

Australian/New Zealand Standard™

Diesel engine systems for underground coal mines

Part 2: Explosion protected



AS/NZS 3584.2:2008

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee ME-018, Mining Equipment. It was approved on behalf of the Council of Standards Australia on 19 January 2007 and on behalf of the Council of Standards New Zealand on 2 February 2007.

This Standard was published on 23 January 2008.

The following are represented on Committee ME-018:

Australasian Institute of Mining and Metallurgy
Australian Chamber of Commerce and Industry
Australian Coal Association
Bureau of Steel Manufacturers of Australia
Chamber of Minerals and Energy of Western Australia
Department of Infrastructure, Energy and Resources (Tasmania)
Department of Labour, New Zealand
Department of Mineral Resources, N.S.W.
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This Standard was issued in draft form for comment as DR 06619.

Australian/New Zealand Standard™

Diesel engine systems for underground coal mines

Part 2: Explosion protected

Originated as AS 3584—1988.
Second edition 1991.
Jointly revised and redesignated as AS/NZS 3584.2:2003.
Second edition 2008.

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Jointly published by Standards Australia, GPO Box 476, Sydney, NSW 2001 and Standards New Zealand, Private Bag 2439, Wellington 6020

ISBN 0 7337 8516 6

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME-018, Mining Equipment, to supersede AS/NZS 3584.2:2003.

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

This Standard is one of the following series of Standards:

AS/NZS

- 3584 Diesel engine systems for underground coal mines
- 3584.1 Part 1: Fire protected—Heavy duty
- 3584.2 Part 2: Explosion protected (this Standard)
- 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. New measures have been included to provide a greater assurance of safety by preventing the propagation of an internal explosion. Its emphasis is to facilitate the implementation of new technology resulting in the increased operational safety of diesel engine systems.

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.

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

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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard **Diesel engine systems for underground coal mines**

Part 2: Explosion protected

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies safety requirements for diesel engine systems that are explosion-protected for use in underground coal mines, including use in explosion-risk zones.

NOTES:

- 1 Compliance to this Standard implies a limited time safe operation in atmospheres containing up to 1% methane, including—
 - (a) the control of surface temperature, to avert ignition of coal dust that could settle on a hot surface;
 - (b) containment or elimination of flames and sparks that could ignite flammable gases and dust that may be present (such as in underground coal mines); and
 - (c) control of diesel emissions.
- 2 This Standard also addresses inadvertent short-term exposure to high methane levels and any consequent abnormal combustion.
- 3 Appendix A gives guidance for demonstrating compliance with this Standard.

1.2 APPLICATION

This Standard is intended for the guidance of manufacturers, users, regulatory authorities, testing authorities and associated interests. It has no legal authority in its own right, but it 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.

This Standard nominates the means by which identified hazards may be managed. Alternative technologies or innovations may also provide solutions to the management of these hazards. An alternative technology or innovation may be adopted, provided the alternative meets or exceeds the applicable requirements of this Standard. A formal risk assessment, meeting applicable Standards, shall be required to provide evidence of such compliance.

In addition to the requirements of this Standard, there may be other requirements set by the regulatory authority. Users of this Standard should, therefore, make themselves aware of any such requirements where the diesel engine system will be used.

1.3 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

- 1019 Internal combustion engines—Spark emission control devices
- 1722 Pipe threads of Whitworth form
- 1722.1 Part 1: Sealing pipe threads

AS

- 2784 Endless wedge belt and V-belt drives
- 4024 Safeguarding of machinery
- 4024.1 Part 1: Safety of machinery (series)
- 4024.1301 Part 1301: Principles of risk assessment
- 4024.1501 Part 1501: General principles
- 4024.1502 Part 1502: Validation
- 4024.1601 Part 1601: Guards—General requirements for the design and construction of fixed and moveable guards
- 4024.1604 Part 1604 Emergency stop—Principles for design
- 62061 Safety of machinery—Functional safety of safety-related electrical, electronic and programmable electronic control systems

AS/NZS

- 1826 Electrical equipment for explosive gas atmospheres - Special protection - Type of protection 's'
- 4871 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 Electrical apparatus for explosive gas atmospheres
- 60079.0 Part 0: General requirements

ISO 9000 Quality management systems—Fundamentals and vocabulary

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

ADR [Australian Design Rules]

30 Diesel engine exhaust smoke omissions

ASTM

D1298 Standard Test Method for Density, Relative Density (Specific gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

HB [Standards Australia handbook]

18 Conformity assessment

18.28 Guide 28: Guidance on third-party certification scheme for products

SAE

J 244 Measurement of intake air or exhaust gas flow of diesel engines

J 255 Diesel engine smoke measurement

J 1003 Diesel engine emission measurement procedure, recommended practice

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, uncontrollable engine running and/or render the explosion protection system ineffective.
- 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 possibility of an explosive atmosphere being present in such quantities that would require special precautions while a diesel engine is operated, serviced or maintained.

NOTES:

- 1 The management of fire and explosion hazards is of particular importance to the safety of underground coal mines.
- 2 It cannot be assumed that areas of a mine that are not classified as being explosion-risk zones are designated safe areas.
- 3 Legislation, regulations or requirements by the relevant statutory authority may define designated safe areas in greater detail.
- 4 The statutory authority may require the use of risk-analysis techniques, to identify designated safe areas. Such techniques may require safe areas to be enclosed by barriers, even where the probability of an occurrence is considered to be very low, or where events having a maximum reasonable consequence of a fatality exist.
- 5 Where a consequence could be catastrophic, the mathematical product of risk and consequence may not be appropriate for the risk assessment decision-making process.

1.4.4 Engine safety shutdown system

A protection system that automatically causes an engine to stop in the event of an unsafe condition occurring.

1.4.5 Emergency 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-protected diesel engine system

A diesel engine that is designed, manufactured and maintained so it will not propagate or generate flame or sparks, which could initiate an explosion of the surrounding atmosphere. The diesel engine system includes—

- (a) inlet systems and inlet flametrap;

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

NOTE: Equipment driven from the output side of a diesel engine flywheel should not be considered to be part of any explosion-protected diesel engine system.

1.4.7 Explosion-risk zone

A place where during the normal course of events there is a possibility that there may be 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.

1.4.8 Fire protection

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

NOTE: Such features are not necessarily intended to prevent the ignition of flammable or explosive gas.

1.4.9 Flametrap

A device that prevents the propagation of an explosion of gas from a diesel engine to the outside atmosphere.

NOTE: Flametraps may be dry (not relying on water for effectiveness) or wet (relying on the retention or presence of water).

1.4.10 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 explosion-protected characteristics of the enclosure.

1.4.11 High-idle speed

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

1.4.12 Low-idle speed

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

1.4.13 Particulate filter

A filter that removes particulates from an exhaust gas stream.

1.4.14 Rated power

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

1.4.15 Rated speed

The speed of an engine while producing rated power.

1.4.16 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 Appendix B); 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 Appendix B); and
 - (ii) the engine speed for rated torque is the peak torque speed $\pm 8\%$ of the high idle speed.

NOTE: Peak torque, peak torque speed and high idle speed values are determined from tests (see Appendix B).

1.4.17 Shall

Indicates that a statement is mandatory.

1.4.18 Should

Indicates a recommendation.

1.4.19 Smoke

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

1.4.20 Spark arrester

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

1.4.21 Statutory authority

The government department or authority that administers safety and health legislation pertaining to coal mines in which a diesel engine system will operate.

1.4.22 Strangler valve

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

1.4.23 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 bodies should be traceable to the Joint Accreditation System of Australia and New Zealand (known as JAS-ANZ), which has been established for the purpose of accrediting testing laboratories to undertake testing.

SECTION 2 DESIGN AND CONSTRUCTION

2.1 ENGINE TYPES

Engines shall be compression ignition, diesel-fuelled and water-cooled types.

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

2.2 CONDITION MONITORING

Suitable sampling points shall be provided to allow monitoring of—

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

2.3 SURFACE TEMPERATURE

The temperature of any surface that comes into contact with the atmosphere shall not exceed 150°C under any condition of operation, including when tested in accordance with Appendix E.

2.4 MATERIALS

2.4.1 Non-metallic materials

The use of non-metallic materials for external components of a diesel engine system shall be kept to a minimum. Where such materials are used, they shall be shielded and routed away from heat sources or be fire-resistant, as specified by the relevant Australian Standard.

2.4.2 Light metals

Rotating components external to the engine (e.g., fan hubs, fan blades, pulleys) shall not be of light metal, as nominated by the statutory authority.

NOTES:

- 1 Where practicable, the use of light metals should be avoided. Where externally exposed non-rotating light metals are used, they should be protected by a coating and contained in an engine compartment. The coating will have to meet the test requirements for impact tests on coated light metal parts (see Appendix N).
- 2 When installed, the engine should be fully within the confines of an engine compartment. The installation of the engine in the engine compartment of the machine is beyond the scope of this Standard and thus is not covered by the requirements herein.

2.4.3 External thermal insulation

External thermal insulation shall be totally enclosed within corrosion and impact-resistant material and effectively prevented from absorbing dust or fluids.

2.5 FLEXIBLE METALLIC PIPES

Any flexible metallic pipes shall be designed and installed to avoid stresses that could cause the pipe to rupture.

Flexible metallic pipes shall not be used between the inlet and exhaust flametraps.

2.6 JOINTS

2.6.1 Designation

Each joint within an explosion-protected diesel engine system shall be designated as being either a fixed connection or an open joint.

2.6.2 Fixed connection

A fixed connection shall—

- (a) be gas tight;
- (b) not include parts or components between which there is or may be relative movement;
- (c) when tested in accordance with Paragraphs M4.1 and M4.2, Appendix M, for component testing of systems, as applicable, withstand the hydrostatic test pressure specified in Table M1;
- (d) have a metallic or fire-resistant gasket interposed between mating surfaces of flanged connections; and
- (e) where screwed fixed connections are used, be gas tight, without the use of thread sealing compounds or materials (see Note 2).

NOTES:

- 1 The fuel system, including the fuel injectors, may be taken to be a fixed connection, provided it meets the requirements for hydrostatic testing.
- 2 O-rings may be used to meet this requirement.

2.6.3 Open joints

Open joints shall comply with the following requirements (see Figures 2.1, 2.2 and 2.3):

- (a) The flamepath length and flamepath gap of any linear continuous open path between the internal parts of an explosion-protected diesel engine system and the surrounding atmosphere shall be within the constraints specified by Figures 2.2 and 2.3.

Piston skirts and cylinder bores are exempt from this provision. The following components are also exempt from this requirement, provided they are capable of passing the flameproof test specified by Appendix L:

- (i) Valve stems and valve guides.
- (ii) Intake and exhaust flametraps.
- (iii) Water injection nozzles fitted to cool or clean the exhaust gas stream and system.
- (iv) Any turbo-charger and any supercharger, where the flametrap is mounted on the inlet side of the turbo charger or supercharger.
- (v) Fuel injectors.
- (b) For joints with a spigot, the length of the flamepath shall be the dimension over the flange and the spigot together, provided both the spigot and the flange are continuous.
- (c) Threaded open joints shall have a minimum of five full threads engaged and a minimum direct axial length of thread engagement of 8 mm.
- (d) Where the internal parts of an explosion-protected diesel engine system are pierced by a spindle, the diametral clearance of the flamepath shall be within the dimensions of flamepath length and flamepath gap specified in Figure 2.2.

- (e) The minimum dimensions for flamepath length and flamepath gap for joint surfaces interrupted by bolt or fastener holes shall be as specified in Figure 2.3.

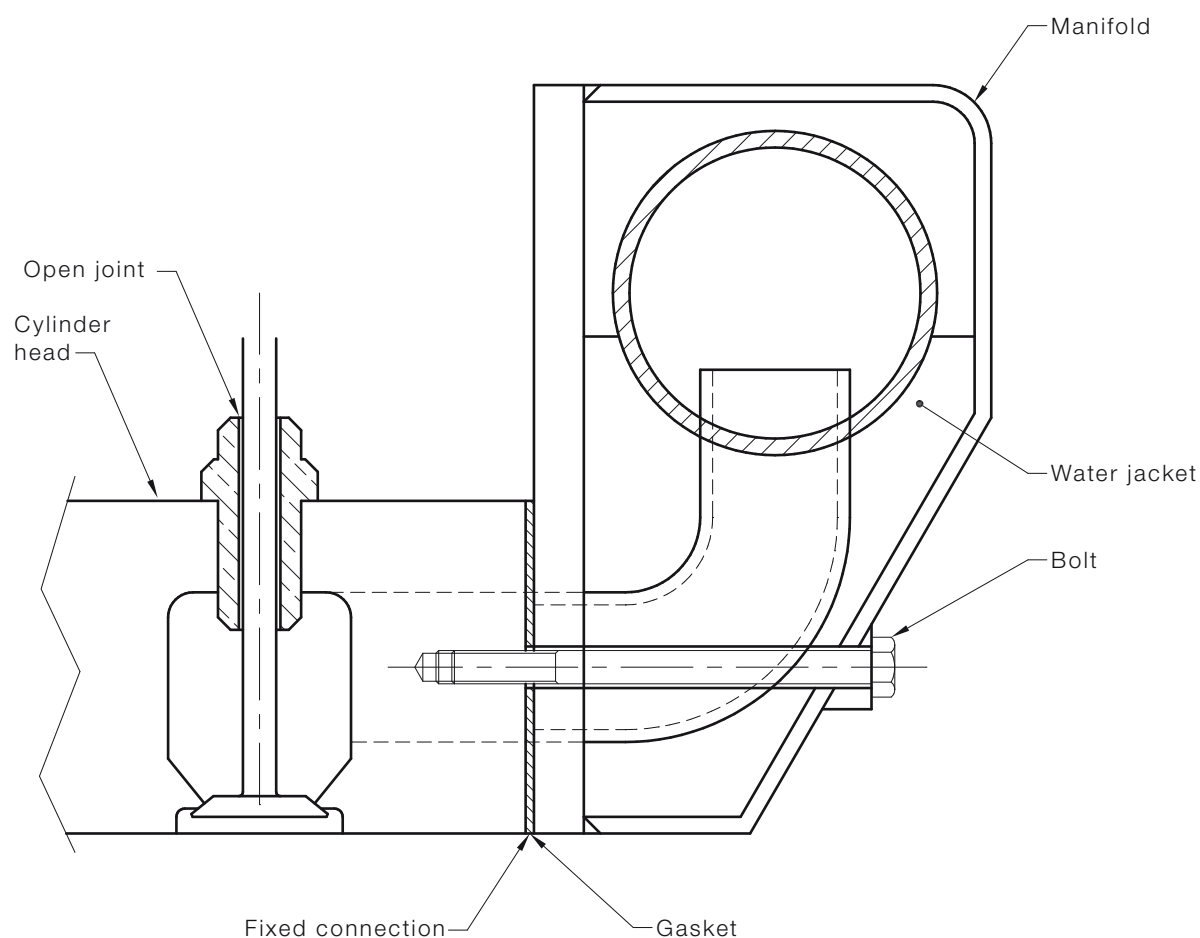


FIGURE 2.1 TYPICAL JOINTS

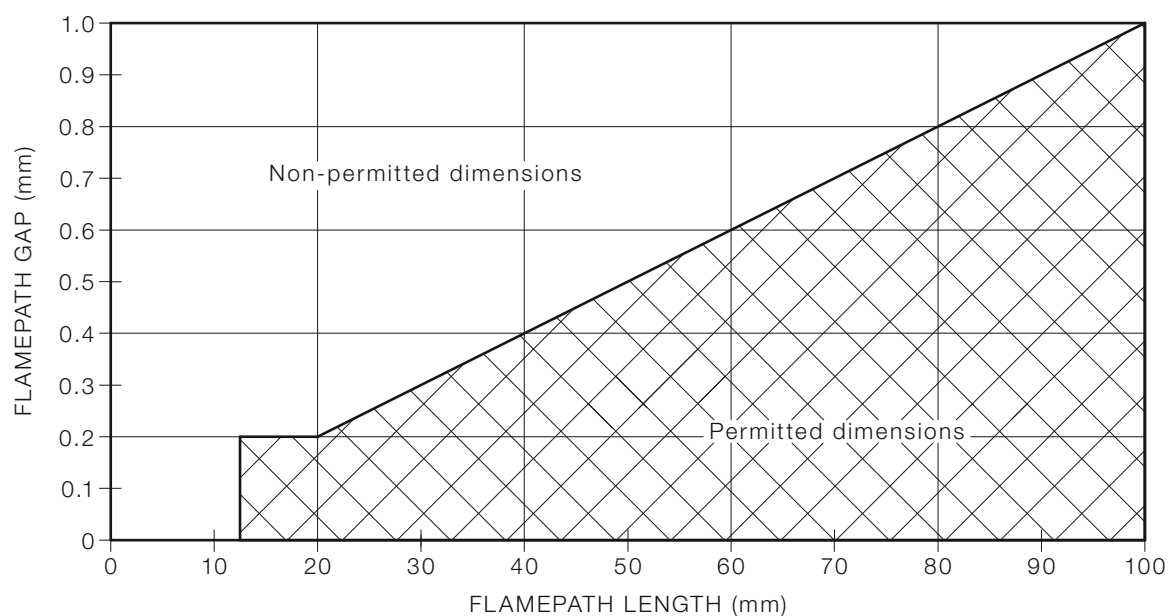
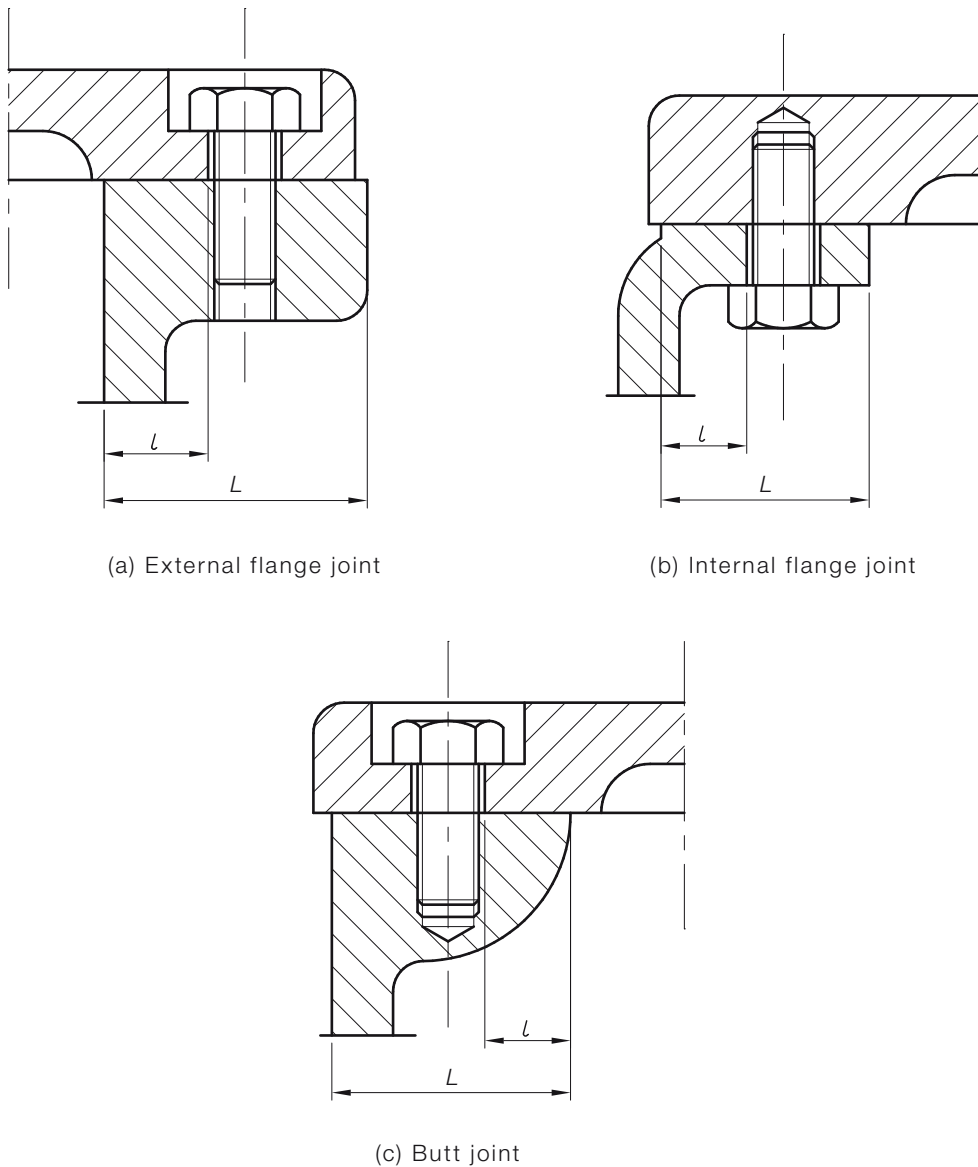


FIGURE 2.2 RELATIONSHIP BETWEEN LENGTH AND GAP FOR FLAMEPATHS



millimetres	
Width of joint, L	Minimum joint width from edge of bolt hole, l
$> 12.5 \leq 25$	8
> 25	9

FIGURE 2.3 PERMITTED DIMENSIONS OF FLAMEPATH LENGTH AND GAP FOR OPEN JOINTS

2.7 TRANSMISSION BELTS

Transmission belts shall be fire resistant and anti-static (FRAS) in accordance with AS 2784.

2.8 ENGINE BREATHER

The discharge from any engine breather shall be directed away from external surfaces of the engine system, so that it will not foul such surfaces with oil.

2.9 STARTING AIDS

Where electrical heating is required to assist with starting the engine and the power supply is part of the engine system, devices used shall be explosion protected. Any glow plugs shall turn off automatically whenever the engine starts, unless the source of electrical power is supplied from an external fixed source.

NOTE: A non-explosion-protected externally powered start-aid system may be used, provided it is incapable of being operated in an explosion-risk zone.

2.10 FUEL SYSTEMS

Setting 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 the occurrence of any unauthorized entry or adjustment, and 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, which may cause damage and failure.

2.11 AIR INLET SYSTEMS

The air inlet system shall be tested in accordance with Appendices L and M.

Air inlet systems shall be fitted with an inlet flametrap, an air filter assembly and an inlet manifold vacuum monitor, which shall be set to operate at less than the diesel engine system manufacturer's recommended minimum intake vacuum. The filter shall be adequately sized.

Any connections made to the air inlet system between the air inlet flametrap and the engine inlet valves shall be fitted with a mechanical flametrap and tested to Appendices L and M.

Unless propagation testing of the flame trap is carried out at the maximum positively controlled operating pressure and temperature of the diesel engine system, then an enhanced margin of safety gas shall be used during flame propagation testing when either—

- (a) the flametrap operates at a boosted pressure; or
- (b) the maximum positively controlled operating temperature is greater than 80°C (refer to Appendix L).

NOTES:

- 1 Oversized dry-type air filters are recommended, to allow for high dust loads.
- 2 The vacuum indicator should be readily visible to the operator.
- 3 The effectiveness of positive flametraps in preventing the propagation of an explosion may be affected by the pressure or temperature of the gas passing through the flametrap. See Appendix O for information on the effects of temperature and pressure on the safety aspects of positive flametraps.

2.12 AIR COMPRESSORS

Compressors forming part of a diesel engine system shall be water cooled.

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

There shall be no valves between the unloader and the compressor.

2.13 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 so 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 4024.1601.
- (e) Fans and fan assemblies shall be constructed so that sparks are not created, in the event of any part of the fan striking a surrounding or neighbouring object.
- (f) Cooling fans manufactured from non-metallic materials shall have an electrical resistance of not more than 1 GΩ, as measured in accordance with AS/NZS 60079.0. Any coating employed to meet this requirement shall include an etching process. Evidence shall be provided to demonstrate the durability and wear resistance of the coating.

2.14 ENGINE SHUTDOWN SYSTEMS

2.14.1 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 rising of an operator alarm or warning, where practicable.

2.14.2 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.

Automatic safety shutdown systems should include fault indication on shutdown.

Shutdown systems shall meet the test requirements of Appendix F.

2.14.3 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 shutdown 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 vehicle or machine fitted with an explosion-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 fitted to meet the requirements of this clause shall have sufficient gas to stop the engine before the gas is expended.

The operation of the emergency stop system shall be tested in accordance with Appendix F, Paragraph F6.3.8.

NOTES:

- 1 A strangler valve may meet this requirement (see Clause 1.4.22). If a strangler valve is used, the following should be taken into consideration:
 - (a) 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 engine types may cause the displacement of the valve stem seal or 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.
 - (b) Consideration should be given to the speed of operation of strangler valves. Sudden operation may cause engine damage.
- 2 An inert gas injection system may meet this requirement.
- 3 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 a carcinogen; and
 - (b) the temperature of the gas is not so cold that it may cause catastrophic failure of engine components when injected.

2.14.4 Manual fuel shut-off valve

The manual fuel shut-off valve shall be clearly identified and labelled including 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 into 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 Appendix F, Paragraph F6.3.7.

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.

2.14.5 Sensing devices

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

- (a) *Engine cooling system* Including the following:
 - (i) One or more coolant temperature sensors installed in the engine jacket coolant circuit, at or as near as practicable to the point or points of hottest temperature. Where there are two or more cooling circuits, a sensor shall be provided for each circuit. The coolant temperature at this location shall not exceed 2°C less than the boiling temperature of the coolant at its designed working pressure.
 - (ii) A coolant pressure, level or flow sensor located in each coolant circuit to monitor coolant loss.
- (b) *Engine oil pressure* 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 recommended pressure.
- (c) *Spark arresters* Spark arrester device shutdown sensors (see Clause 2.15.5).
- (d) *Positive flametraps* A minimum of two exhaust gas temperature sensors (see Clause 2.15.4.2).
- (e) *Water-based flametraps* Three sensors for each water-based flametrap (see Clause 2.15.4.3).
- (f) *Exhaust cooling* Exhaust cooling shutdown sensors (see Clause 2.15.6).
- (g) *Particulate filter* Any exhaust-filter shutdown sensors required by Clause 2.15.7.

NOTES:

- 1 Each sensor may fulfil more than one protection function within any designed system.
- 2 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.

Where the engine system includes a methane sensor, consideration should be given to the automatic shutdown of the system at a nominated level.

2.14.6 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 may be restarted or run.

Following operation of either the manual or automatic safety shutdown system, the engine shall not be able to be started until any fault is rectified, except that the system shall allow automatic override features on low oil pressure and low coolant pressure only. Where automatic override is provided, the period of override shall not exceed the engine manufacturers specifications.

NOTE: The override period should be the shortest practical time. As a guide, a period between 30 and 60s may be appropriate.

No manually operated override system shall be fitted.

2.15 EXHAUST SYSTEMS

2.15.1 General

Any hoses, pipework, fixtures and fastenings within the exhaust system, including any connections to monitoring or shutdown devices, shall be designed and rated for the temperature, pressure, vibration and environment to which they may be subjected.

All devices forming a part of an exhaust system shall be detailed on the drawings submitted and included in the equipment provided to the testing authority for testing. The exhaust system shall be tested in accordance with Appendices L and M.

2.15.2 Required equipment

The exhaust system shall include the following equipment:

- (a) *Flametrapp* A flametrapp that complies with Clause 2.15.4.
- (b) *Spark arrester* A spark arrester that complies with Clause 2.15.5.
- (c) *Exhaust cooling system* An exhaust cooling system that complies with Clause 2.15.6.
- (d) *Monitoring and shutdown devices* Various monitoring and shutdown devices that meet the requirements of Clause 2.14.

The operation of sensors and the shutdown system shall be tested in accordance with Appendix F.

- (e) *Surface temperature control* The means of ensuring that surface temperatures, as measured in accordance with Appendix E, do not exceed 150°C under any condition of load or operation.

NOTES:

- 1 The functions of the various systems may be combined into one device. For example, an exhaust flametrapp may also be a spark arrester, provided it meets the test requirements for both devices.
- 2 The functions of protection devices may be combined to perform multiple functions within the system. For example, a sensor may measure the temperature of exhaust gas as it passes from a water-based flametrapp to a particulate filter. This satisfies the need to measure the temperatures after each flametrapp and before each filter.

2.15.3 Optional equipment

Other devices or systems may be included within the exhaust system, including the following:

- (a) Catalytic converters. Where a regenerative catalyst is used, care shall be taken to ensure that excessive exhaust temperatures do not occur during regeneration.
- (b) Fume diluters and forced-air systems.
- (c) Particulate filters.

2.15.4 Exhaust flametrapp

2.15.4.1 General

Flametrapps shall be tested in accordance with Appendix L to demonstrate that they are capable of preventing the propagation of an ignition of margin-of-safety gas, mixed with air, or enhanced margin of safety gas through the flametrapp.

2.15.4.2 Positive flametrapps

An enhanced margin of safety gas shall be used during flame propagation testing, unless propagation testing of the flame trap is carried out at the maximum positively controlled operating exhaust temperature of the diesel engine system (see Appendix L).

At least two exhaust temperature-sensing devices that will shut down the engine system shall be fitted as follows:

- (a) One sensor shall be fitted where the exhaust meets the mine atmosphere and installed at a point after all treatment devices but before any dilution. This device shall be set at an exhaust temperature not exceeding 150°C.

- (b) One sensor shall be fitted before the positive flametrap. This device shall be set at the temperature at which the flame propagation testing was carried out at (see Paragraph L7.3, Appendix L). This temperature setting requirement does not apply if an enhanced margin of safety gas is used, in which case the device shall be set at an exhaust temperature not exceeding 150°C.
- (c) Where the manufacturer can justify a higher temperature for the sensor nominated under Item (b) above, the higher setting may be adopted (see Clause 1.2).

NOTE: The effectiveness of positive flametraps in preventing the propagation of an explosion may be affected by the pressure or the temperature of the gas passing through the flametrap (see Appendix O).

2.15.4.3 Water-based flametraps

Water-based flametraps shall be of materials resistant to corrosion, caused by water mixed with products of combustion, and suitable for raw exhaust temperature, measured at the inlet to the flametrap.

Where water-based flametraps utilize make-up water from another vessel during operation, then water shall flow between the make-up tank and the water cooling system under each of the following conditions when tested in accordance with Paragraph F6.3.15, Appendix F:

- (a) Exhaust restriction.
- (b) Exhaust back-pressure.
- (c) Any grade of operation.

A low-water test valve shall be provided, with its off-take position at or above the minimum shutdown water level. The test valve shall be tested in accordance with Paragraph F6.3.13(a), Appendix F.

Provision shall be made for draining water-based flametraps for cleaning. The opening of the drain point shall require the use of a tool.

Access shall be provided to the main internal chambers of water-based flametraps, to permit inspection and cleaning. Any inspection ports or openings should be above the minimum shutdown water level.

If a flametrap is reliant on the retention level or flow of water for effectiveness, it shall include the following two independent water level (shutdown) sensing devices:

- (i) *Primary low-water sensor* A primary low-water sensor that will directly sense the level of the water in the water-based flametrap, automatically activate the safety shutdown system and stop the engine at or above the minimum shutdown water level and prevent restarting of the engine, until the minimum shutdown water level is re-established within the water-based flametrap. The sensor shall ensure that the minimum shutdown water level is maintained under all conditions of operation and inclination. This requires sensing of the water level within the water-based flametrap.
- (ii) *Second low-water sensor* A second low-water sensor that will comply with either—
 - (A) the requirements of Item (a) above; or
 - (B) be located upstream of the water make-up valve in which case it shall at least comply with Paragraphs F6.3.13(a)(i) and F6.3.13(b) of Appendix F.

NOTE: In this case, compliance with Paragraphs F6.3.13(a)(ii), F6.3.13(iii) and F6.3.13(iv) is not mandatory.

Manual isolation valves shall not be fitted between any low-water sensing device and the main flametrap chamber.

Float (level) sensing devices shall fail-to-safety. Provision shall be made for testing the primary and secondary low-water shutdown water-level sensing devices independently of each other. Tests shall be performed in accordance with Appendix F.

At least one exhaust gas temperature-sensing device shall be fitted at the point where the gas first meets the atmosphere, which shall shut down the engine system before the exhaust gas temperature exceeds 150°C with the engine operating at high idle speed.

NOTE: It is recommended that the temperature-sensing device be set as low as practicable, in order to minimize the time of operation in a non-explosion-protected condition, in the event of a failure of the primary and secondary shutdown systems.

Where a temperature-sensing device is employed to sense water level or flow, it shall operate before an unsafe condition arises.

2.15.5 Spark arrester

The exhaust system shall be fitted with a spark arrester. The following apply to the spark arrester:

- (a) The spark arrester shall eliminate the emission of sparks and prevent an ignition of flammable materials and gas.
- (b) The spark arrester shall comply with at least one of the following:
 - (i) Appendix G.
 - (ii) AS 1019.
 - (iii) If a water-based type, it shall comply with the requirements for an exhaust flametrap.
- (c) Spark arresters that are reliant on a water level or flow for effectiveness shall be fitted with two sensors that will detect any loss of water that would cause the device to become unsafe or ineffective. Each sensor shall independently cause the engine system to stop automatically, in the event of a loss of the water barrier under any condition of test (see Note). Sensors and associated engine shutdown systems shall fail-to-safety. Sensors may be one of the following:
 - (i) Two minimum safe water level sensors, complying with Clause 2.15.4.3.
 - (ii) Two sensors measuring water flow to the spark arrester.
 - (iii) One sensor measuring the exhaust gas stream temperature and the other measuring the minimum safe level or flow of water.

These sensors shall cause the diesel engine system to stop automatically, before the level or flow of water reaches the minimum safe level (see Paragraph F6.3.1, Appendix F for testing requirements).

NOTE: Appendix G sets out a procedure for testing spark arresters.

- (d) Where a spark arrester coolant circuit is separated and isolated from the main engine coolant circuit, a loss of coolant shall cause the diesel engine system to automatically stop.
- (e) A spark arrester shall not be fitted with a bypass device.
- (f) Sensing devices need not be fitted to positive mechanical spark arresters or to turbochargers that are not fitted with a waste gate.
- (g) Spark arresters shall not be manufactured from flammable material.

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

2.15.6 Exhaust cooling systems

2.15.6.1 General

The exhaust gas cooling system may be a separate device or may be combined with the functions of other devices, including the spark arrester, flametrap, fume diluter or forced-air system.

Where water-based exhaust cooling systems utilize make-up water from another vessel during operation, then water shall flow between the make-up tank and the water-cooling system under each of the following conditions, when tested in accordance with Paragraph F6.3.15, Appendix F:

- (a) Exhaust restriction.
- (b) Exhaust back-pressure.
- (c) Any grade of operation.

Where a positive flametrap is used, the temperature of the exhaust gas stream, where it meets the atmosphere, shall not exceed 150°C.

Where a water-based flametrap is used, the temperature of the exhaust gas stream, at both the point of discharge and where it meets the atmosphere, shall not exceed 77°C for type testing without methane injection and without inlet restriction, when tested in accordance with Appendix E.

Water supply tanks used for water-based flametraps shall be manufactured from corrosion-resistant material. Where contamination from the water tank supply can cause the water-based flametrap water level control valve to fail, the water supply circuit to the water-based flametrap shall include a strainer.

2.15.6.2 Water bath

Where a water bath system is used to cool the exhaust gas stream, it shall be fitted with a minimum of two sensors, which shall independently cause the engine to stop in the event of loss of the water barrier. The sensors and associated engine shutdown systems shall fail-to-safety.

Sensors shall measure the minimum effective safe level, or the flow of water, or the exhaust gas stream temperature. In service, the sensors shall cause the diesel engine system to automatically stop before the exhaust gas stream reaches 150°C, at the point where the exhaust gas first meets the atmosphere and prior to air dilution.

2.15.6.3 Air dilution

An exhaust diluter with a gas temperature of more than 150°C before dilution shall not introduce unfiltered mine air directly into an exhaust gas stream. Unfiltered mine air shall not come in contact with any surface with a temperature greater than 150°C.

Where a fume dilution system is the primary means of cooling the exhaust gas stream, it shall be fitted with at least two independent sensors that will each cause the engine to stop before the exhaust gas temperature reaches 150°C, at the point where the exhaust gas first meets the atmosphere.

Any device employed for the purpose of dilution or the dissipation of exhaust gas into the main air body of a mine shall be designed, constructed and installed so as to minimize the disturbance of dust from the floor, rib or roof of the mine.

2.15.6.4 Heat exchanger

A heat exchanger may be used to achieve the exhaust temperature limits.

Access should be provided for inspection and cleaning of heat exchangers. Where condition-monitoring systems adequately indicate the condition, an inspection access may not be required.

Provision shall be made for in-service cleaning of heat exchangers.

Where the exhaust water-coolant circuit is separated and isolated from the main engine coolant circuit, a loss-of-coolant sensor shall be fitted to the cooling circuit, to automatically cause the diesel engine system to stop in the event of a loss of the coolant.

Every exhaust cooling heat exchanger shall be fitted with one or more sensors that will measure either the temperature or the flow of the coolant. The sensor shall be fitted within the coolant circuit, on the downstream side of and as close as practicable to the heat exchanger. This sensor shall be in addition to any sensor that is fitted to comply with Clause 2.14.5(a).

In the event that the flow rate falls below the minimum required to maintain the temperature of the exhaust to less than 150°C at the point where the exhaust gas stream first meets the atmosphere, the sensor shall cause the diesel engine system to stop automatically.

Where the heat exchanger is the primary means of cooling the exhaust gas, one or more temperature sensors shall cause the engine to stop before the exhaust gas temperature reaches 150°C where the exhaust gas first meets the atmosphere. If two sensors are fitted, one may be fitted before the exhaust filter.

NOTE: The design of heat exchangers should include a substantial margin-of-safety in cooling capacity.

2.15.6.5 *Water injection*

A water injection system may be used to achieve the exhaust temperature limits.

Where a water injection system is used to cool the exhaust gas stream, sensors shall be provided to measure—

- (a) either the flow or pressure in the water supply line; and
- (b) the temperature of the exhaust gas stream, where the gas first meets the atmosphere.

The sensors shall cause the diesel engine system to stop automatically. In the event that the flow rate or pressure falls below the minimum required to maintain the temperature of the exhaust gas to less than 150°C where the exhaust gas first meets the atmosphere.

NOTE: The design of injection systems should include a substantial margin-of-safety in cooling capacity.

2.15.7 **Particulate filter**

2.15.7.1 *General*

Filter systems for the removal of all or part of particulate fractions of smoke shall meet the requirements of Appendices C and H.

Where a failure of a filtering system could cause an unsafe condition, devices shall be fitted to cause the diesel engine system to be automatically stopped, in the event of such a failure occurring.

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, the concentration of smoke shall comply with the requirements of Clause 2.15.8.3, and 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.

2.15.7.2 Replaceable element-type filters

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

- (a) Be rated for continuous operation without ignition, smoking or the production of noxious gases.
- (b) Be fitted on the output side of the spark arrester, unless manufactured from non-combustible material.
- (c) 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) Have either an engine shutdown sensor or a visual indication of a blocked filter.
- (e) Have filter elements that—
 - (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,
 with at least one of these sensors installed upstream and one downstream of the filter assembly; and
 - (iii) are permanently marked with the manufacturer's name, mark, part number and rated maximum continuous operating temperature rating.

2.15.7.3 Filter-ignition temperature measurements

Tests to measure rated maximum continuous operating temperature of the filter and filter-auto ignition temperatures shall be conducted on both a new and a blocked (dirty) filter (see Appendix H).

2.15.8 Exhaust emissions

2.15.8.1 Exhaust

Undiluted exhaust gas emissions shall be measured in accordance with Appendix D, before and after any treatment and prior to dilution. 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;
- (c) 0.11% (1100 ppm) by volume of CO; and
- (d) 0.20% (2000 ppm) by volume of CO, while 1% CH₄ is injected into the intake.

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.

2.15.8.2 Gravimetric emissions (gaseous)

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

NOTES:

- 1 This 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.

2.15.8.3 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 G based on Clause 2.15.8.3(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:

$$G = \frac{V \times n}{60} \quad \text{for naturally aspirated two-stroke engines}$$

$$G = \frac{V \times n}{60} \times \frac{P_b}{P_{\text{atm}}} \quad \text{for two-stroke engines that are turbo-charged or super-charged}$$

$$G = \frac{V \times n}{120} \quad \text{for naturally aspirated four-stroke engines}$$

$$G = \frac{V \times n}{120} \times \frac{P_b}{P_{\text{atm}}} \quad \text{for four-stroke engines that are turbo-charged or super-charged}$$

where

n = crankshaft speed, measured in revolutions per minute (r/min)

V = total cylinder swept volume, in litres

P_b = absolute turbo or super-charge boost pressure at rated power

P_{atm} = atmospheric pressure

NOTE: Refer to Appendix K for a comparison between soot concentration in gravimetric units and Bosch smoke meter values.

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

2.15.8.4 *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 may be measured.

Test points are required—

- (a) as close as possible to the exhaust valves;
- (b) as close as possible to the point where the exhaust gas stream first meets the atmosphere; and
- (c) before final dilution.

2.16 ELECTRICAL SYSTEMS

The entirety of any electrical system or equipment installed on an explosion-protected diesel engine system shall be explosion protected and 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. Explosion protection requirements may be found in AS/NZS 60079.0.

SECTION 3 MARKING

3.1 COMPLIANCE PLATE

A compliance plate shall be provided for each diesel engine system, permanently affixed either to the system or, if impracticable, adjacent to system in an easily seen position. The compliance plate shall include the following information:

- (a) Engine system protection rating (i.e., explosion protected).
- (b) The designation and date of this Standard (i.e., AS/NZS 3584.2:2008).
- (c) The approval or certification numbers that are required by the various relevant statutory authorities (e.g., N.S.W. and Qld).
- (d) Any registration number required.
- (e) The name of the diesel engine system manufacturer.
- (f) The date of manufacture of the diesel engine system.
NOTE: This will normally be the date of testing, prior to dispatch.
- (g) The serial number of the diesel engine system and the original engine serial number (if different).
- (h) The maximum compound, transverse and longitudinal angles of operation.
- (i) The maximum concentrations of undiluted exhaust gas emissions measured during type testing, without methane injection and post treatment, for each of the constituent gases (NO_x , CO, CO_2) at low idle, high idle, rated power, and the weighted, average and gravimetric measurement of each of the gases. The weighted average Bosch index number shall be recorded for smoke.

NOTES:

- 1 The compliance plate may be combined with the specification plate (see Clause 3.2), in which case duplicated information may be omitted.
- 2 Figure 3.1 illustrates a typical compliance plate.