EMESRT

Earth Moving Equipment Safety Round Table

PERFORMANCE REQUIREMENT 4
MOBILE EQUIPMENT FIRES MANAGEMENT

Earth Moving Equipment Safety Round Table

Working with industry since 2006

DOCUMENT CONTROL

1. REVISION HISTORY

Rev	Date	Description	Prepared by	Checked by	Approved by
0.14	February 2021	Document developed, reviewed by EAG and Working Group	Mark Geerssen, Rio Tinto Peter Hasler, Alcoa Tony Egan, Glencore Mike Boyle, Risk Mentor	Equipment Fires Working Group	EMESRT Advisory Group
0.15	October 2021	Updated in line with OEM feedback where appropriate	Mike Boyle, Risk Mentor Eve McDonald, EMESRT	Mark Geerssen, Rio Tinto Tony Egan, Glencore Equipment Fires Working Group	EAG Major OEMs
1.0	December 2021	Final version approved	Mike Boyle, Risk Mentor Eve McDonald, EMESRT	Mark Geerssen, Rio Tinto	EMESRT Advisory Group

2. DISCLAIMER

While every attempt has been made to validate the contents of this Performance Requirement 4 (PR-4) document, the content has been collated from industry leading practice and therefore may change over time. For this reason, EMESRT reserves its right to update and re-issue PR-4 as industry practice evolves.

3. CONDITIONS OF USE

EMESRT has an ambition to reduce the Health and Safety risks from operating and maintaining mobile earth moving equipment. This is achieved by sharing leading practice information that can be referenced by users and designers when seeking to reduce the level of risk to personnel. Connecting through a community collaboration of; end users, OEMs, researchers, and third-party suppliers it allows a deep understanding of the problems needed to be addressed to support industry level improvement.

PR-4 has been developed to embellish the understanding of problems set out in potential unwanted events as documented in Design Philosophy 4 - Fires.

3.1 TRANSLATIONS

PR-4 was developed and reviewed in English only. If PR-4 content, in part or in its entirety is translated, only the English version published by EMESRT is the approved version.

3.2 USAGE

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TABLES

1.0 OVERVIEW

Mobile equipment fires continue to occur regularly in the mining and resources industry and there are clear drivers to improve the understanding and application of fire prevention and mitigation controls.

Mobile equipment fire events:

- Present significant risks for operators, maintainers, and emergency responders
- Can be catastrophic in underground operations
- Create wider operational and commercial issues for earthmoving equipment owners and operators
- Require mandatory statutory reporting in most mining jurisdictions
- Have been extensively analysed and regulators now expect that mine operators will improve their mobile equipment fire management performance

DP-4 is a high-level overview of problems that can lead to adverse consequences from mobile equipment fire events.

This EMESRT Performance Requirement has been prepared to augment Design Philosophy 4 Fires. It applies to the following potential unwanted events (PUE) scenarios:

DP 4.1 Harm from fire arising from damage (including heating, melting and chaffing) to electrical cables and components; hydraulic hoses; and fuel lines due to design inadequacies including:

a. Poor location
b. Inadequate separation of fuel and ignition sources
c. Flaws in clamping or restraints

DP 4.2 Harm from fire arising from heat generated by surface frictions (including tyres)

DP 4.3 Harm from fire igniting in, or being propagated by, the buildup of combustible material e.g. dirt, oily rags

DP 4.4 Harm from entrapment in the cabin due to fire blocking emergency egress

DP 4.5 Harm from entry into hazard zones due to the location of isolation points for fuel sources

DP 4.6 Injury to personnel, either during normal operation or in the event of a roll over or other accident, from inhalation, ingestion, skin abrasion, slips, trips or other mechanism due to:

a. Fire Suppression System components that are poorly located
b. Accidental actuation of the Fire Suppression System

DP 4.7 Harm from excessive/uncontrolled spread of fire, due to:

a. Lack of automatic engine shutdown and/or isolation of fuel sources
b. Inactivation of Fire Suppression System due to the effects of fire and/or other damage
c. Delayed activation of Fire Suppression System due to difficult access to Fire Suppression System controls
d. Reduced effectiveness of Fire Suppression System as a result of OEM fitted options, such as noise suppression blankets

DP 4.8 Design, that fails to adequately separate heat and fuel sources, i.e., rubber rather than fixed steel hydraulic fuel sources routed in engine bay, tyres inadequately shielded from heat sources, due to:

a. Inadequate engine ventilation design that directs air from fuel sources across heat sources
b. Inadequate design of firewall and bulkhead sealing to prevent spread of fire
c. The use of construction materials that fuel a fire, i.e., flammable engine covers and mudguards

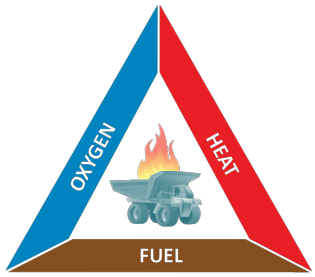
This document should be read in conjunction with DP-4 Fire.

2.0 PERFORMANCE REQUIREMENT OBJECTIVES

The objective of this Performance Requirement is to provide structured and comprehensive information that can be applied by:

- Designers and Manufactures of Original Equipment Manufacturers (OEM)
- Mining companies - Mobile Equipment Users
- Suppliers of fire detection and suppression systems to reduce the number and consequences of mobile equipment fires in earth moving equipment

3.0 DESIGN PRINCIPLES



The information provided is based on the heat, fuel, and oxygen fire triangle.

In a mobile equipment fire situation, the primary goal is to protect personnel, before equipment and adjacent assets.

Mobile Equipment fire prevention and mitigation is based on this sequence:

- Fire risk reviews during factory design of equipment that considers:
  - Prevention of fires – through fuel elimination / segregation design
  - Prevention of fires – through ignition avoidance elimination / segregation design
- Prediction of potential fires with real-time notification to equipment operator, their supervisor, and site emergency response team
- Early fire detection and local response with suppression that allows for safe operator egress
- Early fire detection and local response with suppression and the use of escape devices that allows for safe operator egress
- Early fire detection and local response that extinguishes fire though a combination of fuel elimination, energy isolation, cooling, and oxygen deprivation, etc
- Providing, where practical, connectivity points on mobile equipment that increase site emergency response extinguishment capability e.g. through external connections on excavators for adding deluge fluid beyond that stored in onboard deluge systems
- Provide capability for the operator / site emergency response to isolate fuel and air sources to protect personnel and prevent the fire spreading

4.0 FIRE EVENT TREE AREAS OF INFLUENCE

This Performance Requirement uses a Mobile Equipment Fires Event Tree model in *Figure 1* to define these Mobile Equipment Fire Management areas of influence:

Mobile Equipment Design

Mobile Equipment Maintenance Management

Fire System Detection and Suppression Design

Operating Company Emergency and Crisis Management

Further event tree detail is developed in *Table 1,* where the event tree pathway steps and outcomes are aligned with relevant and overlapping areas of influence.

4.1 EMESRT Mobile Equipment Fire Management Credible Failure Mode Details by Area of Influence

Further details of relevant Credible Failure Modes from the EMESRT Mobile Equipment Fire Management Control Framework sorted by area of influence are provided in three supporting tables:

- *Table 2 - Credible Failure Modes relevant to Mobile Equipment Design*
- *Table 3 - Credible Failure Modes relevant to Mobile Equipment Maintenance*
- *Table 4 - Credible Failure Modes relevant to Fire Detection and Suppression System*

Where relevant illustrative operational examples of failure modes are also provided.

Figure 1 - Mobile Equipment Fire Event Tree with Areas of Influence

Key

- Mobile Equipment Design
- Mobile Equipment Maintenance Management
- Fire System Detection and Suppression Design
- Operating Company Emergency and Crisis Management

Note: this Performance Requirement does not consider the Mobile Equipment User Emergency Management Zone.

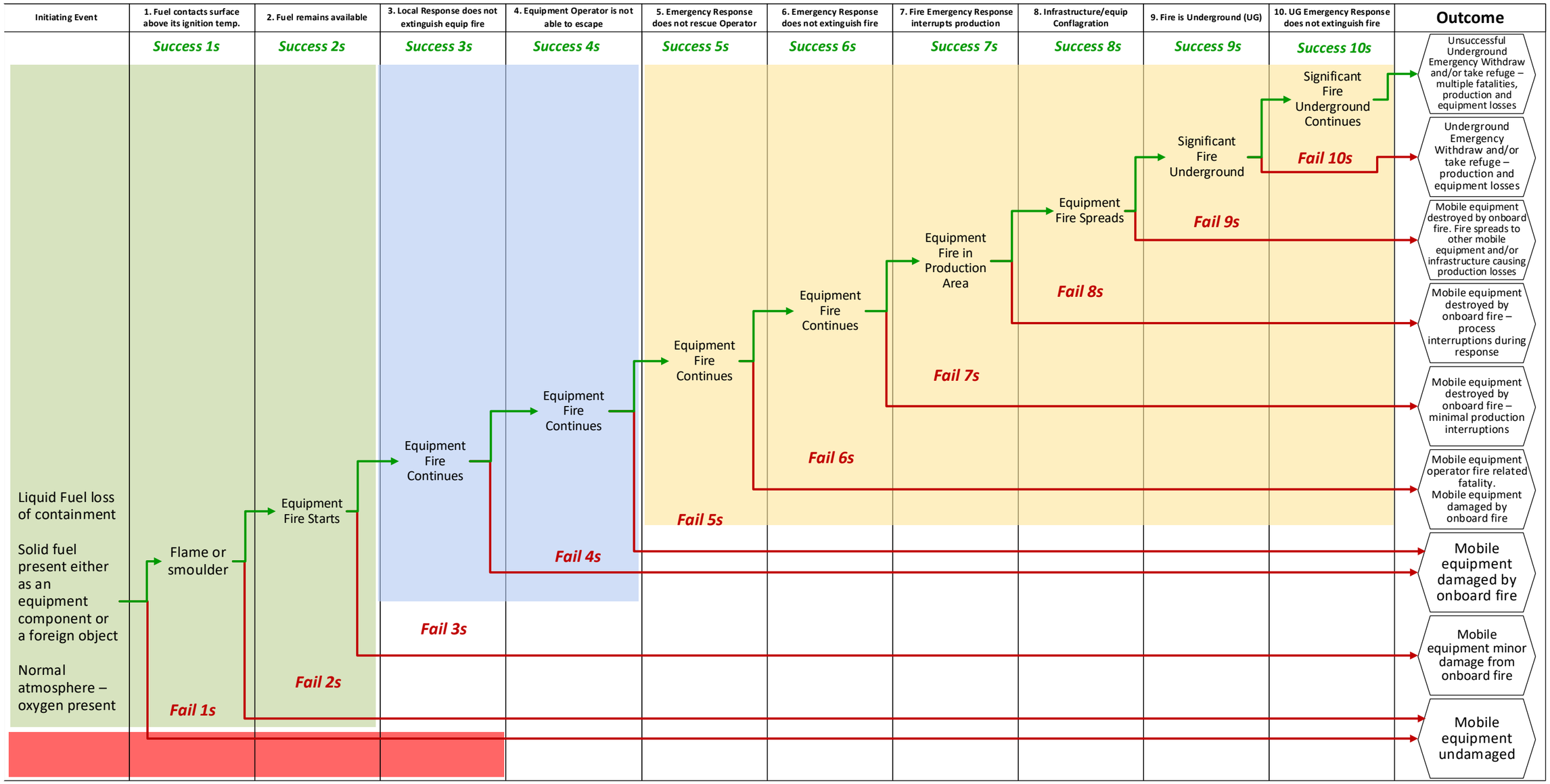


Table 1 - Event Tree Pathway Steps, Outcomes and Areas of Influence

Pathway	Pathway Steps	Outcomes	Area of Influence	Area of Influence Notes
Fail 1s	*Fuel present* *Fuel ignition temperature not reached* *No ignition*	*Mobile equipment undamaged*	**Mobile Equipment Design**	**OEMs** supply mobile equipment with non-flammable equipment components. **OEMs** supply mobile equipment that is maintenance task error tolerant.
			Mobile Equipment Maintenance Management	**Mobile Equipment Maintainers** have processes that confirm maintenance tasks are completed to adequately maintain the design integrity and includes checking for foreign objects and flammable material accumulations.
Fail 2s	*Fuel present* *Fuel ignition temperature reached* *Flame or smoulder* *Flame or smoulder exhausts fuel and self-extinguishes*	*Mobile equipment undamaged*	**Mobile Equipment Design**	**OEMs** supply equipment where should an ignition event occur, there is limited propagation and it self-extinguishes from fuel starvation or equipment component properties. **OEMs** supply mobile equipment that is maintenance task error tolerant.
			Mobile Equipment Maintenance Management	**Mobile Equipment Maintainers** have processes that confirm maintenance tasks are completed to adequately maintain the design integrity and includes checking for foreign objects and flammable material accumulations.
Fail 3s	*Fuel present* *Fuel ignition temperature reached* *Flame or smoulder* *Flame or smoulder has sufficient fuel to establish an onboard fire* *Local response extinguishes fire*	*Minor mobile equipment damage*	**Fire System Detection and Suppression Design**	**OEMs or Third-party Suppliers** supply fire detection and suppressions systems that are capable of detecting and extinguishing onboard fires. **OEMs or Third-party Suppliers** supply fire detection and suppressions systems that are maintenance task error tolerant.
			Mobile Equipment Maintenance Management	**Mobile Equipment Maintainers** have the capability to maintain adequately designed fire detection and suppression systems.

Pathway	Pathway Steps	Outcomes	Area of Influence	Area of Influence Notes
Fail 4s	*Fuel present* *Fuel ignition temperature reached* *Flame or smoulder* *Flame or smoulder has sufficient fuel to establish an onboard fire* *Local response unable to extinguish fire* *Fire continues* *Operator escapes*	*Mobile equipment is damaged*	**Fire System Detection and Suppression Design**	**OEMs or Third-party Suppliers** supply fire detection and suppressions systems that are capable of detecting and alerting operators to respond appropriately and provide time for their safe egress. **OEMs or Third-party Suppliers** supply fire detection and suppressions systems that are maintenance task error tolerant. **Mobile Equipment Maintainers** have the capability to maintain adequately designed and appropriately installed fire detection and suppression systems.
Fail 5s	*Fuel present* *Fuel ignition temperature reached* *Flame or smoulder* *Flame or smoulder has sufficient fuel to establish an onboard fire* *Local response unable to extinguish fire* *Fire continues* *Operator unable to escape* *Trapped operator is rescued*	*Operator may be injured* *Mobile equipment is damaged*	**Operating Company Emergency and Crisis Management**	**No relevant areas of influence in relation to OEM / Third-party equipment design**
Fail 6s	*Fuel present* *Fuel ignition temperature reached* *Flame or smoulder* *Flame or smoulder has sufficient fuel to establish an onboard fire* *Local response unable to extinguish fire* *Fire continues* *Operator unable to escape* *Trapped operator cannot be rescued*	*Mobile equipment operator fire related fatality* *Mobile equipment is damaged*	**Operating Company Emergency and Crisis Management**	**No relevant areas of influence in relation to OEM / Third-party equipment design**

Pathway	Pathway Steps	Outcomes	Area of Influence	Area of Influence Notes
Fail 7s	*Fuel present* *Fuel ignition temperature reached* *Flame or smoulder* *Flame or smoulder has sufficient fuel to establish an onboard fire* *Local response unable to extinguish fire* *Fire continues* *Emergency Response cannot extinguish fire* *Fire exhausts all fuel sources and burns out*	*Mobile equipment destroyed by onboard fire*	**Operating Company Emergency and Crisis Management**	**No relevant areas of influence in relation to OEM / Third-party equipment design**
Fail 8s	*Fuel present* *Fuel ignition temperature reached* *Flame or smoulder* *Flame or smoulder has sufficient fuel to establish an onboard fire* *Local response unable to extinguish fire* *Fire continues* *Emergency Response cannot extinguish fire* *Fire exhausts all fuel sources and burns out* *The fire occurs in a critical production area*	*Mobile equipment destroyed by onboard fire* *Significant production interruptions*	**Operating Company Emergency and Crisis Management**	**No relevant areas of influence in relation to OEM / Third-party equipment design**
Fail 9s	*Fuel present* *Fuel ignition temperature reached* *Flame or smoulder* *Flame or smoulder has sufficient fuel to establish an onboard fire*	*Initiating event mobile equipment destroyed by onboard fire*	**Operating Company Emergency and Crisis Management**	**No relevant areas of influence in relation to OEM / Third-party equipment design**

Pathway	Pathway Steps	Outcomes	Area of Influence	Area of Influence Notes
	Local response unable to extinguish fire *Fire continues* *Emergency Response cannot extinguish fire* *Fire spreads to other mobile equipment and/or infrastructure*	*Other mobile equipment and/or infrastructure fire losses* *Significant production interruptions*		
Fail 10s	*Fuel present* *Fuel ignition temperature reached* *Flame or smoulder* *Flame or smoulder has sufficient fuel to establish an onboard fire* *Local response unable to extinguish fire* *Fire continues* *Emergency Response cannot extinguish fire* *Fire is underground* *Fire spreads to other mobile equipment and/or infrastructure* *Successful underground emergency withdraw and/or take refuge*	*Initiating event mobile equipment destroyed by onboard fire* *Other mobile equipment and/or infrastructure fire losses* *Significant production interruptions*	**Operating Company Emergency and Crisis Management**	**No relevant areas of influence in relation to OEM / Third-party equipment design**
Success 10s	*Fuel present* *Fuel ignition temperature reached* *Flame or smoulder* *Flame or smoulder has sufficient fuel to establish an onboard fire* *Local response unable to extinguish fire* *Fire continues* *Emergency Response cannot extinguish fire*	*Multiple fatalities* *Initiating event mobile equipment destroyed by onboard fire* *Other mobile equipment and/or infrastructure fire losses*	**Operating Company Emergency and Crisis Management**	**No relevant areas of influence in relation to OEM / Third-party equipment design**

Pathway	Pathway Steps	Outcomes	Area of Influence	Area of Influence Notes
	Fire is underground *Fire spreads to other mobile equipment and/or infrastructure* *Unsuccessful Underground Emergency Withdraw and/or take refuge*	*Significant production interruptions*		

EMESRT Mobile Equipment Fire Management Credible Failure Mode Details by Area of Influence

Right: The hierarchy and components of a Control Framework.

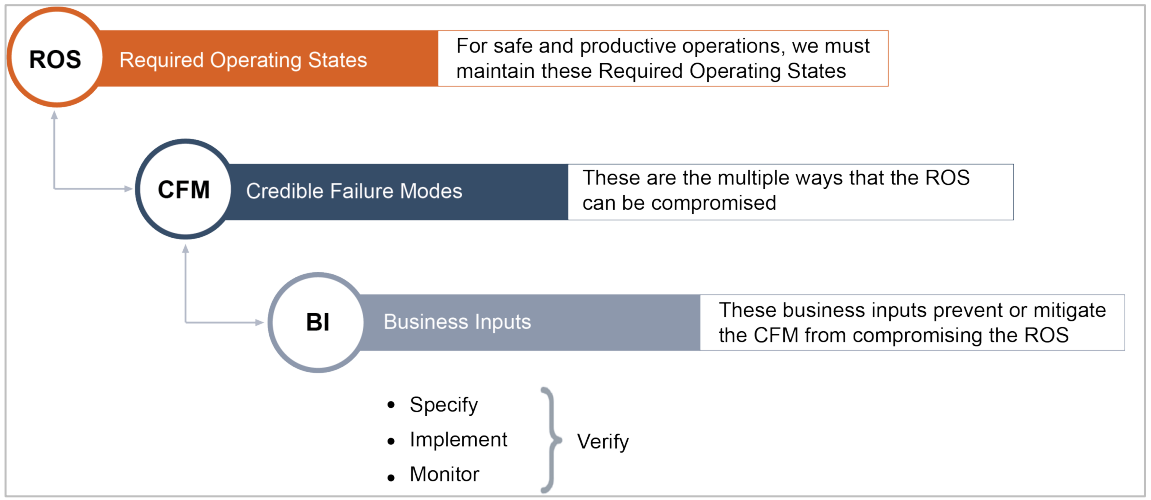


Table 2 - Credible Failure Modes Relevant to Mobile Equipment Design

Design Failure Modes	Mobile Equipment Design Credible Failure Modes - Name and Description
Liquid containment failures	**CFM-DE-01 Liquid fuel loss of containment - design inadequacy** During normal operations, there is a failure of reservoirs, hoses or lines containing fuel, hydraulics, lubrication, coolants, etc. caused by: ▪ Rubbing, vibration, corrosion, etc ▪ The released liquid is a fuel that can be ignited in its specified or particular state e.g. turbo charger, exhaust, electrical fault, atomized fluids at pressure, etc ▪ Pressurised bearings which continue to feed fuel (oil) to turbo even after shutdown of engine triggered ▪ Gravity fed oil to turbo (continues to feed fuel (oil) after shutdown of engine triggered) ▪ Failure to consider the damage exposure of external components (e.g. flammable liquid storage tank caps and breathers, overflow position, etc) ▪ The loss of containment is due to equipment or component design failure from OEM or third-party supplier

Design Failure Modes	Mobile Equipment Design Credible Failure Modes - Name and Description
Flammable mobile equipment components	**CFM-DE-02 Solid fuel present on mobile equipment - specification inadequacy** During normal operations, fuel other than liquid is present and can be ignited including: ▪ Contact of components with a turbo charger, exhaust, electrical fault, etc ▪ The fuel is present through OEM or third-party equipment or component design or design fault, this includes aftermarket retrofits, e.g. combustible covers and guards on mobile equipment ▪ No consideration of products of combustion of flammable components (e.g. FRAS products that produce CN gases) ▪ Batteries (on electrically powered vehicles) are flammable ▪ Solid fuel hazard identification inadequate through - design and design specifications, audits, risk assessments, site acceptance, etc
External fuel accumulation	**CFM-DE-03 Fuel is introduced to mobile equipment - design inadequacy** During normal operations the equipment design does not prevent build ups of external fuel in mobile equipment, including: ▪ Hot component or nearby surfaces that allow accumulation of coal dust, sulphide ores, organic matter, etc
Inadequate insulation or shielding	**CFM-DE-04 Excessive heat is produced and not effectively contained/shielded from fuel sources during mobile equipment operation - design inadequacy** During normal operations, there are exposed hot surfaces above the ignition temperature of probable fuel sources, including: ▪ Electrical failures such as jammed starter motors ▪ Overheated cables or faults due to inadequate excessive load or short circuit protection ▪ Electrical fault around battery with damage to insulation, shorting of leads, and/or contact between live components and machine body ▪ Alternator faults ▪ Thermal insulation of hot surfaces e.g. for turbo chargers, exhaust systems and including insulation for noise attenuation ▪ Inadequate segregation, protection and restraint in cable routing proximate to flammable materials/fuels
Error intolerant design	**CFM-DE-10 OEM does not provide an appropriate maintenance strategy for the supplied plant** Adequate equipment design and supply includes providing the operator with maintenance task information. Some examples of failings are: ▪ Maintenance and servicing requirements not well identified and described e.g. brake systems, hot surface protection service life, mean time to failure for hydraulic hoses, etc ▪ Adequate access and ability to execute the maintenance tasks inhibited by machine design which introduces the potential for error ▪ Components that are critical for fire prevention or suppression not identified in the maintenance strategy as requiring a shorter frequency of inspection and/or replacement ▪ Inadequate identification of fire related machine components (e.g. fuel lines, piping, detectors, rotating component failures, etc.) exposed to damage and premature failure

Design Failure Modes	Mobile Equipment Design Credible Failure Modes - Name and Description
	▪ Inadequate equipment fire risk analysis provided to the mining operator ▪ The minimum design requirements set by the OEM are inadequate to meet site requirements - and this is not identified during the development of the maintenance strategy
Error intolerant design	**CFM-DE-30 External recommendations (alerts) not considered by Designers** Constraints for the adoption of design changes caused by: ▪ Mobile equipment being operated across multiple mining jurisdictions with a range of compliance requirements ▪ Misalignment between regional and global regulations, standards, and guidelines ▪ Recommended design changes not being technically feasible ▪ Recommended design changes not being commercially viable ▪ New designs not being readily adapted for legacy fleet
New technology fire hazards	**CFM-DE-31 New generation of mobile equipment - fire potential and pathways not recognised** The fire risks from new technology are not well understood or inadequately assessed, for example: ▪ Electric or part electric vehicles using downhill regeneration ▪ Incorrect towing of battery electric vehicles ▪ Next generation diesel engines (Tier 4 - T4F) as they operate at higher temperatures with increased potential for exposed hot surfaces ▪ New technology for vehicle control management systems inhibit direct integration with fire shutdown and suppression systems ▪ Inadequate ability to initiate fire systems for remotely operated equipment ▪ Inadequate assessment of the fire response for new generation power storage sources, e.g. Lithium-ion batteries, hydrogen fuel cells, etc

Table 3 - Credible Failure Modes Relevant to Mobile Equipment Maintenance

Design Failure Modes	Maintenance Credible Failure Modes - Name and Description
Component failures that release flammable liquid	**CFM-MN-01 Liquid Fuel loss of containment - substandard maintenance** During normal operations, there is a failure of reservoirs, hoses or lines containing fuel, hydraulics, lubrication, coolant, etc. caused by: ▪ Leaks from over tightening or under tightening of hoses and lines ▪ Rubbing or wear fail because maintenance and re installation of hoses, lines is outside of OEM or third-party supplier recommendations ▪ The released liquid is a fuel that can be ignited by an exposed hot surface e.g. turbo charger, exhaust, electrical fault, etc. ▪ The failure leading to the release of liquid is due to inadequate maintenance of OEM or third-party equipment components ▪ Flammable liquids introduced as part of the maintenance process (e.g. solvents, cleaners, etc.)
Compromised thermal protection and solid fuel	**CFM-MN-02 Solid fuel, components present on mobile equipment become fuel - inadequate maintenance standards** Solid components form a fuel source, caused by: ▪ Flammable components (e.g. covers) left in contact with hot components (e.g. turbo charger, exhaust, etc.) ▪ Installation of component(s) that are flammable and/or outside OEM specifications ▪ Remove/fail to replace protective barriers between hot and flammable components ▪ Inadequate cleaning or removal of flammable fines (e.g. coal) from locations on or near hot components
External fuel is introduced during maintenance	**CFM-MN-03 Fuel is introduced to mobile equipment - inadequate maintenance standards** During normal operations an external fuel source, introduced during maintenance ignites through contact with a hot surface such as a turbo charger, exhaust, etc, caused by: ▪ Cleaning cloths ▪ Grease/lubricants ▪ Solvents and degreaser ▪ Flammable containers ▪ Other flammable material left in engine bay
In service component failures cause an increase in temperature	**CFM-MN-04 Inadequate Maintenance results in excessive heat during subsequent mobile equipment operations** Fires following maintenance, caused by: ▪ During normal operations engine components rise above the ignition temperature of adjacent fuel sources E.g. Turbo failure e.g. heat shielding for turbocharger not replaced ▪ Electrical ignition faults (e.g. inadequate inspection/restoration of cables resulting in cable insulation being pinched/damaged, battery locations being compromised, etc)

Design Failure Modes	Maintenance Credible Failure Modes - Name and Description
	▪ Friction between moving components e.g. collapsed wheel bearings ▪ Maintainers not identifying compromised elements of the fuel, hydraulic or fire response systems (so work orders not raised or not closed to meet site requirements) ▪ Operating without lubricants ▪ Heat protection shielding ▪ Deflection barriers that separate oil hoses and fuel lines from hot surfaces e.g. turbo chargers ▪ Inadequate replacement of components e.g. contained fuel lines and hydraulic hoses that prevent leaks from spraying onto hot surfaces
Hot work system failures	**CFM-MN-05 External heat source is introduced to mobile equipment during maintenance** Maintenance workers introduce heat, caused by: ▪ Conducting hot work maintenance directly on or adjacent to mobile equipment (sparks and slag contact flammable elements) ▪ Failing to adequately follow a hot work process (e.g. no or inadequate fire watch) ▪ Not deploying thermal protection around flammable elements of equipment when conducting hot work ▪ Using faulty hot work equipment (including faulty hot work response equipment)
In service component failures cause an increase in temperature	**CFM-MN-11 Equipment returned to service without adequate inspection and task confirmation** Caused by inadequate quality control: inadequate inspection before returning equipment to service - with inspections not covering: ▪ Service and maintenance work effective and recorded ▪ Hoses and fluid lines leaks not identified / confirmed ▪ Deflectors and hot surface insulation are inadequately installed and maintained ▪ Fire detection, alarm and suppression systems are inoperative/not recommissioned effectively ▪ Use of inadequate design/quality replacement components
	CFM-MN-30 Recommendations from OEM or Third-Party Supplier not implemented Inherent design or manufacturing faults not being rectified, caused by: ▪ Operating sites do not have processes in place to implement recommendations ▪ Actions/work orders raised following OEM/other supplier alerts are not given priority for addressing in required time frames ▪ Not identifying that safety alerts and technical bulletins apply to equipment in use on the site

Table 4 - Credible Failure Modes Relevant to Fire Detection and Suppression

Design Failure Modes	Fire Detection and Suppression System Credible Failure Modes - Name and Description
Detection and suppression systems fail	**CFM-DE-06 Fire suppression systems do not function or are inadequate - design fault** Caused by: ▪ The design of the fire suppression system allows for operator escape, but is inadequate to extinguish some fires through a lack of capacity, suppressant selection, or fire type and intensity e.g. large vertical fires ▪ Ignition source cannot be extinguished due to inadequate storage capacity of suppressant ▪ Fuel source cannot be isolated ▪ Ineffective positioning of sensing lines (pyro-tubes) or suppressant spray nozzles ▪ Automatic deployment of fire suppressions or shut-down system does not activate as designed ▪ Fire suppression system operator interface does not effectively convey the requirement for deployment (no voice command or other notification system) ▪ Vehicle systems are damaged or impaired due to collision or rollover
Interface logic integration between equipment and fire systems	**CFM-DE-32 Fire suppression system fails because of interface logic issues** Caused by: ▪ Automatic or manual system activation signal sent but not received by fire suppression system ▪ Automatic or manual system activation signal sent and received by fire suppression system which activates but fails to suppress the fire because of a sequence or timing issue, i.e. cooling fans are still running, incorrect time delay, not integrated with base machine design
Fire detection and suppression systems design are inadequate	**CFM-DE-33 Fire suppression systems design, configuration and installation outsourced to third party - provided to operator without specification or OEM oversight** Fire suppression system design does not adequately control the fire risk: ▪ Inadequate or ineffective information about relative fire potential during operations is provided by OEM ▪ Vulnerable install, i.e. suppression system activators are disabled by the fire ▪ Installation of a fire suppression system compromises equipment operation including damaging existing components that can lead to a fire event ▪ Suppression agent pipe runs are susceptible to mechanical damage ▪ Detection has inadequate coverage of high-risk areas ▪ Ineffective integration of a multi designer sourced component system, i.e. hybrid system ▪ Inadequate 'acceptance for site operation' or approval for operations process that does not identify and rectify manufacturing and or design faults ▪ OEM equipment design has inadequate provision for third-party fire suppression (insufficient space for suppressant cylinders, cables, hoses, clamps, etc)

Design Failure Modes	Fire Detection and Suppression System Credible Failure Modes - Name and Description
Inadequate installation of fire detection and suppression systems	**CFM-DE-34 Fire suppression system specification, design, install, test and maintenance involves multiple designers and suppliers** Inadequate specification and installation of the system leading to integration faults caused by: • Inadequate communication of the performance and technical requirements for design and installation between OEMs and third-party designers • Inadequate and or ineffective maintenance and testing by the operating company, OEM, dealer or third-parties due to inadequate knowledge of the integrated systems operation

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