Ardent Vehicle Fire Protection

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A guide to the principles, technology and design decisions behind the current generation of vehicle fire suppression systems.

Vehicle fire suppression systems

Design and selection

Contents

To assist you in your choice of system, this document provides a general overview of the components of fire suppression systems and the factors that dictate the design of an effective system. We will also discuss the basics of the combustion process and how different hazards, environments and applications demand a different approach.

1.0 Introduction

The aim of this document is to help anyone with an interest and/or responsibility for the protection of off-road mobile plant to fully understand the principles, technology and design decisions behind the current generation of vehicle fire suppression systems.

Vehicle fire suppression has come a long way. Over the past decade, significant developments have taken place on mobile plant fire protection systems. The result is that today's equipment is more refined and rugged than ever before and provides extensive protection for off-road vehicles in many types of inhospitable environments. However, experience shows that in many cases fire suppression systems are often only installed as an after-thought, if indeed they are fitted at all.

The benefits of installing reliable fire detection and suppression systems are self-evident, both from an economic and, perhaps more importantly, a safety point of view. The decision on whether to fit these systems, rests with either the end-user, OEM dealer and occasionally the insurer.

To assist you in your choice of system, this guide provides a general overview of the components of fire suppression systems and the factors that dictate the design of an effective system. We will also discuss the basics of the combustion process and how different hazards, environments and applications demand a different approach.

2.0

Why fires start on vehicles or plant and how to prevent them.

The combustion process

2.0
The combustion process

Each class of fire involves a different mode of combustion. To gain a better understanding of vehicle fire suppression systems and how they operate, it's worth taking a closer look at the combustion process and the different fire risks present in the workplace.

Classification of fires

In Europe, fires are classed in five types, namely A, B, C, D and F denoting respectively carbonaceous fires, flammable liquid fires, flammable gases, metal fires and cooking fires.

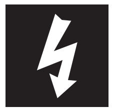
Class A
Fires involving solid materials normally of an organic nature, in which there are glowing embers, such as wood, cloth, rubber, plastic, paper, biomass, coal, etc.

Class B
These are fires involving liquids or liquefiable solids, which may be divided into 2 groups:
1. Those that are miscible (dissolve) with water, and
2. Those that are immiscible (do not dissolve) with water.

Class C
These are fires involving methane, propane, liquid petroleum gases, medical or other flammable industrial gases.

Class D
These are fires involving combustible metals such as magnesium, titanium, sodium, potassium etc.

Class F
These are fires that involve combustible cooking media such as oils, grease, fat etc.



Electrical
In Europe, electrical fires are not generally considered as a class as they are an ignition (heat) source rather than a fire type. Once the electrical ignition source has been isolated, the fire can be treated as either a Class A or Class B fire (depending on the scenario).

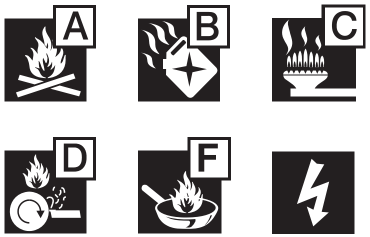
These classifications are subject of BS EN 2:1992 entitled 'Classification of Fires'.

2.0

The combustion process

Classification of fires

What these classifications mean.



Class A fires

Class A fires involve combustion of the volatile gases resulting from the decomposition of the fuel as well as combustion within the mass of the fuel. The former is called flaming combustion and the latter 'glowing' or deep seated combustion. While the two modes generally occur concurrently, either can precede the other, depending on the fuel type and configuration. Flaming combustion involves rapid vapour-phase oxidation and heat transfer back to the fuel. Deep-seated combustion is characterised by slow rate of heat loss and slow rate of reaction of oxygen with the fuel, which is controlled by diffusion.

Class B and Class C fires

The combustion of volatile liquids and gases are considered Class B and Class C fires and involve the rapid vapour-phase oxidation of the fuel, subsequent evaporation of more fuel due to radiated heat transfer, and cracking of the fuel in the vapour-phase.

In this type of fire, the combustion process is characterised by a chemical chain reaction involving rapidly reacting species called radicals, which are fragments of the fuel and/or oxidising agent molecules.

It should be noted that although plastics are considered Class A hazards, some plastics can decompose into volatile liquids which then present a Class B hazard.

Class D fires

The combustion of metals depends primarily upon the physical state and the chemical nature of the metal. In general, finely divided metals (dusts) and liquid metals will oxidise rapidly and burn at temperatures in excess of 1100°C. The rate of oxidation is extremely rapid (explosive) with some finely divided metals and slower with liquid metals. This reaction is dictated by the presence of moisture and temperature of the metal.

Class F fires

We would not normally expect to see Class F Fires in vehicle fire protection.

Electrical fires

Electrical fires usually start because of short circuiting machinery or overloaded wiring. When electrical equipment short circuits, it is possible that the wire will heat up because of an increase in current. The materials around the equipment or wiring (usually plastic or metals) can combust or melt. This in turn may start a fire and damage other electrical components. Electrical fires are not considered a class of fire, as they are an ignition source of heat, which usually results in a class A, B or C fire. Once the power has been shut-off the fire can be treated as any of the above.

2.0
The combustion process

Combustion and inhibition

The basics of combustion and the methods for inhibiting a fire.

From these classifications, it is clear that there are four basic prerequisites for any fire:

- **Heat**
- **Fuel**
- **Oxidising agent**
- **Suitable chemical reaction path**

Armed with this knowledge, it follows that any method for inhibiting a fire must involve one or more of the following:

- ***The removal of heat at a faster rate than it is released***
- ***Separation of the fuel and the oxidising agent***
- ***Dilution of the vapour-phase concentration of fuel or oxidising agent below that needed to continue combustion***
- ***Termination of the chemical chain reaction path***

3.0

Extinguishing agents

Having studied the elements that make up the combustion process, it is worth considering how fire suppression agents obstruct and inhibit this reaction. Here is a guide to the most common options.

3.0 Extinguishing agents

Fire suppression agents (namely wet and dry chemicals, liquids, gases, or foam) work in a number of ways, for example, by separating the fuel and air, reducing the concentration of oxygen in the atmosphere around the fire below the amount needed to sustain combustion, or absorbing the heat from the combustion (either by chemically inhibiting the reaction or as a consequence of its thermal properties).

3.1 Water

Water is one of the most common agents used in general industrial fire fighting because of its cost, availability and its Class A effectiveness.

Pros:

Water has outstanding thermal properties in that converting one kilogram of water at 0°C to steam at 100°C requires 2688 kJ of energy and in the process, a volumetric expansion of 1700 occurs. These two factors account for the extinguishing mechanism (cooling and dilution of the oxygen concentration).

Cons:

Water has a high freezing point at 0°C, high surface tension (72.8 dynes/cm) and low viscosity. The high freezing point can be overcome by the addition of a freezing point depressant such as calcium chloride or ethylene glycol. However, in accordance with the NFPA (National Fire Protection Association) update regarding antifreeze (April 5th, 2011), glycol concentrations may not exceed 48% by volume and propylene glycol concentrations may not exceed 38% by volume.

The low viscosity of water also poses a problem, especially in relation to the application of water to vertical surfaces. This can often be overcome by the use of thickening agents such as fire fighting foams.

3.0
Extinguishing agents

The agents currently favoured for protecting off-road plant are multi-purpose dry chemical (monoammonium phosphate based powder) and wet chemical (either Aqueous Film Forming Foam - AFFF - or other liquid based agents). These extinguishing agents have proven to be the most effective on the types of fires commonly experienced in vehicle and mobile plant. However, numerous fire-fighting agents are available. Here is a guide to the most common options.

3.2
Fire-fighting foams

Fire-fighting foams attempt to overcome some of the disadvantages of water. Fire-fighting foam is a stable mass of small bubbles lighter than oil or water. The foam is a watery suspension of gas – usually nitrogen or air – in the form of bubbles separated by films of solution. Foam is produced mechanically rather than by chemical reaction. It is created by mixing a liquid concentrate with water and forcing the gas into this solution. This produces a watery suspension of air/ nitrogen in the liquid solution, which is mainly bubbles.

The most common foam used in vehicle fire protection systems is Aqueous Film Forming Foam (AFFF).

Aqueous Film Forming Foam (AFFF)

AFFF is a water based agent and therefore has the advantage that it can cool the area down, lessening the chance of the fire reigniting. An incidental benefit of these systems is that the 'run off' agent may suppress secondary fires which may occur under the vehicle should the fuel, etc. have collected and subsequently ignited. AFFF has been the preferred agent for vehicle fire protection systems in Australia and some parts of the Pacific Rim, where temperature constraints are not so severe.

Pros:

AFFF creates a thin film on the fuel surface stopping fuel from evaporating and reducing its oxygen supply. AFFF has controlled test fires in 36-60% of the time needed by other foams and can be used in concentrations as low as 1%. Low recharge costs. Discharge time at least 1 minute to give good cooling.

Cons:

Because the premix solution is usually 94% water (can be 99%), the solution has a high freezing point of 0°C. This can be reduced to as low as -30°C and as high as 99°C by introducing additives, but this degrades the performance and life of the AFFF.

The AFFF containers are also relatively large, which can sometimes pose difficulties. Nozzle placement/location is critical.

3.0 Extinguishing agents

3.3 Wet chemical

Wet chemical agent is a blend of organic and inorganic salts coupled with surface active agents. It has similar properties to AFFF but it provides a strong measure of freeze protection (as low as -50°C).

Many off-road vehicles have large volumes of oils and hydraulic fluids under pressure. With the large amount of fuels available, a variety of fires can occur, such as pressure, three dimensional, Class A and spill.

Foams and wet chemical can flow into hard to reach areas where flammable fuels may also have flowed. This can also be achieved using additives (e.g.'Drench' additive that lowers the surface tension of water).

Pros:

Freeze protection to a possible -50°C and the foaming properties of other foams (e.g. Aquagreen XT). Discharge times up to 2 minutes to give good cooling effect.

Cons:

Similar to AFFF, wet chemical systems are relatively large compared to dry chemical systems. This may make installation of the systems difficult. Expensive to recharge.

3.0 Extinguishing agents

Common variants:

Potassium Salt based
Potassium bicarbonate, potassium chloride, urea – Good against fluid fires (classes B, C), but not recommended for class A.

BC Powder
Sodium bicarbonate based and is good against fluid fires (classes B, C), but not recommended for class A, mild saponification effect on hot grease. Trade names for BC powder include Monnex and Purple K.

ABC Powder
Monoammonium phosphate based, is good against Classes A, B and C and does not possess a saponification characteristic. However it is inappropriate for chlorine or oxidizer fires as well as certain class D fires. Foray is an example of a trade name for ABC dry chemical.

3.4 Dry chemical & powders

This agent is currently the most widely used agent in the vehicle suppression market. Having proved its effectiveness on all classes of fires, it is the agent currently with the highest level of documentary evidence as to its effectiveness.

Dry chemical systems are relatively compact in size requiring little if any modification to the vehicle during installation. On a weight basis they are probably the most effective agent in extinguishing fires and provide rapid fire knockdown capabilities. These systems also have a broad operating temperature range of -54°C to 98.9°C without any form of modification.

Dry chemical extinguishing agents are comprised of a finely-divided powdered material that has been specifically treated to be water repellent and capable of being fluidised and free-flowing when under expellant gas pressure. There are several types of dry chemical extinguishing agents available, each having its own distinct capabilities. Dry chemicals are available for almost all types of fires and almost instantaneously quench flames by chemical inhibition.

Pros:
The most widely used agent in the vehicle suppression market. Proven effectiveness on all classes of fires. Compact and light.

Cons:
Poor post fire security and a possibility of the fire reigniting once the powder has settled. Improperly sealed containers can also be contaminated with moisture, leading to caking of the powder and reduced suppression qualities. Messy.

3.0
Extinguishing agents

3.5
Gaseous fire-fighting agents

Gaseous fire-fighting agents work by diluting the concentration of oxygen around the combustion. In order to effectively use a gas extinguishing agent, the hazard area needs to be well sealed.

For vehicles and mobile plant, it is usually impractical for a compartment to be air tight. This means gases are usually discounted as a suitable extinguisher agent.

Pros:
Clean and leave no residue. Fast acting.

Cons:
Systems must be designed and vehicles modified to retain the gas for a long as possible. Can be very difficult to achieve. Sometimes used to protect containerised engines/ powerpacks, or electrically powered machines/ cabinets or transformers.

3.6
Twin agents

Twin agent systems use a combination of dry chemical and AFFF/wet chemical to give fire suppression and surface cooling in the hazard area. The multi-purpose dry chemical discharges to give rapid fire knockdown.

At the same time, the AFFF/wet chemical agent will discharge to give effective cooling, preventing the fire from reigniting.

Pros:
Arguably the twin-agent solution is the best solution on the market.

Cons:
Twin-agent systems tend to be large (in terms of volume) and expensive.

4.0

Detection systems

Even the most effective suppression agents depend upon a reliable, rapid detection system. This chapter describes the most common types of detectors and the advantages and disadvantages of each.

4.0

Detection systems

Types of detection systems

These types of detectors are commonly used to sense the presence of fire, heat, smoke and flame.

4.1 Flame detectors

Flame detectors sense the infra-red, visible or ultra-violet light emitted by the fire.

4.2 Smoke detectors

Smoke detectors sense the presence of visible or invisible particles of combustion.

4.3 Heat detectors

Heat detectors are generally classified as either ‘fixed temperature’ or ‘rate of rise’ detectors.

4.0 Detection systems

4.1 Flame detectors

Modern flame detectors use infra-red, visible and ultra violet radiation to detect fires. These are used widely in the vehicle and mobile heavy plant industry. Some models also have the capability to detect a wide range of electro-magnetic radiation (emitted from combustion or other sources), meaning that the detectors can eliminate false alarms from sources such as sunlight, welding torches and other heat sources.

Pros:
Ultra-fast detection in less than 5 milliseconds.

Cons:
All electromagnet flame detectors require line of sight. Maintenance of the detectors is crucial and it is important that they are tested frequently. Expensive.

4.2 Smoke detectors

Smoke detectors sense the presence of visible or invisible particles released in combustion. In a hostile/off-road environment, the debris generated by exhausts or the dust and debris in the atmosphere would generate frequent false alarms and this makes them unsuitable for use on vehicles. They are best used in industrial or commercial premises where the atmosphere is normally clean.

Pros:
Fast detection of visible and invisible particles.

Cons:
Susceptible to frequent false alarms and unsuitable for vehicle suppression.

4.0
Detection systems

4.3.1
Point or spot heat detectors

These are set temperature detectors or rate of rise sensitive detectors. Spot detectors are used in vehicle and mobile heavy plant because of their rugged design and simple actuation. Spot heat detectors come in different formats and with varying actuation temperatures, to suit different applications. Most spot heat detectors work on a normally closed circuit (current is running through them in normal operation). When the detector reaches the predetermined temperature, it opens the circuit and the current being carried back to the control unit is lost initiating the fire warning system.

Pros:
Spot heat detectors are a relatively low cost and effective means of detecting fire.

Cons:
Unlike flame detectors, they have fewer checks in order to determine if a fire or heat source is a false alarm. By their very nature, spot heat detectors only monitor a local area for temperature.

4.3.2
Linear heat detectors

The most common type of linear detector used in vehicle fire protection is a linear detection cable that uses two spring steel conductors, separated by a heat sensitive insulator. At a predetermined temperature, the insulation melts. This allows the conductors to come into contact, resulting in a change in signal relayed back to the control module. To overcome the problems of different temperature sensing requirements, spot heat detectors or thermal switches can be placed in areas requiring specific point detection. These can then be interlinked with linear detection cable.

Pros:
Relatively low cost, reliable.

Cons:
Linear detector is a 'one shot' operation. Therefore following any fire or overheat the cable needs to be replaced. Detection time (small flame) can be 20 seconds.

4.0 Detection systems

4.3.3 Linear pressure heat detectors

How linear pressure detectors work
Pressurised nylon tube type, the tubing melts at a predetermined temperature and causes a pressure drop that triggers the extinguishing systems.

Pneumatic and pressure detectors have been used for many years and operate by using simple mechanical/pneumatic principles. A pressurised detection tube runs throughout the protected area, and when ruptured, by heat or flame, the pressure is released. This pressure release actuates the extinguishing system, by either operating a firing head on the expellant gas tank or, in the case of some pre-pressurised extinguishing systems, by opening a valve. This allows the extinguishing agent to enter the distribution pipe work.

These systems can be used without electronics, and can be used in hazardous areas, where the expense of using intrinsically safe or flame-proof electrical systems may be prohibitive. This makes them relatively low cost compared to electronic systems.

Pros:
No need for electronic control, it can be used in hazardous locations eg ATEX. Low cost.

Cons:
Relatively low ambient temperature rating – 120°C. Reliant on reservoir of gas to keep the tubing pressurised.

4.0
Detection systems

4.3.4
Pneumatic heat detectors

How linear pneumatic detectors work

An increase in temperature causes an increase in pressure, closing a pressure switch and bridging the circuit. This system will respond to either an increase in the overall ambient or localised temperature.

This is achieved by the use of a detection tube filled with helium surrounding a metal hydride core. When the ambient temperature increases, the helium pressure increases. This will correspond to a particular detection pressure and if either the local or ambient temperature is high enough it will initiate the extinguishing system.

Pressurised fire and overheat detectors are used on many aircraft and railway locomotives. They require little, if any, scheduled maintenance.

The detectors are pneumatically operated by heating the sensor tube, which contains Helium and a metal hydride core material, to actuate and release Hydrogen at a predetermined temperature.

The application of heat to the sensor causes an increase in internal gas pressure, which in turn operates a pressure diaphragm and closes an electrical contact, actuating the alarm circuit. The pressure diaphragm within the responder housing serves as one side of the electrical alarm contact and is the only moving part. Mechanical damage to the tubing cannot result in false alarm; it will instead give a 'fault' indication.

The detector has two sensing functions. It responds to an overall average temperature threshold or to a highly localised 'discrete' temperature caused by flame or hot gases. Both the 'average' and 'discrete' temperatures are factory pre-set.

They also have a fire resistance of 1100°C for 5 minutes and resets all function after use. However, if the detector is physically damaged then the whole unit will need to be replaced.

Pros:

These types of detector have two sensing function. They can alarm due to a rise in 'ambient temperatures or an 'overheat'. Or they can respond to a fire, where a flame impinges on or close to the detector. Rugged and reliable, often used in aerospace.

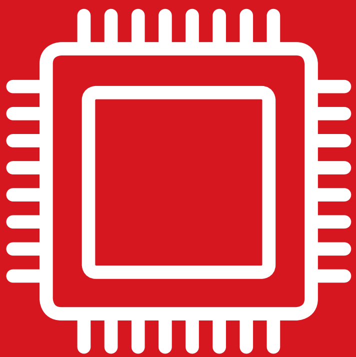
Cons:

Very expensive.

5.0

Control systems

While extinguishing agents and detectors are key components of any fire suppression system, it is the control system that co-ordinates and dictates the response to fire. While the subject of control systems is worthy of a book in its own right, in this chapter we will briefly outline the control system process and the features currently available.



5.0

Control systems

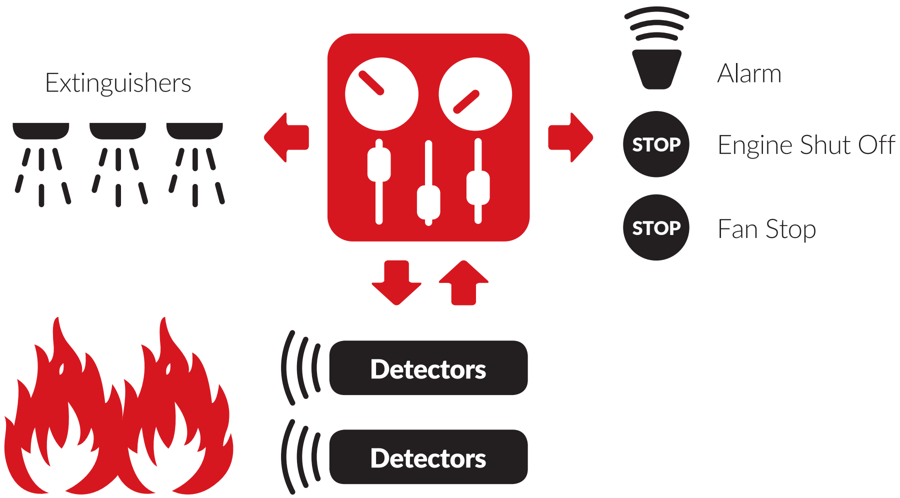
How control systems work

In short, fire control panels can be made as simple or as complicated as necessary, depending on the requirements of the system.

Control systems essentially process the information relayed by the sensors and detectors, then process this information to decide whether or not there is a fire. They then deploy the necessary measures to ensure operator and equipment safety.

The simplest systems only provide fire warning, therefore requiring the operator to stop, shut down the engine, manually operate the fire suppression system and then evacuate the vehicle.

How a basic system works



An operator must always be in control of a machine. An operator must have the ability to delay the activation of the fire suppression system and engine shutdown sequence, until he deems it safe to do so. This is for the safety of the operator and people working in and around a machine, and also to comply with mandatory international standards such as the EU Machinery Directive.

However, more complicated systems offer 24-hour stand alone protection. Of these systems the most sophisticated can electronically monitor the actuation, power, release and communication circuits, and interface signalling measures such as: engine/fuel shutdown, stopping the engine fan, activating a high decibel alarm, isolating the main battery, deploying a fire suppressing agent and venting the hydraulic system.

5.0
Control systems

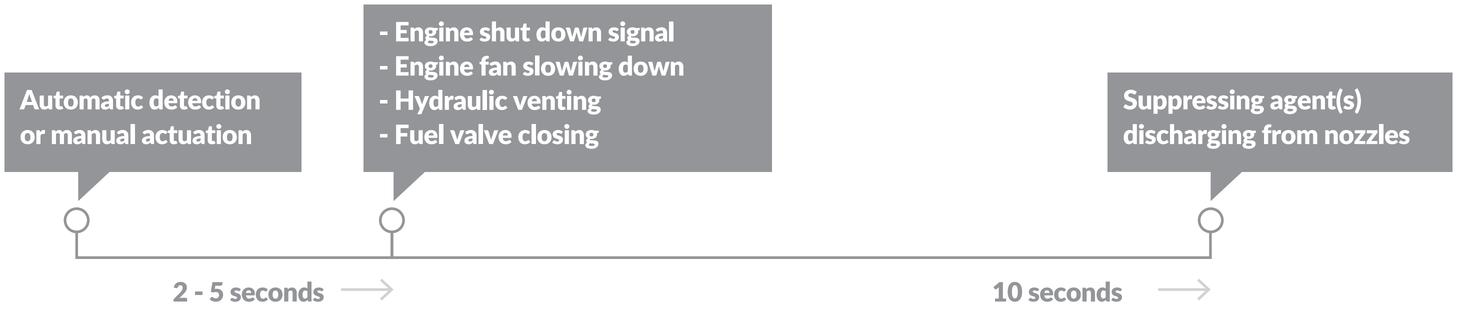
The total time between the detection of fire and full deployment of suppression agent can vary depending on the type of vehicle and the quality of the system.

Detection time

In almost all vehicles, an engine fan is used to cool the air around the engine. This can produce air flow speeds of up to 2.5 – 11.5 cum/s. In order to achieve optimum coverage by the suppressing agent the fan needs to be stopped. When running at maximum rpm it can take some fans up to 10 seconds to completely stop. The same applies for hydraulic system venting. As hydraulic fluids are often flammable and under high pressures they can increase the likelihood of fire or reignition and therefore need to be removed if deemed necessary.

Self-contained control modules

Control modules are sometimes self-contained units. This means that the equipment does not need to be connected to the vehicle power supply and has its own independent supply. So in the event of the main battery being damaged or disconnected, then power will still be available and surges cannot damage the control unit. Electrical faults are the single largest cause of vehicle fires and so it is also recommended that an automatic battery isolator is installed. This ensures the main battery power is switched ‘off’ on activation of the fire system, thereby reducing damage to wiring looms, and the possibility of fire re-ignition. Wherever possible, the control module should be mounted where it is visible to the operator, but manual deployment controls should be available both in the cab and, if applicable, at ground level or outside.



6.0

No fire suppression system is complete without the correct suppression agent tanks; they are used to store the suppression agent and play a vital role in the dispersion of the agent upon system activation.

Suppression agent tanks

6.0 Suppression agent tanks

Understanding extinguisher types

Stored pressure and cartridge operated tanks are commonly use in vehicle fire suppression systems.

Both types of agent tank will perform well when used in the right application and environment. However, it is important to understand their key differences.

Stored pressure extinguishers

In stored pressure tanks, the suppression agent is stored in the same canister as the propellant, typically compressed nitrogen gas. This gas carries the agent from the cylinder, through the nozzles, to the targeted fire hazard area.

A pressure gauge is fitted to the tank to allow operators and maintenance personnel to check that the tank is properly pressurised, this can be done by simply verifying that the needle on the gauge is in the green segment.

Cartridge operated extinguishers

Cartridge operated units store the extinguishing agent in a non-pressurised container and the propellant gas in a separate cartridge.

When the system is activated, the propellant cartridge pressurises the agent tank. The pressure within the agent tank rises until the outlet rupture disc pressure is reached, thereby allowing the pressurised agent to be propelled through the distribution network. Cartridge operated tanks cannot be visually inspected to ensure they are properly pressurised.

6.0

Suppression agent tanks

Potential agent tank issues

Dry chemical compaction

Settling and compaction (time consolidation) can occur over time in both stored pressure and cartridge operated tanks using dry chemical extinguishing agent. This is due to vibration on vehicles and mobile plant.

While suppression agent tanks are designed to counteract this, excessive compaction can affect the performance of the fire suppression system and can cause it to fail.

High quality manufacturing techniques can be used to produce a more finely milled dry chemical powder. This milling process means that compaction is less severe, and the system is able to discharge easily and efficiently. Milling also contributes to the higher dispersion rates of the dry chemical agent, aiding coverage of the fire hazard areas.

Shock and vibration

Shock and vibration are commonly observed on vehicles, especially off-road vehicles and plant. This is major concern to anything that is bolted to the vehicle, such as extinguishing agent tanks, and can lead to part failure, metal fatigue, and system failure. Thorough testing is needed to ensure they perform under these challenging conditions.

Pressure leakage

Loss of pressure can occur within fire suppression systems for a number of reasons, including manufacturing defects, damage to the system or shock and vibration. If propellant gas leaks are not detected, this could result in the pressure in the extinguishing agent tank dropping below the threshold for fire suppression system activation.

6.0

Suppression agent tanks

The importance of inspection

Just like the vehicles that they are designed to protect, all fire suppression systems require periodic inspection and maintenance. National Fire Protection Association (NFPA) Standard No. 17, the Standard for Dry Chemical Extinguishing Systems, outlines the monthly and semi-annual inspection requirements for both stored pressure and cartridge operated systems..

In addition, every 10 years all pressurised cylinders used in fire protection applications are legally required under the British/European Standard BS EN 1968:2002 to be hydrostatically tested. This tests the strength and integrity of the pressurised cylinder to ensure that they are in safe working condition. The responsibility for hydrostatic testing lies with the person in possession of the cylinder, and failure to test the cylinders can lead to fines of up to £5,000 and, in some cases, imprisonment.

This testing is vital for pressurised containers, as, over time, corrossion and cracking can cause cylinders to fail, leading to disastrous consequences such as explosions. In cases where a tank becomes damaged, it is also important to test the cylinder in order to ensure that is still in good, safe, working order.

7.0

Hazard analysis

Vehicle Fire Suppression systems have advanced considerably over the last few decades. However, the best form of fire protection remains prevention.

7.0 Hazard analysis

This section focuses on analysing fire protection needs, determining fire hazards and taking the necessary steps to ensure vehicle and operator safety.

Fire risk analysis

Before undertaking any risk analysis, it is essential to know the capabilities of the fire suppression system and the hazards that exist in the equipment. This can be obtained by following the steps described below. A good understanding of national and local fire protection codes and standards is also recommended.

It is always preferable to identify fire hazards before installation, while you have design flexibility. As once the system is installed, adding protection for additional hazards becomes more problematic.

In general, few systems are designed to protect every square inch of the equipment. Areas of protection are often fixed at installation and are limited in number. Therefore a hand held portable fire extinguisher adds a degree of flexibility and extend the reach of the system.

In addition, fires may occur due to unforeseeable causes (fuel spills, welding heat etc.) and these fires may not be protected by the suppression system (as systems are often designed to protect the areas with highest likelihood of fire and damage).

Designing systems to limit risk

Effective system design is therefore based on a thorough hazard analysis. Fire can only occur in the presence of heat, fuel and oxygen and a hazard is any place where these three elements could be brought together. As oxygen is always present, it is crucial that sources of fuel and heat are identified.

Common fuel sources

Common fuel sources in vehicles also include flammable liquids, greases, rubber, plastics, upholstery and environmental debris; such as wood chips or coal dust. Vehicles with large amounts of combustible fuel (e.g. hydraulic fluid) are considered as special types of hazard.

Common heat sources

Common vehicle heat sources are engines, exhaust systems, particulate filters, pumps and turbochargers; as well as bearings, gears, brakes and electrical equipment. A potential hazard exists when fuel comes into contact with any heat source.

7.0
Hazard analysis

Common fuel sources
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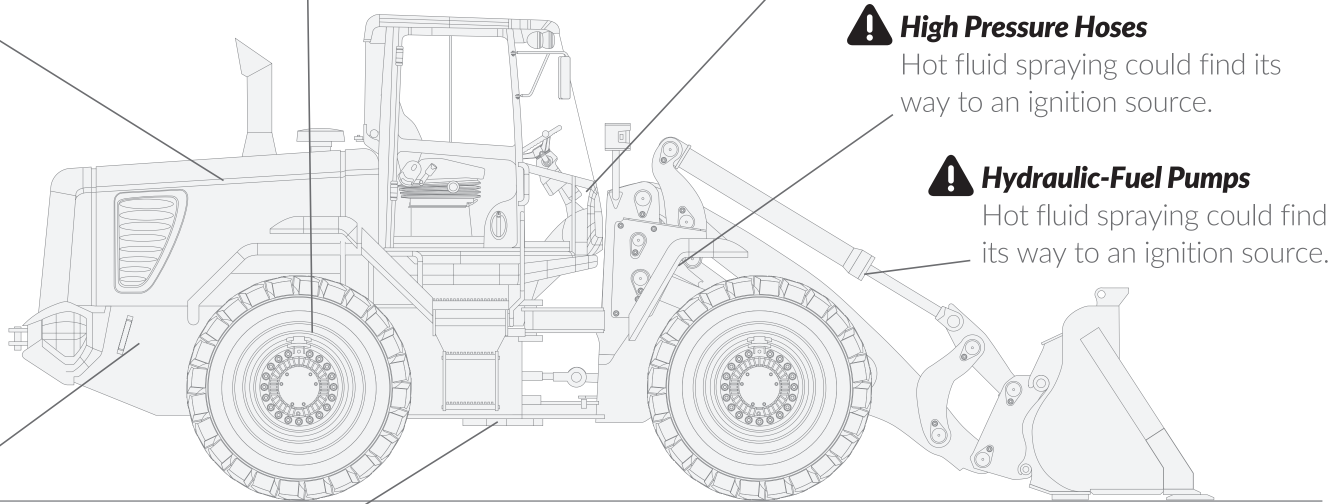
Engine Compartment
Contains an assortment of flammable fluids, fuels, oils and greases as well as congested wires, hoses and combustible debris.

Transmissions, Particulate Filters, Torque Converters, Parking Brakes
All these are possible high heat sources and could cause ignition to combustible materials.

Electrical Equipment
Any short circuiting electrical equipment can cause class A or class B fires and it is important that any cables carrying high current be shielded and protected.

High Pressure Hoses
Hot fluid spraying could find its way to an ignition source.

Hydraulic-Fuel Pumps
Hot fluid spraying could find its way to an ignition source.



Battery Compartment
These can present a fire hazard when combustible materials build up on top of the battery, and when wet could cause a short circuit.

Belly Pan
Could collect fuel and debris, if a fire started (because of location) could engulf entire vehicle.

Consulting with experienced operators or owners of similar equipment can help to identify locations of previous fires and special hazards not normally considered as common hazards.

8.0

Nozzle coverage and location

Having identified the key hazards and areas which require protection, it is important to determine what nozzles are needed and where they should be placed.

8.0 Nozzle coverage and location

After completing any hazard analysis, it is essential to determine the size of the hazard and compare this to the nozzle's effective discharge pattern.

It is critical when using any nozzles that obstructions don't interfere with the discharge pattern. Hovewer, obstructions that are unavoidable can often be overcome by installing additional nozzles in different locations, so coverage is complete.

Nozzles must additionally be fitted with blow off caps in order to prevent debris such as wood chippings or coal dust entering and clogging the nozzle. When the system is activated the pressure exerted by the extinguishing agent will remove these caps and begin discharge.

It is important to remember that different makes and models of nozzle will vary in their discharge patterns. This allows system designers to avoid wasting any agent and provide coverage specific to the shape of the hazard area.

When selecting nozzles and nozzle locations, the following rules apply:

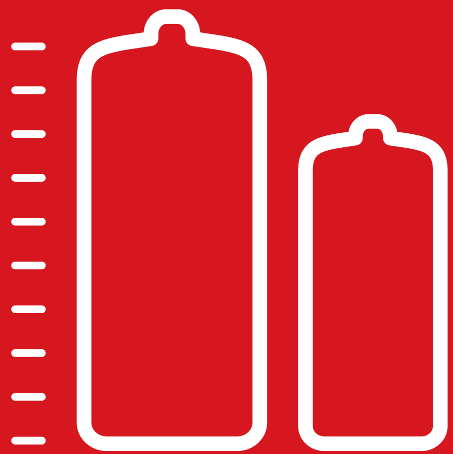
- When choosing the proper nozzle, remember the entire hazard area must be within the nozzle's pattern and maximum effective discharge range.
- Some hazard areas may exceed the area coverage of one nozzle and may require additional nozzles for protection.
- In some cases, a single nozzle can cover more than one hazardous area such as a transmission and torque converter. This is acceptable, but it is important to remember that the discharge pattern must cover the entirety of all hazard areas.
- When planning nozzle locations, make certain the effective flow of extinguishing agent to all recognised hazard areas will not be obstructed.
- If obstructions cannot be avoided, additional nozzles may be needed to provide complete coverage of the hazard area.
- In areas where the environment may cause extreme build-up of class A materials, such as wood debris, coal dust, garbage or oil, it is advised that designers use the largest system tank available and keep nozzles per tank to a minimum. This allows the maximum amount of chemical per nozzle and gives the longest discharge time.

After completing a hazard analysis and having established nozzle quantity and location, the type and quantity of extinguishing agent tanks can be determined. We will look further into this area in the next chapter.

9.0

Tank quantity requirements

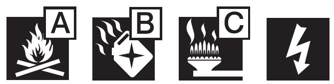
Once a hazard analysis has been carried out and the possible fuel types and hazards present have been identified, it is necessary to calculate the size of tank required to deliver a sufficient amount of agent.



9.0
Tank quantity requirements

Typical tanks and their characteristics

The choice of tank and the agent used will be dictated by the environment, hazards and application.

System	Temperature range	Suitable for
Dry Chemical	-54°C to +99°C	
AFFF	-17°C to +49°C	
Wet Chemical	-50°C to +49°C	

9.0 Tank quantity requirements

Determining the amount of agent

Once the number of nozzles required to completely cover all hazard areas has been calculated, the next stage is to determine the amount of agent required.

So the system provides a sufficiently long discharge time. Nozzle quantities, size of agent tanks and discharge rate per nozzle are all factors that affect the discharge time. This can be calculated using the following formula:

$$\text{Required discharge time} = \frac{\text{Total amount of agent stored in tanks}}{(\text{Quantity of nozzles} \times \text{Flow rate of nozzles})}$$

As a rule, the smaller the agent tanks, and the more nozzles there are, the lower the total discharge time of the extinguisher.

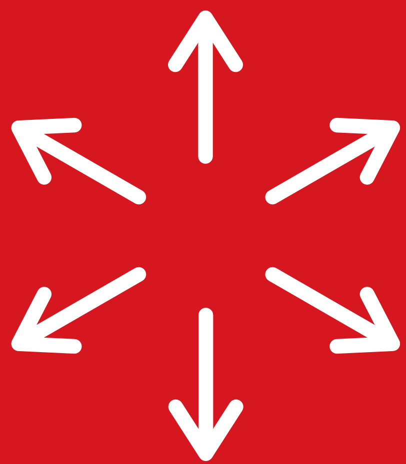
Conversely, the longer the discharge time, the greater the cooling effect on the hazard areas and the smaller the risk of reignition after the fire has been extinguished.

When the number of tanks has been determined, the next step in the design process is to determine the distribution pipe network.

10.0

Distribution system requirements

When the tanks and nozzle locations have been determined, it is necessary to sketch the pipe routings to each nozzle and make sure that they can be included without interfering with the vehicle components.



10.0 Distribution system requirements

Most agent distribution systems have a maximum supply or branch line length and this should always be adhered to ensure the system works properly.

Fire suppression systems are either 'Engineered' or 'Pre-Engineered'. This means that all the distribution pipework must be designed and installed in accordance with the manufacturer's design guidance. This is to ensure the correct quantity of extinguishing agent reaches the nozzle/ hazard area at the correct flow rate to supress the fire.

Factors to consider when designing distribution system layouts. Pipe routing – Pipes need to be installed so that they are correctly supported, and they do not interfere with the operation or maintenance of the machine. Pipes and hoses must be routed so that they operate with design temperature. In certain applications such as steel mills, the pipework may need to be protected with heat resistant sleeving.

Factors to consider when designing distribution systems:

- Many vehicles now have smaller clearances in which to fit fire suppression systems. Some engine-access panel clearances are less than 10mm, leaving very little volume of hoses or nozzles. By using CAD software, nozzle and hose locations can be decided before attempting to install them in the machine.
- All hoses must either meet SAE 100 R5 or 100 R1 hose specifications and should also meet the required operating temperatures to ensure proper system performance.

11.0

Conclusion

Vehicle fire is a real risk for heavy plant machinery in harsh environments.

11.0 Conclusion

Fire not only represents a serious safety hazard to operators, but can also result in considerable damage to equipment and delays to production.

Instances of fires on medium to large mobile equipment used in mining (surface and underground), quarrying, forestry, construction and agricultural operations have increased in recent years.

Equipment like excavators capable of producing high horse power rely upon high-pressure hydraulics, high torque engines or high amperage motors; and when combined with continuous operation, constant vibration and rugged environments, the risk of fire can be high. A single malfunction in any one of these areas could cause a sudden ignition, engulfing the engine and cab area in flame.

It is therefore in a company's best interests to install reliable fire protection systems; a fact confirmed by numerous economic studies. This is especially true on high risk, heavy plant machinery like excavators, off-road trucks, dozers, loaders, shovels, draglines, drill rigs and landfill compactors.

When you consider that the cost of fitting effective fire suppression systems roughly equates to 1.5-8% of the purchase (or replacement) cost of the equipment in question, and in some instances even lower, this makes perfect sense.

While regular service costs must be added to the initial investment cost, these costs can be minimised by training on-site engineering staff to perform maintenance. Alternatively, this procedure can be undertaken by a qualified fire equipment supplier or agent.

While vehicle fire is a real risk for heavy plant machinery in harsh environments, we hope that this guide has demonstrated how a correctly specified and well-maintained vehicle fire suppression system can help to keep these risks to a minimum.

Appendix

Approvals.

Due to the complexity and critical nature of fire suppression systems, it is recommended that you choose a system which carries an internationally recognised standard of approval.

These standards of approval are a guarantee that the fire suppression equipment has been tested and approved for the particular application. Equipment should also carry an approval registration and certificate number. These international approvals are recognised worldwide by most, if not all, insurance companies.

FM Global, Factory Mutual:

- FM 5970

UL, Underwriters Laboratories:

- UL 1254

NFPA, National Fire Protection Association:

- NFPA 17
- NFPA 17A
- NFPA 120
- NFPA 121

AS, Australian Standard:

- AS 5062-2006

SP Technical Research Institute of Sweden:

- SP Test Method 4912
- SPCR 199
- SPCR 197

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At Ardent we know how crucial it is to protect machinery from fire. Machinery that is usually production-critical so the cost of one being at a standstill can be thousands a day.

For this reason we've built our reputation on making sure every system we design and install is the best and most effective it can be. To suit the specific role a vehicle performs; the environment it works in and meets the business challenges our customers face.

Our policy is to be the very best in every thing we do and offer. We never cut corners or take short cuts. Because we understand that effective protection against vehicle fires doesn't just save downtime and money - it can save lives too.

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