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Diesel engine systems for underground coal mines

Part 2: Explosion protected



AS 3584.2:2021

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- Department of Resources, Qld
- Engineers Australia
- Minerals Council of Australia
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Diesel engine systems for underground coal mines

Part 2: Explosion protected

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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 3584.2:2008.

After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this document as an Australian Standard rather than an Australian/New Zealand Standard.

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

A list of all parts in this series can be found in the Standards Australia online catalogue.

This document introduces the requirements for an ignition hazard assessment and functional safety assessment to be performed on the diesel engine system.

The major changes in this edition are as follows:

- (a) The maximum methane concentration for continuous operation has been increased to 1.25 %.
- (b) [Section 3](#) Design and construction now includes all performance requirements.
- (c) The test appendices now include all test requirements.
- (d) Exhaust gas temperature tests have been revised.
- (e) Rated torque speed has been replaced with intermediate speed.
- (f) References to product certification schemes have been removed.
- (g) Testing for replacement particulate filter elements have been added.

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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Australian Standard®

Diesel engine systems for underground coal mines

Part 2: Explosion protected

Section 1 Scope and general

1.1 Scope

This document sets out the explosion protection requirements for diesel engine systems designed for safe operation in underground coal mines, including use in explosion-risk zones. Conformance with this document implies sufficient protection for continuous operation in atmospheres containing up to 1.25 % methane, including—

- (a) the control of surface temperature, to avert ignition of coal dust that could settle on a hot surface or fluid fires; and
- (b) containment or elimination of flames and sparks that could ignite flammable gases and dust that may be present.

This document also addresses inadvertent short-term exposure to high methane levels and any consequent uncontrolled combustion.

NOTE Diesel engine systems that meet the requirements of this document (Part 2) are also fire protected.

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document.

NOTE Documents referenced for informative purposes are listed in the Bibliography.

AS 1019, *Internal combustion engines — Spark emission control devices*

AS 3584.4, *Diesel engine systems for underground coal mines, Part 4: Emissions*

AS 4024.1502, *Safety of machinery, Part 1502: Design of safety related parts of control systems — Validation*

AS 4024.1503, *Safety of machinery, Part 1503: Safety-related parts of control systems — General principles for design*

AS 4024.1601, *Safety of machinery, Part 1601: Design of controls, interlocks and guarding — Guards — General requirements for the design and construction of fixed and moveable guards*

AS 4024.1604, *Safeguarding of machinery, Part 1604: Design of controls, interlocks and guarding — Emergency stop — Principles for design (ISO 13850:2017 (ED.3.0), MOD)*

AS 61508.1, *Functional safety of electrical/electronic/programmable electronic safety-related systems, Part 1: General Requirements*

AS/NZS 3584.3, *Diesel engine systems for underground coal mines, Part 3: Maintenance*

AS/NZS 4024.1204, *Safety of machinery — Electrical equipment of machines, Part 1204: General requirements (IEC 60204-1:2016 (ED. 6.0) MOD)*

AS/NZS 4871.1, *Electrical equipment for mines and quarries, Part 1: General requirements*

AS/NZS 4871.6, *Electrical equipment for mines and quarries, Part 6: Diesel powered machinery and ancillary equipment*

AS/NZS 62061, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems (IEC 62061:2005+AMD1:2012+AMD2:2015 CSV (ED.1.2)/COR1:2015 MOD)*

AS/NZS 60079.0, *Explosive atmospheres, Part 0: Equipment — General requirements (IEC 60079-0:2017 (ED. 7.0), MOD)*

AS ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 1813, *Belt drives — V-ribbed belts, joined V-belts and V-belts including wide section belts and hexagonal belts — Electrical conductivity of antistatic belts: Characteristics and methods of test*

ISO 9563, *Belt drives — Electrical conductivity of antistatic endless synchronous belts — Characteristics and test method*

ISO 13849-1, *Safety of machinery — Safety-related parts of control systems, Part 1: General principles for design*

ISO 13849-2, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

ASTM D1298 12b, *Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method*

1.3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

1.3.1

catalytic converter

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

1.3.2

effective ignition source

potential ignition source which is able to ignite an explosive atmosphere when consideration is taken of when it occurs (i.e. in normal operation, expected malfunction or rare malfunction)

Note 1 to entry: An effective ignition source is a potential ignition source which can ignite the explosive atmosphere if protective measures are not used.

Note 2 to entry: For example the frictional heat which may be produced by a bearing is a possible ignition source. This is an equipment related ignition source if the piece of equipment contains a bearing. If the energy which may be produced by the friction in the bearing is capable of igniting an explosive atmosphere, then this is a potential ignition source. Whether this potential ignition source is effective depends on the likelihood that it will occur in a particular situation.

[SOURCE: ISO 80079-36:2016, 3.1.4]

1.3.3

explosion-protected diesel engine system

ExDES

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

Note 1 to entry: The diesel engine system includes—

- (a) inlet systems and inlet flame arrester;
- (b) exhaust systems and exhaust flame arrester;
- (c) combustion chamber;
- (d) cooling systems;

- (e) starting systems;
- (f) fuel system;
- (g) shutdown and protection systems; and
- (h) other ancillary equipment attached to or driven by the engine, or are associated with the engine operation or engine control.

Note 2 to entry: Equipment driven from the output side of the engine flywheel is excluded.

1.3.4 explosion-risk zone

place where during the normal course of events there is a possibility of an accumulation of flammable gas or dust or explosive gas or dust that could create a hazard for the operation, servicing or maintenance of a ExDES

Note 1 to entry: Legislation for underground coal mines may define certain parts of the mine as explosion-risk zones. They may use the term “hazardous zone” to describe an explosion-risk zone.

1.3.5 flame arrester

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

1.3.6 high idle speed

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

1.3.7 intermediate speed

speed used in the non-road steady state (NRSC) test cycle

Note 1 to entry: Refer to AS 3584.4 for more information on NRSC cycles.

1.3.8 low-idle speed

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

1.3.9 malfunction fault

situation where equipment or components which do not perform their intended function with respect to explosion protection

Note 1 to entry: For the purposes of this document this can happen due to a variety of reasons, including—

- (a) failure of one (or more) of the component parts of the equipment or components;
- (b) external disturbances (e.g. shocks, vibration, impact);
- (c) design error or deficiency;
- (d) disturbance of the power supply or other services; or
- (e) loss of control by the operator.

1.3.9.1 expected malfunction

disturbances or equipment malfunctions which normally occur in practice

1.3.9.2**rare malfunction**

type of malfunction, which may happen, but only in rare instances

[SOURCE: IEC 60079-0:2017, 3.56.2]

Note 1 to entry: Two independent expected malfunctions which, separately, would not create a source of ignition, but which, in combination, do create a source of ignition, are regarded as a single rare malfunction.

1.3.10**may**

indicates the existence of an option

1.3.11**normal operation**

operation of equipment conforming to its design specification and used within the limits specified by the manufacturer

[SOURCE: ISO 80079-36:2016, 3.2]

1.3.12**particulate filter**

filter that removes particulate matter from an exhaust gas stream

1.3.13**potential ignition source**

equipment related ignition source which has the capability to ignite an explosive atmosphere (i.e. to become effective)

[SOURCE: ISO 80079-36:2016, 3.1.3]

1.3.14**rated power**

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

1.3.15**rated speed**

speed of an engine while producing rated power

1.3.16**safety components**

passive systems or things such as fixed components, exhaust manifolds, gaskets, joints, and positive flame arresters

1.3.17**safety function**

active system intended to achieve or maintain a safe state for the diesel engine system in respect of a specific hazardous event

1.3.18**shall**

indicates that a statement is mandatory

1.3.19**should**

indicates a recommendation

1.3.20**spark arrester**

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

1.3.21**strangler valve**

valve inserted into the intake air stream capable of completely shutting off the supply of intake air to the ExDES and stopping the engine

1.3.22**testing authority**

body acceptable to the relevant statutory authority to carry out the tests prescribed herein

Note 1 to entry: Normally a nationally accredited testing authority.

1.3.23**uncontrolled combustion**

unintended or out of control combustion in the engine

Note 1 to entry: Uncontrolled combustion may be caused by induced flammable gas, liquid or vaporized hydrocarbons.

Note 2 to entry: Uncontrolled 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.

1.4 New designs and innovations

This document 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 document. The suitability of any alternative technology or innovation shall be subject to a risk assessment.

Section 2 Hazard identification and control

2.1 Ignition hazard assessment

The ExDES shall be assessed to identify all reasonably foreseeable lifecycle potential ignition sources that could occur. The assessment shall—

- (a) evaluate the entirety of the ExDES;
- (b) evaluate reasonably foreseeable misuse and reasonably foreseeable human error;

NOTE 1 A means of demonstrating reasonably foreseeable misuse, violation and reasonably foreseeable human error may require a study of available industry safety related data and bulletins to identify relevant issues.
- (c) identify whether the potential ignition sources could occur during normal operation, expected malfunction or during rare malfunction;
- (d) identify all effective ignition sources which are capable of igniting an explosive atmosphere;
- (e) evaluate the effect of the ExDES operating in a methane-enriched atmosphere; and
- (f) determine possible failure modes of the ExDES, including and without limitation—
 - (i) loss of functionality of engine cooling system;
 - (ii) loss of functionality of engine lubrication system;
 - (iii) loss of functionality of engine exhaust cooling system;
 - (iv) loss of functionality of exhaust conditioner as an effective spark arrester and flame arrester; and
 - (v) catastrophic failure of the ExDES.
- (g) identify potential ignition sources that could occur during uncontrolled combustion.

Without limitation, hazardous ignition sources may include—

- (i) hot surfaces, greater than 150 °C;
- (ii) flames;
- (iii) mechanically generated sparks;
- (iv) hot gases being expelled in the mine atmosphere, greater than 150 °C;
- (v) hot exhaust particles being expelled into the mine atmosphere;
- (vi) static electricity;
- (vii) faulty or inadequately protected electrical equipment; and
- (viii) possible failure modes that could generate ignition sources.

NOTE 2 ISO 80079-36 provides guidance on ignition hazard assessment.

2.2 Fire hazard

The ExDES shall be assessed to identify the potential to initiate, sustain and propagate a fire. This assessment shall consider reasonably foreseeable misuse and reasonably foreseeable human error.

Without limitation, hazardous heat sources may include—

- (a) hot surfaces, greater than 150 °C;
- (b) hot gases being expelled in the mine atmosphere, greater than 150 °C; and
- (c) hot exhaust particles being expelled into the mine atmosphere.

2.3 Ignition control measures

2.3.1 General

All effective ignition sources identified in the ignition hazard assessment shall be controlled. Control measures shall be either—

- (a) safety functions; or
- (b) safety components.

The effectiveness of the control measures shall be determined over the lifecycle of the ExDES. The component life and the conditions required to maintain the required level of protection shall be stated.

NOTE Control measures may include lifecycle changeout of components and periodical proof testing to detect dangerous failures.

2.3.2 Safety functions

All safety functions shall be clearly identified and documented in the safety file (refer to AS/NZS 3584.3).

As a minimum, the following safety functions shall be provided:

- (a) Control surface temperature as specified in [Clause 2.1](#).
- (b) Prevent engine overspeed.
- (c) Prevent exhaust gas temperature exceeding 150 °C at the point where it meets the mine atmosphere.
- (d) Emergency stop.
- (e) Shutdown the ExDES before the atmospheric methane concentration exceeds 1.25 %.

Where the safety function relies on fluid power for control, the effect of contamination shall be evaluated and the required level of filtration specified.

Functions that alert the operator shall provide means for the operator to acknowledge the alert or be such that it is unlikely the operator would not be aware of the alert.

Safety functions should be monitored for failure and incorporate warning systems to detect faults.

2.3.3 Risk reduction required

The integrity level for identified safety functions shall meet the minimum performance level (PL) or safety integrity level (SIL) specified in [Table 2.1](#).

Table 2.1 — Risk reduction

Effective ignition source occurring during	Risk reduction
Normal operation	PLd or SIL 2
Expected malfunction	PLd or SIL 2
Rare malfunction	PLb or SIL 1

2.3.4 Assessment and validation

Safety functions shall be assessed and validated in accordance with either of the following:

- (a) For PL, to AS 4024.1503 and AS 4024.1502; or ISO 13849-1 and ISO 13849-2.
- (b) For SIL, to AS 61508.1 or AS/NZS 62061.

A safety requirements specification shall be generated as an integral part of functional safety assessment.

2.3.5 Safety components

Safety components shall be designed, analysed, tested and documented using current engineering principles and in accordance with applicable Australian standards.

Systematic analysis methods such as failure modes and effects analysis, fault tree analysis or other similar methods shall be used to—

- (a) determine all reasonably foreseeable failure modes;
- (b) verify a sufficient level of reliability has been achieved in the design; and
- (c) determine lifecycle inspection, maintenance, test and discard requirements.

NOTE Fatigue testing or analysis may be applicable.

Section 3 Design and construction

3.1 Engine types

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

3.2 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 pressure;
- (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.

3.3 Surface temperature

The temperature of any external surface that comes into contact with the mine atmosphere shall not exceed 150 °C under any condition of operation, including when tested in accordance with [Appendix C](#). Sensors should be installed at the hottest point(s) on the ExDES.

3.4 Materials

3.4.1 Non-metallic materials

The use of non-metallic materials for external components of a ExDES shall be kept to a minimum. Where such materials are used, they shall be shielded and routed away from heat sources. Materials shall be tested for fire resistance and/or static electricity buildup as required by the ignition hazard assessment.

3.4.2 Light metals

Rotating components external to the engine (e.g. fan hubs, fan blades, pulleys) shall not be of light metal. Uncoated or unprotected light metal alloys shall not be used.

3.4.3 External thermal insulation

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

3.5 Flexible metallic pipes

Flexible joints may be used between the inlet and exhaust flame arresters on any ExDES, provided the engineering analysis considers potential for fatigue failure.

3.6 Joints

3.6.1 Designation

Each joint (including test points) within an explosion-protected ExDES shall be designated as being either a fixed connection, liquid immersed joints (Ex k) or an open joint.

3.6.2 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 [Appendix H](#), for component testing of systems, as applicable, withstand the hydrostatic test pressure specified in [Table H.1](#);
- (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).

NOTE 1 The fuel system, including the fuel injectors, may be taken to be a fixed connection, provided it meets the requirements for hydrostatic testing.

NOTE 2 O-rings may be used to meet this requirement.

Formed in-place gaskets or seals may be employed. Where used they shall—

- (i) have an applied operating temperature rating of not less than 250 °C;
- (ii) not be corrosive to mating materials in the joint; and
- (iii) be resistant to engine combustion products, water, glycol/water and methanol/water mixtures, diesel fuel, mineral and synthetic lubrication oils and kerosene fluids.

3.6.3 Open joints

Open joints shall conform to the following requirements (see [Figures 3.1](#), [3.2](#) and [3.3](#)):

- (a) The flamepath length and flamepath gap of any linear continuous open path between the internal parts of an explosion-protected ExDES and the surrounding atmosphere shall be within the constraints specified by [Figures 3.2](#) and [3.3](#).

NOTE 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 G](#):

- (i) Valve stems and valve guides.
 - (ii) Intake and exhaust flame arresters.
 - (iii) Water injection nozzles fitted to cool or clean the exhaust gas stream and system.
 - (iv) Any turbocharger and any 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 ExDES 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 3.2](#).
- (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 3.3](#).

Turbochargers, superchargers, water injection nozzles, and external joints on flame traps may only be exempt from open joint requirements when—

- (i) the tolerances creating the minimum flamepath length and maximum gap are known; and
- (ii) the component passes the flame propagation tests with length below the minimum known flamepath length and gaps exceed the maximum known gap.

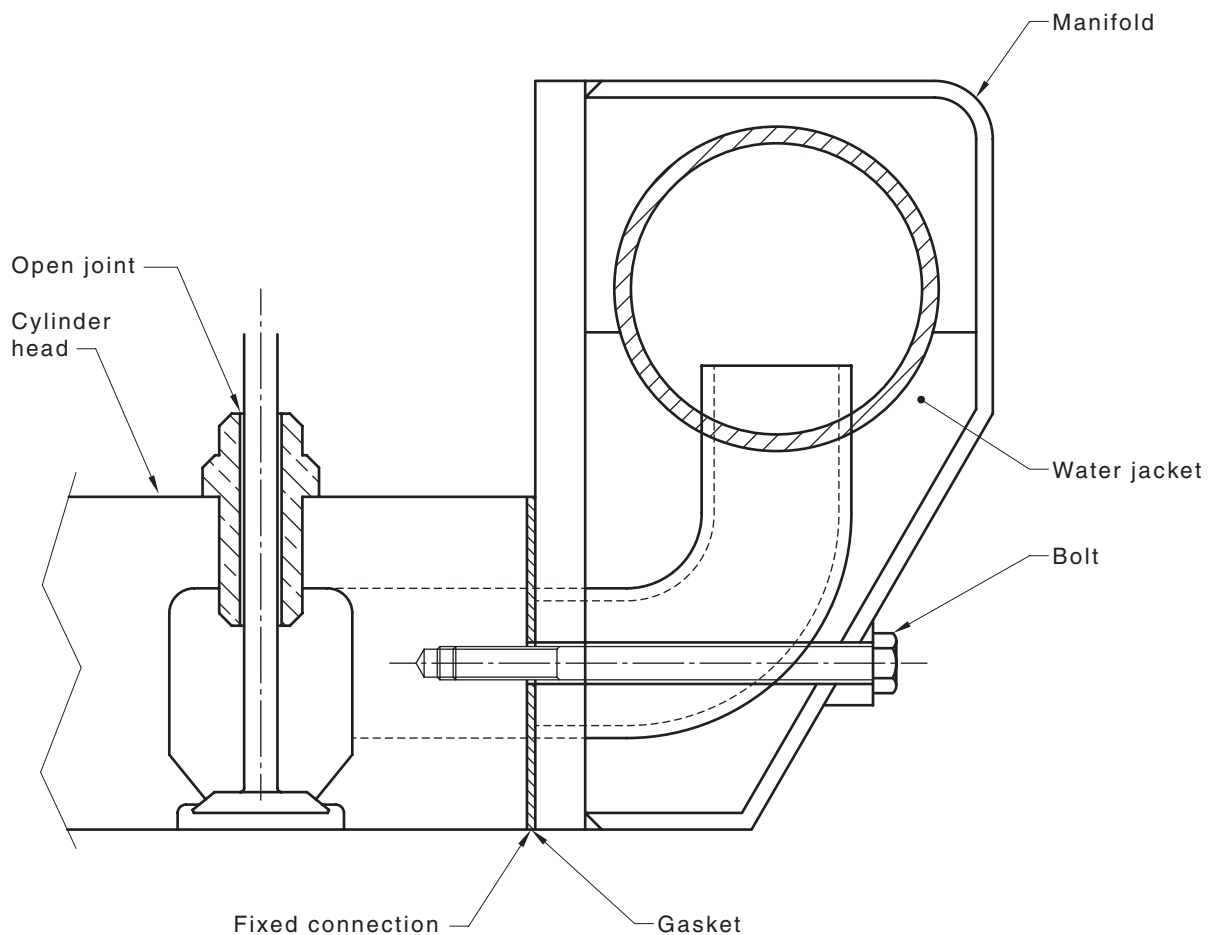


Figure 3.1 — Typical joints

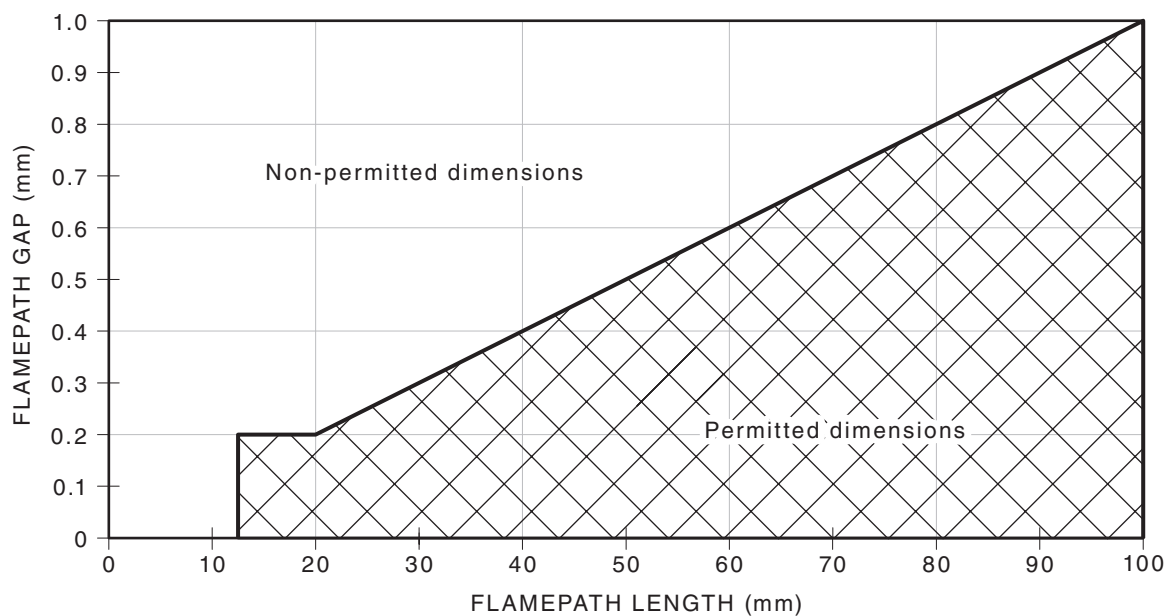
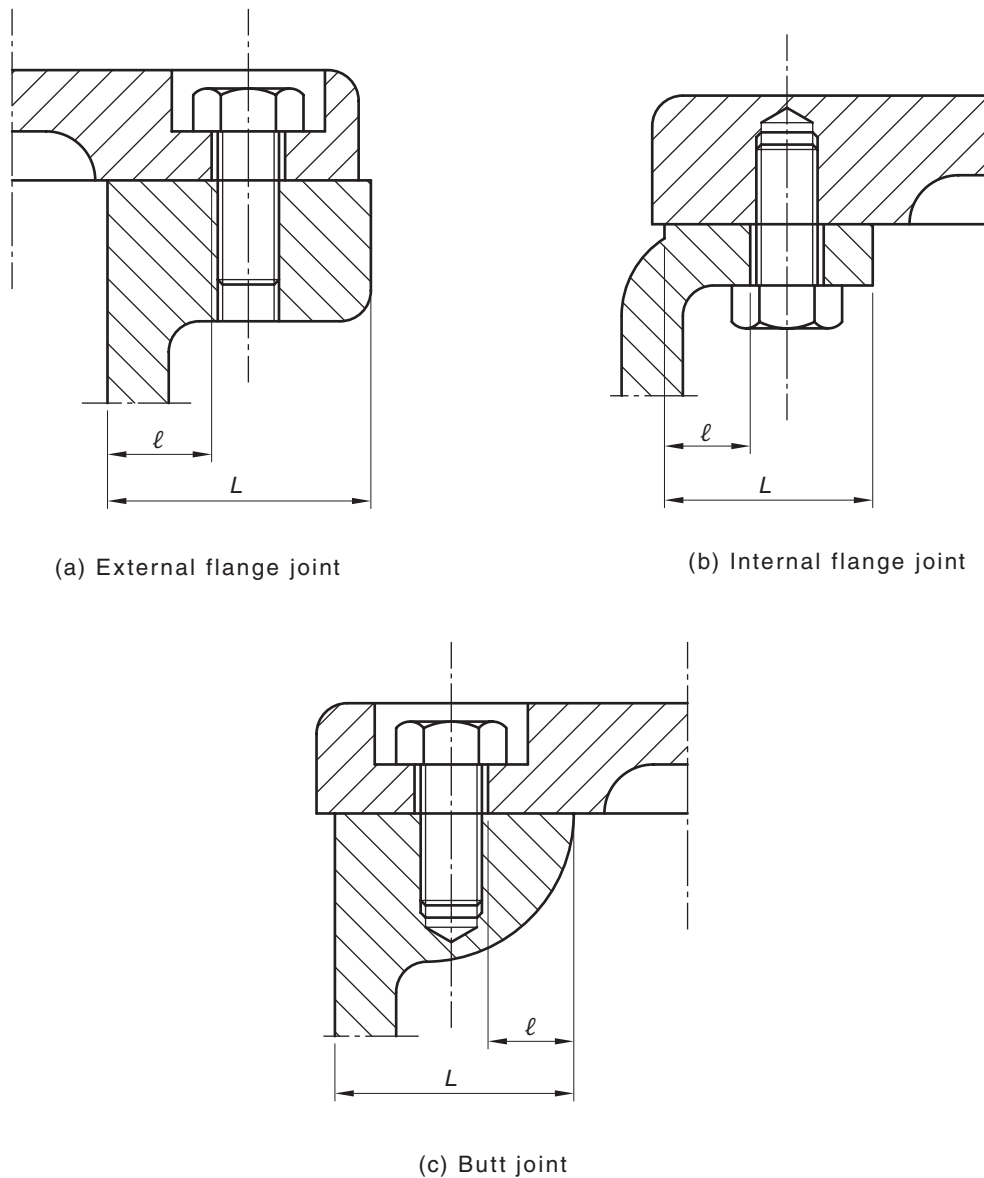


Figure 3.2 — Relationship between length and gap for flamepaths



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

Figure 3.3 — Permitted dimensions of flamepath length and gap for open joints

3.7 Transmission belts

Transmission belts, including all drive belts driving auxiliary equipment on the ExDES, shall be fire resistant and anti-static (FRAS).

Drive belts shall meet the requirements of ISO 1813 and ISO 9563.

3.8 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.

3.9 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.

3.10 Fuel systems

The fuel system for the purposes of this document comprises all components from the manual shut-off valve to the fuel injection system.

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 the occurrence of any unauthorized entry or adjustment.

High-pressure fuel lines shall conform to the engine manufacturer's specification.

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

3.11 Air inlet systems

3.11.1 General

The inlet system shall be designed to—

- (a) prevent propagation of an internal explosion to the mine atmosphere;
- (b) withstand the pressure of an internal explosion without structural failure; and
- (c) control the surface temperature as specified in [Clause 3.3](#).

All connections made to the air inlet system shall meet the requirements for fixed connection [Clause 3.6.2](#) or open joints [Clause 3.6.3](#).

3.11.2 Flame propagation

Any explosion initiated in the inlet system shall not ignite gas external to the inlet system during flame propagation testing when tested in accordance with [Appendix G](#).

3.11.3 Structural integrity

During pressure testing in accordance with [Appendix H](#), there shall be no—

- (a) leakage through welds; or
- (b) structural failure.

Following removal of pressure there shall be no—

- (i) loss of tension in fasteners;
- (ii) stretched or bent fasteners;