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Mine Safety

MINING DESIGN GUIDELINE | MDG 43

Technical standard for the design of diesel engine systems for use in underground coal mines

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MDG 43: Technical standards for the design of diesel engine systems for use in underground coal mines

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NSW Mine Safety Operations

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Foreword

This is MDG 43 *Technical standard for the design of diesel engine systems for use in underground coal mines*.

Diesel engines operate by controlling the ignition of diesel fuel in a combustion chamber. Diesel engines introduce heat, ignition sources and toxic emissions into a mine environment. Diesel engine performance and heat generation is also affected by a volume of methane in mine atmospheres. Historically, evidence shows this has resulted in uncontrolled operation of the diesel engine system with excessive heat generation.

Coal mines contain potentially explosive atmospheres of material through coal dust and methane. Diesel engine systems have a high potential to ignite an explosive atmosphere. As such the need for fit-for-purpose diesel engine systems in underground coal mines is crucial to the safe operation of the mine.

This technical standard sets out standards for the design of diesel engine system for use in underground coal mines.

At the time of publication, this technical standard is published for the purpose of plant design registration for diesel engine systems for use in underground coal mines under clause 177 of the *Work Health and Safety (Mines) Regulation 2014* and Part 5.3 of the *Work Health and Safety Regulation 2011*.

Contents

1 Purpose and scope

1.1 Purpose

The purpose of this technical standard *Design of diesel engine systems for use in underground coal mine*' is to minimise risks to health and safety associated with the use of diesel engine systems in underground coal mines.

1.2 Scope

This technical standard *Design of diesel engine systems for use in underground coal mine*' sets out design standards for the design, testing and performance of diesel engine systems for use in underground coal mines.

Compliance with this standard does not negate the designer's work health and safety duties under section 22 of *the Work Health and Safety Act 2011.*

1.3 Application

This technical standard *Design of diesel engine systems for use in underground coal mine*' is applicable to the design of all diesel engine systems intended to be design registered under clause 177(5) of the *Work Health and Safety (Mines) Regulation 2014* and part 5.3 of the *Work Health and Safety Regulation 2011*.

1.4 Interpretation

AS is a reference to Australian Standards.

AS/NZS is a reference to Australian/New Zealand Standards.

Diesel engine system: a diesel engine intended to be used in an underground coal mine and includes its inlet system, air boost systems, exhaust system, cooling systems, recirculation systems, starting systems, shutdown systems, control systems, emissions treatment systems and other ancillary equipment specifically used to start and run the diesel engine such as air compressors, hydraulic pumps, alternators and batteries.

Chief Inspector is a person appointed under the *Work Health and Safety (Mines) Act 2013*.

CO: carbon monoxide

DF: deterioration factors

DP: diesel particulate

EC: elemental carbon

ExDES: an explosion-protected diesel engine system

FpDES*:* a fire-protected diesel engine system

Hazard: explosion hazard, fire hazard, toxic emissions hazard and abnormal combustion hazard

HC: hydrocarbons

ISO: International Organisation for Standardisation.

Light metal alloy: an alloy containing aluminium, magnesium or titanium (or a combination of those metals), but only if:

a) those metals make up more than 15% of the weight of the alloy

b) magnesium and titanium make up more than 6% of the weight of the alloy.

MDG: NSW government produced mining design guidelines and published on the Department of Industry website www.resourcesandenergy.nsw.gov.au/safety

NIOSH: the United States, National Institute of Occupational Safety and Health.

NO_x: oxides of Nitrogen

NRSC: non-road steady cycle.

NRTC: non-road transient cycle.

Regulation: the *Work Health and Safety (Mines) Regulation 2014.*

TC: total carbon.

Safety-related componentry: passive systems or things such as fixed components, exhaust manifolds, gaskets, joints, positive flametraps, etc.

Safety-related function: an active system that is intended to achieve or maintain a safe state for the diesel engine system in respect of a specific hazardous event.

UN Reg096r3: the United Nations Economic Commission for Europe, UN Vehicle Regulations – 1958 Agreement, Addendum 95: Regulation No. 96 – Rev. 3, 11 March 2014*, Uniform provisions concerning the approval of compression ignition (C.I.) engines to be installed in agricultural and forestry tractors and in non-road mobile machinery with regard to the emissions of pollutants by the engine*.

2 Design requirements

2.1 Design object

All diesel engine systems designed for use in underground coal mines must be designed to minimise lifecycle risks associated with the use of diesel engine systems in underground coal mines by:

a) minimising the potential risk of an ignition of methane or coal dust (ExDES)

b) minimising the potential risk of initiation of a fire (ExDES and FpDES)

c) providing fit-for-purpose risk control measures on diesel engine systems

d) the provision of diesel engine systems that shut down safely in emergency situations

e) providing designs that ensure lifecycle emissions from diesel engine systems are as low as reasonably practicable.

2.2 Design classification and design operating environment

1. All diesel engine systems must be identified as being either ExDES or FpDES.

2. ExDES must be designed to operate safely:
   a) continuously in a mine atmosphere containing coal dust; and
   b) continuously in a mine atmosphere containing up to 1.25% methane; and
   c) for limited duration in an explosive atmosphere.

3. FpDES must be designed to operate safely:
   a) continuously in a mine atmosphere containing coal dust; and
   b) continuously in a mine atmosphere containing up to 0.25% methane.

2.3 Standards for design

1. All diesel engine systems must be designed in accordance with this technical standard, the relevant Australian or International Standards and current engineering principles.
2. Without limiting 2.3.1 above, the following engineering standards must be considered in the design of diesel engine systems, but only so far as this technical standard specifies:

   a) AS 1019-2000 Internal combustion engines - Spark emission control devices;
   b) AS/NZS 3584.1:2008 Diesel engine systems for underground coal mines - Fire protected - Heavy duty;
   c) AS/NZS 3584.2:2008 Diesel engine systems for underground coal mines - Explosion protection;
   d) AS/NZS 3454.3:2012 Diesel engine systems for underground coal mines - Maintenance;

e) AS 4024.1501:2006 (R2014) Safety of machinery - Design of safety-related parts of control systems - General principles for design;
f) AS 4024.1502:2006 (R2014) Safety of machinery - Design of safety-related parts of control systems – Validation;
g) AS/NZS 4024.1503:2014 Safety of machinery - Safety-related parts of control systems - General principles for design;
h) AS 5062-2006 Fire protection for mobile and transportable equipment;
i) AS 61508.1:2011 Functional safety of electrical/electronic/programmable electronic safety-related systems – General requirements;
j) AS 62061-2006 Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems;
k) ISO 8178-1:2006 Reciprocating internal combustion engines - Exhaust emission measurement -- Part 1: Test-bed measurement of gaseous and particulate exhaust emissions;
l) ISO 8178-4:2007 Reciprocating internal combustion engines -- Exhaust emission measurement -- Part 4: Steady-state test cycles for different engine applications;
m) ISO 13849-1:2006 Safety of machinery -- Safety-related parts of control systems -- Part 1: General principles for design;
n) ISO 16852:2008 Flame arresters -- Performance requirements, test methods and limits for use;
o) NIOSH Manual of Analytical Methods, Fourth Edition, Elemental Carbon (Diesel Particulate): Method 5040;
p) MDG 29:2008 Guideline for the management of diesel engine pollutants in underground environments;
q) MDG 3608:2012 Guideline for Non-metallic materials for use in underground coal mines;
r) UN Reg096r3.

3. In this technical standard, all references to the engineering standards at 2.3.2(a) and 2.3.2(e) to r) above is a reference to such standard, as amended from time to time.
4. Where a difference occurs between those engineering standard at 2.3.1 or 2.3.2 and this technical standard, this technical standard must be complied with.

2.4 Hazard identification

2.4.1 Ignition of explosive atmosphere

1. All ExDES must be assessed to identify all reasonably foreseeable lifecycle potential ignition sources that could occur. The assessment must:
   a) consider the entirety of the diesel engine system
   b) consider reasonably foreseeable misuse and reasonably foreseeable human error
   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) consider the effect of the diesel engine system operating in a methane-enriched atmosphere
   f) consider possible failure modes of the diesel engine system, including and without limitation:
      (a) loss of functionality of engine cooling system
      (b) loss of functionality of engine lubrication system

(c) loss of functionality of engine exhaust cooling system

(d) loss of functionality of exhaust scrubber as an effective spark arrester and flametrap

(e) catastrophic failure of the diesel engine system.

2. Without limitation, hazardous ignition sources may include:
    a) hot surfaces, greater than 150°C
    b) flames
    c) mechanically generated sparks
    d) hot gases being expelled in the mine atmosphere, greater than 150°C
    e) hot exhaust particles being expelled into the mine atmosphere
    f) static electricity
    g) faulty or inadequately protected electrical equipment
    h) possible failure modes that could generate ignition sources.

2.4.2 Fire on diesel engine systems

1. All ExDES and FpDES must be assessed to identify the potential to initiate, sustain and propagate a fire. This assessment must consider reasonably foreseeable misuse and reasonably foreseeable human error.
2. Without limitation, hazardous heat sources may include:
    i) hot surfaces, greater than 150°C;
    j) hot gases being expelled in the mine atmosphere, greater than 150°C;

a) hot exhaust particles being expelled into the mine atmosphere.

2.4.3 Toxic emissions from diesel engine systems

1. All diesel engine systems must be assessed to identify the potential for the diesel engine system to emit harmful emissions into the mine atmosphere. The assessment must consider:
    a) lowering the harmful emissions to the lowest level reasonably practicable
    b) the diesel engine systems duty and lifecycle
    c) the effect of methane and dust on diesel emissions
    d) reasonably foreseeable misuse and reasonably foreseeable human error
    e) excessive exhaust backpressure or intake vacuum
    f) possible failure modes of emission control measure including means to detect those failures
    g) if used as a control measure, whether replaceable type particulate filters are fit for purpose.

2.4.4 Abnormal combustion of the diesel engine system

All diesel engine systems must be assessed to identify the potential for abnormal combustion to occur.

2.5 Risk control measures - general

1. Control measures must be provided to minimise risks, arising from explosion, fire, toxic emissions and abnormal combustion hazards. Control measures must be fit for purpose and control the risk to a level as low as is reasonably practicable. For ExDES, all effective ignition sources must be controlled.
2. Control measures must be applied in the following order, so far as is reasonably practicable:
   a) engineering control measures that do not rely on human intervention and minimise the likelihood of risks arising from the hazard
   b) engineering control measures that do not rely on human intervention and minimise the severity of risks arising from the hazard
   c) use of control measures that rely on human intervention.
3. The lifecycle effectiveness of the control measures must be assessed to ensure they are reliable and provide the required level of protection under all stated conditions within a stated period of time.
4. Control measures must be identified as either:
   a) a safety-related function
   b) a safety-related componentry.
5. Control measures must be designed to be sufficiently reliable so as to operate for the entire period between diesel engine system overhauls without loss of functionality. Control measures may include lifecycle change out of components and periodical proof testing to detect dangerous failures.

2.6 Safety-related componentry

1. All safety-related componentry must be designed, analysed, tested and documented using current engineering principles and relevant Australian and International Standards.
2. Safety-related componentry must be systematically analysed to determine all reasonably foreseeable failure modes and to verify that a sufficient level of reliability has been achieved.
3. Systematic analysis methods such as a failure modes effects analysis, fault tree analysis or other similar analysis methods must be used to assess safety-related componentry and to determine lifecycle inspection, maintenance, test and discard requirements, as required for lifecycle functionality.
4. Consideration must be given to fatigue testing or analysis, where applicable.

2.7 Safety-related functions

1. All safety-related functions arising from the hazard assessments at 2.4 above must be clearly identified.
2. Safety-related functions must be assessed using the following functional safety standards, as amended from time to time, as applicable to the design architecture and type of components used:
   a) application of performance levels (PL) in accordance with AS/NZ 4024.1503:2014 or ISO 13849-1:2006, and AS 4024.1502:2006; or
   b) application of safety integrity levels (SIL) in accordance with AS 61508.1:2011 or AS 62061:2006; or
   c) application of safety categories (CAT) to AS 4024.1501:2006 and AS 4024.1502:2006; or
   d) other relevant functional standards, provided an equivalent level of safety can be demonstrated.
3. Without limiting ignition, fire and abnormal combustion hazard assessments safety-related functions must, where applicable, be provided to protect against:
   a) high surface temperature

b) engine over speed (for ExDES)

c) high exhaust temperature

d) high methane in operating environment.

4. For safety-related functions that control effective ignition sources on ExDES, the following risk reductions must be achieved, so far as is reasonably practicable:

Frequency of effective ignition source during:	Risk reduction
Normal operation	PLd, SIL 2, or CAT 3
Expected malfunction	PLd, SIL 2, or CAT 3
Rare malfunction	PLb, SIL 1, or CAT 2

5. For safety-related functions that control effective ignition hazards or fire hazards on FpDES, the following risk reductions must be achieved, so far as is reasonably practicable:

Frequency of effective ignition source during:	risk reduction
Normal operation	PLd, SIL 2, or CAT 3
Expected malfunction	PLc, SIL 1, or CAT 2
Rare malfunction	Good engineering practice

6. So far as is reasonably practicable, safety-related functions must be monitored for failure and incorporate warning systems to detect faults.
7. Circuit contamination and effective filtration must be considered for all safety-related functions that rely on fluid power for control.
8. All safety-related functions must be independently assessed and verified that the required risk reduction has been achieved, so far as is reasonably practicable. The person carrying out this functional safety assessment must be competent with the functional safety standard at 2.7 above. The functional safety assessment must include:

   a) validation though evidence documentation

   b) a review of possible lifecycle systematic failures and corrective measures taken

   c) documentation on any assumptions used, such as those that relate to proof test intervals, periodic inspection and tests, environmental conditions and human behaviour.
9. For safety-related functions that provide an alert to the operator, the alert should provide a means for the operator to acknowledge the alert or be of such a nature that it is unlikely the operator would not be unaware of its activation.

2.8 Emergency stop safety function

1. All diesel engine systems must be provided with an emergency stop safety function.
2. The emergency stop safety function must be capable of stopping the diesel engine system independently from the normal diesel fuel shutdown system and must be capable of safely stopping the diesel engine system in an emergency under all foreseeable circumstances.
3. The emergency stop safety functions must be able to be manually activated by the operator of the diesel engine system.
4. Manual activation of the emergency stop safety function, including human factors must provide a probability of failure on demand of 0.1 as a minimum. So far as is reasonably

practicable this requires a risk reduction of PLd, SIL2 or CAT3 for the circuitry, excluding human factor.

5. The functional safety analysis must determine whether the emergency stop function needs to be automatically operated.
6. The emergency stop function must not damage the diesel engine system when activated.
7. The diesel engine system must be able to be restarted and used following activation of the emergency stop function.
8. Where emergency stop proof testing is required, it must be carried out with the diesel engine systems operating at load with the diesel engine system in an explosion protected (or fire protected) state.

2.9 High methane in operating environment

1. The diesel engine system must be provided with an automatic stop function to safely stop the diesel engine system in the event the volume of methane in mine atmospheres where the diesel engine system is operating exceeds:
   a) 1.25% methane for ExDES
   b) 0.25% methane for FpDES.
2. Prior to the diesel engine system automatically shutting down, a warning of high methane must be provided to the operator.
3. A function must also be provided to prevent a diesel engine system from starting whenever the volume of methane in the mine atmosphere is greater than -
   a) 1.25% methane for ExDES; and
   b) 0.25% methane for FpDES.
4. Indication, alarm or warning must be given to the operator whenever the methane concentration in the mine atmosphere is greater than 1.25% by volume.
5. The following risk reductions must be achieved for this automatic stop function, so far as is reasonably practicable;
   a) for ExDES - PLc, SIL1 or CAT 2; and
   b) for FpDES - PLd, SIL 2 or CAT 3.
6. The functional assessment must consider the location of any methane sensor(s).
7. Methane type gas monitors must be design registered.
8. For FpDES, the design must take into consideration -
   a) the time for the diesel engine system to stop turning when the methane sensor is activated, with the diesel engine system operating at rated power
   b) the time for a cold methane sensor to provide accurate readings when powered up.
9. So far as is reasonably practicable, methane monitors must record and save methane events.
10. FpDES must be provided with a zone protection system to prevent the diesel engine system operating in a hazardous area of the mine or any other areas within the mine where the atmosphere concentration is known to be greater than 0.25% methane by volume.

2.10 Specific design requirements – ignition and fire hazards

1. ***Surface temperature*** - The surface temperature of any external surface that comes into contact with the mine atmosphere must not exceed 150 degrees Celsius, under any condition of operation. Consideration should be given to sensors being installed at the hottest point(s) on the diesel engine system.
2. ***Materials*** - Clause 2.8 of AS/NZS 3584.1:2008 and clause 2.4 of AS/NZS 3584.2:2008 must be complied with. Non-metallic materials should be assessed against parts 4, 6 or 7 of MDG 3608:2012.

3. ***Light metal alloys*** - Uncoated or unprotected light metal alloys or aluminium must not be used:
   a) on any ExDES
   b) in any rotating component or in any component subject to impacts of any diesel engine system.
4. ***Flexible pipes and joints*** – where used, flexible pipes and joints must be designed and installed to avoid stresses that could cause premature rupture. Flexible joints may be used between the inlet and exhaust flametraps on any ExDES, provided the engineering analysis considers potential for fatigue failure.
5. ***Fuel systems*** – Clause 2.12 of AS/NZS 3584.1:2008 and clause 2.10 of AS/NZS 3584.2:2008 must be complied with.
6. ***Air inlet system*** - Clause 2.13 of AS/NZS 3584.1:2008 and clause 2.11 of AS/NZS 3584.2:2008 must be complied with. Where applicable, flame arresters must comply with the relevant parts of ISO 16852:2008.
7. ***Air compressors*** – Clause 2.14 of AS/NZS 3584.1:2008 and clause 2.12 of AS/NZS 3584.2:2008 must be complied with.
8. ***Cooling systems*** - Clause 2.15 of AS/NZS 3584.1:2008 and clause 2.13 of AS/NZS 3584.2:2008 must be complied with.
9. ***Fire suppression system (for FpDES)*** **-** All FpDES must be fitted with a fire suppression system that complies with AS 5062-2006, so far as is reasonably practicable.
10. ***Exhaust spark arrester*** – Clause 2.17.3 of AS/NZS 3584.1:2008 and clause 2.15.5 of AS/NSZ 3584.2:2008 must be complied with only in so far as those clauses relate to the testing of spark arresters. Otherwise, the spark arrester must comply with AS 1019:2000 *Internal combustion engines – Spark emission control devices* (as amended from time to time).
11. ***Particulate filter*** - Clause 2.17.5 of AS/NZS 3584.1:2008 and clause 2.15.7 of AS/NZS 3584.2:2008 must be complied with only in so far as those clauses relate to markings and testing for maximum continuous operating temperature and auto ignition temperature of the replaceable filter element.
12. ***Maintainability*** – FpDES and ExDES must be designed for maintainability and must taking into consideration the relevant parts of clause 3.2 of AS/NZS 3584.3:2012.
13. ***Maintenance information*** – Without limitation, design information must include the relevant parts of clauses 2.2 and 2.4 of AS/NZS 3584.3:2012

2.11 Additional design requirements – ExDES

1. ***Explosion protected joints*** - Clause 2.6 of AS/NZS 3584.2:2008 must be complied with. Despite the requirements of clause 2.6, the following applies:
   a) joints are not limited to being designated as fixed or open. Liquid immersed joints may be used; and
   b) water injection nozzles, turbochargers, superchargers and external joints on flame traps may only be exempt from open joint requirements when maximum tolerances are known and the component passes the required flame propagation tests at a tolerance exceeding that maximum.
2. All fixed connections must be engineered to withstand, without permanent deformation, the required test pressure in accordance with Appendix M of AS/NZS 3584.2:2008 using current engineering principles and relevant Australian or International Standards.
3. ***Explosion protected enclosures*** must be engineered to:
   a) withstand the pressure of an internal explosion
   b) withstand the proof testing pressure required for the enclosure to at least 1.5 times the maximum explosion pressure without deformation

   c) prevent propagation of an internal explosion to the outside of the explosion protected enclosure.

4. All electrical plant must be designed to comply with the relevant parts of clause 78, *Use of plant in hazardous zone (explosion-protection required)* of the Regulation. Where applicable, a systems assessment must be carried out by an independent competent person to verify the entity parameters on each electrical component is compatible and matched when assembled as an electrical control system, for the diesel engine system.
5. ***Exhaust flametrap*** – Clause 2.15.4 of AS/NSZ 3584.2:2008 must be complied with only in so far as that clause relates to the testing of flametraps.

2.12 Specific design requirements – emissions

1. Emission sampling points must be installed to sample raw exhaust and tail pipe emissions for the purpose of regular testing when the engine is installed in a machine. The sampling points must be:
   a) readily accessible to a person carrying out regular routine test in field testing
   b) designed for regular removal and replacement
   c) installed before any explosion testing
   d) comply with requirements for fixed or open joints (for ExDES)
   e) designed to minimise potential for the sample point to be left in an non-explosion protected state following sampling (for ExDES).
2. In the event the exhaust backpressure or intake vacuum exceeds the limit specified by the diesel engine system manufacturer a means must be provided to bring the diesel engine to a safe state or otherwise alert the operator, so far as is reasonably practicable.

3 Testing requirements

3.1 Test facility

1. The test facility used for type testing must be a test facility that is unrelated to the designer, manufacturer or supplier.
2. The test facility must either be:
   a) a test facility in Australia and accredited for conducting the tests and for the issue of reports for those tests by the National Association of Testing Authorities or
   b) a facility acceptable to the Chief Inspector having regard to test equipment, equipment calibration, quality processes, work methods, past test experience and independent technical verification.
3. In the case of diesel emissions either be:
   a) a person holding a licence for the sampling or analysing of diesel engine exhaust in accordance with Part 9 of the Regulation at a suitable test facility or
   b) a person acceptable to the Chief Inspector having regard to test equipment, equipment calibration, quality processes, work methods and past sampling and analysing experience.

3.2 Test standards and diesel fuel

1. All diesel engines must be tested using the relevant equipment, methods and test cycles as specified in this technical standard and, so far as is reasonably practicable consistent with:
   a) ISO 8178-1:2006 or UN Reg096r3 Annex 4A or Annex 4B and Annex 5 for the relevant power band
   b) ISO 8178-4:2007 for the relevant steady state cycle as specified by test cycle C1 '*Off-road vehicles, diesel-powered off-road industrial equipment*' (known as NRSC) and test cycle

D2 '*generating sets with intermittent load'*, or UN Reg096r3 Annex 4A or Annex 4B and Annex 5 for the relevant power band

c) UN Reg096r3, Annex 4A or Annex 4B and Annex 5, for the NRTC

d) MDG 29:2008 clauses 5.2, 5.3, 6.2 and 6.3.

2. All testing must be carried out using diesel fuel complying with

- the Fuel Quality Standards Act 2000 of the Commonwealth and
- the Fuel Standard (Automotive Diesel) Determination 2001 made under that Act, and clause 6 of ISO 8178-1:2006.

3.3 Functional testing of explosion protected properties of ExDES

1. Testing of the explosion protected properties of a diesel engine system must be carried out in accordance with the relevant parts of AS/NZS 3584.2:2008, as specified below:
   a) Clause 4.1 applies only in so far as the clause relates to explosion protection
   b) Appendix E must apply the relevant test modes of NRSC in ISO 8178-4:2007, or relevant parts of UN Reg096r3, Annex 4A or Annex 4B and Annex 5 for the relevant power band
   c) Appendix F applies only in so far as the procedure is concerned. Testing of safety related functions must be carried out in accordance with the functional safety analysis and functional safety standard in 2.7.2
   d) Appendix G
   e) Appendix H applies for disposable type filters
   f) Appendix L
   g) Appendix M
   h) Appendix N.
2. Surface temperature testing must be carried out using an air intake of 1.25% methane by volume.
3. Surface temperature testing must include the regeneration of exhaust treatments devices and the worst case for heat during regeneration, taking into consideration any foreseeable operating conditions.
4. All testing must be carried out on components and joints with tolerance limits and surface finish set to produce the worst result for explosion protection and exceed those limits stated in manufacturing drawings, so far as is reasonably practicable. This does not include valve stems, valve guides, pistons, cylinder rings or fuel injectors.

3.4 Functional testing of fire protected properties of FpDES

1. Testing of the fire protected properties of a diesel engine system must be carried out in accordance with the relevant parts of AS/NZS 3584.1:2008, as specified below:
   a) Clause 4.1 applies only in so far as the clause relates to fire protection
   b) Appendix E must apply the relevant test modes of ISO 8178-4:2007 , cycles C1 or D2, or UN Reg096r3 Annex 4A or Annex 4B and Annex 5 for the relevant power band
   c) Appendix F applies only in so far as the procedure is concerned. Testing of safety-related functions must be carried out in accordance with the relevant functional safety analysis and functional safety standard
   d) Appendix G
   e) Appendix H applies to disposable type filters.
2. Temperature testing must be carried out using either:
   a) an air intake of 0.25% methane by volume
   b) an air intake without methane with additional calculations to simulate the expected rise of surface and exhaust temperature due to methane injection of the diesel engine system.

3. Temperature testing must include the regeneration of exhaust treatment devices and the worst case for heat during regeneration, taking into consideration any foreseeable operating conditions.

3.5 Testing for exhaust emissions – steady state cycle

1. All volumetric calculations must be reported at 25^{o} C and 1 atmosphere (101.3kPa).
2. Test equipment and procedures must comply with 3.2 above.
3. Diesel particulate measuring equipment must be either a partial or full flow dilution tunnel.
4. When tested on the relevant steady cycle, the following emissions must be measured for at the engine exhaust manifold (raw, untreated exhaust, engine out) and at the diesel engine system tail pipe (undiluted and treated exhaust), with gaseous emissions measured before any liquid-based flame arrestor. Emissions must be measured at each modal point on the test cycle:
   a) Carbon Dioxide (CO_2);
   b) Carbon monoxide (CO);
   c) Nitric Oxide (NO);
   d) Nitrogen Dioxide (NO_2);
   e) Hydrocarbons (HC);
   f) Oxygen (O_2);
   g) Diesel particulate (DP);
   h) Elemental Carbon (EC) – using a quartz filter in the dilution tunnel to collect DP and the NIOSH 5040 method for analysis of total carbon (TC), elemental carbon (EC) and organic carbon (OC).
5. Emissions must be reported as follows:
   a) a concentration of exhaust flow
   b) weighted brake specific emissions
   c) mass flow in grams/hr emitted.
6. Where removable type particulate filters are used, results must be reported with and without the filter installed.
7. All testing must be carried out using the discrete mode method with the exception of DP and EC, which may use a ramped modal cycle.
8. The DP signature must be calculated for both DP and EC as specified in clause 5.2 of the MDG 29:2008, using specific emissions from the NRSC as specified in this technical standard, and using a concentration of 0.1mg/m^3 for EC and 0.2mg/m^3 for DP.
9. Where removable type particulate filters are used, the particulate signature must be calculated both with and without the filter installed.
10. The DP filter efficiency must be calculated for DP using the specific emissions for the diesel engine system. Where removable type filters are used, a new filter must be used at the start of steady state cycle and transient cycle tests (where applicable).
11. The effectiveness of the gaseous emissions treatment system must be calculated for NO_x, CO and HC using the specific emissions for the diesel engine system.
12. The specific EC/TC ratio for the engine must be calculated.
13. The specific results must be adjusted for the following multiplicative DFs, unless the DFs to be applied are otherwise specified and validated by the diesel engine system manufacturer.

Test cycle	CO	HC	NOx	PM
NRSC, constant speed or NRTC	1.3	1.3	1.15	1.05

Multiplicative deterioration factors (DFs)

Additive DFs may be used, where appropriate evidence can validate the nominated values.

14. In addition to the above, gaseous and particulate emissions from the diesel engine system must be measured as follows:
    a) with the air inlet restricted to 5.3kPa
        - at rated speed
        - loaded at intermediate speed
        - at high-idle speed, with no load
    b) at rated speed, with the exhaust outlet restricted to the maximum back pressure specified by the diesel engine system and without inlet restriction
    c) for ExDES engines, at rated speed and at intermediate speed with 0.6% methane by volume in the intake air.
15. For each mode over the steady state cycle, a signature of the diesel engine exhaust particle size and numbers must be recorded. Particle count or particle sizing must be carried out on a particle analyser of a laboratory standard which is capable of measuring particle sizing between 5nm to 500nm.

3.6 Testing for exhaust emissions – transient cycle

1. Diesel engine systems of greater than 56kW rated power must be tested on the NRTC as specified in UN Reg096r3, Annex 4A (power bands E to P) or Annex 4B (power bands Q and R) and Annex 5, so far as is reasonably practicable. Testing to the transient cycle is not required for constant speed engines or engines of less than 56kW rated power.
2. The NRTC must be run twice. The first time (cold start) after the engine has soaked to room temperature. The second time (hot start) after a 20 minute hot soak that began immediately after completion of the cold start cycle.
3. DP and EC emissions must be measured for both cold and hot runs and reported in g/kWh.
4. Composite weighted results must be calculated by weighting cold start (10%) and the hot start (90%).
5. A regression analysis must be carried out to validate the results.
6. The weighted results must be adjusted for DFs.
7. Filter efficiency must be calculated using the NRTC.

3.7 Testing for exhaust emissions – removable particulate exhaust filters

1. The diesel engine system must be operated at intermediate speed at full throttle setting for at least 6 hours with a clean particulate filter installed. The test must be carried out with the engine dynamometer set at a speed priority mode, with the torque values decreasing as filter blockage increases.
2. Gaseous emissions, exhaust backpressure and exhaust temperature must be recorded at the start and end of the test.
3. DP or EC readings, using a device which complies with section 8 of MDG 29:2008, must be taken at 0, 5, 10, 15 minutes and then every 15 minutes thereafter for six hours. In addition DP readings should be taken each hour using a partial or full flow dilution tunnel.
4. For constant speed engines, this test must be carried out at rated speed at full throttle setting.

5. The diesel engine system must still be in a safe condition of use at the end of the six hours.

3.8 Testing for exhaust emissions – regenerative type treatment devices

1. Diesel engine systems with fixed element particulate filters must be tested for:
   a) regeneration of the particulate filter for level of exhaust emissions
   b) regeneration of particulate filters for excessive temperature
   c) the regeneration period, whether continuous or intermittent
   d) the lowest exhaust temperature for regeneration
   e) effects of blockage on the filter
   f) lifecycle degradation.

4 Performance standards

4.1 Explosion protected and fire protected properties.

1. ExDES and FpDES must pass the specific performance requirements in 2.7 to 2.10 of this technical standard.
2. In addition to 4.1.1 above:
   a) ExDES must pass the specific performance requirements in 2.11 and 3.3 of this technical standard
   b) FpDES must pass the specific performance requirements in 3.4 of this technical standard.
3. When carrying out the pressure determination testing and hydrostatic testing (for ExDES), there must be no leakage or permanent deformation of fixed connections or manifolds during any testing.

4.2 Exhaust emissions

1. The diesel engine system must pass the following performance outcomes (after adjustment for DFs), for undiluted tail pipe brake specific emissions on the relevant steady cycle.

	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
Pass criteria	3.0	1.3	8.0	0.04
Pass criteria after 1 July 2017	1.5	1.3	8.0	0.025
Pass criteria after 1 July 2020	1.0	1.0	5.5	0.025

2. The diesel engine system will be labelled according the to the following table:

Power band	**Net Power (kW)**	**Max limits (g/kWh) CO**	**Max limits (g/kWh) HC**	**Max limits (g/kWh) NOx**	**Max limits (g/kWh) PM / filter**	**Engine label** SC
E	130 ≤ P ≤ 560	3.0	1.0	6.0	0.04	SC-2
F	75 ≤ P ≤ 130	3.0	1.0	6.0	0.04	SC-2
G	37 ≤ P ≤ 75	3.0	1.3	7.0	0.04	SC-2
D	18 ≤ P ≤ 37	3.0	1.5	8.0	0.04	SC-2
H	130 ≤ P ≤ 560	3.0	4.0		0.04	SC-3
I	75 ≤ P ≤ 130	3.0	4.0		0.04	SC-3
J	37 ≤ P ≤ 75	3.0	4.7		0.04	SC-3
K	19 ≤ P ≤ 37	3.0	7.5		0.025	SC-3
L	130 ≤ P ≤ 560	1.0	0.19	2.0	0.025	SC-3B
M	75 ≤ P ≤ 130	1.0	0.19	3.3	0.025	SC-3B
N	56 ≤ P ≤ 75	1.0	0.19	3.3	0.025	SC-3B
P	37 ≤ P ≤ 56	1.0	4.7		0.025	SC-3B
Q	130 ≤ P ≤ 560	1.0	0.19	0.4	0.025	SC-4
R	56 ≤ P ≤ 130	1.0	0.19	0.4	0.025	SC-4

3. For CO, NO2 and NO the maximum unweighted gaseous emissions for each mode and for the tests specified in 3.5.14 above, must comply with the following:

Pollutant emitted from exhaust (mg/s)	<	$\underline{(TWA_{Pollutant}(mg/m^3)x(Nameplate\ ventilation\ (m^3/s))}$ /(DF)

4. The diesel engine system must pass the following performance outcomes (after adjustment for DFs), for undiluted tail pipe DP on the NRTC:

	PM (g/kWh)
Pass criteria	0.04
Pass criteria after 1 July 2017	0.04
Pass criteria after 1 July 2020	0.025

5. FpDES that comply with the UN Reg096r3, for stage IIIB or stage IV emissions (power bands L to R) may be deemed to comply with this technical standard, in so far as emissions are concerned and do not need to be tested for emission, provided the diesel engine system:
   a) is in accordance with the stage rating;
   b) meets the CO limits in 4.2.1;
   c) There is technical justification that all modifications to the certified engine configuration to meet surface and exhaust emission temperatures and other requirements of this Technical Standard do not increase emissions beyond certification limits.

4.3 Nameplate ventilation quantity – Clean air basis

1. The nameplate minimum ‘clean air’ ventilation requirement for the diesel engine system will be the maximum value of:
   a) 0.06m^3/s/kW at maximum rated power output; or
   b) 3.5m^3/s; or
   c) the particulate signature.
2. Where an diesel engine system is labelled SC3B or SC4 as in 4.2.2 above, the nameplate minimum ‘clean air’ ventilation requirement for the diesel engine system will be the maximum value of:
   a) the highest of the ventilation rates achieved by diluting each of the pollutants NO_2, NO, CO and HC to 30% of their respective TWA limits using the DFs adjusted specific values
   b) the particulate signature.

4.4 In vehicle/machine type tests

When a diesel engine system is first installed in a type machine, the following must be carried out to confirm type testing performance in that machine:

a) validate baseline emissions are within the type testing results, so far as is reasonably practicable, in accordance with clause 5.3 of MDG 29:2008 and ISO 8178.2:2008, as applicable. This must be done using the dedicated sampling point and procedure for the diesel engine system in that particular machine;

b) for ExDES, validate inclination testing of flametraps as set out in AS/NZS 3584.2:2008;
c) validate functionality of all safety functions as set out by the functional safety analysis.

4.5 Ongoing design performance

So far as is reasonably practicable, diesel engine systems must be manufactured in accordance with a quality system consistent with the following standards, as amended from time to time:

a) Sections 4 to 8 of AS/NZS ISO 9001:2008 *Quality management systems –Requirements*; and

b) Sections 4 to 9 of AS/NZS 80079.34:2012 *Explosive atmospheres - Application of quality systems for equipment manufacture.*