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Fire Detection and Suppression Systems for Mobile Port Equipment

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Contents

Executive Summary

This information paper addresses the increased awareness of fire risks associated with heavy equipment since the mid-1970s and proposes the installation of fire detection and suppression systems in port equipment. Frequent equipment fire incidents have progressed the installation of such systems in engine compartments from non-existent to commonplace. The development of standards and legislation initially concentrated in Europe, North America, and Australia, has progressively expanded to include regions such as the Middle East and India. While primarily addressing the risks associated with internal combustion engines (ICE), this information paper outlines recommendations and solutions for enhancing safety, operational continuity, and environmental responsibility in the dynamic landscape of maritime operations under the following headings:

Safety and Operational Continuity

Fire suppression systems are identified as effective safety measures, that swiftly and effectively respond to fire incidents to protect lives and minimise downtime.

Challenges in Suppressing Fires

The paper acknowledges the challenges associated with combating fires in complex equipment, and identifies the importance of precise and fast response to mitigate damage and operational disruptions.

Environmental Responsibility

The environmental impact of traditional firefighting methods is highlighted, as is the adoption of eco-friendly fire suppression systems that minimise damage to the ocean ecosystem.

Enhanced Fire Safety Measures

The paper proposes comprehensive fire safety measures, regular maintenance, collaborative risk assessments, and compliance with industry standards and mandatory regulations.

The information paper concludes with the recommendation for the mandatory installation of fire suppression systems on port equipment. This recommendation is proposed to enhance fire safety standards in global port handling operations, thereby protecting lives, preserving the environment and ensuring continuity of operations. It is considered that this approach will result in a safer and more sustainable future for the maritime industry and its stakeholders.

1. Introduction

In the ever-expanding landscape of international shipping and material handling industries, reflected in the rapid growth of ports and terminals worldwide, operations and equipment technologies are evolving at an unprecedented pace. Understanding the fire risks associated with these technological developments is now more critical than ever. This paper aims to highlight the increase in fire risks associated with such developments in the industry. It addresses the benefits of fire suppression systems in protecting lives, minimising downtime and safeguarding high-value equipment and facilities in ports.

Ocean shipping accounts for 90% of global trade and therefore, securing continuous material handling at ports is of paramount concern. The annual shipment of over 200 million containers highlights the requirement to minimise downtime and enhance efficiency to meet stringent deadlines. As port equipment technology evolves, the inherent fire risks have become more pronounced.

The global adoption of automated equipment, accelerated by the COVID-19 pandemic's priority to protect on-site workers, has become an established feature of the port industry. The application of modern technology, which includes automated cranes and other port equipment, is now commonplace in many ports. Understanding and addressing the fire risks associated with such autonomous equipment is critical to uninterrupted operations.

The global shift toward electrification of equipment and machinery as port operators transition from traditional combustion engines to modern hybrid and fully electric machines, while reducing the risk of fuel-related fires, adds another dimension to fire risk management.

Recognising that port equipment and facilities represent substantial financial investments, this paper highlights how fire suppression systems play a dual role. Firstly as a proactive measure to protect lives and ensure operational continuity and as a frontline defence for high-value equipment and facilities. By addressing fire risks and implementing effective suppression measures Port operators can secure their assets and maximise equipment availability.

2. Background

Vehicle fire suppression systems are an effective medium to mitigate fire hazards in engine compartments should a thermal event occur. These systems were introduced in the mid-70s in the forestry industry where machines frequently caught fire. In this application fires mainly originated in the engine compartment due to the challenging environment which includes flammable liquids, heat, high levels of airflow and in many cases large openings, all of which increase the likelihood and severity of a fire. As a result, insurance companies took multilateral action making it a requirement for insurance cover that forestry equipment and any other heavy-duty mobile equipment operating in hazardous environments be equipped with a fire suppression system. As a result, the Swedish Fire Protection Association was appointed to develop the standard SBF 127 to test and evaluate the fire suppression performance of such systems.

Even though not regulated in the Port equipment industry today, fire suppression systems are extensively deployed. This is not universally the case as many machines in the sector remain unprotected.

As part of the risk management process, a risk assessment profile of the equipment is vital. This should include identifying potential sources of fires and the location of firefighting equipment.

3. Problem Definition

Fire suppression systems are designed to protect lives, ensure the continuity of operations, maximise safety and minimise downtime.

Even with first responders on-site or in the vicinity, there are still challenges in extinguishing fires due to the complexity of the equipment. Increased response times can lead to fires growing in intensity, more likely to cause extensive equipment damage and difficult to extinguish.

From an environmental perspective, the contaminated fire extinguishing water from the first responders' actions could potentially damage the environment considering the proximity of port terminal operations to rivers and seas.

There are specific risks associated with autonomous equipment. With fewer people on or close to operating equipment on automated terminals, the detection of fire risks and outbreaks has become more complex. The application of manual fire detection systems on automated equipment can cause delays in the deployment of fire suppression agents. These delays relate to the time lag between the equipment communicating with the remote operator, who in turn has to respond and initiate the suppression agent.

Case Study: Fire Incident at Halmstad Port – A Wake-up Call for Fire Suppression Systems (FSS)

In September 2012, the Port of Halmstad experienced a significant fire incident that illustrates the serious consequences of inadequate fire safety measures (Eriksson, 2012). The fire, which started approximately twenty minutes before ten in the evening, quickly escalated in intensity. By a quarter past eleven, the local fire department had to make the critical decision to transition from an offensive firefighting strategy to a defensive one. The uncontrollable nature of the fire necessitated this shift in tactics. Remarkably, it took nearly three days before the fire was extinguished.

While the fortunate orientation of winds during the incident helped direct toxic gases from the fire towards the sea, firefighters at the scene remarked that had the wind changed towards the city the outcome could have been entirely different.

The fire's origin was traced to a warehouse used for storing salt, the structure of which was burned to the ground and never rebuilt. The outcome of this fire was significant economic losses, although the exact amount remains undisclosed. The firefighting operation undertaken by the Halmstad Fire Department was at the time one of its most extensive engagements. The company renting the warehouse initiated negotiations for a new facility within the Port of Halmstad, however, it ultimately relocated to another city. The Port of Halmstad is located close to the city centre with commercial and residential properties. A more catastrophic outcome was narrowly avoided, given less favourable wind conditions during the incident.

Despite exhaustive investigations and various theories being proposed, the precise cause of the fire remains unknown. The Fire Department has suggested that an electric forklift charging overnight as the most plausible origin (Eriksson, 2012). The forklift did not have a Fire Suppression System (FSS) installed. While not definitive, a different outcome might have resulted if such a system had been in place.

Such incidents serve as a backdrop for this paper, emphasising the importance of Fire Detection and Suppression Systems across all industry sectors, with particular focus on port equipment. FSS is often perceived as an optional cost rather than a necessity. However, the incident above highlights why FSS systems should be considered for all port handling equipment.

Such real-world incidents underscore the critical importance of fire safety measures and are the basis for our recommendations for industry-wide guidelines for container and bulk-handling equipment.

Fire Incident at Halmstad Port

4. Fire Triangle and Tetrahedron – Theory of Fire Initiation

4.1 Fire Triangle

The fire triangle is a simple model that explains what elements need to be present for a fire to start. It consists of three elements heat, fuel, and oxygen. Without these three elements, a fire cannot start or sustain itself.

4.1.1 Heat: The First Element

Heat is necessary to start a fire. It can come from various sources, including open flames, electrical sources, and friction. Once ignited, a fire will continue to produce heat, causing it to spread and intensify. This heat can cause burn injuries or ignite other combustible materials. The heat generated is what sustains the fire and keeps it burning.

Flash Point vs Fire Point

Heat also plays a vital role in determining a material's flash point and fire point. The flash point is the temperature at which a material will ignite, while the fire point is the temperature at which the material will continue to burn. Knowledge of these points for specific chemicals and materials is important in understanding the potential dangers and preventing fires.

4.1.2 Fuel: The Second Element

Just as a vehicle needs fuel to run, a fire also needs fuel to sustain itself. Fuel refers to any combustible material that can burn when exposed to heat and oxygen.

Various fuel types contribute to fires, ranging from natural materials such as wood, paper, and leaves to synthetic materials like lubricants, fuels and plastics. It is essential to note that different fuels burn at different rates and temperatures, producing various flames and smoke types.

A flashover is a deadly phenomenon occurring when all combustible materials in a room reach their ignition temperature simultaneously. When this happens, the heated gases burst into flames, creating a massive fireball that engulfs the area.

4.1.3 Oxygen: The Third Element

The role of oxygen in a fire is to oxidize or break down fuel molecules into smaller combustible compounds, releasing energy and heat. Oxygen acts as an oxidiser and supports combustion and without it, fires would not exist. The oxygen in the surrounding air diffuses in and reacts with the fuel, making the fire hotter and brighter. The availability of an adequate supply of oxygen can make the flame burn brighter, hotter, and faster.

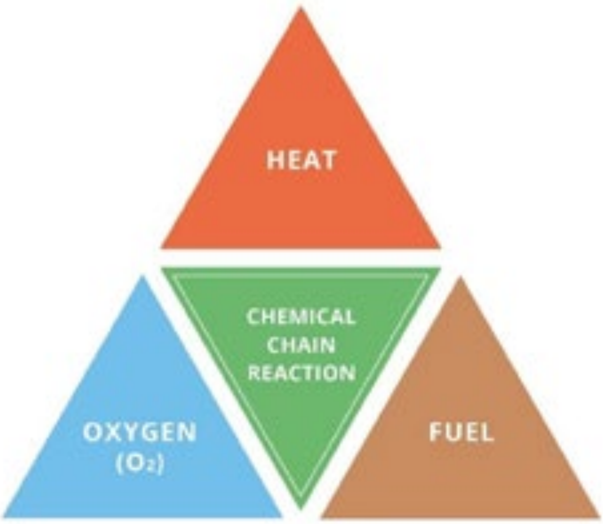
During a fire, a constant supply of oxygen is available as it diffuses from the surrounding air. The amount of oxygen present can influence the rate and intensity of the flame. To extinguish a fire, the oxygen component can be removed by smothering the flame with an agent that blocks the oxygen supply. In wildfires, oxygen concentration together with moisture and wind play a crucial role in determining fire intensity and spread.

4.2 Fire Tetrahedron

A slightly more complex version of the fire triangle, the fire tetrahedron includes an extra element. In addition to the original three elements of oxygen, fuel and heat, the fire tetrahedron contains a chemical chain reaction.

For a fire to ignite and then be sustained, sufficient energy must be generated which is caused by a chemical chain reaction. The fire tetrahedron represents this additional element with the four sides of the shape each featuring one of these core factors.

Combustion is the chemical reaction that feeds more heat to a fire allowing it to continue. Once a fire has started, the resulting exothermic chain reaction sustains the fire allowing it to continue until or unless at least one of the elements of the fire is removed. The only difference between the two diagrams is the introduction of the chemical chain reaction, and just like with the other three elements of a fire, it cannot be sustained if one is missing.



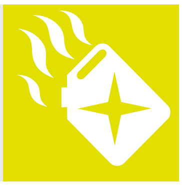
5. Classification of Fire Types

Fires can be classified according to type;
One common classification is the one used in Europe.

The European definition is as follows:

A Fires involving ordinary combustible materials, such as wood, paper, rubber, and plastic.

B Fires involving flammable liquids, such as gasoline, diesel, kerosene and alcohol.



C Fires involving flammable gases, such as ammonia, hydrogen, methane and propane.

D Fires involving combustible metals, such as magnesium, sodium, potassium, and aluminium.

F Fires involving cooking oils and fats, such as vegetable oil, butter, and lard.

Other countries like the USA and Australia may have different definitions.

6. Fire Detection & Suppression Technologies

6.1 Activation Principles

6.1.1 Loss of Pressure (LOP) Fire Suppression Systems

A Loss of Pressure (LOP) fire suppression system is a safety solution employed in various industrial settings, particularly within the engine compartments of heavy machinery. LOP systems continuously monitor the pressure within the fire suppression system. Under normal operating conditions, the system maintains a specified pressure range. However, if a rupture occurs due to a malfunction or discharge event (due to a fire), that results in a pressure drop below a predefined threshold the LOP detection system activates. It triggers alarms, visually alerts personnel to the potential fire or system issue and simultaneously initiates the release of the fire suppression agent. LOP systems help protect equipment, personnel, and the environment ensuring a rapid response to fire incidents, minimising potential damage, and enhancing safety during operations. The system can also be activated manually in addition to the automatic functionality.

6.1.2 Rise of Pressure (ROP) Fire Suppression Systems

A Rise of Pressure (ROP) fire suppression system is a safety solution designed to detect and respond to fire incidents without the need for constant pressurization of the fire suppression agent tank. Unlike the LOP systems, which maintain pressure at all times, ROP systems remain unpressurised until a fire event is detected or a significant pressure increase is experienced. When a fire or pressure anomaly is detected, the system activates the fire suppression agent, ensuring a rapid response to control and extinguish the fire. This approach reduces the risk of leaks, minimises maintenance requirements, reduces cost, and promotes efficient use of the fire suppression agent. This makes ROP systems an effective and environmentally friendly choice for fire safety in various industrial applications. The system can also be activated manually in addition to the automatic functionality.

6.1.3 Sensor-Activated Fire Suppression Systems

Sensor-activated fire suppression systems include:

1) Flame sensors: detect flames through the infrared or ultraviolet spectrum.

2) Smoke sensors: identify smoke particles indicative of the early stages of a fire.

A flame or smoke sensor detects a fire situation and triggers an alarm directly or via the machine control panel. This in turn activates the fire suppression system releasing the fire suppression agent, ensuring a rapid response to control and extinguish the fire. The system interacts with the machine control system as defined by the OEM to switch off engines and pumps and de-energised electrical equipment.

Rapid activation ensures minimal delay between detection and agent discharge, effectively containing fires. Regular maintenance and testing, including inspections and functional tests, must be employed to ensure system reliability and effectiveness.

6.2 Suppression Agents

The choice of fire suppression agents, such as water mist, foam, dry chemical powders, or gaseous agents, depends on the specific application and environment.

6.2.1 Aerosol

Aerosol fire suppression systems are fire protection solutions that use aerosol particles to suppress fires. These systems are efficient, compact, and eco-friendly. When a fire is detected, the system releases a fine aerosol mist that consists of tiny solid particles and gaseous compounds. This mist suppresses the fire by disrupting the chemical reaction of the combustion process and cooling the flames.

A significant advantage of aerosol systems is their associated minimal secondary damage. Unlike traditional fire suppression methods that employ water or dry chemical agents, aerosol systems leave little residue. This makes them ideal for protecting sensitive equipment, data centres, and valuable assets. Their compact design allows for ease of installation in various settings, including confined spaces. Aerosols are sensitive to airflows, and this factor must be considered during system design and installation.

6.2.2 AFFF - Aqueous Film Forming Foam

Aqueous Film Forming Foam (AFFF) consists of a mixture of water, foam concentrate, and air, which, when applied to a fire, forms a blanket-like layer of foam that extinguishes the flames and prevents re-ignition. These systems are particularly effective in industries handling combustible fuels, such as petrochemical plants, aircraft hangars, and fuel storage facilities.

One of the key advantages of AFFF systems is their ability to create a stable, long-lasting foam layer that not only smothers the fire but also prevents the release of flammable vapours, minimising the risk of re-ignition. They work well on hydrocarbon-based fires Class B and some Class A fires involving ordinary combustibles.

AFFF systems can be configured as fixed installations, mobile units, or portable fire extinguishers, offering flexible fire protection options. It is however important to consider environmental factors as some AFFF formulations have faced scrutiny due to their potential impact on groundwater and ecosystems. As a result, there has been a shift towards more environmentally friendly alternatives in recent years.

6.2.3 DCP - Dry Chemical Powder

Dry Chemical Powder (DCP) fire suppression systems are versatile and widely used for controlling fires in various environments. They are particularly effective against Class A, B, and C fires. This makes them suitable for a wide range of applications, including industrial settings, commercial spaces, and certain types of equipment.

DCP systems discharge a dry chemical powder, typically monoammonium phosphate or sodium bicarbonate, which disrupts the chemical reaction in the fire triangle. When applied to a fire, the powder forms a barrier that smothers the flames and prevents the release of combustible vapours, effectively suppressing the fire.

Key advantages of DCP fire suppression systems include their rapid flame knockdown capabilities. They lack cooling capacity, however. One consideration is that the discharged powder can be difficult to clean and may damage sensitive equipment or electronics which makes them less suitable for certain environments.

6.2.4 Dual Agent - DCP and AFFF

Dual agent systems combine two different suppression agents to increase the systems' performance. A common combination is a DCP system and an AFFF system known as a wet chemical system, but other combinations are possible. The principle of operation in this example is a rapid knockdown of the flames by the DCP while the AFFF system wets and cools the compartment to reduce the risk of re-ignition. Depending on the system type the two agents can be activated simultaneously or in sequence. In essence, this is not one system but two individual suppression systems.

6.2.5 Water Mist

Water mist fire suppression systems for heavy machinery offer a highly effective and versatile approach to safeguarding these valuable assets from fire hazards. Designed to combat Class A, B, and C fires, they use fine water droplets to extinguish flames and cool hot surfaces. Such systems are well-suited for environments where heavy machinery operates, including construction sites, mining operations, and forestry.

Water mist systems work by atomising water into small droplets creating a mist that absorbs heat and reduces oxygen levels around the fire. This dual-action approach suppresses the fire and prevents re-ignition by cooling.

Key advantages of water mist systems for heavy machinery include their ability to provide localised protection and reduce the risk of secondary damage while effectively combating fires in critical areas like engine compartments, hydraulic systems, or operator cabins. Additives to enhance the performance are common.

6.2.6 Wet Chemical

Wet chemical fire suppression systems are specialised safety solutions designed to protect heavy equipment, such as port machines, construction equipment and forestry machines from fire hazards. These systems are particularly valuable in industries where the risk of fire in engine compartments or hydraulic systems is significant.

The wet chemical agent in these systems is specifically formulated to combat Class A, B, and C fires. When discharged, it forms a cooling and smothering foam that suppresses the fire, cools hot surfaces, and prevents re-ignition. Wet chemical systems are noted for their ability to handle the unique challenges posed by heavy machinery, including hot surfaces, hydraulic oil, and fuel sources.

One key advantage of wet chemical systems for heavy machinery is their ability to provide localised protection in critical areas of the equipment such as the engine compartment or hydraulic systems. This targeted approach minimises damage to the machinery while effectively suppressing the fire.

Table 1 An overview of Suppression Agents and Applications

	Inert Gas	Clean Agent	Aerosol	Dry Chemical, BC	Dry Chemical ABC	Foam Spray / AFFF	Wet Chemical Spray	Wet Chemical Mist
Hot Surfaces	✗	✗	✗	✗	✗	✗	(✓)	✓
Forced Airflow	✗	✗	✗	✓	✓	✓	✓	✓
Hidden Fires	✓	✓	✓	✓	✓	✗	✗	✗
Combustible Fuels (Class A)	✗	✗	✓	✗	✓	✓	✓	✓
Flammable Liquids (Class B)	✓	✓	✓	✓	✓	✓	✓	✓
Flammable Gases (Class B)	(✓)	(✓)	(✓)	✓	✓	✗	(✓)	✓
Free Radical Inhibition	✗	✓	✓	✓	✓	✗	(✓)	✓
Clean Up	✓	✓	(✓)	✗	✗	(✓)	(✓)	(✓)
Suitable for ICE Compartments	✗	✗	✓	✗	✗	✗	✓	✓
Suitable for EV Compartments	✗	✗	✗	✗	✗	(✓)	(✓)	✓

✗ Unsuitable

✓ Suitable

(✓) Depends on Application

6.3 Detection Systems

6.3.1 Flame Detection

Flame detectors are devices designed to detect the presence of flames. There are a variety of sensor types. Examples include UV detectors, IR detectors and combinations thereof. Flame detectors generally have fast response times but the associated cost is typically higher than other detection methods. Furthermore, dirty environments can affect the maintenance intervals.

6.3.2 Gas Detection

Gas detection devices are advanced sensors that detect one or more gases in a protected environment. Gas detection devices are not generally used in engine compartments since a gas release does not always result in a fire. Gas sensors can also be designed to react to combustion gases like carbon monoxide and carbon dioxide to indicate that a fire has been initiated. Gas detection can also be utilised in combination with fire detection systems to give an early warning without activating the fire suppression system. Gas detection devices typically require periodical calibration to ensure their functionality.

6.3.3 Heat-based Detection (linear heat detector wire, pressurised tube etc.)

There are numerous solutions and technologies for heat detectors, this being the most widely used for engine compartments. The most common types are linear heat detectors (LHD) and loss of pressure (LOP).

LHD consists of a twisted conductor pair with a heat-sensitive material in between them. When a fire occurs the two conductors come in contact creating an electrical connection signalling a fire.

LOP consists of a pressurised tube. When a fire occurs the tube is punctured and the pressure is lost. A pressure sensor registers the pressure drop and the fire alarm is activated.

Other solutions such as bi-metal sensors, thermistors, thermocouples, and specialised devices are also available. Heat detectors have historically been used in engine compartments since they are relatively low-cost and insensitive to dirt. Linear detectors such as LHD and LOP cover a greater area when compared with spot sensors such as bi-metal and thermistor units. This can be beneficial in compartments with complex geometry and high airflow.

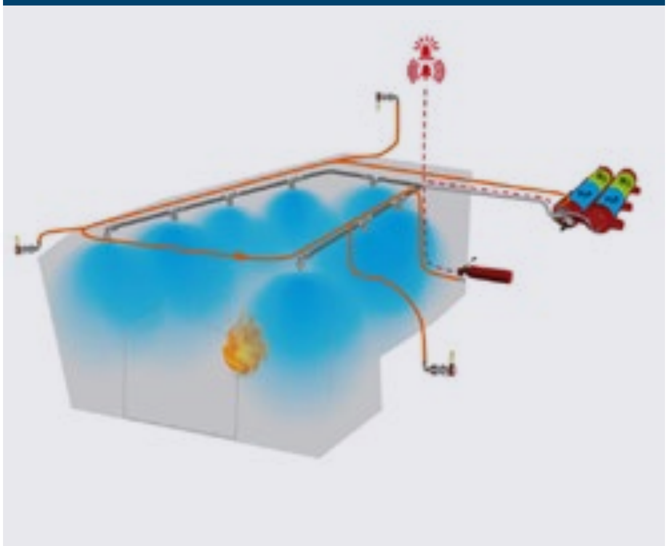
6.3.4 Smoke Detection

Smoke detectors are common in households and commercial and industrial buildings. There are different technologies and different levels of complexity and can include combinations that include heat detection. Smoke detectors are typically unsuitable for engine compartments because of the relatively dirty environment. Exhaust fumes, water droplets induced by the fan, water steam created by a cold engine heating up etc. can cause false alarms. For more environmentally controlled compartments however, smoke detectors provide fast detection and cover relatively large areas.

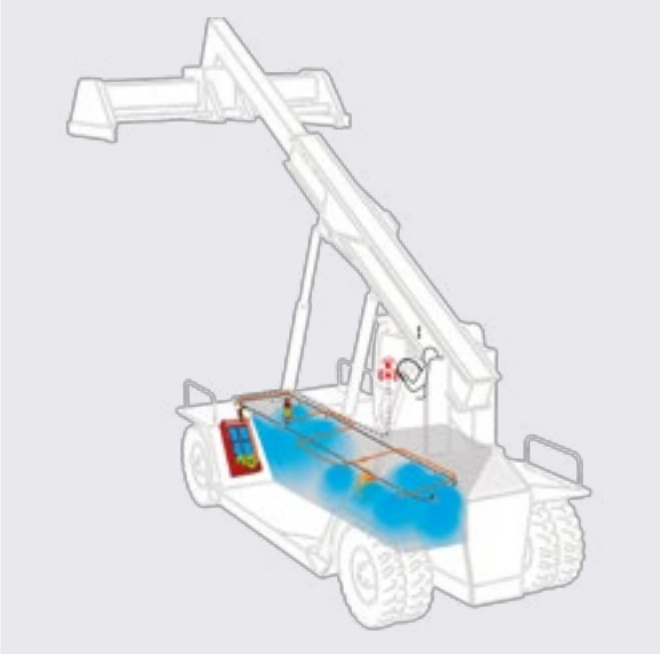
6.4 Schematic Examples of Fire Suppression Systems

Installation configurations on mobile equipment.

6.4 Example 1

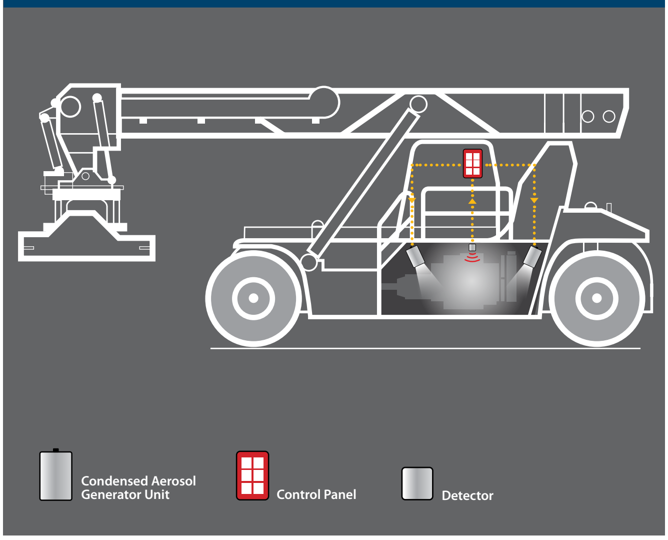


6.4 Example 2



6.4 Example 3

6.4 Example 4



6.5 Examples of Fire Suppression Components

The following are examples of FSS components as applied on port equipment.

6.5 Example 1

6.5 Example 2

6.5 Example 3

7. Fire Hazards Associated with Port Equipment

In the dynamic world of Port equipment, the large variety of hazardous locations, components and associated fire risks highlight the need for exceptional diligence. Identifying these risks and deploying effective fire detection and suppression systems are key to safeguarding personnel, equipment, and the continuity of port operations. This comprehensive analysis explores the wide range of fire hazards associated with port handling equipment and highlights the importance of fire suppression systems in mitigating these risks.

7.1 Risk Sources

Port equipment operates in a harsh and often unforgiving environment subject to ever-changing conditions. Understanding the technicalities and complexities of these conditions is critical to fire prevention and mitigation. Several factors define the basis for classifying these areas of machines as hazardous.

7.1.1 Internal Combustion Engines (ICE)

The prime power source of mobile heavy port machinery is the Internal Combustion Engine (ICE). Engines can generate temperatures up to 90 degrees Celsius, with components such as the turbocharger and manifold reaching temperature levels of several hundred degrees Celsius. This environment creates a potential fire hazard especially when coupled with ruptured fuel or hydraulic lines in conjunction with accumulated combustible materials such as leaves dry grass and airborne materials.

7.1.2 Hydraulic Systems

Port equipment employs hydraulic systems often operating at high hydraulic pressures. Hydraulic hoses and lines form an integral part of such installations. A failure when pressurised of these hydraulic components can result in hydraulic oil being sprayed onto high-temperature engine components such as manifolds or turbochargers. Such an occurrence can transform these components into incendiary devices creating an ignition source that increases the fire risk.

7.1.3 Diesel Particulate Filters (DPF)

The increased utilisation of Diesel Particulate Filters (DPFs) in port equipment required under the emission standard legislation for Stage IV - V engines, results in increased temperature of exhaust gases. This increase in temperature amplifies further the risk of fire initiation. Therefore, particular attention must be paid to DPF-associated fire hazards.

7.1.4 Connectors and Wire Harnesses

Electrical systems in Port equipment comprise connectors wire harnesses and associated switching components, all susceptible to a malfunction that can result in fires. These include short circuits, corrosion, vulnerability to vibrations and abrasions, overheating, improper installations, and substandard maintenance practices.

7.1.5 Pumps, Motors and Compressors

Port equipment generally includes pumps, motors and compressors that include rotating components and belts. Should these components be overloaded, seized or immobilised, the resultant increase in temperature can generate excessive heat. This situation can cause self-combustion of the components themselves, or ignite adjacent materials such as drive belts and other drive components.

7.1.6 Battery and Electric Compartments

Port equipment utilises batteries and includes electric compartments and components that result in unique fire hazards. The process of identifying and mitigating these risks necessitates careful consideration. One critical issue involves selecting the most appropriate fire suppression agent or method based on the identified risks. Additionally, effective cooling mechanisms are a key consideration in the overall strategy if fire hazards are to be mitigated within these compartments.

8. Electrification of Port Equipment

The electrification of Port equipment represents a significant shift in the maritime industry's journey of enhancing operational efficiency and reducing environmental impact. As ports increasingly adopt electrically operated equipment the potential fire risks associated with this transformation must be analysed. This section explores the electrification trend its benefits and the fire safety considerations essential for its safe implementation.

8.1 Electrification Trend

Electrification in the port industry involves replacing traditional diesel-powered equipment with electrical alternatives. This transition aligns with global efforts to reduce greenhouse gas emissions and mitigate the environmental footprint of port operations. Key elements of electrification include:

8.1.1 Electric Cranes

Ship-to-shore (STS) cranes, and rail-mounted gantry (RMG) cranes typically operate from the electrical power grid. Rubber-tyred gantry (RTG) cranes and Harbour Mobile Cranes are nowadays being electrified to reduce emissions and noise pollution. Electric cranes are quieter, do not emit exhaust gases, and result in better energy efficiency.

8.1.2 Battery-Powered Equipment

Electric straddle carriers, shuttle carriers, reach stackers, AGV's, Terminal tractors and forklifts powered by lithium-ion batteries are becoming the norm in the industry. These batteries provide ample power and can be recharged quickly using High-power charging equipment.

8.1.3 Hybrid Solutions

Some port equipment, such as mobile harbour cranes and straddle carriers utilise a hybrid configuration combining diesel engines with battery technology to reduce emissions and improve fuel efficiency.

8.2 Fire Risks Associated with Electrical Port Equipment

While electrification offers numerous benefits it also introduces specific fire risks that require careful consideration. Understanding and managing these risks is crucial for safe and sustainable port operations:

8.2.1 Battery Fires

Lithium-ion batteries are commonly used in electrified port equipment. Thermal runaway is a critical condition that may occur within a battery characterised by an excessive rise in temperature leading to ignition and potential combustion. Battery fires of this type because of their characteristics can be challenging to extinguish and pose risks to equipment and personnel.

8.2.2 Electrical Faults

Electrical components and systems in port equipment can experience short circuits, overloads, and other malfunctions which can potentially result in electrical fires.

8.2.3 Charging Infrastructure

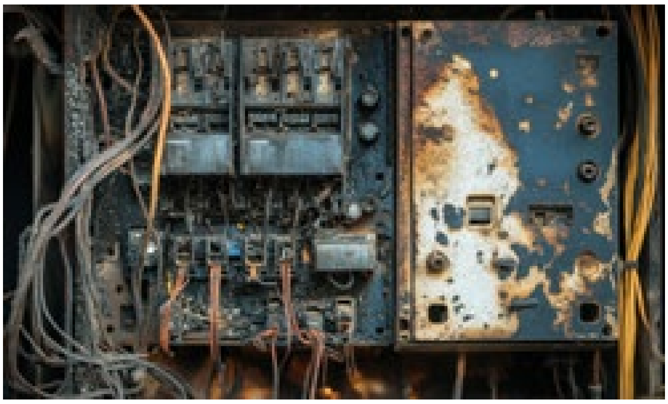
The monitoring of charging infrastructure for battery-powered equipment is critical. Faulty charging stations or improper charging procedures can result in fire incidents.

8.2.4 Overheating Motors

Electric motors if not properly cooled and maintained can overheat potentially leading to fires.

8.2.5 Arcing and Sparks

In the presence of flammable materials arcing or sparks from electrical components can ignite fires.



8.3 Maintenance Service and Repairs

Maintenance activities on electrified equipment must be performed safely to avoid accidental fires. This is particularly the case when working with high-power electrical components. Regular maintenance activities include inspections, testing, and potential component replacements all of which are integral to sustaining the system's operational readiness. Adherence to routine maintenance procedures and service intervals is a requirement to meet regulatory standards and serves as a proactive strategy to mitigate the risk of system failures or malfunctions.

Fire suppression systems are critical measures for safeguarding life property and assets. It is, however, imperative to highlight that the installation of such systems is not a reason to neglect essential service and maintenance obligations.

8.4 Fire Protection Systems for Battery Electrical Equipment: Early Detection and Prevention

A critical element when ensuring the safe operation of battery electrical port equipment is the implementation of fire protection systems. These systems prioritise early detection and prevention to mitigate fire risks effectively:

8.4.1 Detection

It is notable, that currently no fire suppression system capable of suppressing a battery fire that experiences thermal runaway exists. Therefore, early detection is paramount. Fire protection systems are equipped with sensors and monitoring devices that continuously monitor lithium-ion, or similar battery technologies by way of the battery's condition temperature and other critical parameters. Any anomalies or signs of thermal runaway trigger immediate alerts to operators and safety personnel.

8.4.2 Thermal Management

Cooling systems integrated into electrified equipment are designed to maintain optimal operating temperatures for batteries. When a thermal runaway scenario is detected, these systems are activated to cool the battery and designed to halt the thermal runaway process and prevent the escalation of the incident.

8.5 Fire Suppression Measures – Battery Installations

8.5.1 Fires Initiated Inside the Battery

Thermal runaway within a battery presents significant challenges for traditional fire suppression systems which may not effectively extinguish such internal fires. These systems are designed to contain and suppress secondary fires that could result from thermal runaway preventing the spread to nearby flammable materials or equipment.

Early detection is critical in managing thermal runaway incidents. Advanced fire suppression systems incorporate sensors that detect abnormal temperature rises within the battery. Some systems can detect various gases indicative of a thermal runaway event although this functionality is not universal.

The early application of appropriate cooling techniques can significantly increase the likelihood of delaying the thermal runaway process. This delay is crucial as it provides additional time for safe evacuation procedures, particularly important in passenger vehicles. Moreover, in many cases, the early use of fire suppression and cooling can prevent the situation from escalating maintaining the battery in a safer state.

The optimal solution requires the fire suppression actions to be applied directly inside the battery. This approach ensures that the suppression agent reaches the core of the thermal event effectively managing and mitigating the internal fire. Proactive containment strategies coupled with advanced early detection and internal suppression methods are essential in managing the risks associated with battery fires and ensuring the safety of both personnel and assets.

8.5.2 Fires Outside the Battery

Fire suppression systems have a critical role in scenarios where fires originate outside the battery. Such systems are adept at detecting external fires promptly and activating the suppression equipment to prevent the spread of the fire thereby protecting the electrical equipment including the battery pack. Such incidents may arise from external factors such as flammable materials in the environment or equipment malfunction. The effectiveness of these systems must comply with regulatory requirements such as those outlined in UNECE Regulation 100.

8.6 Emergency Response

Robust emergency response plans tailored specifically for electrified equipment including detailed procedures for equipment shutdown, evacuation, and the safe management of thermal runaway incidents must be in place. Operators and personnel should be well-trained to ensure that these plans are promptly and safely implemented and must be supported by regular fire safety drills.

8.7 Safety in Electrically Operated Port Equipment

The electrification of Port equipment promises a sustainable and efficient future for maritime operations. However, it brings with it specific fire risks that demand particular attention. Fire protection systems that incorporate early detection, activation and prevention functionality play a pivotal role in safeguarding personnel, equipment, and the environment. By implementing these systems, personnel training and adhering to strict safety protocols ports can fully embrace electrification while ensuring the utmost safety of their operations. Fire suppression systems, like any complex safety infrastructure demand consistent and meticulous maintenance to ensure their efficacy when deployment is required.

Balancing sustainability with safety is the key to a successful and responsible electrified future for port equipment.

9. Regulation and Testing of Fire Suppression Systems for Port Equipment

In the Port equipment sector, the application of fire suppression systems is an important safety measure. At this point, the adoption of such systems lacks comprehensive regulations mandating universal adoption or standardised testing protocols. This section addresses the current landscape of fire suppression systems for Port equipment highlighting the role of safety initiatives and the importance of adhering to local standards and regulations.

It is to be noted that standards and regulations where they exist define the minimum requirements. Therefore, a comprehensive analysis of the entire system design should be undertaken through rigorous risk assessment procedures.

9.1 Regulatory Landscape

Currently, no global regulations mandating the installation of fire suppression systems in Port equipment exist. Consequently, the installation of such systems is typically driven by safety initiatives implemented mainly by large port operators within their global terminals. These initiatives have resulted from the operators' commitment to enhancing the safety of their operations and protecting valuable assets.

9.2 Testing and Evaluation

In the absence of universally accepted standards for testing the fire suppression performance of suppression systems, safety initiatives by industry stakeholders rely on various local standards and guidelines. These local standards may vary between one region or country and another leading to a lack of standardised evaluation criteria.

Examples of standards applied by some port operators are:

SBF 127:17 – Rules for Fire Protection on Construction Vehicles (Swedish Fire Protection Association).

SBF 127 provides comprehensive guidelines for fire protection on construction equipment, including forestry and construction machinery. It outlines requirements for fire suppression systems by detailing the design, installation, maintenance, and inspection processes. The standard highlights the importance of identifying fire hazards, implementing appropriate suppression systems, and ensuring the systems are maintained and inspected regularly. Specific requirements are defined for different equipment types and safety classes that ensure tailored fire protection measures. The document aims to enhance fire safety and minimise fire-related risks in construction environments, by promoting the safety of equipment and personnel.

AS 5062 – Fire Prevention and Protection for Mobile and Transportable Equipment (Standards Australia).

AS 5062 is a standard developed by Standards Australia that focuses on fire prevention and protection for mobile and transportable equipment. It provides guidelines for identifying fire hazards, estimating and evaluating fire risks, and implementing effective fire risk management strategies. The standard outlines the design, installation, and maintenance of fire suppression systems to ensure they effectively protect equipment from fire hazards. It highlights the importance of regular inspections, maintenance, and adherence to safety protocols. AS 5062 aims to enhance fire safety in industries using heavy machinery by promoting systematic fire risk management practices.

SP Method 5289 – Fire Risk Management Procedure for Vehicles (RISE).

SP Method 5289 provides a comprehensive fire risk management procedure for vehicles and mobile machines, addressing new and operational units. The method highlights the identification of fire hazards and includes risk assessment, evaluation, and reduction measures. It incorporates a systematic approach to assess ignition sources, fire spread potential, and the effectiveness of fire protection measures. This method also proposes recommendations for common designs, procedures, and systems, leveraging research fire investigations and industry insights. While it does not guarantee the elimination of fires its application promotes enhanced fire safety by aiding manufacturers and operators in proactive fire risk management.

9.3 The Importance of Local Standards and Regulations

Without a global mandate, port operators and equipment manufacturers must follow applicable local standards and regulations. Adherence to these standards ensures that products and services meet the highest performance and minimise liability exposure within a specific jurisdiction. These local standards provide guidance on equipment specifications, testing procedures, and safety measures. This allows stakeholders to evaluate the effectiveness and reliability of fire suppression systems accurately.

9.4 Benefits of Standardisation

The absence of standardised testing protocols for fire suppression systems can lead to inconsistencies in performance evaluations. Standardisation enhances safety by providing clear benchmarks for evaluating the effectiveness of fire suppression systems. It promotes transparency, reliability and accountability across the industry.

In the absence of global regulations and standards, it is crucial that industry stakeholders, including port operators, equipment manufacturers, and safety organisations, collaborate and share knowledge and best practices. By pooling expertise, these entities can collectively work towards enhancing safety and establishing effective fire suppression system standards and guidelines that can benefit the entire Port equipment industry.

10. Environmental Implications of Contaminated Extinguishing Water in Port Equipment Fires

The environmental considerations associated with Port equipment fires extend beyond the use of fire suppression systems and include the generation and disposal of contaminated extinguishing water by first responders. This section explores the potential environmental impacts of firefighting efforts in port environments, particularly due to the proximity to the waterways and ocean.

10.1 Challenges in Fire Suppression and Environmental Impact

Addressing fires in a port environment with multiple complex machines presents formidable challenges even when first responders are onsite or nearby. Delays in response times can lead to fires spreading quickly, growing larger, and increasing the environmental risks associated with the firefighting efforts.

From an environmental perspective, the response to a fire incident typically involves substantial amounts of water and suppression agents. This is of particular concern in ports which are by definition situated near the water. The runoff from firefighting activities, including the water and suppression agents used by first responders, can result in contaminated extinguishing water that poses a significant threat to the environment and the adjacent waterways and ocean ecosystems.

10.2 Environmental Impacts of Contaminated Extinguishing Water Generated by First Responders

10.2.1 Chemical Contamination

Firefighting actions utilise agents like foams, powders, or gases, which mix with the firefighting water creating chemical residues harmful to aquatic ecosystems. Key contaminants include per- and polyfluoroalkyl substances (PFAS), polyaromatic hydrocarbons (PAHs), heavy metals (lead, cadmium, mercury), phosphates, nitrates, surfactants, solvents, chlorides, sulphates, and cyanides. These substances can persist in the environment, cause toxicity, disrupt ecosystems, and lead to bioaccumulation, eutrophication, and algal blooms. Effective management of firefighting water runoff is essential to mitigate these environmental impacts.

10.2.2 Bioaccumulation

Chemicals discharged into the ocean can persist in the water and accumulate in marine organisms over time. This process, known as bioaccumulation, can cause contamination of seafood and other aquatic resources, potentially posing health risks to humans and wildlife.

10.2.3 Water Quality Impact

The discharge of contaminated extinguishing water can result in immediate and long-term water quality issues in the vicinity of the port. This can affect the health of marine life, compromise water supply sources, and disrupt the overall ecological balance.

10.2.4 Habitat Disturbance

In addition to chemical contamination, the sheer volume of extinguishing water used in firefighting can lead to habitat disturbance. The force of water discharge and the inundation of areas with fire suppressants can disrupt sediment and sensitive marine habitats.

10.3 Mitigating Environmental Impact when Firefighting by First Responders

Minimising the environmental impact of contaminated extinguishing water generated by first responders in Port equipment fires requires a concerted effort. Several measures can be employed to mitigate these impacts:

10.3.1 Environmentally Friendly Agents

First responders can utilise environmentally friendly firefighting agents that have minimal ecological impact.

10.3.2 Containment and Filtration Systems

Port operators can implement effective containment and filtration systems for extinguishing water used by first responders. These systems capture and treat the water, minimising the release of harmful substances into the environment.

10.3.3 Spill Response Plans

Developing comprehensive spill response plans for firefighting activities can facilitate swift and effective containment and cleanup in the event of a fire incident.

10.3.4 Regular Monitoring and Reporting

Monitoring of water quality and environmental assessments should be continuously conducted to promptly identify and address potential environmental issues. Reporting mechanisms should be in place to notify relevant authorities of any incidents.

10.3.5 Training and Education

Provide training for first responders on the environmental consequences of firefighting measures and the importance of responsible environmental management.

10.3.6 Regulatory Compliance

Compliance with environmental regulations and standards should be central to firefighting activities. This includes adherence to discharge limits and the performance of environmental impact assessments.

In summary, contaminated extinguishing water generated by first responders during Port equipment fires presents significant environmental challenges. Addressing these challenges requires a comprehensive approach highlighting the responsible use of firefighting agents, implementation of containment and filtration systems, and ongoing monitoring and reporting to safeguard the marine ecosystems surrounding the port.

11. Autonomous Equipment

The transition from traditional, man-operated Port equipment to autonomous machines represents a paradigm shift in the maritime industry. This transformation carries a set of unique risks and challenges concerning fire incidents. In particular, it highlights the critical importance of rigorous fire risk assessments, adherence to international methodologies such as SP Method 5289, meticulous documentation, and seamless integration of risk analysis into system design and equipment supply. The requirement for fire suppression systems and comprehensive fire mitigation strategies is even more relevant in this evolving autonomous landscape.

11.1 Autonomous Equipment vs. Manned Equipment: Risk Dynamics

11.1.1 Reduced Human Oversight

Autonomous Port equipment operates without the constant presence of human operators. While this can enhance efficiency, safety, and productivity, it also diminishes human intervention in detecting and responding promptly to fire risks.

11.1.2 Complex Electrical and Control Systems

Autonomous equipment heavily depends on complex electrical drives and control systems. Such systems, like any sophisticated installation, are susceptible to electrical faults, short circuits, and malfunctions that can potentially act as ignition sources.

11.1.3 High Voltage Batteries

Autonomous equipment can include batteries configured for high voltages as is required for the power demand. These batteries pose inherent fire risks, particularly when they overheat or experience thermal runaway.

11.1.4 Limited Fire Detection

Autonomous equipment may have fewer sensors or detection mechanisms for fire incidents when compared to man-occupied equipment, potentially leading to delayed fire detection. Remote monitoring technology applied in such applications must be assessed for suitability and reliability.

11.2 Fire Risk Assessments and Methodology for Autonomous Equipment

Rigorous fire risk assessments are key to understanding, quantifying, and mitigating the unique fire risks associated with autonomous Port equipment. Adherence to internationally recognised methodologies like SP Method 5289 provides a structured approach to risk analysis. This methodology encompasses factors such as the assessment of ignition sources, fire spread potential, and the effectiveness of fire protection measures. Following established methods, organisations can systematically evaluate risks and make informed decisions.

11.3 Robust Risk Assessment Procedures

The establishment of comprehensive risk assessment procedures tailored to autonomous equipment is paramount. These procedures should encompass:

11.3.1 Risk Identification

Identifying potential fire hazards and the ignition sources within the autonomous vehicle's systems and components.

11.3.2 Risk Evaluation

Assessing the likelihood and consequences of fire incidents, considering the unique characteristics of autonomous equipment.

11.3.3 Risk Mitigation

Developing strategies to mitigate identified risks, including selection of appropriate fire suppression systems and prevention measures.

11.3.4 Regular Review

Continuously monitoring and updating risk assessment procedures to respond to evolving technologies and changing operational environments.

11.4 Documenting Risk Assessments

Thorough documentation of risk assessments is essential for accountability and compliance. This documentation serves several critical purposes:

11.4.1 Transparency

Transparently communicates identified risks and mitigation strategies to stakeholders, fostering a shared understanding of potential hazards.

11.4.2 Compliance

Supports compliance with industry regulations and standards, demonstrating due diligence in addressing fire risks associated with autonomous equipment.

11.4.3 Continuous Improvement

Serves as a foundation for continuous improvement by enabling organisations to learn from past assessments and refine risk mitigation strategies.

11.5 Implementation of Risk Analysis into System Design

Integrating risk analysis into the system design and supply of autonomous Port equipment is a proactive approach to risk management. This includes:

11.5.1 Design Modifications

Modifying equipment design to minimise fire risks such as incorporating fire-resistant materials or enhanced electrical system design details.

11.5.2 Suppliers' Accountability

Equipment suppliers must adhere to established risk assessment procedures when integrating fire suppression systems into equipment design.

11.5.3 Emergency Response Planning

Design of equipment with emergency response capabilities, including fire suppression systems, to address fire incidents swiftly.

11.6 Reasons for Fire Suppression Systems and Comprehensive Fire Mitigation Strategies

Considering the risks associated with autonomous Port equipment, fire suppression systems and comprehensive fire mitigation strategies are considered indispensable:

11.6.1 Early Detection Activation and Response

Fire suppression systems equipped with advanced sensors and monitoring devices provide early detection of fire incidents, enabling rapid and targeted responses.

11.6.2 Agent Selection

Tailoring suppression agents to the specific risks identified in risk assessments ensures effective fire mitigation.

11.6.3 Cooling Strategies

Integrated cooling systems are key to maintaining safe operating temperatures in autonomous equipment, particularly in battery and electrical compartments.

11.6.4 Proactive Prevention

Fire suppression systems also contribute to fire prevention by detecting and addressing potential ignition sources before they escalate into full-blown fires.

The shift from man-occupied to autonomous port equipment necessitates a heightened focus on fire risk assessments, adherence to established methodologies, robust risk assessment procedures, thorough documentation, and integration of risk analysis into equipment design and supply. This holistic approach, coupled with fire suppression systems and comprehensive fire mitigation strategies, ensures the safety and sustainability of operations in the evolving landscape of autonomous port handling equipment.

12. Conclusion and Recommendations

This paper has addressed the importance and benefits of implementing fire detection and suppression systems in port equipment where complex equipment interacts with maritime operations. The paper recognises the impact on safety, damage mitigation, operational continuity, environmental responsibility, and, most crucially, the preservation of human life. The following recommendations are proposed to ensure enhanced fire safety in the Port environment:

- **Comprehensive Fire Safety Measures:** Port operators should prioritise the installation of state-of-the-art fire suppression systems in all Port equipment, including autonomous machines.
- **Regular Maintenance:** Routine inspections, adherence to manufacturers' service protocols and remote monitoring for autonomous equipment are crucial to ensuring system functionality.
- **Collaborative Risk Assessments:** Collaboration between fire suppression system suppliers, equipment manufacturers and port operators should identify specific fire risks and hazards to develop tailored safety solutions.
- **Mandatory Regulations:** Authorities having responsibility for safety and the insurance industry should consider mandating the installation of fire suppression systems.

In conclusion, fire detection and suppression systems in port equipment are considered critical safety components. It is recommended that the installation of such systems and the strict enforcement of industry standards should be mandated by safety authorities and the insurance industry and supported by equipment manufacturers, terminals, and other stakeholders.

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Founded in late 2004, PEMA's mission is to provide a forum and public voice for the global port equipment and technology sectors, reflecting their critical role in enabling safe, secure, sustainable and productive ports, and thereby supporting world maritime trade.

Chief among the aims of the Association is to provide a forum for the exchange of views on trends in the design, manufacture and operation of port equipment and technology worldwide.

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