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Review

OPTIMIZING PHARMA INDUSTRY FIRE HAZARDS: BALANCING, SAFETY, EFFICACY AND INNOVATION

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ABSTRACT

Any actions, materials, or conditions that might increase the size or severity of a fire or that might cause a fire to start are called fire hazards. This topic outlines the fundamental principles of fire science, including the fire triangle concept, and explores various types of fire hazards such as electrical issues, smoking, human error, combustible dust, arson, heating equipment malfunctions, mechanical friction, flammable substances, and employee negligence. This content emphasizes critical fire prevention strategies, including regular electrical system maintenance, proper smoking material disposal, employee training, dust control measures, security protocols, equipment maintenance, safe handling of flammable materials, and encouraging hazard reporting. It also discusses different classes of fires (A, B, C, D, and K) and various types of fire extinguishers (dry chemicals, CO2, wet chemicals, and foam). This content underscores the importance of implementing comprehensive fire safety programs, conducting regular inspections, maintaining equipment properly, and establishing clear safety protocols. This information provides a foundation for developing effective fire prevention and response strategies in workplace settings, ultimately contributing to enhanced occupational safety and reduced fire risks.

Keywords: Fire hazards, Fundamental principles, Prevention strategies, Fire safety programs.

INTRODUCTION

Fire possesses a significant risk to industries worldwide, and Indian industries are no exception. The potential for devastating fires can lead to loss of life, destruction of property, and severe disruptions to business operations. It is crucial for industries in India to conduct thorough fire risk assessments various potential hazards that commonly exist in industrial settings, ranging from electrical systems and chemical storage to machinery and structural weaknesses. Fire safety is the set of practices intended to reduce the destruction caused by fire. Fire safety measures include those that are intended to prevent ignition of an uncontrolled fire, and those that are used to limit the development and effects of a fire after it starts. Fire safety measures include those that are planned during the construction of a building or implemented in structures that are already standing, and those that are taught to occupants of the building. Threats to fire safety are commonly referred to as fire hazards. Fire safety is often a component of building safety. A working knowledge of basic fire science and chemistry is essential for developing and implementing a successful fire safety program. [1]

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Definition of Fire

A fire is a chemical reaction. There are many variables that can affect a fire. Effective fire safety management programs control the variables that can affect a fire. A fire is self-sustained oxidation of a fuel that emits heat and light. A fire requires three variables to initiate: a fuel, oxygen, and heat.

COMBUSTION TRIANGLE

Fire prevention involves managing the variables of the fire triangle fuel, heat, and oxygen—to prevent

their interaction and the subsequent initiation of a fire. Once a fire starts, it requires four elements, known as the fire tetrahedron, to sustain combustion: fuel, oxygen, heat, and chemical chain reactions.

Fuel

Fuels are combustible solids, liquids, or gases that provide energy for combustion. Solids like wood and coal, and liquids such as gasoline and kerosene, must first be converted into gases to burn, while gaseous fuels like propane and acetylene can ignite directly. Some liquids produce vapours that can burn without heating, but many solids and liquids need to be heated to release enough gas for combustion. Safety managers should be aware of the various fuels in their workplace to effectively manage fire risks.

Oxygen

The atmosphere contains approximately 21% oxygen by volume. During combustion, the oxygen necessary for oxidation is sufficiently provided from the surrounding air. When the oxygen content of the atmosphere falls below 15%, a free-burning fire will begin to smoulder. When the oxygen content of the atmosphere falls below 8%, a smouldering fire will stop burning (Bryan, 1982). Oxygen can also be provided by other sources that release oxygen molecules during a chemical reaction. The safety manager should be aware of these oxidizers in the workplace and segregate them from any fuels.

Heat

Safety managers must monitor heat sources in the workplace, as they can ignite fires by providing the energy needed for combustion. Key ignition sources include open flames from welding, cigarettes, sparks from equipment, hot surfaces like motors, radiated heat from boilers, lightning, static discharges, arcing from electrical systems, compression from hydraulic oil, and exothermic chemical reactions.[2]

Classes of Fire

Fires are categorized into five classes based on the type of fuel involved, each requiring specific extinguishing methods.

Class A- fires involve ordinary combustibles like wood and paper, best extinguished with water or dry chemicals.

Class B- fires, fuelled by flammable liquids and gases such as gasoline, are effectively smothered using foam, carbon dioxide, or dry chemicals.

Class C- fires, which involve energized electrical equipment, require non-conductive agents like dry chemicals or inert gases; de-energizing the equipment first is ideal.

Class D -fires involve combustible metals such as magnesium and sodium, need specialized extinguishing agents designed for the specific metal.

Class K- fires, typically occurring in commercial kitchens due to cooking oils and fats, are managed with Class K fire extinguishers. [3]

Common Causes of Fire Hazards in Industries

Common causes of fire hazards in industries include electrical problems, smoking, human error, combustible dust, arson, heating equipment issues, mechanical friction, and flammable liquids and gases. Electrical fires often result from overloading circuits, damaged wiring, misuse of extension cords, and outdated systems. Smoking materials, if not properly disposed of or managed, can ignite nearby flammable materials. Human error, such as leaving cooking appliances unattended or improper storage of flammable materials, also contributes to fire risks. Combustible dust, prevalent in industries like food processing and metalworking, can cause fires if not properly controlled. Arson, or intentional fires set by individuals, can be mitigated through security measures and fire-resistant building materials. Heating equipment, including space heaters and central heating systems, poses risks if not maintained correctly. Mechanical friction from overheated machinery can lead to fires if proper maintenance is neglected. Lastly, flammable liquids and gases require careful storage and handling to prevent ignition.

Fire Extinguisher

Fire extinguishers are essential tools for controlling small fires in emergencies, but they are not suitable for large or uncontrolled fires. They come in two main types: stored-pressure and cartridge-operated. Stored-pressure extinguishers have the expellant and firefighting agent in the same chamber, while cartridge-operated models have a separate cartridge for the expellant. There are several types of extinguishing agents:

1. **Dry Chemical**: This powder-based agent, including monoammonium phosphate (ABC dry chemical) and sodium bicarbonate, interrupts the chemical reactions in the fire triangle. Monoammonium phosphate is effective on Class A, B, and C fires but is corrosive. Sodium bicarbonate is used for Class B and C fires, releasing carbon dioxide to smother the fire but is less effective for Class A fires.

2. **CO_2 Fire Extinguishers**: Identified by their black label, CO_2 extinguishers are ideal for electrical fires and flammable liquids because they do not conduct electricity and leave no residue. They are not effective as coolants and can worsen Class A or F fires.

3**. Wet Chemical Extinguishers**: With a yellow label, these extinguishers are designed for fires involving combustible cooking media like oil and fat, and

sometimes for Class A and B fires. They are effective at cooling and smothering fires, reducing the risk of re-ignition.

4. **Foam Fire Extinguishers**: Featuring a cream label, foam extinguishers are suitable for Class A and B fires and sometimes for electrical fires.[4][5]

Safety Inspection

This emphasizes needed for strict fire prevention and safety measures, which are being embraced by many countries around the world. The safest way to deal with fire is to prevent it. Fire inspection checklists, form an integral part of this compliance process.

Complete Checklist for Fire Inspection

A fire code violation would lead to serious penalties and fines including an arrest and prosecution. This makes it important to ensure that you dot all your I's and cross your T's on fire inspection compliances.
Checklist for Fire Safety:-

Fire Safety Equipment

1. Ensure the stipulated number of fire extinguishers is present (within 75 feet of any location).
2. Confirm extinguishers are the correct size, rating, and type for your business (at least 2A-10BC rating).
3. Verify that extinguishers, fire alarm panels, and fire sprinklers have been serviced and inspected within the last 12 months.
4. Check that extinguishers are wall-mounted according to fire safety recommendations.
5. Ensure no warning lights are displayed on the fire alarm panel.
6. Inspect for leakage, physical damage, or corrosion on all equipment

Fire Exit Routes

1. Verify the presence of at least two stipulated fire exits.
2. Ensure all exit doors are unlocked during occupancy.
3. Check that aisles leading to and from fire exits are unobstructed.
4. Confirm pathways to exit doors are wide enough.
5. Ensure fire exits are equipped with panic hardware.
6. Verify that all exit doors open easily in an emergency.
7. Provide easy access to fire protection devices, such as extinguishers and the fire alarm control panel.

Good Practices for Fire Safety

- Store all combustible materials in fireproof cabinets.
- Ensure occupancy levels do not exceed maximum limits.
- Avoid overloading electrical sockets and using improper multi-plug adapters.
- Keep electrical panels easily accessible with no obstructions.
- Store potentially flammable materials away from electrical panels.

Field service software

It will help to keep on top of fire safety requirements and pass fire inspections carefully and successfully.

Automation of fire inspection activities:

It can help to maintain a regular practice of fire safety and incorporate it into daily routine.

Maintenance of fire safety equipment by helping you keep tabs on fire safety equipment service schedules, so your equipment is serviced with updated service tags before inspections come around.

Eliminate paper heavy processes by using barcodes, RFID tags, and digital forms and checklists to achieve time and cost efficiencies.

Access to pre- defined electronic checklist with a complete reference to all fire safety guidelines and standards. The one click feature helps ensure all compliances are checked with a single click for each item.

Intelligent reporting through photo uploads and dynamic checklists, helping to provide periodic management summaries of inspections quickly and efficiently.

Fire safety education

This is the process of teaching and learning about fire safety principles and practices. Fire safety education can be delivered through various methods, such as lectures, demonstrations, videos, brochures, posters or websites. Fire safety education can cover various topics, such as fire preventions, fire protections, fire escape, fire extinguisher use, or fire emergency procedures. Fire safety education can also involve conducting fire drills or simulations to practice and evaluate the fire safety skills and knowledge of participants. A fire safety inspection involves examining the fire safety features and conditions of a building or facility and ensuring compliance with fire codes, regulations and standards.[5][6]

FIRE DETECTION DEVICES

1. Smoke detectors: optical, photoelectric, and ionic
2. Temperature detectors: thermal and thermovelocimetric
3. Flame detectors: infrared, ultraviolet and combined IR + UV

4. Linear infrared detectors
5. Gas detectors
6. Detector cable or temperature sensor for fires

Fire detection system

A fire detection system is designed to identify fires in their early stages and alert users to prevent them from spreading. It typically includes a central fire panel, auxiliary elements like power supplies, and field components such as alarm buttons, sirens, and detectors. Fire detection systems can be either conventional or analog. Conventional systems group multiple detectors together to trigger a general alarm without pinpointing the exact location of the fire. In contrast, analog systems offer advanced technology by precisely identifying the source of the alarm, providing specific information about the location of the fire.

Optical smoke detector

An optical smoke detector identifies smoke by drawing it into a chamber where light-emitting diodes (LEDs) illuminate the area. The light is reflected off the smoke and detected by a photodiode, which converts the reflected light into an electrical signal to determine the presence of smoke. These detectors are commonly used in environments prone to rapid smoke generation, like warehouses storing fabrics or wood.

Photoelectric smoke detectors

These detectors use light to detect smoke, but respond faster than optical detectors because the detection technology is simpler: no need for an LED or laser beam to scan the camera, as would be the case with an optical model. The speed with which these devices react makes them ideal for areas where protection against fires that are expected to grow rapidly is needed, such as kitchens.

Ionic smoke detectors

These devices are similar to photoelectric devices in that they respond quickly without relying on a complicated scanning mechanism; however, its sensors work by measuring ion levels in the surrounding air, not visible light as its counterpart technologies do. This means that ionic detectors tend to be more effective in fires where a large amount of smoke is not expected, being especially used in chemical environments.

Temperature detectors:

a) Thermal detectors

They are used to detect high temperatures, activating an alarm signal once the predefined temperature threshold has been exceeded in camera. These sensors can be platinum resistance thermometers (PRTs) or thermocouples, which detect temperature change in wire.

b) Thermovelocimetric detectors

The thermovelocimetric (TV) classes of fire detectors are a type of smoke detector that uses a thermistor to detect the temperature rise of a fire. A thermistor is a semiconductor whose electrical resistance varies with temperature. The thermistor is placed in a stream of air and connected to an electronic circuit, which measures changes in voltage as the temperature of the air increases. When smoke enters the air stream, it absorbs heat and lowers its temperature. This causes the changes in voltage measured by the thermovelocimeter detector circuit, which activates an alarm signal.

Flame detectors: infrared, ultraviolet and combined IR+UV

These models of flame detectors use infrared or ultraviolet light sensors to detect the characteristic spectrum of a flame. They are often combined with smoke detectors to create a more effective fire detection system.

a) IR Infrared Flame Detectors

It is a device that detects infrared radiations emitted by flames. Infrared flame detectors contain an emissive sensing element that converts infrared radiations into electrical output signals.

b) UV Ultraviolet Light Flame Detectors

It uses a combination of light sensors, filters, and photodetectors to detect the ultraviolet light emitted by flames. A beam of light is directed through the area monitored by the detector and if an object blocks the light in any way, it will cause a break in the beam and trigger an alarm.

Gas detectors

It is used to detect the presence of combustible gases. Gas detectors are used in industrial applications, but are also becoming more common in residential applications.

Gas detectors are designed to detect the presence of explosive and toxic gases.

Fire detector cable or temperature sensor

The cable of a fire detector or temperature sensor is made up of two parts: the primary and the secondary conductor. The primary conductor is usually copper, while the secondary is aluminium. It prevents fire or smoke from reaching the control panel, where it could damage it or cause it to shut down prematurely during a fire emergency. It measures the temperature by contact of a surface, a liquid or gas.[6][7]

PREVENTION STRATEGIES

A fire prevention strategy or fire risk assessment should include detailed and a full consideration of the

issues, including issues arising from the heat, oxygen and fuel.

❖ **Heat**

It can be generated by work processes and is an essential part such as cooking. This heat must be controlled and kept away from fuel unless carefully controlled.

❖ **Heat Safeguards**

- Ensure employees are aware of their responsibility to report dangers
- Control sources of ignition
- Have chimneys inspected and cleaned regularly
- Treat independent building uses, such as an office over a shop as separate purpose groups and therefore compartmentalise from each other
- Have regard to relevant Authority Safety Alerts, e.g. Mobile Phone "Expert XP-Ex-1", Filling LPG Cylinders

❖ **Smoking**

- Provide no-smoking signs at appropriate locations
- Ensure smoking area(s) are away from flammable materials
- Arrange for cigarettes and matches to be disposed of safely and away from other combustible rubbish.

❖ **Plant and Equipment**

- Ensure all work equipment protects against catching fire or overheating
- Ensure proper housekeeping, such as preventing ventilation points on machinery becoming clogged with dust or other materials - causing overheating
- Have electrical equipment serviced regularly by a competent person to prevent sparks and fires
- Use a planned maintenance programme to properly maintain plant and equipment. Review your programme if you already have one.
- electrical malfunction, frictional heat
- flammable materials used in contact with hot surfaces
- leaking valves or flanges which allow seepage of flammable liquids or gases.

❖ **Portable Heaters**

- Do not use portable heaters unnecessarily.
- They should have emergency tip-over switches, and thermostatic limiting controls.
- Turn them off if people leave the room or are going to sleep
- Ensure they are 1m away from anything that can burn [8]

❖ **Hot Work**

Hot work often arises from construction and/ or maintenance activities. Hot work is work that might generate sufficient heat, sparks or flame to cause a fire.

- Only allow hot work if no satisfactory alternative.
- Ensure relevant contractors are aware of hot work procedures and controls.
- Use a hot work permit system including.
- Remove or protect combustible or flammable materials.
- Prevent, suppress and control sparks, heat.
- Provision of and training on suitable fire-fighting equipment.
- Particular precautions for special risks, e.g. confined space.

❖ **Electrical safety**

- All electrical equipment and installations designed, constructed, installed, maintained, protected, and used to prevent danger
- Get a qualified electrical contractor to carry out installation and repairs to electrical equipment and fittings
- Maintain proper pest control to avoid rodent damage to electric wiring and equipment
- Check electrical equipment and remove defective equipment
- Ensure electrical cords are in good condition
- Use extension cords safety - not under carpets or across walking areas
- Use only one device per outlet [9]

❖ **Arson**

The possibility of arson should be considered as a component of your risk assessment and it is one that you can do much to control. The majority of deliberately started fires occur in areas with a known history of vandalism or fire-setting. Appropriate security measures, including the protection of stored materials and the efficient and prompt removal of rubbish, can therefore do much to alleviate this particular problem.

- Provide adequate security: exterior/interior lighting, intrusion alarms, guard service, well-secured access openings
- Prevent access by unauthorised personnel
- Keep flammables properly stored and secured.

❖ **Oxygen**

The main causes of fires and explosions when using oxygen are.

Oxygen Safety

- Avoid materials incompatible with oxygen.
- Operate oxygen equipment carefully and correctly.
- Seek guidance if unsure about oxygen safety.
- Prevent oxygen enrichment: ensure leak-tight, well-maintained equipment.
- Check for adequate ventilation.
- Handle oxygen cylinders and equipment with care.
- Open oxygen cylinder valves slowly.
- Use only approved replacement parts for oxygen service.

Fuel Safeguards

- Report dangers promptly.
- Follow LPG safety guidelines from the Authority.
- Use the Code of Practice for Avoiding Danger from Underground Services.
- Ensure furnishings and fittings meet fire safety codes.
- Conduct risk assessments for flammable gas/vapour presence.
- Install, maintain, and service gas detection equipment as needed.

Flammable materials

- Identify all flammable materials so that proper controls can be put in place
- Reduce quantities of flammable materials to the smallest amount necessary for running the business and keep away from escape routes
- Replace highly flammable materials with less flammable ones
- Train employees on safe storage, handling and use of flammable material [10-12]

Figure 1: Combustion triangle

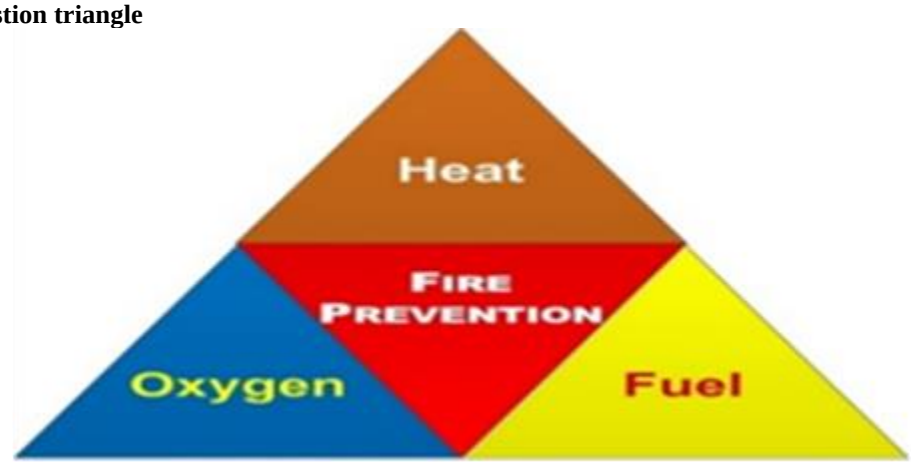


Figure 2: Showing classes of fire.

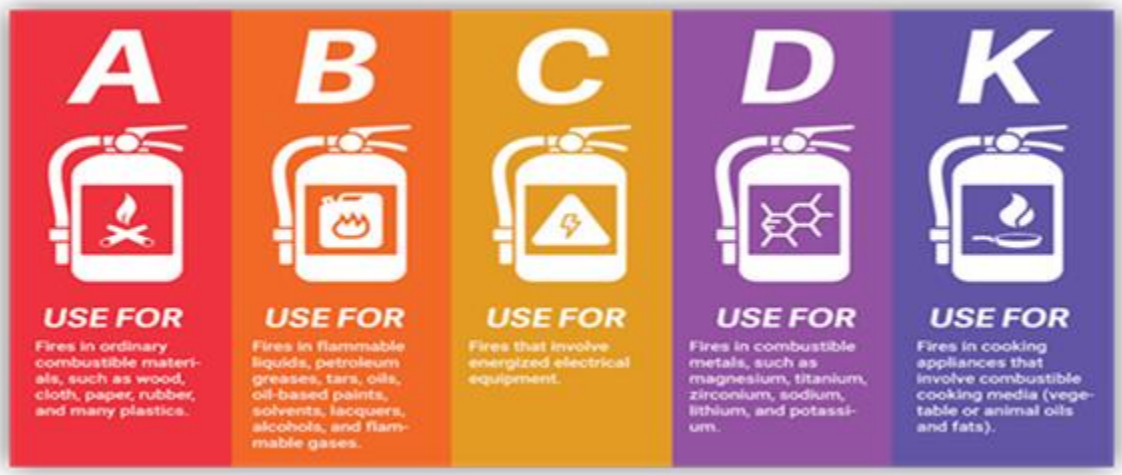
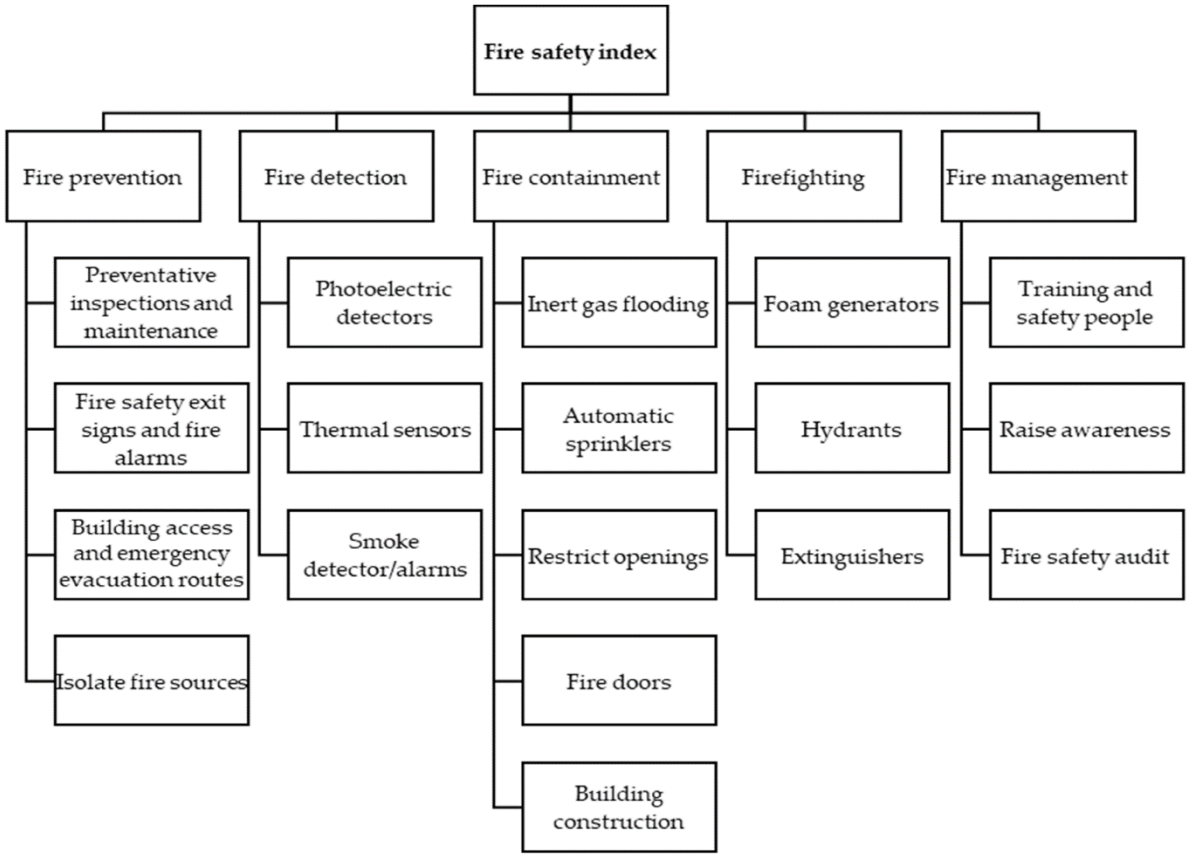


Figure 3: Fire detectors.

Figure 4: Flowchart of Fire Safety Index.



CONCLUSION

Effective fire risk assessment and management are crucial for safeguarding Indian industries against the devastating impacts of fires. By thoroughly understanding and addressing the components of the fire triangle—fuel, heat, and oxygen—and implementing a robust fire safety program, industries can significantly mitigate the risks associated with fire hazards. Comprehensive fire prevention strategies, including regular safety inspections, proper maintenance of fire safety equipment, and adherence to fire safety regulations, are essential in creating a safe working environment.

Education and training play a vital role in equipping employees with the knowledge to prevent, detect, and respond to fires. Employing advanced fire detection devices and systems further enhances the ability to identify and manage fires before they escalate.

Ultimately, a collaborative effort involving regular inspections, timely maintenance, effective training, and stringent adherence to safety protocols will foster a safer industrial environment, minimizing the risk of fire-related incidents and protecting lives, property, and business operations.

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