2 below.

a) Testing equipment shall comply with clause 8.2 *Diesel Particulate Monitoring Equipment.*

   Note: It is not possible to use the Bosch Smoke Meter for the above tests due to its inability to measure over a 60 second sampling period.

b) Exhaust sampling and analysis shall be carried out by a person competent to the satisfaction of the mine mechanical engineer to carry out such test or by a licensed laboratory.

c) The diesel engine shall be operated until the engine temperature stabilises. Exhaust particulate sampling and analysis shall be performed when the diesel engine is at normal operating temperature.

d) The vehicle must be safely chocked and the vehicle brakes must be applied.

Important Safety Notice

As engines must be tested in the load condition requiring the drive train to be engaged during testing it is important the vehicle is adequately chocked or restrained and the brakes applied to ensure it cannot "jump" or run away while the diesel engine is under throttle during the test.

e) Place vehicle in third gear or other gear as specified by the equipment manufacturer to carry out the test.

f) Run the engine at idle speed.

g) Insert sensor probe into the undiluted raw exhaust before any particulate treatment.

Note: This may be downstream of catalytic converters and water based scrubbers but must be before any particulate filter.

h) Testing shall be carried out over a 60 second cycle and on the undiluted raw exhaust as indicated in ***Figure 1*** below.

Notes:

1. It is important that the timing of the idle and full throttle settings is as accurate as possible. To ensure good repeatability, it is advisable for the operator to practice the procedure several times prior to collecting a sample.
2. Sampling should commence in the first idle period and continue until the final idle period.
3. Engines with a constant load, such as a diesel should be analysed with the load applied over the full 60 seconds.

i) Start sampling timer on analyser.

j) After 20 seconds have an operator quickly apply full throttle to engine (still in third gear) and hold for 20 seconds.

k) Quickly release throttle and allow engine to decay to idle while sampling for 20 seconds.

l) Stop sampling timer on analyser.

m) The total sampling time is 60 seconds. The sampling must pick up rise and decay of the engine from idle to full throttle and return to idle.

n) Remove the probe if no further testing is required.

o) Record the mean (average) engine exhaust diesel particulate concentration in (mg/m^3).

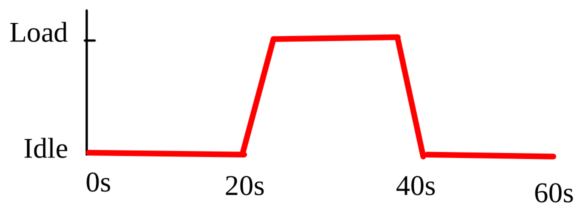


Figure 1 – Diesel particulate load cycle – Standard method

6.3.2.2 Alternative Method

Where testing in accordance with clause 6.3.2.1 above is not practicable (such as engines fitted with manual clutches) diesel particulate testing of the undiluted raw exhaust of diesel engines shall be carried out as follows:

a) Testing equipment shall comply with clause 8.2 *Diesel Particulate Monitoring Equipment.*

Note: It is not possible to use the Bosch Smoke Meter for the above tests due to its inability to measure over a 60 second sampling period.

b) Exhaust sampling and analysis shall be carried out by a person competent to the satisfaction of the mine mechanical engineer to carry out such test or by a licensed laboratory.

c) The diesel engine shall be operated until the engine temperature stabilises. Exhaust particulate sampling and analysis shall be performed when the diesel engine is at normal operating temperature.

d) The vehicle brakes must be applied.

Important Safety Notice

It is important the vehicle is adequately chocked or restrained and the brakes applied to ensure it cannot "jump" or run away in the event the gear control lever is accidentally engaged while carrying out the test.

e) Place vehicle in neutral to carry out the test. Ensure the transmission is not engaged.

f) Run the engine at idle speed.

g) Insert sensor probe into the undiluted raw exhaust before any particulate treatment.

Note: This may be downstream of catalytic converters and water based scrubbers but must be before any particulate filter.

h) Testing shall be carried out over a 60 second cycle and on the undiluted raw exhaust as indicated in ***Figure 2*** below.

Notes:

1. It is important that the timing of the idle and full throttle settings is as accurate as possible. To ensure good repeatability it is advisable for the operator to practice the procedure several times prior to collecting a sample.
2. Sampling should commence in the first idle period and continue until the final idle period.
3. During the acceleration stages of these tests a full fuel load is being delivered to the engine until it is near its governed speed.

i) Start sampling timer on analyser.

j) Continue to idle until timer indicates 8 seconds.

k) Have an operator quickly apply full throttle, hold until timer indicates 16 seconds and quickly release throttle.

l) Idle engine until timer indicates 24 seconds.

m) Quickly apply full throttle again, hold until timer indicates 32 seconds and quickly release throttle.

n) Idle engine until timer indicates 40 seconds.

o) Quickly apply full throttle again, hold until timer indicates 48 seconds and quickly release throttle.

p) Idle engine until timer indicates 60 seconds then stop sampling timer on analyser.

q) The total sampling time is 60 seconds. The sampling must pick up rise and decay of the engine from idle to full throttle and return to idle for each cycle.

r) Remove the probe if no further testing is required.

s) Record the mean (average) engine exhaust diesel particulate concentration in (mg/m^3).

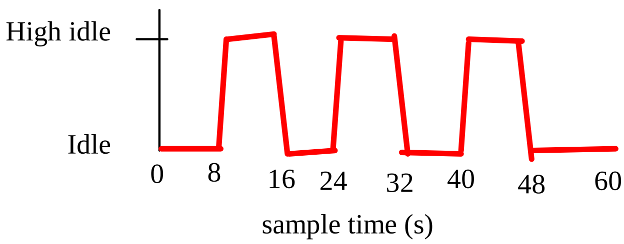


Figure 2 - Diesel particulate load cycle – Alternative method

6.3.3 Atmospheric Workplace Diesel Particulate Sampling

A number of approaches have historically been employed for the atmospheric monitoring of diesel particulate. These include respirable combustible dust, gravimetric, coulometry and more recently carbon speciation (elemental carbon).

The most common approach is the use of elemental carbon in the submicron fraction of dusts as determined by NIOSH Method 5040 (NIOSH 2003). This may be determined using a respirable size selective dust sampling device (i.e. standard mini cyclone) where dust levels are moderate and minor interference due to other organic or carbon-containing particulate is present.

In coal mines a submicron size selective sampling device is required. The SKC diesel particulate cassette with impactor Part No. 225-317 is such a device and can be fitted to respirable dust cyclones used in most jurisdictions. The limit of detection of this method is in the order of 1 $\mu g/m^3$.

Samples should be collected in the breathing zone of workers using the principles as described in AS 2985 and using a quartz filter and/or a selective sampling device (eg SKC Part No. 225-317) as described above.

Sufficient samples should be collected during normal operations (including Longwall moves) to ensure worker exposures to diesel particulate (measured as EC) are adequately assessed.

Guidance as to an appropriate workplace monitoring programme for establishing the level of risk in respect to atmospheric exposure to diesel particulate can be obtained from the publication "Simplified Monitoring Strategies" published by the Australian Institute of Occupational Hygienists.

6.4 NOISE TESTING AND EVALUATION PROCEDURES

6.4.1 General

Two alternative procedures are given for noise testing and evaluation.

Method A

A simplified method to estimate the driver and passenger noise exposures using sound exposure meters (noise dosimeters). This is a simple method that will provide noise exposure levels in an environment that approximates actual working procedures and environment. Measurements can be done on a surface test track or preferably underground.

Method B

Operator and passenger noise exposure levels are measured using a range of specified gears and speeds on a test track. This test can provide more detailed information on noise exposure under different driving conditions. It can also be used for detailed comparison of different vehicle models.

Because they are simulated tests, the results give exposure estimates only and will not directly give actual noise exposures for operators and passengers in vehicles underground. The information can be used by manufacturers and end users to determine a predicted daily noise exposure and the relative advantages of vehicles when they are used under specific conditions. These procedures should be used in conjunction with Australian Standard AS/NZS 1269-2005: *Occupational Noise Management* - in particular Part 1 – *Measurement and assessment of noise emission and exposure.*

The estimated noise exposures from tested vehicles must be added to other noise exposures experienced by the occupants of the vehicles when performing their other duties in the mine.

6.4.2 Test Site

Test Methods (A) and (B)

A large flat free field area is required that has no large buildings, trees, equipment, etc. closer than 20 metres from the test track. This is to minimise reverberation effects. The surface can be sealed or unsealed. The test site or track should have sufficient space to drive the vehicle at full speed.

Test Method (A)

As an alternative to the above ground track, tests can be conducted in an underground tunnel environment, which is long enough to simulate typical operating speeds.

6.4.3 Equipment

A small integrating Type 2 sound level meter, which gives a minimum of 60 second $L_{Aeq,60\ sec}$ and $L_{C,peak}$ Sound Pressure Level (SPL). The $L_{Aeq,T}$ function is basically the average noise level over a given period. Many modern sound level meters have this feature. The meter can be either hand-held or placed on a stand, which positions the microphone near to the operator's or passenger's ear. The microphone should be isolated from vehicle borne vibration, refer to AS/IEC 61672.1 – 2004, *Electroacoustics – Sound Level Meters – Specifications*.

The sound exposure meter (noise dosimeter) should have the function to produce a histogram of 60 sec average noise levels as well as an overall average for the measurement period. Refer to AS/NZS 2399-1998, *Acoustics – Specifications for personal sound exposure meters*.

All sound level meters used should be field calibrated at the start and end of the testing period (See AS/NZS 1269).

6.4.4 The Vehicle

The vehicle is to be complete with all covers, guards and attachments and with full tanks and unladen.

6.4.5 Test Procedure

Either test method can be used to estimate driver and passenger daily noise exposures. The test results may apply to new vehicles of the same make and model. Individual tests on each vehicle are recommended for used vehicles.

Simplified Method (A)

The following procedure is to be applied to the operator and all passengers in the vehicle. It may be possible to minimise testing by assessing only the operator and the passenger in the worst position for noise exposure.

This test is preferably done underground but may be conducted on a test track outdoors. If conducted outdoors, the result will need to be adjusted to account for the reverberant underground environment.

a) The vehicle must be driven until all functions have reached normal operating temperatures and pressures prior to beginning the test.

b) Attach a personal sound exposure meter (SEM), (noise dosimeter) to the driver and relevant passenger.

c) Start the dosimeter logging and immediately begin the test run.

d) Operate the vehicle in a way that simulates the function and speed of typical runs underground. This test should last at least 5 minutes but should preferably be longer to give a more accurate result.

e) Ensure that there are no other loud noise sources operating during the tests.

f) The data is to be recorded with date of test, vehicle tested, make, model and serial number of the sound level meter or SEM and any special conditions of the test.

g) Download data from SEM. Record the overall average $L_{Aeq,10min}$ and $L_{C,peak}$ levels. Take care interpreting the peak levels. This type of vehicle should not produce peak levels above 130 dBC and high peaks may be due to bumping the microphone of the dosimeter. If in doubt, record peak levels with a hand-held meter.

h) Add 3 dBA to the result if the test was conducted above ground on a test track. This is the equivalent underground average noise exposure for 10 minutes.

i) Estimate the total time the driver and passenger will spend riding in the vehicle per shift

j) Calculate the daily noise exposure level using the methods described in Appendix E.

Detailed Method (B)

The following procedure is to be applied to the operator and all passengers in the vehicle. It may be possible to minimise testing by assessing only the operator and the passenger in the worst position for noise exposure.

a) The vehicle must be driven until all functions have reached normal operating temperatures and pressures

b) The vehicle is then tested as a minimum (where applicable) under the following conditions for a minimum of 60 seconds to determine $L_{Aeq,T}$ and $L_{peak\ (lin)}$ SPLs. Each test is to be conducted at the operator or passenger's ear nearest the noise source and repeated three times and averaged for a final result

   i) Background with vehicle engine stopped

   ii) Stationary vehicle low idle engine speed (park brake applied, transmission in neutral)

   iii) Stationary vehicle high idle engine speed (park brake applied, transmission in neutral)

   iv) Stationary vehicle transmission stall with engine at full throttle

   v) Stationary vehicle hydraulic stall with engine at full throttle

   vi) Stationary vehicle combined stall (transmission and hydraulics)

   vii) Full speed in each gear in forward and reverse

   The design of some types of vehicles may make testing under some of the above conditions impossible or require testing under different conditions. The conditions listed are a minimum and should be conducted if possible. Other tests may be added as required by the manufacturer or end user.

c) The data is to be recorded with date of test, make, model and serial number of the sound level meter and any special conditions of the test.

NOTES:

1. Tested noise levels should be more than 15 dB(A) above background to ensure background noise does not contribute.

2. For the purposes of calculating the effects of underground reverberation, 3 dB(A) is to be added to the final calculations of Daily Noise Exposure.

6.5 WHOLE-BODY VIBRATION TESTING AND EVALUATION PROCEDURE

6.5.1 General

The method is based on measurements of whole-body vibration while a test vehicle is driven either on a test track that simulates underground conditions or in a suitable underground section of the mine. Currently available vibration monitoring instruments are not yet approved for use in hazardous zones in underground mines so tests must be carried out in non-hazardous zones.

The results of these tests will give an indication of likely whole-body vibration exposures in the vehicles tested. It is important that the test track ride closely simulates typical rides in the mine, including any jolts and jars experienced underground.

Measurements of whole-body vibration are to be made for the driver and passenger seats and can be conducted in conjunction with the noise evaluation tests (Section 6.4), if a suitable test track is available that satisfies the requirements for both tests. These procedures should follow those described in the Australian Standard, AS 2670-2001, *Evaluation of human exposure to whole-body vibration.*

The estimated vibration exposures from tested vehicles must be added to other vibration exposures experienced by the occupants of the vehicles when performing their other duties in the mine.

6.5.2 Test Site

A test track should simulate the roughness of the usual ride of the vehicle when operating underground.. The test site or track should have sufficient space to drive the vehicle at full speed.

6.5.3 Equipment

A whole-body vibration meter with a tri-axial accelerometer seat pad is required. The instrumentation should be capable of measuring, logging and assessing root mean square (r.m.s.) whole-body vibration acceleration levels as well as Vibration Dose Values (VDV). Equipment should comply with the requirements of Australian Standard, AS 2670-2001, *Evaluation of human exposure to whole-body vibration.*

6.5.4 The Vehicle

The vehicle is to be complete with all covers, guards and attachments and with full tank and unladen.

6.5.5 Test Procedures

This test is preferably done underground but may be conducted on a test track outdoors. The test results may apply to new vehicles of the same make and model. Individual tests on each vehicle are recommended for used vehicles.

The following procedure is to be applied to the driver and passengers in the vehicle. It may be possible to minimise testing by assessing only the driver and the passenger in the worst position for vibration exposure.

a) Vehicle tyres must be adjusted to normal operating pressures. Vehicle and seat suspensions should be adjusted as recommended by the manufacturer.

b) Fix the seat pad of the vibration instrument to the seat with cloth tape. The driver or passenger should sit directly on the middle of the pad (ischial tuberosities on the centre of the pad).

c) Program the vibration meter to log one minute average r.m.s acceleration levels and overall Vibration Dose Values (VDV).

d) Start the meter and immediately begin the test run.

e) Operate the vehicle in a way that simulates the function and speed of typical runs underground. This test should last at least 10 minutes but should preferably be longer to give a more accurate result.

f) The data is to be recorded with date of test, vehicle tested, make, model and serial number of the vibration meter and any special conditions of the test.

g) Download and record the average r.m.s vibration level and the VDV for the test run. Calculate the time taken to reach the Caution Zone and Likely Health Risk Zone as described in AS 2670-2001, *Evaluation of human exposure to whole-body vibration.*

h) Estimate the total time the driver and passenger will spend riding in the vehicle per shift and compare with the exposure times calculated in (g).

SECTION 7 EXTERNAL AUDITS AND REPORTS

7.1 DIESEL EMISSION DATABASE

7.1.1 Reporting of Analysis data to the Department

The licensed test laboratory shall supply a record of all diesel analysis reports issued for licence testing purposes as required by SECTION 5 to the:

Mine Safety Technology Centre

NSW Department of Primary Industries,

8 Hartley Drive, Thornton NSW 2322

PO Box 343, Hunter Region Mail Centre NSW 2310

Phone: 02 4924 4000
Fax: 02 4924 4080

These records shall be submitted within 30 working days after the end of each month of issue and be in accordance with 7.1.2.
These results may be submitted via email to: MineSafety.diesel@dpi.nsw.gov.au

7.1.2 Standard Report Format

The format of each test report shall contain all the elements as identified in clause 6.1.2.1 *Licensed Laboratories and Appendix D – Elements for Licensed Exhaust Emissions Report.*

The licensed laboratory should contact the Manager of the Mine Safety Technology Centre to enable effective integration with the Department's database.

The licensed laboratory shall provide the data to the Mine Safety Technology Centre for integration with their database.

The data shall be provided in the following form:

1. Be kept in an electronic format as specified by the Mine Safety Technology Centre. In the absence of specification the data can be directly imported into Microsoft Excel version 2003 without any modification.
2. Unless specified otherwise by the Mine Safety Technology Centre contain the following fields in the following order:
   - (i) Name of licensed laboratory.
   - (ii) Laboratory license number.
   - (iii) Name of person carrying out the test.
   - (iv) Date of test.
   - (v) Name of owner of diesel engine system.
   - (vi) Name of mine where engine is in use.
   - (vii) Plant (machine) make.
   - (viii) Plant (machine) model number.
   - (ix) Plant (machine) serial number.
   - (x) Engine make.
   - (xi) Engine model.
   - (xii) Engine serial number.
   - (xiii) Engine DE or item registration number.

(xiv) Full load;

- CO_2 (%),
- CO (ppm),
- NO_x (ppm), and
- NO_2 (ppm) if measured by direct sampling.

(xv) Particulate emissions (mg/m^3).

(xvi) Pass/ fail of diesel engine.

7.1.3 Database

A database of diesel exhaust emissions shall be established by the Mine Safety Technology Centre.

Trend analysis reports will be issued periodically to the Mine Safety Division of the Department of Primary Industries.

Owners will be able to obtain analysis data and trends for their particular equipment.

State-wide mine engine comparison data (excluding the names of mines) will be available to all mines.

7.2 DOCUMENTARY SYSTEM

7.2.1 Documented System

The licensed laboratory shall develop and maintain a documented system that addresses the technical aspects, quality control and administration of its operations in regards to diesel exhaust emission testing.

The documented system shall include the following:

a) Laboratory Quality Manual.

b) Technical methods manual pertaining to diesel testing.

c) Calibration records of equipment.

d) Records of the gases used for span checks and frequency that checks are conducted.

7.2.2 Availability of Documents

The documented systems shall be made available as required to the Department of Primary Industries, Mine Safety Division.

7.3 DEPARTMENTAL AUDITS

7.3.1 Service Provider Audit

Laboratories providing a diesel exhaust emission testing service are to have their license status reviewed each year. This will be conducted by way of an audit conducted by the Mine Safety Technology Centre. These audits will include comparison tests at nominated sites and also involve an audit of the documented system.

Where possible these audits will be co-ordinated with the NATA surveillance assessments of the test laboratories.

7.3.2 Strategy Audit

The Mine Safety Technology Centre will periodically conduct audits to measure the effectiveness of diesel emission testing programs. This will involve independent testing at mines.

SECTION 8 TESTING EQUIPMENT AND STANDARDS

8.1 EXHAUST GAS TEST EQUIPMENT SPECIFICATIONS

8.1.1 Specification of Gas Analysis Instruments

Instruments to be used in the measurement of exhaust gas emissions from diesel engines for use in underground coal mines shall comply with *Table 6* below.

1	2	3	4	5	6	7
Gas	**Analytical principle**	**Concentration range (by vol.)**	**Accuracy (% full-scale)**	**Repeatability (% full-scale)**	**Response time (s)**	**Interference <1% of the range in column 3**
CO	Non-dispersive infra-red	up to 2000 ppm	±3	±1	≤15	5 % CH_4 10 % CO_2 90 % RH
NO, NO_2 NO_x	Chemilumin-escence	up to 2000 ppm	±3	±1	≤15	5 % CH_4 10 % CO_2 0.2 % CO 90 % RH
CO_2	Non-dispersive infra-red	up to 20 %	±3	±1	≤15	5 % CH_4 0.2 % CO 90 % RH

Table 6 – Criteria for Gas Analysis Instrument

Notes:

1. Higher concentration ranges may be used provided that equivalent accuracy, repeatability, response time and interference are obtained.
2. Response time does not include the sample draw time.
3. NO, NO_2 and NO_x are commonly analysed by a single instrument which measures NO and NO_x and determines NO_2 by difference.
4. Other analytical techniques may be used provided that they are equivalent to the above in terms of performance.

Gas detection type tubes must not be used for exhaust gas sampling.

In addition to the above engine RPM readings are to be taken with a tachometer that is readable to within 20 rpm.

8.1.2 Exhaust Analysis System

The instruments shall be configured into an analysis system that provides for;

a) simultaneous reading of the constituents to be measured,

b) the regular calibration of the gas instruments,

c) control of sample flow through the system to ensure that the equipment manufacturer's requirements are met,

d) removal of water from the sample gases or a system which gives a constant water vapour content to both the sample and calibration gases, and

e) filtration of the sample gas to remove diesel particulates.

8.1.3 Gas Sampling Bags

Where samples are to be collected using a gas sample bag then the bag shall be manufactured from the polymer polyvinylidene chloride (commercially available under the trade names of Saran and Saranex) or other alternative polymer acceptable to the Department of Primary Industries.

In a coal mine where such bags contain an aluminium outer layer then the bag must be placed in a suitable cover and must not be discarded, disposed of or removed from the cover while underground.

The licensed laboratory must have a documented methodology covering the use of gas sample bags and the procedures employed when sampling with these.

8.1.4 Measuring Equipment

Where electrical equipment is to be taken underground in a coal mine it must meet the relevant requirements of the Coal Mine Health and Safety Regulation 2006.

8.2 DIESEL PARTICULATE MONITORING EQUIPMENT

8.2.1 Ambient Atmosphere Monitoring

8.2.1.1 Sample Collection

For the monitoring of EC in coal mines a size selection device shall be used.

Devices which conform to this requirement are:

a) SKC Diesel Particulate Cassette,

b) With Impactor Part No. 225-317 (or equivalent)

8.2.1.2 Analysis

Analysis of filter for elemental carbon shall be conducted by a laboratory NATA accredited (or equivalent) for the analysis using NIOSH Method 5040 (NIOSH 2003).

8.2.2 Raw Exhaust Monitoring

The following instrumentation and/or methods are considered appropriate for the analysis of diesel particulate in the raw exhausts of engines:

a) Air Quality Technologies Diesel Particulate Monitoring System Model LLSP-M-03 series instruments.

   The instrument should be calibrated to read raw exhaust EC directly.

b) The Rupprecht & Patashnick Co Inc Series 5100 Elemental Carbon Analyser.

c) The collection of diesel particulate matter on a quartz filter and subsequent analysis by NIOSH Method 5040 (NIOSH 2003).

Each instrument must be calibrated in accordance with the manufacturer’s recommendations.

8.2.3 Alternative Monitoring Equipment for Diesel Particulate

The above list of equipment is that which is currently known to be useful for monitoring EC in the exhausts of engines.

Alternative monitoring equipment may be used however it must be validated to the satisfaction of the Department of Primary Industries, Mine Safety Division.

A comparison against Method 5040 as specified in 8.2.2 c) above must be made to individual test modes across the engine’s power range using at least three different diesel engines of varying types and varying sizes.

Note: Confirmation should be sought from NSW DPI before carrying out comparison tests.

8.3 LABORATORIES & SERVICE PROVIDERS

8.3.1 Diesel Exhaust Emission Testing

Laboratories wishing to provide a diesel exhaust emission testing service to the NSW mining industry shall be licensed by the NSW Department of Primary Industries.

Only analysis results from licensed laboratories are accepted for the purposes of specified license testing in SECTION 5 *Monitoring of Diesel Engine Pollutants*.

In order to be licensed a laboratory must satisfy the following criteria, but not limited to:

a) Hold current National Association of Testing Authorities (NATA) accreditation covering this work.

b) Use equipment that at least meets the minimum instrument specifications.

c) Have and maintain a quality management system.

d) Conduct testing in accordance with these guidelines.

e) Employ staff with the appropriate subject knowledge.

f) Have a competency based training and testing program for the employment of staff for the purpose of diesel exhaust testing.

g) Have independent periodic reviews and audits of their quality system.

h) Satisfy departmental inspections/audits.

i) Other requirements as specified by the NSW Department of Primary Industries.

Note: The above criteria could be formally acknowledged through QA accreditation.

8.3.2 Ancillary Tests on Diesel Equipment

Laboratories wishing to provide these services to the NSW coal mining industry do not require specific licensing by the NSW Department of Primary Industries but are expected to adhere to the relevant standards and for the test report to specify the test method and procedures used.

Such testing is envisaged to include;

a) noise emission testing,

b) vibration, and

c) operator position vision survey.

MDG 1 **-** “Guideline for Free Steered Vehicles” provides details on these tests for underground coal mining equipment.

SECTION 9 APPENDICES

9.1 APPENDIX A – ASSOCIATED DOCUMENTS

9.1.1 Reference Documents

The following documents have been referred to in the preceding document:

[1] AIOH (2004): A Guideline for the Evaluation & Control of Diesel Particulate in the Occupational Environment; Davies B. and Rogers A., AIOH April 2004.

[2] Birch, E & Noll, J (2004): Submicron Elemental Carbon as a selective measure of Diesel Particulate matter in Coal Mines; *Journal of Environmental Monitoring Vol.6, pp799-806, 2004.*

[3] Di Corletto R, Coles G and Firth I. (2003) Heat Stress Standard and Documentation Developed for Use in the Australian Environment. *Australian Institute of Occupational Hygienists*:

[4] McPhee B, Foster G and Long A. (2001) Bad Vibrations. A Handbook of Whole-Body Vibration in Mining. *Joint Coal Board Health and Safety Trust*, Sydney.

[5] McPhee B. (2005). Practical Ergonomics. Human Factors at Work. *Coal Services Health and Safety Trust*, Sydney

[6] MSHA (2001): Diesel Particulate Matter Exposure of Underground Coal Miners: Final Rule; Diesel Particulate Matter Exposure of Underground Metal & Non Metal Miners: Final Rule; *US Federal Register, Friday January 19, pp5526-5706.*

[7] NIOSH (2003): Diesel Particulate Matter (as elemental carbon) and Appendix Q, NIOSH Manual of Analytical Methods, 4th Edn. *NIOSH Publication 2003-154*.

[8] Noll, J & Birch, E (2004): Evaluation of the SKC DPM Cassette for Monitoring Diesel Particulate Matter in Coal Mines; *Journal of Environmental Monitoring Vol.6, pp799-806, 2004.*

[9] Noll, J. Timko, R. McWilliams, L. Hall, P. and Haney, R. (2005): Sampling Results of the improved SKC Diesel Particulate Matter Cassette; *Journal of Occupational & Environmental Hygiene 1 (1), pp29-37 January 2005.*

[10] Rogers, A. Davies, B. & Conaty, G. (1993): Diesel Particulate – Health Effects, Measurement and Standard Setting: *Proceedings AIOH Annual Conference, Perth WA, 5-8 December 1993.*

[11] US EPA (2002): Health Assessment Document for Diesel Engine Exhaust; *US Environmental Protection Agency, Document EPA/600/8-90/057F May 2002.*

[12] AIOH (2001): Simplified Monitoring Strategies; Graham D, AIOH November 2001

[13] Department of Minerals and Energy Western Australia: Adjustment of Exposure Standards for Extended Workshifts Guideline; Document No. ZME263AA

9.1.2 Australian Standards

AS 2106.2 :2005	Methods for the determination of the flash point of flammable liquids (closed cup) - Determination of flash point - Pensky-Martens closed cup method
AS/NZS 1269:2005	Occupational noise management
AS 2670:2001	Evaluation of exposure to whole-body vibration – General Requirements.
AS 2985:2004	Workplace Atmospheres – Method for Sampling and Gravimetric Determination of Respirable Dust; *Standards Australia 2004.*
AS/NZS 2399:1998	Acoustics - Specifications for personal sound exposure meters
AS 3570:1998	Automotive diesel fuel
AS 3584.1:2005	Diesel engine systems for underground coal mines - Fire protected - Heavy duty
AS 3584.2:2003	Diesel engine systems for underground coal mines - Explosion protected
AS 3584.3:2005	Diesel engine systems for underground coal mines - Maintenance
AS 4801:2001	Occupational health and safety management systems - Specification with guidance for use
AS IEC 61672.1:2004	Electroacoustics - Sound level meters - Specifications

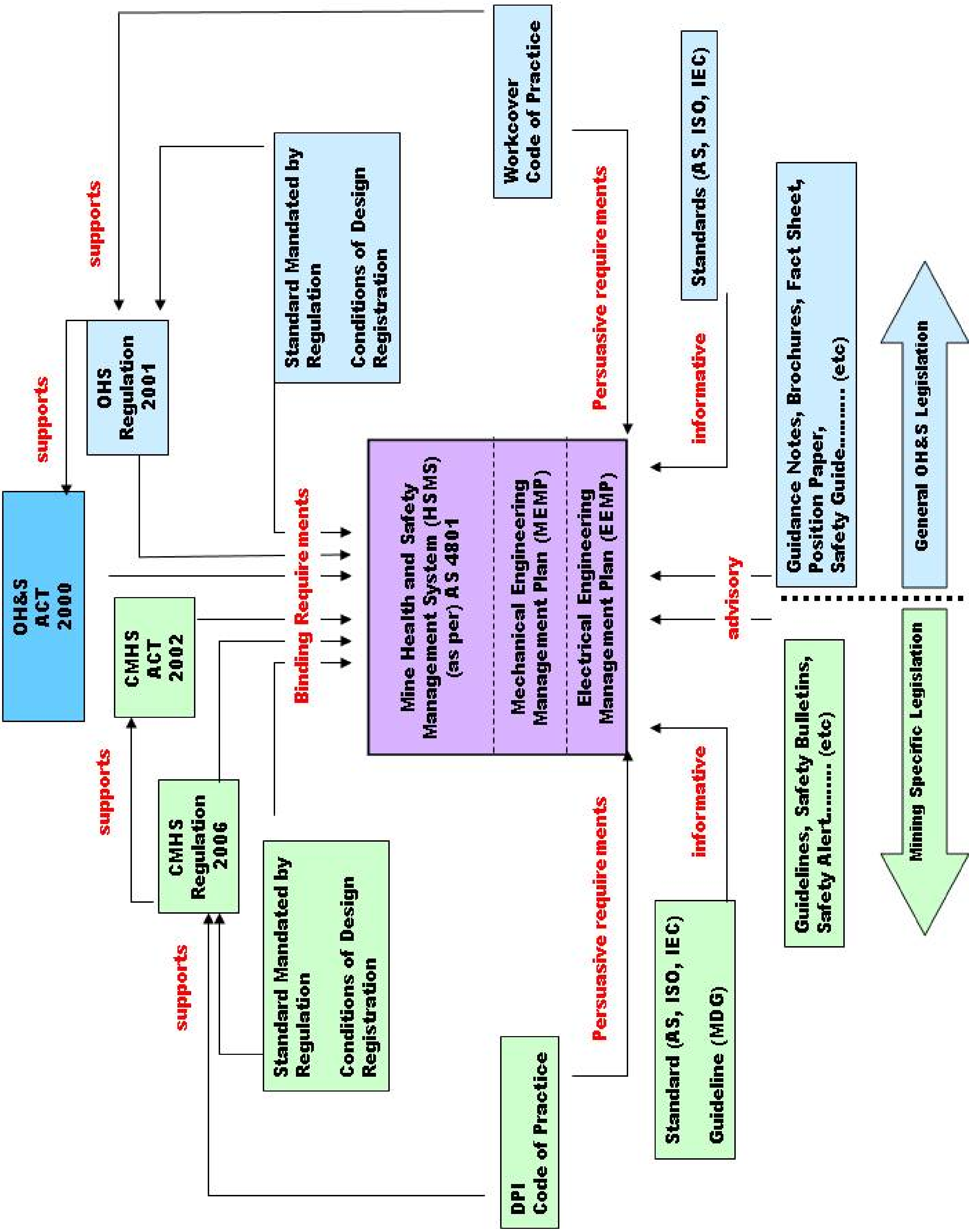
9.1.3 OHS National Standards and Codes

NOHSC:1007(2000)	National Standard for Occupational Noise
NOHSC:2009(2004)	National Code of Practice for Noise Management and Protection of Hearing at Work - 3rd Edition

9.1.4 International Standards

ISO 8178	Reciprocating internal combustion engines—Exhaust emission measurement

9.2 APPENDIX B –LEGISLATIVE FRAMEWORK FOR MINING IN NSW



9.3 APPENDIX C – OUTCOME BASED TESTING

Q: What should be the outcome of emissions control?

A: The desired outcome is that no worker should suffer adverse health effects over a working lifetime due to exposure to diesel exhaust emissions.

Q: This outcome may operate over a time-frame of 30 or 40 years and problems may be discovered too late to prevent harm. What short-term outcome would help safeguard the health of workers?

A: The desired outcome could be stated as: *"No contaminant shall be present in the workplace at a concentration above a recognised workplace exposure limit".*

But the health effects of contaminants can add together and some are synergistic. (That is they reinforce each other so that they have more impact than the sum of each one.)

So the outcome would be more fully stated: *"No contaminant shall be present in the workplace at a concentration above a recognised workplace exposure limit and the combination of contaminants shall be at sufficiently low concentrations to avoid additive or synergistic effects".*

Q: Then exposures are the key issue. Should diesel emissions be regulated by measuring personal exposures in the workplace?

A: It is always good OH&S practice to control the source of a problem first. If personal exposures are monitored it will be hard to determine the source of the problem. And the concentrations to be measured are low which makes measurement more difficult.

So it is better to measure the undiluted emissions from each engine. A high result immediately pinpoints the source.

Q: That points to measurement of emissions at the 'tailpipe'. That's not too hard – there are only 4 (CO, NO, NO_2 and particulate) so they can be monitored before they are finally diluted into the atmosphere.

A: It's not that simple. Researchers have identified over 400 components in diesel exhaust. Many of these are toxic and some are recognised as capable of causing cancer. Our desired outcome would require us to measure them all and determine whether they would all be below workplace exposure limits.

Q: So is the department intending to list 400 components to be controlled? And how would they be measured?

A: No, this would be rather difficult. Sampling and measurement of these components in the exhaust would require a complicated array of very expensive analytical equipment in conjunction with a dilution system. The results would be difficult to replicate because the analysis techniques are so difficult and some of the components are reacting with each other even as they are being sampled.

And exposure limits do not exist for many of the components.

Q: You're saying that we need to monitor hundreds of components but that it's completely impractical. So where do we stand?

A: We need to measure indicators that re-assure us that these other components are not being produced in excessive concentrations. This means that the combustion must be monitored by measuring emissions before any after-treatment.

The undesirable components in the exhaust are partly products of poor or incomplete combustion and partly by the interaction of one component with another. If the production of these components is minimised during combustion there is also less scope for interactions between them.

Carbon monoxide (CO) is believed to be a key intermediate product in the process of combustion.

It is also involved in the production of many of the minor toxic components in the exhaust. If CO is produced in large concentrations in the combustion process it is very likely that other un-measured components will be present in excessive amounts.

It is therefore very important to ensure that the CO concentration is within desired limits before any after-treatment.

Q: *Doesn't after-treatment reduce all the undesirable components?*

A: No. Catalysts are designed to remove CO but their effect on other organics is far less certain.

Also, high CO production during combustion is also usually accompanied by high particulate production. The particulate is likely to coat a catalytic converter reducing its effectiveness. Limiting the production of CO at the combustion stage therefore has multiple benefits in terms of cleaner emissions.

Q: *Isn't this hard on engines designed to operate with after-treatment?*

A: No. There are 'old technology' engines that easily pass the exhaust emission requirements for underground engines. The newer engines are claimed to have cleaner combustion and should not be troubled by these limits.

Q: *If it's important to test gases before after-treatment why is it acceptable to measure particulates after all treatment - including a filter?*

A: Testing the gases before treatment re-assures us that the engine is not generating excessive amounts of DPM – both elemental carbon and organic carbon. Testing for particulates determines whether the release of particulate into the atmosphere is excessive (or after a filter it can show the effectiveness of the filter).

Q: *Where did the existing ventilation requirement of 0.06 m^3/kW/sec come from?*

A: This figure was derived from the airflow needed to dilute NO_x at the maximum allowed in raw exhaust to the (then) exposure limit for NO_x. The required dilution was about 38:1.

Q: *Why is there now so much emphasis on diesel particulate?*

A: There is an increased emphasis. It's due to the increased awareness of the possible harm from exposure to elemental carbon and its associated organics. As we are concerned with long-term exposure – during a working life – the possibility of harm from exposure to potential carcinogens must be given a high priority.

9.4 APPENDIX D – ELEMENTS FOR LICENSED EXHAUST EMISSIONS REPORT

Note: Each report should include the data specified on this page. Refer clause 6.1.2 *Testing Results.*

NAME OF LABORATORY:

License number:

DATE OF REPORT:

Type of Test: Type test, Baseline; monthly; 3 monthly; 6 monthly

Test Report No.:

Location test carried out:

Owner of diesel engine:

Make of Diesel:

Engine Number:

Engine manufacturer/model number:

Machine manufacturer/type/model:

Machine serial/plant number:

Method of Loading gaseous emissions:

Method of Loading particulate emissions:

Method of Sampling gaseous emissions:

Method of Sampling particulate emissions

Date Tested:

Date Last Tested:

DES or Design Registration No.

DE No or Item Registration No.

Flight RPM:

Full load RPM:

Hour meter Reading:

Analysis Results

Description	Limits	Baseline test	Previous test ***'date'***[*4]	This test	Variance to baseline	PASS / FAIL / EXCEED [*3]
Full Load						
CO_2	>6%					
CO (ppm)	1100					
NO_x (ppm)	750					
O_2 (%) [*1]						
Diesel particulate						
Before treatment (mg/m^3)						
After treatment (mg/m^3)						

Description	Limits	Baseline test	Previous test ***'date''***[*4]	This test	Variance to baseline	PASS / FAIL
Idle [*2]						
CO_2						
CO (ppm)	1100					
NO_x (ppm)	750					
Half blocked intake load [*2]						
CO_2	>6%					
CO (ppm)	1100					
NO_x (ppm)	750					

[*1] If measured

[*2] Required for baseline test only

[*3] Refer clauses 4.1 and 4.2

[*4] The previous test may be included on a separate page showing history

For baseline testing:

- CO2 concentration does not exceed that obtained during type testing by more the 8% - PASS/EXCEED.
- Other gaseous concentrations do not exceed 15% of type testing results or other similar diesel engine baseline tests (refer 5.3) **- PASS / EXCEED**

Maximum emission levels recorded during type testing are included for information:

CO_2%:

CO (ppm):

NO_x (ppm):

NOTE: Other Elements may be required as part of the NATA Registration but are not necessary for inclusion in the department's database

Signature of Testing Officer ....

Name of Testing Officer ....

9.5 APPENDIX E – NOISE

9.5.1 Example Noise Test (Method A)

DATE OF TEST:................... 12-1-2007

TEST LOCATION:................... Mulhall colliery

TEST VEHICLE

MAKE: .... Dawes

MODEL:................... XIKJM

SERIAL NUMBER............. O410T

CONDITIONS:......... Windy day (Wind shield fitted). Tested on track in outdoor storage area.

TEST METER

MAKE:................... XYZ

MODEL:................... 2000 SOUND EXPOSURE METERS (3)

SERIAL NUMBERS.............. 123456, 123457, 123458

CALIBRATED TO............... 12-6-2007

TEST OFFICER................... P Smith

COMMENTS………… Measurements made simultaneously for each operator. Test run simulated typical underground speeds & procedures.

Test Results

Test No	Operator	Position in vehicle	Start test	Stop test	Test duration	Average noise level, (dBA) $L_{Aeq,T}$	Peak noise level (dBC) L_{Cpeak}	Description of test (vehicle speed, gears used)
1	Tom Jones	Driver	09:05	09:15	10 min	88	106	Simulation of typical underground ride
2	Mathew Brown	Front passenger	09:05	09:15	10 min	89	108	Simulation of typical underground ride
3	Peter Thomas	Rear passenger	09:05	09:15	10 min	90	110	Simulation of typical underground ride

The procedures used to calculate the daily noise exposure contribution from the vehicle is described in Appendix E of AS/NZS 1269.1 – 2005. The example summarises the calculations and can be used to incorporate other noise exposures in addition to the test vehicle noise.

Calculation method outline:

a. Measure a representative sample of noise level exposure to specific source or task.
b. Estimate the total time of exposure to that source over the entire shift.
c. Convert the noise level to Pa^2 (Pascal squared) using Table E2 in AS/NZS 1269.
d. Multiply the total exposure hours by the Pa^2 value to give Pa^2h.
e. Sum all Pa^2h values from each different noise exposure. In this example there is only one Pa^2h value.
f. Divide the sum of Pa^2h values by 8 to give the 8 hour daily noise exposure.
g. Convert the final Pa^2h value to the 8-hour noise exposure level using Table E2 in AS/NZS 1269.

The final result of these calculations gives the daily noise exposure level for an 8-hour shift assuming this was the only noise exposure. For a 12-hour shift, 3 dBA must be added to the 8-hour exposure level.

Calculation of daily noise exposures – for Test Method A.

Test No	Operator	Position	Average noise level, (dBA) $L_{Aeq,T}$	Adjust by +3 dBA[1]	Pa^2 (from AS/NZS 1269)[2]	Daily exposure duration (hours)	Pa^2h	Divide Pa^2h by 8	Convert to $L_{Aeq,8h}$	Add 3 dB for 12-hr shift
1	Tom Jones	Driver	87	90	0.40	6.5	2.6	0.33	89	**92**
2	Mathew Brown	Front passenger	88	91	0.50	2	1.0	0.13	85	**88**
3	Peter Thomas	Rear passenger	89	92	0.32	1	0.32	0.04	80	**83**

Note 1: Adjusted by +3 dBA to account for reverberation in the underground environment.
Note 2: Values given in Table E2 of AS/NZS 1269.1-2005.

The driver receives a daily noise exposure level (12-hour shift) of 92 dBA when exposed to 6.5 hours of vehicle noise. The $L_{C,peak}$ level measured did not exceed the 140 dBC limit.

Hearing protection is recommended for all occupants of the test vehicle.

Example Noise Test

Date Of Test: 12-1-2007

Test Location: Mulhall colliery

TEST VEHICLE

Make: Dawes

Model: XIKJM

Serial Number: O410T

Special Conditions: Windy day (Wind shield fitted). Tested on large asphalt car park area.

TEST METER

Make: B & K

Model: 2225

Serial Number: 123456

Calibrated To: 12-6-2007

Test Officer: P Farrell

T Time interval secs	60	60	60	
	Test 1 dB(A)	**Test 2 dB(A)**	**Test 3 dB(A)**	**Average**
$L_{Aeq,T}$ background eng. Stopped	55	55	55	55
$L_{Aeq,T}$ High idle stationary	85	85	85	85
$L_{peak\ (lin)}$ High idle stationary	90	89	91	90
$L_{Aeq,T}$ Low idle stationary	72	73	74	73
$L_{peak\ (lin)}$ Low idle stationary	89	89	89	89
$L_{Aeq,T}$ 1st gear full speed	86	86	86	86
$L_{peak\ (lin)}$ 1st gear full speed	99	100	101	100
$L_{Aeq,T}$ 2 nd gear full speed	88	87	86	87
$L_{peak\ (lin)}$ 2 nd gear full speed	101	102	103	102
$L_{Aeq,T}$ 3 rd gear full speed	89	88	90	89
$L_{peak\ (lin)}$ 3 rd gear full speed	102	105	108	105
$L_{Aeq,T}$ Full stall (Hyd. & Trans)	83	84	85	84
$L_{peak\ (lin)}$ Full stall (Hyd. & Trans.)	93	94	95	94
$L_{Aeq,T}$ Transmission stall	83	84	85	84
$L_{peak\ (lin)}$ Transmission stall	95	96	94	95
$L_{Aeq,T}$ Hydraulic stall	82	83	84	83
$L_{peak\ (lin)}$ Hydraulic stall	92	93	94	93

9.5.2 Example Evaluation of Noise

These results can be used to interpolate a model for the use of the vehicle underground by applying them to Section 3 of AS/NZS 1269-2005. Additionally, it is generally accepted that reverberation underground gives an additional 3-5 dB(A) to the free field results. For the purposes of this assessment 3 dB(A) will be applied. Therefore using this "underground factor" and a knowledge of the work cycle an expected noise exposure can be mathematically determined from the test results. This tool will be a valuable asset to the engineers procuring new equipment for mines because an accurate comparison can be made between manufacturers and models of machines. It also allows for upgrades to existing machine to be measured and cost benefit analysis made.

From the above example test and applying an estimate (Manufacturer or end user) of the DURATION of exposure we can develop the following table:

CONDITION	**$L_{aeq,T}$ dB(A)**	**$L_{Aeq,T}$ dB(A) +3 dB(A)**	**DURATION (Hours)**
$L_{Aeq,T}$ Background	55	58	2
$L_{Aeq,T}$ Low idle stationary	73	76	0.75
$L_{Aeq,T}$ High idle stationary	85	88	0.25
$L_{Aeq,T}$ 1st gear full speed	86	89	0.5
$L_{Aeq,T}$ 2 nd gear full speed	87	90	0.5
$L_{Aeq,T}$ 3 rd gear full speed	89	92	1.5
$L_{Aeq,T}$ Full stall (Hyd. & Trans)	84	87	0.5
$L_{Aeq,T}$ Transmission stall	84	87	0.25
$L_{Aeq,T}$ Hydraulic stall	83	86	0
	TOTAL		**6.25**

The same procedure outlined in Method A is used to calculate the daily noise exposure level. However, in this case the noise exposures for each condition are summed.

Condition	**LAeq,T + 3 dB(A)**	**Daily exposure duration**	**Pa^2 (from AS/NZS 1269)^2**	**Pa^2h**
$L_{Aeq,T}$ Background	58	2	0.00	0.00
$L_{Aeq,T}$ Low idle stationary	76	0.75	0.02	0.01
$L_{Aeq,T}$ High idle stationary	88	0.25	0.25	0.06
$L_{Aeq,T}$ 1st gear full speed	89	0.5	0.32	0.16
$L_{Aeq,T}$ 2 nd gear full speed	90	0.5	0.40	0.20
$L_{Aeq,T}$ 3 rd gear full speed	92	1.5	0.63	0.95
$L_{Aeq,T}$ Full stall (Hyd. & Trans)	87	0.5	0.20	0.10
$L_{Aeq,T}$ Transmission stall	87	0.25	0.20	0.05
$L_{Aeq,T}$ Hydraulic stall	86	0	0.16	0.00
Sums	**-**	**6.25 hours**	**-**	**1.54**
		Divide Pa^2h by 8		**0.19**
		Convert to $L_{Aeq,8h}$		**87dBA**
		Add 3 dB for 12-hr shift		**90dBA**

The driver of the test vehicle received a daily noise exposure of 90 dBA when adjusted for the 12-hour shift. The $L_{C,peak}$ level measured did not exceed the 140 dBC limit.

Hearing protection is recommended for the driver of the test vehicle.

9.5.3 Noise Assessments

National Code of Practice for Noise Management and Protection of Hearing at Work [NOHSC: 2009(2004)] 3RD Edition.

Extract of - *Section 7: Noise Identification and Assessment*

Noise Identification

7.1 Identification of noise hazards in a workplace enables people who may be exposed to excessive noise to be identified so that their exposures can be assessed. It also enables situations where immediate control measures are possible to be recognised and acted on and provides information for the person carrying out the detailed assessment.

7.2 No special skills re needed to conduct noise identification, but it should be done in consultation with those who understand the work processes, affected employees and/or their employee representative(s). One way is to conduct a walkthrough of the workplace, identifying noise processes and tasks. As an informal guide, when a raised voice is needed to communicate with someone about one metre away, a workplace noise assessment is needed. Other information can be gathered from plant manufacturers and suppliers (see Appendix 1 – www.ascc.gov.au)

7.3 A noise identification checklist is provided in Appendix 2 (www.ascc.gov.au) to help with the process.

7.4 When no prior information is available a noise assessment should be made to establish if exposure to noise is acceptable or not.

Noise Assessment

7.5 All workplaces where it is considered that employees may be exposed to noise exceeding the *National Standard for Occupational Noise* [NOHSC: 1007 (2000)] should be assessed, unless the exposure to noise can be reduced below the national standard immediately. Workplaces where exposure is marginally below the national standard should be re-assessed whenever any changes are made that may increase exposure.

7.6 People employed to carry out a noise assessment should meet the competency requirements in Appendix A of Part 1 of Australian/New Zealand AS/NZS 1269[1].

7.7 A noise assessment may be simple or quite complex, depending on the type of workplace, the number of employees and the information already available regarding noise exposure levels. The detail and accuracy needed will depend on individual circumstances.

7.8 The time intervals between noise assessments should be determined by management in consultation with employees through established consultative processes. Assessment should be repeated at intervals not exceeding five years or wherever there is:

(a) installation or removal of machinery likely to cause a significant change in noise levels;

(b) a change in workload or equipment operating conditions likely to cause a significant change in noise levels;

(c) a change in building structure likely to affect noise levels; or

(d) modification of working arrangements affecting the length of time employees would spend in noisy workplaces

7.9 Noise assessment records should be made in a consistent format and, where practicable, should be kept at or near the premises to which they apply. Where this is not practicable, for example because of the itinerant nature of the work, such as construction work, the records should be kept available at a designated office. Assessment records should be made available to management, employee representative(s) and relevant authorities.

Objectives

7.10 The general objectives of these assessments are to:

(a) Identify all employees likely to be exposed to noise above the national standard. This will generally involve the evaluation of $L_{Aeq,8h}$ and measurements of peak noise levels where relevant;

(b) Obtain information on noise sources and work practices that will help employers decide what measures should be taken to reduce noise;

(c) Check the effectiveness of measures taken to minimise exposure (provided that a base-line has been established in a more comprehensive assessment, it might be possible to restrict such surveys to measurement of noise levels at a few defined positions and under a restricted range of working or loading conditions of the equipment involved);

(d) Assist in the selection of appropriate personal hearing protectors; and

(e) Delineate hearing protector areas.

How To Carry Out A Noise Assessment

7.11 In some cases, more complex measurements are required in order to determine employees' exposure to noise with acceptable accuracy, or for the selection of personal hearing protectors. For example, octave band analysis of the noise may be desirable if it contains intense tonal, high frequency or low frequency components.

7.12 More detailed guidance on noise measurement and recording is available in Part 1 of Australian/New Zealand Standard AS/NZS 1269[1].

Instruments

7.13 Sound level meters (SLM) have four principal grades of precision:

Type/Description	**Tolerance**
0 – Laboratory reference meter	± 0.4dB
1 – Precision	± 0.7dB
2 – General Purpose	± 1.0dB
3 – Survey	± 1.5dB

7.14 Noise assessments should be performed with Type 2 general purpose meters, or better. Type 3 survey meters are usually inexpensive but may have wide precision tolerances and some models cannot be calibrated. Type 3 survey meters are only suitable for preliminary noise checks to find out whether more accurate assessments are needed.

7.15 The sound level meter may be equipped with an integrating/averaging function that enables the meter to process a continuous, variable, intermittent or impulsive signal to give a single integrated level or L_{eq} for the sampling period. A meter with this function is an integrating/averaging sound level meter (ISLM).

7.16 This sound level meter may have a peak detector-indicating characteristic. This is necessary to measure the C-weighted peak noise level. The C-weighted peak noise level should not be confused with the maximum sound pressure level.

7.17 Sound exposure meters (SEM) or noise dosemeters, can be worn by employees for a given period, for example, a working day. The SEM records the personal noise exposure of the employee. Some SEMS are capable of recording a time history of an employee's noise exposure level for the measurement period. A typical time-history report will provide a histogram of minute by minute noise exposure levels. This is a great advantage in identifying major contributors to the average daily noise exposure level that can be further investigated with a hand held meter.

7.18 The following points should be considered when using a SEM:

(a) Reflection of sound from the clothes and body can cause an increase of about 1 – 3 dB.

(b) The microphone should be attached as close as possible to the ear. Other inappropriate positioning of the microphone may give higher or lower results. For example, if the microphone is attached to the lower part of the collar or pocket, it may be much closer to a noise source than the ear and an unduly high result will be recorded. Also, the body may shield a noise source.

(c) The assessment of exposure over just one day may not give a representative sample. If possible, it is best to take measurements over a few days.

(d) It is advisable to check the SEM results with a hand-held sound level meter.

(e) Some SEMs do not measure impulse sound adequately.

7.19 Sound exposure meters should comply with Australian/New Zealand Standard AS/NZS 2399[2].

7.20 All SLMs and ISLMs should comply with the specifications laid down in Australian Standards AS 1259.1 and AS 1259[3] respectively. Octave band filters should comply with the specifications laid down in Australian Standard AS/NZS 4476[4].

7.21 A full calibration of measuring systems should be performed at regular intervals not exceeding two years by a laboratory that produces calibration test reports that are recognised by the National Association of Testing Authorities, Australia, covering the relevant accredited tests.

7.22 Meters should be checked with an acoustic calibrator immediately before and after the measurements.

Referenced documents

1. Standards Australia, AS/NZS 1269 *Occupational Noise Management Parts 0-4* Standards Australia, Sydney

2. Standards Australia, AS/NZS2399 *Acoustics – Specifications for Personal Sound Exposure Meters,* Standards Australia, Sydney

3. Standards Australia, AS 1259.2 – *Acoustics – Sound Level Meters, Part 2: Integrating- Averaging,* Standards Australia, Sydney

4. Standards Australia, AS/NZS 4476 *Acoustics – Octave Band and Fractional Octave Band Filters,* Standards Australia, Sydney.

9.6 APPENDIX F – HEAT STRESS AND AIR COOLING

Table 7 below shows air cooling power as a function of velocity. Where a heat stress problem may be apparent, this table could be used to assist in assessing appropriate ventilation.

Air velocity (m/s)	**Wet bulb temperature (^{0}C)**					
	20.0	**22.5**	**25.0**	**27.5**	**30.0**	**32.5**
0.1	176	153	128	100	70	37
0.25	238	210	179	145	107	64
0.5	284	254	220	181	137	87
1.0	321	290	254	212	163	104

Table 7 – Air cooling power as a function of air velocity (W/m^2)

Note:

1. The values given in the above table are the clothing corrected air-cooling power at varying wet bulb temperatures and air velocities.
2. The radiant temperature is taken to be equal to the dry bulb temperature, which is typically 100C higher than the wet bulb temperature.
3. This table is an extract from the WorkCover draft code of practice for tunnels under construction - June 2006

9.7 APPENDIX G – EXAMPLE OF PARTICULATE SIGNATURE CALCULATION

The following is an example on how the particulate signature can be calculated. Refer 6.3.1 *Diesel Particulate Signature.*

9.7.1 No Particulate Filter Installed

The diesel particulate signature of a 150kW diesel engine is to be calculated.

a) The engine is a four cycle engine naturally aspirated.

b) Temperature on the day of testing was 23 deg C, and atmospheric pressure 101.3kPa.

c) Engine has 6 cylinders with total swept volume of 7.2 litres.

d) The engine is naturally aspirated.

Speed	Units	Low idle	Rated Torque speed			Rated power speed			
Test number		1	2	3	4	5	6	7	8
Torque %		0%	100%	75%	50%	100%	75%	50%	10%
Torque (T)	Nm	0	750	562.5	375	700	525	350	70
Speed (n)	rpm	800	1700	1700	1700	2000	2000	2000	2000
Power (P_{test})	kW	0	134	100	67	147	110	73	15

e) The exhaust volumes can me measured directly, if set up during testing or calculated as follows, using $q_1 = \frac{2Vn}{s_t 60} x \frac{P_b}{P_{atm}}$ where V = swept volume (l), n = crankshaft speed (rpm), P_b=boost pressure, P_{atm}= atmospheric pressure, s_t = number of strokes on engine cycle (4 or 2)

f) $Q_1 = 3.6q_1$

g) Q_2 is calculated using gas equation $Q_2 = Q_1 \frac{P_1}{T_1}\frac{T_2}{P_2}$, where

h) T is measured in Kelvin = ^{o}C+273.2

i) ISA = 15^{o}C or 288.2K

j) Therefore the table can be expanded as follows;

Speed	Units	Low idle	Rated Torque speed			Rated power speed			
Test number		1	2	3	4	5	6	7	8
Exhaust Volumes									
Engine nominal intake air flow	l/s	48	102	102	102	120	120	120	120
Engine nominal intake air flow (Q_1)	m^3/hr	173	367	367	367	432	432	432	432
Engine nominal flow rate adjusted to ISA[2] (Q_2)	m^3/hr	168	357	357	357	420	420	420	420

k) When the diesel engine was on the dynamometer the following EC particulate readings can be recorded, using one of the instruments in clause 8.2 *Diesel Particulate Monitoring Equipment*.

Note: If the diesel engine complies with the American EPA Tier II or European EPA Stage 2 emission such that dynamometer testing was not required, refer clause 5.2.4 *Engine Dynamometer Testing* then the following information may be extrapolated from the engine's EPA performance data.

Speed	Units	Low idle	Rated Torque speed			Rated power speed			
Test number		1	2	3	4	5	6	7	8
Particulate Concentration (EC)									
EC concentration (*EC_{Vtest}*)	mg/m^3	5	20	55	40	18	30	35	15
Total EC per hour (per test No.) (*EC_{Qtest}*)	mg/hr	841	7146	19651	14291	7566	12610	14712	6305

l) Using the formulae as shown in *Table 5 – Procedure for calculating the diesel particulate index* the particulate index can be calculated as follows:

Speed	Units	Low idle	Rated Torque speed			Rated power speed			
Test number		1	2	3	4	5	6	7	8
Weighted Results									
Weighting factor		0.15	0.1	0.1	0.1	0.15	0.15	0.15	0.1
Weighted EC per hour (*$EC_{Qtestweight}$*)	mg/hr	126	715	1965	1429	1135	1891	2207	630
Weighted power (*$P_{testweight}$*)	kW	0	13	10	7	22	16	11	1
Sum of Weighted Results									
Sum of weighted EC per hour (EC_{kW})	mg/hr	10098							
Sum of weighted power (*P_{WA}*)	kW	81							
Average EC per kW per hour (*EC_{KWH}*)	mg/kW/hr	125							
Minimum mine ventilation per kW (Q_{VentKW})	m^3/s/kW	0.346							
Minimum mine ventilation quantity $Q_{DP(min)}$	**m^3/s**	**28**							

m) Therefore the minimum mine ventilation quantity for that particular diesel engine to meet a 0.1 mg/m^3 EC atmospheric exposure is 28m^3/s with no particulate filter installed. i.e.

$Q_{DP(min)}$ (without a filter installed) = 28 m^3/s

9.7.2 With Particular Filter Installed

Now using the above example and assuming a particular filter is installed which has an 85% efficiency the calculation then becomes:

Speed	Units	Low idle	Rated Torque speed			Rated power speed			
Test number		1	2	3	4	5	6	7	8
Torque %		0%	100%	75%	50%	100%	75%	50%	10%
Torque (T)	Nm	0	750	562.5	375	700	525	350	70
Speed (n)	rpm	800	1700	1700	1700	2000	2000	2000	2000
Power (P_{test})	kW	0	134	100	67	147	110	73	15
Exhaust Volumes									
Engine nominal intake air flow	l/s	48	102	102	102	120	120	120	120
Engine nominal intake air flow (Q_1)	m^3/hr	173	367	367	367	432	432	432	432
Engine nominal flow rate adjusted to ISA[2] (Q_2)	m^3/hr	168	357	357	357	420	420	420	420
Particulate Concentration (as EC)									
Without filter (EC_{Vtest})	mg/m^3	5	20	55	40	18	30	35	15
With filter 85% efficient - (EC_{Vtest})	mg/m^3	0.75	3	8.25	6	2.7	4.5	5.25	2.25
Total EC per hour (per test No.) (EC_{Qtest})	mg/hr	126	1072	2948	2144	1135	1891	2207	946
Weighted Results									
Weighting factor		0.15	0.1	0.1	0.1	0.15	0.15	0.15	0.1
Weighted EC per hour ($EC_{Qtestweight}$)	mg/hr	19	107	295	214	170	284	331	95
Weighted power ($P_{testweight}$)	kW	0	13	10	7	22	16	11	1
Sum of Weighted Results									
Sum of weighted EC per hour (EC_{kW})	mg/hr	1515							
Sum of weighted power (P_{WA})	kW	81							
Average EC per kW per hour (EC_{KWH})	mg/kW/hr	19							
Minimum mine ventilation per kW (Q_{VentKW})	$m^3/s/kW$	0.05							
Minimum mine ventilation quantity $Q_{DP(min)}$	**m^3/s**	**4**							

Therefore the minimum mine ventilation quantity for that particular diesel engine to meet a $0.1 mg/m^3$ EC atmospheric exposure in $4 m^3/s$ with no particulate filter installed. i.e.

$Q_{DP(min)}$ (with filter installed) = $4\ m^3/s$

9.7.3 Minimum Ventilation quantity

The manufacture is then required to provide the following information to all users of this diesel engine. Refer 4.3 *Minimum Ventilation Quantity*.

The minimum ventilation quantity for:

(i) Gaseous emissions = 0.06x150 = 9 m^3/s

(ii) Particulate emission with no particulate filter installed = 28 m^3/s

(iii) Particulate emissions with a particulate filter installed = 4 m^3/s