

Australian/New Zealand Standard™

Diesel engine systems for underground coal mines

Part 1: Fire protected—Heavy duty



AS/NZS 3584.1:2008

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Australian Chamber of Commerce and Industry
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Department of Consumer and Employment Protection (WA)
Department of Labour New Zealand
Department of Mines and Energy (Qld)
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Australian/New Zealand Standard™

Diesel engine systems for underground coal mines

Part 1: Fire protected—Heavy duty

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME-018, Mining Equipment, to supersede AS/NZS 3584.1:2005.

The objective of this Standard is to promote the safety of fire-protected diesel engine systems that are used underground in coal mines.

This Standard is one of the following series of the standards:

AS/NZS

- 3584 Diesel engine systems for underground coal mines
- 3584.1 Part 1: Fire protected (this Standard)
- 3584.2 Part 2: Explosion protected
- 3584.3 Part 3: Maintenance

This edition allows for the implementation of new technology in diesel engine systems, including the use of dry exhaust systems, limiting the emission of diesel aerosol particulates and generally reducing the emission of pollutants. This edition facilitates the use of electronically managed diesel engine systems. Its emphasis is to facilitate the implementation of new technology resulting in the increased operational safety of diesel engine systems.

Statements expressed in mandatory terms in notes to tables are deemed to be requirements of this Standard.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND**Australian/New Zealand Standard
Diesel engine systems for underground coal mines****Part 1: Fire protected—Heavy duty****SECTION 1 SCOPE AND GENERAL****1.1 SCOPE**

This Standard specifies safety requirements for diesel engine systems that are fire protected for use in designated safe areas in underground coal mines. It applies to diesel engine systems with heavy duty applications. Whether a particular application is heavy duty will need to be determined by the end user and the manufacturer, using risk management processes.

NOTES:

- 1 Designated safe area is defined in Clause 1.4.3.
- 2 The Appendices in this Standard are included in a logical sequential order:
 - (a) Appendix A provides guidance for demonstrating compliance to this Standard.
 - (b) Appendix B nominates the requirements for determining load-speed characteristics.
 - (c) Appendix C nominates the requirements for determining the constituents of the exhaust gas.
 - (d) Appendix D nominates the requirements for determining gaseous emission levels.
 - (e) Appendix E nominates the requirements for duration testing for temperatures and fluid usage.
 - (f) Appendix F nominates the test requirements for protection systems.
 - (g) Appendix G nominates the test requirements for spark arresters.
 - (h) Appendix H nominates the test requirements for particulate filter components.
 - (i) Appendix I specifies measuring equipment.
 - (j) Appendix J specifies diesel fuel used for testing.
 - (k) Appendix K provides a chart to compare smoke measurements using different units of measure.
- 3 This Standard addresses abnormal combustion.

1.2 APPLICATION

This Standard is intended for manufacturers, users, regulatory authorities, testing authorities and associated interests. It has no legal authority in its own right, but may acquire legal standing in one or more of the following ways:

- (a) Adoption by a regulatory authority.
- (b) Reference to compliance with the Standard as a contract requirement.
- (c) Claim by a manufacturer or manufacturer's agent of compliance with the Standard.

The requirements of this Standard shall apply to fire-protected diesel engine systems manufactured following the publication date of this Standard. This provision need not apply where a contract for the supply of a fire-protected diesel engine system has been entered into prior to that time.

NOTES:

- 1 There is a high probability that a fire-protected diesel engine will be an ignition source if operated in flammable or explosive atmospheres.
- 2 Statutory authorities may provide guidelines related to the use and application of the technologies described in this Standard.

1.3 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

1019	Internal combustion engines—Spark emission control devices
1023	Low voltage switchgear and control gear—Protection of electric motors
1023.1	Part 1: Built-in thermal detectors and associated control units
1319	Safety signs for the occupational environment
1722	Pipe threads of Whitworth form
1722.1	Part 1: Sealing pipe threads
2149	Starter batteries—Lead-acid
4024.1	(Series) Safety of machinery
4024.1301	Part 1301: Risk assessment—Principles or risk assessment
4024.1501	Part 1501: Design of safety related parts of control systems—General principles for design
4024.1502	Part 1502: Design of safety related parts of control systems—Validation
4024.1604	Part 1604: Design controls, interlocks and guarding—Emergency stop—Principles for design
5062	Fire protection for mobile and transportable equipment
60529	Degree of protection provided by enclosures (IP Code)
60947	Low-voltage switchgear and controlgear
60947.4.1	Part 4.1: Contactors and motor-starters—Electromechanical contactors and motor-starters
62061	Safety of machinery—Functional safety of safety-related electrical, electronic and programmable electronic control systems
ISO/IEC 17025	General requirements for the competence of testing and calibration laboratories

AS/NZS

3584	Diesel engine systems for underground coal mines
3584.2	Part 2: Explosion protected
3584.3	Part 3: Maintenance
4871.1	Electrical equipment for coal mines, for use underground
4871.1	Part 1: General requirements
4871.2	Part 2: Distribution, control and auxiliary equipment
4871.3	Part 3: Substations
4871.4	Part 4: Mains powered electrical mobile machines
4871.5	Part 5: Battery powered electrical mobile machines
4871.6	Part 6: Diesel powered machinery and ancillary equipment
60079	Explosive atmospheres
60079.11	Part 11: Equipment protection by intrinsic safety ‘i’
ISO 9001	Quality management systems—Requirements
ISO 9004	Quality management systems—Guidelines for performance improvements

ISO	
8178	Reciprocating internal combustion engines—Exhaust emission measurement
8178-1	Part 1: Test-bed measurement of gaseous and particulate exhaust emissions
8178-4	Part 4: Test cycles for different engine applications
ASTM	
D1298	Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
SA	
HB 18	Conformity assessment
HB 18.28	Guide 28: Guidance on a third-party certification system for products
SAE	
J1003	Diesel engine emission measurement procedure
J244	Measurement of intake air or exhaust gas flow of diesel engines
ADR	
30	Diesel engine exhaust smoke emissions

1.4 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

1.4.1 Abnormal combustion

Unintended or uncontrolled combustion in the engine.

NOTES:

- 1 Abnormal combustion may be caused by induced flammable gas, liquid or vaporized hydrocarbons.
- 2 Abnormal combustion may cause intake flashbacks, high exhaust temperature or high surface temperatures or catastrophic engine failure, engine overspeed and uncontrollable engine running.
- 3 Abnormal combustion may not be apparent to an operator except for a marginal change of power and/or emissions.

1.4.2 Catalytic converter

Equipment that modifies the constituents of an exhaust gas stream by means of a catalyst.

1.4.3 Designated safe area

A place in which there is a minimum likelihood of an explosive atmosphere being present, which would require special precautions while a diesel engine is operated, serviced or maintained.

NOTES:

- 1 It cannot be assumed that areas of a mine that are not classified as being explosion risk zones are designated safe areas.
- 2 Legislation, regulations or requirements by the relevant statutory authority may define a designated safe area in greater detail.

1.4.4 Emergency stop system

A device or devices, fitted to stop the diesel engine system, in the event of the failure of the automatic safety shutdown system, manual shutdown system and the simultaneous failure of the manual fuel shut-off valve to cause the engine to stop.

1.4.5 Engine safety shutdown system

A system fitted to stop the diesel engine in the event of the failure of the other systems to stop the engine.

1.4.6 Explosion-risk zone

A place where during the normal course of events there is a possibility of an accumulation of flammable or explosive gas that could create a hazard for the operation, servicing or maintenance of a diesel engine system.

NOTE: Legislation for underground coal mines may define certain parts of the mine as explosion-risk zones and may use the term 'hazardous area' to describe an explosion-risk zone.

1.4.7 Fire-protected diesel engine system

A diesel engine and its—

- (a) inlet systems;
- (b) exhaust systems;
- (c) cooling systems;
- (d) starting systems;
- (e) shutdown and protection systems;
- (f) associated electrical items, including alternators, batteries and wiring; and
- (g) other ancillary equipment attached to or driven by the engine, including systems that start the engine or are associated with the engine operation or engine control.

It excludes equipment driven from the output side of the engine flywheel.

1.4.8 Fire protection

Design features that will prevent the diesel engine system from igniting flammable material or substances, excluding flammable gas.

NOTE: Fire-protected diesel engine systems do not provide explosion protection (see AS/NZS 3584.2).

1.4.9 Gland

A device for attachment to an electrical enclosure, which allows for the entry of cables, including flexible cables and cords, without detriment to the characteristics of protection of the enclosure.

1.4.10 High idle speed

The maximum governed speed of an engine with minimal output power from the engine and the ancillary equipment.

1.4.11 Low idle speed

The minimum governed speed of an engine with minimal output power from the engine and the ancillary equipment.

1.4.12 Particulate filter

A filter that removes particulates from an exhaust gas stream.

1.4.13 Rated power

The maximum continuous output power, at rated speed, of an engine, as determined by the testing authority in accordance with this Standard.

1.4.14 Rated speed

The speed of an engine while producing rated power.

1.4.15 Rated torque

The torque at speed, developed at maximum fuel rate (i.e., at full throttle), that is provided by either—

- (a) peak torque from engine test results (see Note); or
- (b) engine test results as modified by the manufacturer, where—
 - (i) rated torque is not less than 95% of peak torque as determined from engine tests (see Note); and
 - (ii) engine speed for rated torque is the peak torque speed $\pm 8\%$ of the high free idle speed.

NOTE: Peak torque, peak torque speed and high free idle speed values are determined from tests given in Appendix B.

1.4.16 Shall

Indicates a mandatory requirement.

1.4.17 Should

Indicates a recommendation. Neither adoption, nor omission of the recommendation results in non-compliance.

1.4.18 Smoke

Aerosols, including particulates, in an engine exhaust stream that obscure, reflect or refract light.

1.4.19 Spark arrester

A device, system or method that prevents glowing exhaust particles produced by a diesel engine from contacting combustible materials and from being emitted into the surrounding atmosphere.

1.4.20 Statutory authority

The government department that administers acts and regulations pertaining to coal mines in which a diesel engine system will operate.

1.4.21 Strangler valve

A valve, inserted into the intake airstream, capable of shutting off the supply of intake air to the diesel engine system.

1.4.22 Testing authority

A body acceptable to the relevant statutory authority to carry out the tests prescribed herein (normally a nationally accredited testing authority).

NOTE: Testing laboratories should be registered by NATA (National Association of Testing Authorities) relevant to the required testing. International laboratories recognized by NATA may be acceptable.

SECTION 2 DESIGN AND CONSTRUCTION

2.1 DESIGNATED SAFE AREA BARRIER

Fire-protected diesel engine systems that are not explosion protected shall be provided with a control system to prevent the diesel engine system from operating in locations that are not designated as safe areas as defined by Clause 1.4.3.

A risk assessment shall be carried out to demonstrate the integrity of the control system.

The risk assessment shall meet the requirements of AS 4024.1301. The control system shall be assessed and validated against the relevant category or safety integrity level in accordance with AS 4024.1501, AS 4024.1502, AS 62061 or other similar Standards.

NOTE: The risk assessment should be in a form that systematically analyses the failure of individual components of the control system. Upon failure of a sensing device, consideration should be given to the rising of an operator alarm or warning, where practicable.

2.2 METHANE DETECTION

A visible or audible indication of the methane concentration in the atmosphere in which the engine is operating shall be provided. It should be integral with, or associated with, the diesel engine shutdown system and should automatically stop, and prevent the starting of the diesel engine system in the event that any detected methane exceeds the maximum acceptable concentration(s) nominated by the statutory authority. Where a methanometer is fitted as part of the diesel engine system, it shall conform with the relevant Australian Standard in respect to response time, accuracy and cross-sensitivity.

Where a methanometer is fitted as a part of any diesel engine system, then, in the event that the detected methane exceeds the maximum acceptable concentration (nominated by the statutory authority), the methanometer shall cause both the automatic and emergency stop systems to operate, causing the engine system to stop.

NOTES:

- 1 The above requirement may be met by providing one or more of the following:
 - (a) A methanometer that is mounted on the vehicle in which the diesel engine system is installed and interconnected with the engine shutdown system.
 - (b) A means by which the permanently installed mine-monitoring system may communicate with the diesel engine system and cause it to stop.
 - (c) A methane-monitoring system designed to prevent the engine from being started up and any non-intrinsically safe (Ex 'ia'), electrical systems from being energized in the event that the concentration of methane exceeds the maximum acceptable limit nominated by the statutory authority.
- 2 See Clause 1.1.1 for requirements for battery isolation switches.
- 3 See AS/NZS 60079.11 for requirements for intrinsically safe (Ex 'ia') electrical apparatus.

2.3 FIRE SUPPRESSION

Where a fire suppression system is fitted, it should be installed and tested in accordance with AS 5062.

2.4 ENGINE TYPES

Engine types shall be compression ignition, distillate fuelled and liquid cooled.

NOTE: Engines may be naturally aspirated, turbo-charged and/or super-charged.

2.5 CONDITION MONITORING

Suitable sampling points shall be provided to allow monitoring of the—

- (a) engine lubricating oil pressure;
- (b) engine speed;
- (c) engine water temperature;
- (d) inlet manifold vacuum;
- (e) exhaust back-pressure; and
- (f) gas stream emissions, both before and after exhaust treatment.

A method of monitoring the safety system status, providing fail/healthy indication for each fault condition, should be provided.

2.6 SURFACE TEMPERATURE

The temperature of any surface that comes into contact with the atmosphere shall not exceed 150°C under any condition of operation.

2.7 ABNORMAL COMBUSTION

Any hazards arising from abnormal combustion arising from induced flammable gas, liquid or vaporized hydrocarbons shall be controlled.

NOTE: For some engine systems and in some circumstances, abnormal combustion may cause intake flashback, high exhaust temperature or high surface temperatures or catastrophic engine failure, engine over-speed, uncontrollable engine running and render the explosion protection system ineffective. For some engine systems and some circumstances, abnormal combustion may not be apparent to an operator except for a marginal loss of power and increased emissions.

2.8 MATERIALS

2.8.1 Non-metallic materials

Where non-metallic materials are used, they should be shielded, routed or located away from heat sources or be fire-resistant as specified by the appropriate Australian Standard.

2.8.2 Insulation materials

Where external insulation is employed to control surface temperatures, the insulation shall be—

- (a) protected against the impregnation of flammable dusts or fluids into the materials;
- (b) if friable or brittle, protected against mechanical damage; and
- (c) fixed and positioned so that it cannot be easily displaced in use or mechanically damaged.

2.8.3 Use of light alloys

Statutory authorities may limit the use of certain light alloys.

2.9 VEE-PULLEYS

Vee-pulleys shall not be manufactured from pressed steel discs.

2.10 ENGINE BREATHER

The discharge from any engine breather shall be directed away from external surfaces of the engine system, so that such surfaces do not become fouled with oil.

2.11 STARTING AIDS

Where electrical heating is required to assist with starting, the devices used need not be explosion protected. Where fitted, glow plugs shall be designed to turn off automatically.

2.12 FUEL SYSTEMS

Settings, including electronic controls, screws and stops on fuel injection pumps shall be sealed after adjustment, using a method that indicates any unauthorized entry or adjustment.

Injectors with external means of adjustment shall be sealed after adjustment, using a method that indicates any unauthorized entry or adjustment. Injectors shall be clearly marked with a part number.

High-pressure fuel lines shall comply with the engine manufacturer's specification.

Low-pressure fuel lines shall be installed so that they are shielded from any heat that may cause damage and failure.

2.13 AIR INLET SYSTEMS

Air inlet systems shall be fitted with an air filter assembly and an inlet-manifold vacuum monitor. The filter should be adequately sized.

The air inlet system may be fitted with a strangler valve (see Clause 1.4.21) or an inert gas system as a part of the emergency stop system (see Clause 2.16.3).

The fitment of these devices should not significantly increase the inlet vacuum.

NOTES:

- 1 Oversized dry-type air filters are recommended, to allow for high dust loads.
- 2 Air inlet vacuum should not exceed 5.3 kPa under any condition of load or speed.
- 3 The vacuum indicator should be readily visible to the operator.

2.14 AIR COMPRESSORS

Air compressors forming part of a diesel engine system shall not exceed a surface temperature of 150°C under any condition of operation. Liquid-cooled compressors are deemed to meet this requirement.

Hoses that are attached to an air compressor delivery port shall be of PTFE steel-wire reinforced braided construction or equivalent heat-resisting material.

NOTE: A compressor associated with an airconditioning system is not deemed to be an air compressor.

2.15 COOLING SYSTEMS

Cooling systems shall comply with the following requirements:

- (a) The systems shall—
 - (i) be designed to allow the engine to operate satisfactorily in an atmosphere with a minimum ambient temperature of 40°C;
 - (ii) not entrap air within the system; and
 - (iii) safely vent excess pressure to atmosphere.
- (b) Each radiator filler and radiator cap shall be arranged or interlocked so that coolant pressure behind the fill point cap or radiator cap is safely released prior to the cap being able to be removed.
- (c) Pressurized coolant systems shall be fitted with a means of checking the level of coolant in the system without the need to remove pressure from the system.
- (d) Cooling fans and rotating parts shall be guarded in accordance with AS 4024.1

2.16 ENGINE SHUTDOWN SYSTEMS

2.16.1 General

A risk assessment shall be carried out to demonstrate the integrity of the engine safety shutdown systems.

The risk assessment shall meet the requirements of AS 4024.1301. The engine shutdown system shall be assessed and validated against the relevant category or safety integrity level in accordance with AS 4024.1501, AS 4024.1502, AS 62061 or other similar standards.

NOTE: The risk assessment should be in a form that systematically analyses the failure of individual components of the engine shutdown systems. Upon failure of a sensing device, consideration should be given to the raising of an operator alarm or warning, where practicable.

2.16.2 Automatic safety shutdown system

The engine shall be fitted with a fail-to-safety automatically operated engine (fuel) shutdown system.

The system shall also be able to be stopped by manual actuation of the automatic shutdown system.

NOTE: The manual control for the automatic fuel shut-off valve should be easily accessible to the operator in the normal operating position.

The system shall cause the engine to stop (fail-to-safety) in the event that the shutdown system fails. A failure modes effect analysis (FMEA) shall be prepared to substantiate that the system fails to safety.

2.16.3 Emergency stop system

The engine system shall be fitted with an emergency stop system.

The emergency stop system shall be capable of operation in the event that the automatic safety shut down system fails to cause the engine system to stop for any reason.

The emergency stop control system shall be designed so that a single fault in the controls shall not lead to the loss of the safety function.

The emergency stop system shall be in accordance with AS 4024.1604.

The emergency stop system may be automatically operated.

In addition to any automatic means of operating the emergency stop system, it shall be capable of manual operation in an emergency. The manual control shall be located so that it can be easily reached by the operator (driver) of a machine (vehicle) fitted with fire-protected diesel engine system. The manual control shall be clearly identified and labelled. Gas systems shall not rely on the operator to continually hold down the emergency stop device to discharge the gas. Consideration shall be given to providing additional gas to shut down the engine on a second occasion in an emergency situation.

The emergency stop system shall be capable of being tested independently of all other engine-stopping systems.

Any stored pressure inert gas system that is fitted to meet the requirements of this Clause shall have sufficient gas to stop the engine before the gas is expended (see Note 2).

The operation of the emergency stop system shall be tested in accordance with Paragraph F6.3.12, Appendix F.

NOTES:

- 1 For guidance as to fault management in emergency stop control systems, see AS 4024.1501 and AS 4024.1604.

- 2 A strangler valve may meet the above requirement (see Clause 1.4.21.) Care should be taken in the selection of a strangler valve to ensure that it will seal under vacuum conditions. (Many commercial valves may be rated for high pressure but leak under relatively low vacuum conditions). A sudden vacuum applied in the inlet systems of some later engine types may cause valve stem seal to become displaced, or cause other failures. The original engine manufacturer should be consulted. For such an engine, a partial sealing strangler valve may need to be combined with other means of ensuring a complete engine stop in an emergency.
- 3 An inert gas injection system may meet this requirement. Care should be taken in the selection of any inert gas employed to ensure—
 - (a) the gas does not form chemicals under diesel combustion temperatures and pressures that may be poisonous or carcinogenic; and
 - (b) the temperature of the gas is not so cold that it may cause catastrophic failure of engine components when injected.
- 4 Cold inert gas systems may not be safe for turbo-charged engine systems.

2.16.4 Manual fuel shut-off valve

The manual fuel shut-off valve shall be clearly identified and labelled and include operating instructions. The label shall be as close as practicable to the valve.

In addition, the physical location of the valve shall be clearly indicated by a second label readily visible to the operator (driver) of any vehicle to which an explosion-protected engine system is fitted.

The manual fuel shut-off valve should be connected to the fuel system after all supply (lift) pumps and filters, to minimize the time required to shut down the engine system after operation of the valve.

The operation of the manual fuel shut-off valve shall be tested in accordance with Paragraph F6.3.7, Appendix F.

NOTE: The connection of 'fuel return' lines to the fuel tank, or filters from the injection pump, may require the fitment of check valves to ensure that, when the manual fuel shut-off valve is closed (non-passing), flow cannot reverse in 'fuel return' lines causing the engine to continue to run.

2.16.5 Sensing devices

The engine safety shutdown system shall include the following sensors, which shall automatically shut down the system:

- (a) One or more coolant temperature sensors installed in the engine jacket cooling circuit, at or near the point or points of highest temperature.
- (b) Where there are two or more cooling circuits, each circuit shall be fitted with a coolant temperature and pressure sensor.
- (c) A sensor to measure low engine oil pressure, which shall be set to operate at a pressure of not less than the engine manufacturer's minimum recommendation.
- (d) Spark arrester device shutdown sensors, if required by Clause 2.17.3.
- (e) Any exhaust filter shutdown sensors, if required by Clause 2.17.5.
- (f) Exhaust cooling shutdown sensors, if required by Clause 2.17.4.
- (g) Any sensors or other means to monitor methane (see Clause 2.2).

NOTES:

- 1 The functions nominated above may be combined in any mechanical or design configuration, provided the designed assembly complies with the requirements for testing in Section 4.
- 2 A data acquisition or a logging device is recommended.

2.16.6 Engine start and restart

Following any manual operation of the emergency stop system, the system shall be required to be deliberately and manually reset before the engine is restarted or run.

Following operation of the automatic safety shutdown system, the engine shall not be able to be restarted until the fault is rectified, except that the system shall allow override features for a period of not more than 30 s on low oil pressure or low coolant pressure, to permit the engine to be started under normal circumstances. For engines with factory-fitted electronic controlled injection systems, the override periods for the factory-fitted shutdown sensors for low oil pressure or low coolant pressure, built into the electronic control module, shall be acceptable.

Following a shutdown on methane detection, no electrical system shall remain live unless it is explosion protected. This does not include the engine starting battery meeting the requirements of Clause 2.18 and its connection to the isolator.

NOTE: Magneto, self-excited or permanent magnet alternators remain alive while rotating and may not meet this requirement.

The engine shall not be able to be started, and non-explosion-protected electrical systems shall not be restored, until the methanometer has had sufficient time to detect the methane level as being less than the nominated safe set point.

2.17 EXHAUST

2.17.1 General

The exhaust system shall include the following:

- (a) A means of arresting sparks.
- (b) A means of cooling the exhaust gas stream to less than 150°C at the point of discharge to atmosphere.
- (c) A means of maintaining surface temperatures to not more than 150°C under all conditions of operation.
- (d) Monitoring and shutdown devices complying with the various requirements of Clause 2.16.

NOTE: Single sensing devices may be used to satisfy multiple combinations of the shutdowns required by Clause 2.16.

In addition, any hoses or pipework used in the exhaust system, including any connections to monitoring devices, shall be rated for the temperature, pressure and environment to which they are intended to be exposed.

The design of the exhaust exit should minimize the raising of dust from the mine roadway.

2.17.2 Exhaust systems

Exhaust systems may also include the following:

- (a) A diluting device, to dilute the exhaust gas stream with air.
- (b) A catalytic device, to modify the constituents of the exhaust gas stream.
- (c) A filtration system, to reduce the discharge of smoke.

NOTES:

- 1 The functions nominated above may be combined in any mechanical or design configuration, provided the designed assembly meets the requirements of Section 4 (Testing).
- 2 The exhaust gas entering the atmosphere should not impinge on any person or flammable material.

2.17.3 Spark arrester

The exhaust system shall prevent the discharge of sparks capable of igniting flammable materials and shall comply with the following:

- (a) Where spark arresters reliant on a water level or flow for effectiveness are fitted, they shall include two sensors that will detect the loss of liquid, which would cause the device to become unsafe or ineffective. Both sensors shall independently cause the engine system to stop automatically in the event of a loss of the liquid barrier under any condition of test (see Appendices F and G for tests). Sensors and associated engine shutdown systems should fail-to-safety. Sensors may be—
 - (i) two sensors measuring the minimum effective safe water level;
 - (ii) two sensors measuring water flow to the spark arrester; or
 - (iii) one sensor measuring the exhaust gas stream temperature and another measuring the minimum safe level or flow of water.
- (b) Where a spark arrester cooling circuit is separated and isolated from the main engine cooling circuit, a loss-of-coolant monitoring device that will cause the diesel engine system to automatically stop in the event of a loss of coolant shall be fitted to the spark arrester coolant circuit.
- (c) Where mechanical devices not reliant on the retention or flow of liquid for effectiveness are fitted, they shall meet the requirements of AS 1019 or Appendix G. Sensing devices are not required for a positive mechanical spark arrester or a turbo-charger.

NOTE: Spark arresters may be of various designs, including but not limited to water spray, water injection, water bath, labyrinth or screen type devices.

2.17.4 Exhaust cooling

The exhaust gas cooling system may be a separate device or may be combined with the functions of the spark arrester (see Clause 2.17.3) or a fume diluter.

An air dilution device may be used to achieve the exhaust temperature limits.

Each exhaust system shall be provided with two sensors, at least one of which senses the exhaust gas temperature downstream of any cooling device that will cause the diesel engine system to stop automatically whenever the temperature of the exhaust gas stream exceeds 150°C at the point of discharge.

2.17.5 Particulate filter

2.17.5.1 General

Where a filtering system is required to comply with the requirements of Clause 2.17.6.4, the filter systems shall meet the requirements of Appendices C and H.

Where a blocked-filter bypass (waste-gate) valve is fitted, an audible or visual indicator indicating bypass operation shall be fitted.

Where a filtering system is required to comply with the requirements of Clause 2.17.6.4, a nameplate shall be fitted in a conspicuous location on the filter housing. The nameplate shall state that the system shall not be operated without a filter fitted and that a blocked-filter bypass shall not be fitted.

2.17.5.2 Replaceable element-type filters

Any replaceable element-type filter system shall comply with the following:

- (a) It shall be rated for continuous operation without ignition, smoking or the production of noxious gases.

- (b) It shall be fitted on the output side of the spark arrester, unless manufactured from non-combustible material.
- (c) It shall be fitted with a stainless steel nameplate that is permanently fixed to the outside of the filter carrier housing and marked with the manufacturer's name or mark, the replacement element part number and the element's safe operating temperature rating.
- (d) It shall have either an engine shutdown sensor or a visual and/or audible indication of a blocked filter.
- (e) It shall have filter elements that either—
 - (i) withstand a temperature greater than the maximum exhaust temperature that may be reached while the exhaust gas cooling device is removed or disabled; or
 - (ii) have at least two independent sensors so that the diesel engine system will stop automatically if the exhaust gas stream temperature becomes hotter than either—
 - (A) 50°C below the auto ignition temperature of the filter assembly; or
 - (B) 25°C below the rated maximum continuous operating temperature of the filter assembly.

At least one of these sensors shall be installed upstream and one downstream of the filter assembly.

Filter elements shall also be permanently marked with the manufacturer's name, mark, part number and rated maximum continuous operated temperature rating.

2.17.5.3 *Filter-ignition temperature measurements*

New and blocked (dirty) filters shall be tested in accordance with Appendix H to measure rated maximum continuous operating temperature of the filter and filter auto ignition temperatures.

2.17.6 Exhaust emissions

2.17.6.1 *General*

The provision of evidence of compliance with Tier 2/Stage II emissions is sufficient evidence of compliance with this Clause. The engine system manufacturer shall provide evidence of compliance after any modification to the engine system that would influence its emissions to the extent it would fail its Tier 2/Stage 2 tests.

NOTES:

- 1 Limited multi-point sample testing meets this requirement.
- 2 Tier 2 and Stage II are American and European Standards for emissions.

2.17.6.2 *Exhaust*

Undiluted exhaust gas emissions shall be measured in accordance with Appendix C, before and after any treatment. The manufacturer may nominate that the exhaust constituents are to be sampled prior to any water-based device.

NOTE: Water-based devices may reduce some of the constituents in the exhaust gas stream.

Emissions after treatment shall not contain more than—

- (a) 0.010% (100 ppm) by volume of NO₂;
- (b) 0.09% (900 ppm) by volume of NO; and
- (c) 0.11% (1100 ppm) by volume of CO.

Test results for untreated exhaust emissions shall be recorded for reference purposes.

NOTES:

- 1 Statutory authorities may—
 - (a) require diesel gas emissions and/or particulate matter (DPM) and/or smoke readings to be measured and recorded in a particular way; and
 - (b) set pass/fail criteria from time to time.
- 2 Testing authorities and manufacturers should check with the appropriate statutory authority prior to testing the engine system.

2.17.6.3 Gravimetric emissions (gaseous)

The exhaust gas emissions shall be measured in accordance with Appendix D.

NOTES:

- 1 Such data should provide users with information in a form that will enable the exposure limit values to be more easily calculated, for any power or condition of operation, and enable users to make meaningful comparisons between different diesel engine systems.
- 2 No pass/fail criteria are nominated for these results.

2.17.6.4 Smoke

Prior to any dilution, the smoke shall be measured in accordance with Appendix C, both before and after exhaust treatment. After exhaust treatment, the Bosch index number of the smoke shall comply with the following:

- (a) *Duty cycle test* The calculated weighted Bosch smoke unit index shall be less than that indicated by the graph line in Figure C1, Appendix C, with the calculation of the exhaust gas flow rate (G) based on Clause 2.17.6.4(b).
- (b) *Single point tests* At each point tested, the Bosch index number shall be within the limits of the graph line in Figure C2, Appendix C.

The exhaust gas flow rate (G), in litres per second, shall be determined as follows:

$$G = \frac{V \times n}{60} \times \frac{P_{\text{atm}} + P_{\text{b}}}{P_{\text{atm}}} \quad \text{for two-stroke engines}$$

$$G = \frac{V \times n}{120} \times \frac{P_{\text{atm}} + P_{\text{b}}}{P_{\text{atm}}} \quad \text{for four-stroke engines}$$

where

- n = crankshaft speed, in revolutions per minute (r/min)
- V = total cylinder swept volume, in litres
- P_{b} = turbo or super-charge boost pressure at rated power; or
= 0 for naturally aspirated engines
- P_{atm} = atmospheric pressure

NOTE: For a comparison between soot concentration in gravimetric units and Bosch smoke meter values, see Appendix K.

Test results for untreated exhaust shall be recorded for reference purposes.

2.17.6.5 Test point

Test points with an RC 1/8-6 thread, as specified in AS 1722.1, shall be provided before and after each exhaust treatment device, so that emissions and temperatures in the exhaust system can be measured.

2.18 ELECTRICAL SYSTEMS

The entirety of any electrical system or equipment installed on a fire-protected diesel engine system shall conform to the relevant requirements of AS/NZS 4871.1, AS/NZS 4871.2, AS/NZS 4871.3, AS/NZS 4871.4, AS/NZS 4871.5 and AS/NZS 4871.6, as applicable.