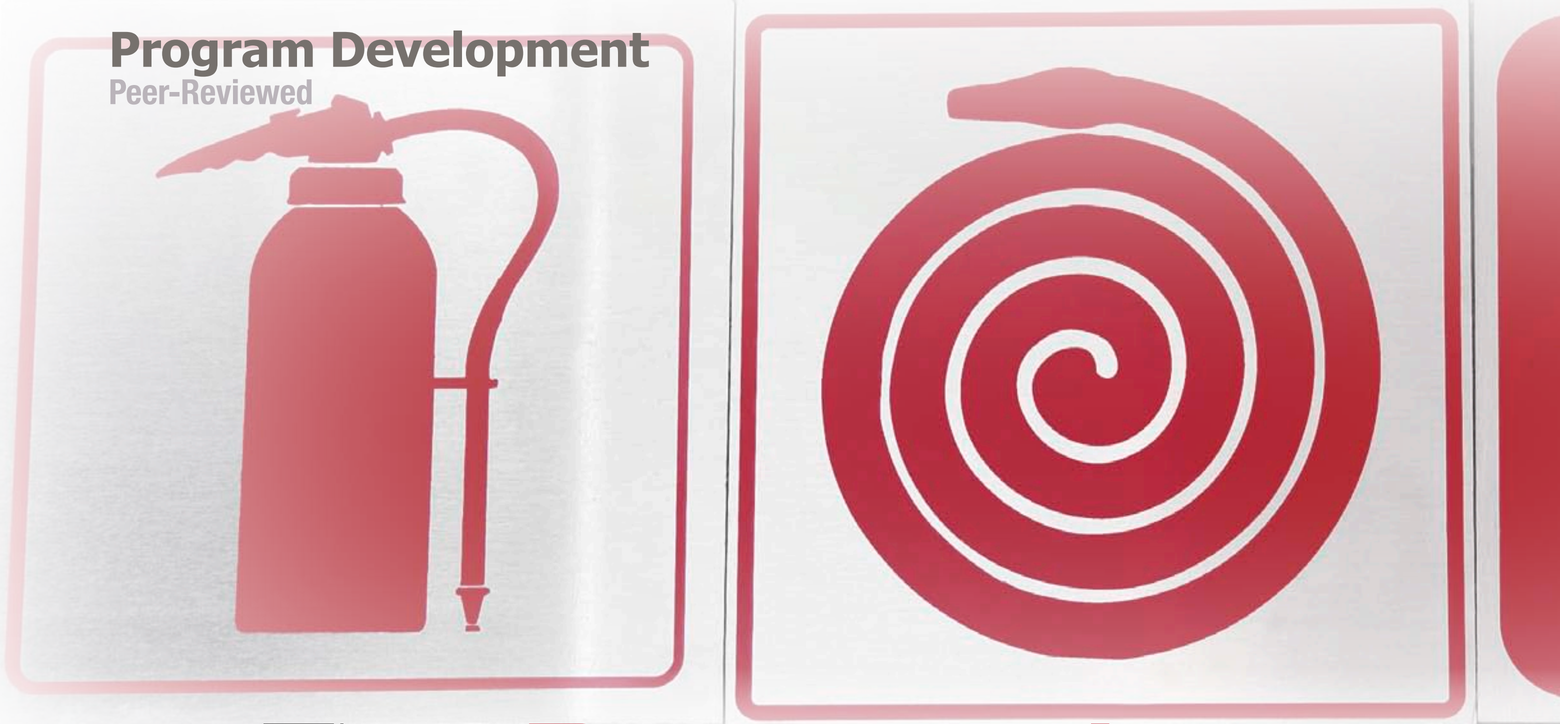

Fire Prevention

A Guide to Protecting Employees & Property

By Peggy E. Ross

IN BRIEF
- **A fire prevention and control program is designed to safeguard facility occupants; protect property and prevent operational loss; and manage incidents, support bottom-line profitability and control fire insurance premiums.**
- **Fire prevention plans should be written and risk-based, and must consider fire principles, life safety and fire prevention program elements.**

Fire prevention is important for nearly every workplace. Fires and smoke injure or even kill victims as well as cause substantial property damage. Suppression systems such as water from sprinklers and large quantities of water used by the fire department can significantly damage property.

In addition, company profitability can be directly affected by medical costs, operation downtime, clean up and rebuilding. Employees may not have a worksite to report to if fire damage is severe. Insurance premiums may increase following claim submission. If the company ceases to operate, the surrounding community may receive less tax income. The financial burden associated with job loss and fire response costs may further affect the community. For these reasons, operations must manage fire risk as part of their safety program.

Primarily, a fire prevention and control program is designed to protect facility occupants. It also helps protect property and prevent operational loss, helps personnel manage incidents, supports bottom-line profitability and helps control fire insurance premiums. This article reviews basic fire, life safety and fire prevention program principles that are critical to a sound fire prevention program.

Fire Principles

The goal of most programs is to prevent fires from occurring and control fires that do occur to reduce losses (Schroll, 2002). The first step is to gain an understanding of basic fire dynamics, terms and concepts. Next, a company should assess fire risk. A fire prevention risk assessment provides the foundation for a sound fire prevention program. Once a company identifies risks, it can implement key prevention elements to prevent fires and mitigate losses.

"Fire was originally believed to be based on the presence of three elements: fuel, air and heat" (Klinoff, 2007, p. 89). Clearly, a fire will not burn without fuel. For most substances, fuel must reach the ignition temperature for a fire to start (Schroll, 2008, p. 430). Klinoff (2007, p. 90) clarifies that air is actually an oxidizer and heat is caused by the release of energy. Sufficient oxygen (the oxidizer) must be present for a fire to burn.

Recent literature replaces the traditional triad with a tetrahedron—a 3-D pyramid that has four triangular faces (Figure 1, p. 65). The fourth face represents "the chemical or uninhibited chain reaction, resulting in the production of free radicals" (Schroll, 2008, p. 430). Free radicals are unstable atoms that are active and recombine with the oxidizer to form more heat. This chain reaction causes the fuel to break down further, and the process repeats as long as fuel, oxidizer and energy are present (Klinoff, 2007, p. 90).

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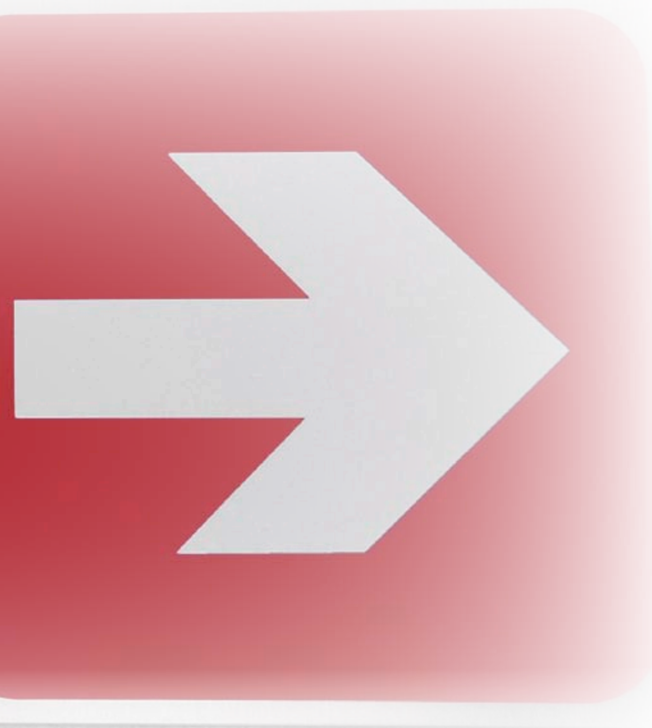

An uninhibited chain reaction differs from the chemical reaction in that the exothermic heat reaction generates so much heat that it actually ignites vapors even when the original ignition source is no longer present (Schroll, 2008, p. 430). The heat release associated with uninhibited chain reactions has obvious implications for fire spread. In addition to heat and flames, fire produces "the smoke particulate and the toxic and corrosive gases that form the products of combustion" (NFPA, 1997). These toxic gases and smoke can cause suffocation and death.

Combustibles, Flammables

Combustible materials, by definition, are capable of catching fire. A flammable substance may be "easily ignited, burns intensely or has a rapid rate of flame spread" (NSC, 1997, p. 780). Combustibles and/or flammables may be solids, gases, liquids or some combination of the three. Gasoline- or solvent-soaked rags are examples of flammables or combustibles that are both solid and liquid.

Some substances are so flammable that they need no ignition source to catch fire. These substances are known as *pyrophoric*. Materials such as alkali metals (Na, K), white phosphorus and metal powders (e.g., magnesium) are examples of pyrophoric solids. Silane is a pyrophoric gas that ignites spontaneously when exposed to air (Plog & Quinlan, 2002, p. 154).

The source of the fire also may be a liquid. Flammable and combustible liquids give off vapors. Fire burns vapor, not liquid (Wallace, 2007, p. 5). The tendency for a liquid to evaporate is often referred to as *volatility*. "Liquids [such as] alcohol and gasoline, because of their well-known tendency to evaporate readily, are called volatile liquids" (Plog & Quinlan, 2002, p. 1048). Due to the volatility of gasoline, after a gasoline tank is emptied, vapors remain. When a worker conducts welding activity on an empty tank, a spark may ignite the vapors and cause an explosion if the concentration of vapors is in the flammable range (Wallace, p. 5).

Flammable Range

The vapor concentration in air must be in the flammable range for ignition to occur (Plog & Quinlan, 2002, p. 157). If the concentration is below the lower flammable limit (also referred to as the lower explosive limit, or "too lean to burn"), a fire will not ignite even if an ignition source is present (Klinoff, 2007, p. 99).

On the other hand, the concentration of vapors may fill the space completely, leaving insufficient oxygen for the mixture to burn. This is the upper flammable limit (also known as the upper explosive limit). In this case, the mixture is "too rich to burn" and "it is not possible to ignite the vapors" (Klinoff, 2007, p. 99). This can cause a serious problem.

For example, a natural gas leak could occur in a vacation home that is closed for the season. When the owner arrives to open the house, s/he opens the door and fresh air (containing oxygen) rushes into the room. The mixture (previously too rich to burn) may drop into the flammable range. While the person may smell the vapors, s/he may not recognize the hazard and, as a result, a serious reaction could occur when s/he turns on the light switch. The spark may be sufficient to cause ignition and an explosion.

For this reason, fire response personnel must understand the general concepts of flammable and combustible materials. Flammable/combustible gas meters are used to detect flammable atmospheres (atmospheres within the flammable range). These detectors sense the presence of flammable vapors before the level reaches the flammable range that would support a fire. Equipment is set with a safety margin so the warning alarm sounds at 10% of the flammable range.

For a spill that has just occurred, this signals a warning to personnel that vapors are building toward the flammable range. Action should be taken to evacuate, shut down processes, eliminate ignition sources and ventilate (if safe to do so). Personnel should use combustible gas detectors in accordance with manufacturer's instructions. They are calibrated for specific gases. Cross readings are possible and when a mixture is present, the most they can tell the user is that a flammable atmosphere exists.

Temperature Considerations for Liquids

Another important consideration is how temperature affects a liquid. For example, the autoignition temperature of a liquid reflects "the lowest temperature at which a liquid will ignite without an external ignition source" (Wallace, 2007, p. 1). In other words, "the flash point of a liquid is the lowest temperature at which it gives off enough vapor to form an ignitable mixture with the air near the surface of a liquid or in a vessel capable of flame propagation away from the source of the ignition" (Plog & Quinlan, 2002, p. 154). Flammable and combustible liquids are, therefore, classified by their flash points. A combustible liquid has a flash point at or above 100 °F.

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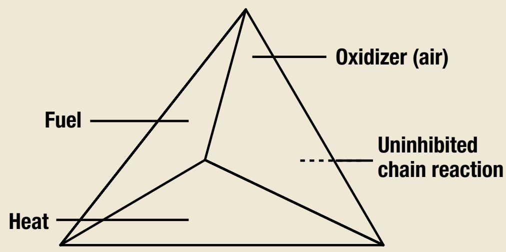
Figure 1
Tetrahedron



Combustible liquids are further classified into Class II, IIIA and IIIB. Class II liquids have a flash point of 100 °F but less than 140 °F. Examples include diesel fuel, kerosene, motor oil and fuel oil. Class IIIA liquids have flash points of 140 °F or greater but less than 200 °F. Examples include mineral oil and oil-based paints. Class III combustibles have flashpoints at 200 °F or above. Examples include ethylene glycol and glycerine (Wallace, 2007, p. 2).

Flammable liquids are more likely to burn because they ignite at lower temperatures. In other words, the lower the liquid's flash point, the more flammable it is. Flammable liquids are classified as Class IA, IB and IC.

•Class IA has a flash point of less than 73 °F and a boiling point below 100 °F. Examples include vinyl chloride, heptane, pentane and ethyl ether.

•Class IB has a flash point of less than 73 °F and a boiling point of 100 °F or above. Examples include acetone, ethanol, gasoline, isopropyl alcohol, methanol, methyl ethyl ketone and toluene.

•Class IC liquids have flash points of 73 °F or above but less than 100 °F. Examples include isobutyl alcohol, mineral spirits, xylene and turpentine (Wallace, 2007, p. 2).

It also is important to note that not all fires are visible. For example, burning hydrogen is not visible to the naked eye. Firefighters may approach a compressed tank of hydrogen with the straw end of a broom first to identify the flame and reduce risk of injury.

Fire Classification

Fires are classified by the type of fuel involved (Table 1). This classification helps identify appropriate fire extinguishing methods. Each fire class is represented by specific fire symbols. Klinoff (2007, p. 106) provides a copy of these symbols.

Life Safety Principles for the Workplace

Fire prevention should support life safety and is necessary in all industries and environments such as shipping, warehouse, offices, manufacturing and retail. Ideally, fire prevention and protection would begin with a building's design, construction and maintenance. "How a building is constructed will determine how long it can endure exposure to a fire" (Baker, 2008b, p. 37).

NFPA classifies construction materials as Type I, II, III, IV and V, with Type I offering the greatest fire resistance. Letters and numbers following the type designation identify the material with which a building is constructed and the hourly rating of its main structural members (beams, trusses, floors, roofs, columns and exterior/interior weight-bearing walls). Companies can use model building codes and NFPA 220, Standards for Types of Construction, to determine the type of construction used in a building.

Companies should consult NFPA 101, Life Safety Code, and model building codes to determine how close buildings of certain types can be to the property line and/or other buildings. Selection of construction materials should be appropriate to the business operation. Sprinkler systems and fire detection systems are complex, so companies should consult subject-matter experts to determine appropriate selection, piping and wiring requirements.

In addition, companies should consider what chemicals (e.g., flammables, combustibles) will be stored in the building, the quantities to be stored, building height and occupancy. For high-hazard-class areas or tall buildings, firefighting systems may be incorporated into the original building design (e.g., booster pumps). Water-supply fittings (for extinguishing fires) must be compatible with local fire department equipment. Standpipe and hose systems must be conspicuously identified; properly equipped with lined hose; have fittings compatible with the local fire department; be readily accessible and easy to use; and be protected against mechanical damage (NFPA, 2007b).

Because various regulations may apply, those involved must conduct research to determine construction requirements. The International Code Council is an excellent place to find construction

Table 1
Classification of Fires

Fire class	Fuel sources
Class A	Ordinary combustibles: paper, wood, natural fibers, cloth, rubber, plastics
Class B	Flammable or combustible liquids: oils, greases, oil-based paints, lacquers, tar
Class C	Energized electrical equipment (power must be present either in stored energy or because the power is on)
Class D	Combustible metals: magnesium, titanium, sodium, potassium
Class K	Kitchen/cooking fires: cooking grease, oils (animal/vegetable) or fats. Class K was added when special kitchen fire extinguishers were introduced.

code standards. Local fire codes, community building codes, OSHA regulations and NFPA requirements also should be reviewed. Determining the building, regulatory and fire code requirements for the business's hazard class and occupancy class before selecting a final building design prevents future problems.

For example, if a flammable storage area is planned inside the building, a company must determine specific construction requirements and storage quantities allowed inside the building (according to chemical class and building design). In addition, facility design should consider other life safety elements such as egress and fire suppression. Life safety elements apply to existing as well as new construction.

Egress

Safe egress from a building is essential to life safety during a fire. In the U.S., OSHA 1926.34(a) mandates that "in every building or structure exits shall be so arranged and maintained as to provide free and unobstructed egress from all parts of the building or structure at all times when it is occupied" (OSHA, 1993b). Similar legislation exists in many countries. Based on the building's occupancy, an adequate number of exits are required. Fire department personnel or other fire prevention experts often provide consultation on exit door placement.

To clarify what is required for safe egress, the term *egress* is commonly broken down into three elements: 1) the pathway leading to the exit (exit access); 2) the exit; and 3) the exit discharge. The pathway to an exit must be clear. Evacuation routes are used to direct individuals to the nearest exit in an emergency. Evacuation routes may be horizontal, vertical (e.g., stairwells) or both.

Consideration also must be given to how to provide for safe egress of disabled individuals. Also, assess how to evacuate people from more difficult locations such as interior rooms, corridors, balconies, elevators and other unique areas (Haight, 2008, p. 410). Elevators should not be used during a fire.

Emergency exits must be clearly marked by a readily visible (illuminated) sign (OSHA, 1993b). Exit doors must be carefully selected; be of adequate width; unlocked from the inside; and must open outward. Interior door swing requirements vary with the type of facility, occupancy and hazards. Facilities must have an adequate number of fire exits that lead employees to exit doors which are not locked on the inside, have panic-exit hardware where required and open outward in the direction of exit flow.

Fire doors always must be shut completely to be effective. Emergency lighting also must guide occupants to the exits (battery backup lighting is required). Emergency exit route maps should be posted where building occupants can readily see them. Designating a spot labeled "you are here" and orienting the maps for the reader (rather than north-to-south) can facilitate rapid identification of the nearest exit location. Once occupants pass through the exit and reach the outside, a clear pathway must lead them to a safe location upwind from the fire.

Alarms & Notification Systems

A system must be established to signal an evacuation, if necessary. Automatic or manual fire alarm notification systems notify the fire department directly in the event of a fire emergency at the facility. Audible fire alarms, word-of-mouth or paging systems may signal to occupants that an evacuation is immediately necessary. "Automatic alarm systems provide the most rapid notification, allowing maximum escape time" (Schroll, 2002, p. 54).

Automatic fire detection systems identify smoke, heat or flame, and activate alarms and/or sprinkler systems. Fire detectors should be installed in locations in accordance with NFPA 72 (NFPA, 2007c). Manual alarms increase response time since fire or smoke must be discovered and the alarm must be manually activated (e.g., the individual pulls the alarm or the fire department must be contacted via telephone). Manual alarms also require a decision. "If the person who discovers the emergency does not think of the alarm or decides that the emergency is not significant enough to activate the alarm, another delay occurs" (Schroll, 2002, p. 55).

Alarms provide an excellent audible signal of the need to evacuate. Paging systems often are used to notify occupants of the evacuation and location of the fire so individuals do not evacuate in an unsafe direction. For example, hospitals often page using a code and location system (e.g., code red, cafeteria north). Appropriately informed by the page, hospital personnel are trained not to evacuate patients in the direction of the fire. Paging systems also may indicate whether the evacuation is a drill.

Strobe lights may be used to supplement audible alarms by attracting attention. Strobes are useful in noisy areas and for the hearing impaired. For example, Baxter International headquarters in Deerfield, IL, uses strobes to notify evacuees on stairwells whether it is safe to exit via the normal route or to proceed to an alternate prescribed route.

Fire Suppression Principles

How a fire will be extinguished should be planned before a fire starts. It is important to determine whether adequate resources exist to minimize injury and protect property. A key part of a fire prevention risk assessment is to determine the capabilities of local fire department resources. A few questions to consider:

1) Is adequate water available?

2) How is the water supplied (via hydrants, tankers or reservoirs)?

3) What water resources are currently on site?

4) Are the firefighters volunteer or salaried employees?

5) What is the expected response time?

6) What is the insurance carrier fire rating for the property?

7) Does the fire detection system connect directly to the fire department?

Ideally, fire prevention and protection would begin with a building's design, construction and maintenance.

Establishing open communication with the fire department promotes a strong working relationship. Marking the location of fire suppression devices, extinguishers, equipment, fire water-line connections and power shut-off on facility drawings can be useful to a fire department during response. These drawings must be easily accessible when an emergency event occurs. Facilities may provide a copy of facility drawings and chemical inventories (with storage locations clearly documented) to the local fire department or store a copy with security at the facility's entrance.

Sprinklers are another important component of fire suppression. "If building protection systems such as automatic sprinklers or standpipes and hose stations (for fire department use) are in place, their support and use can be critical to effective control and extinguishment of a fire" (Baker, 2008b, p. 37). Since "about 96% of all fires are controlled or extinguished by an automatic sprinkler system if the building is properly equipped" (Baker, p. 37), consider whether sprinklers should be installed if not already in place. As part of the fire risk assessment and to help determine where sprinklers are needed, determine whether combustibles or flammables are stored in the facility.

Companies should follow general rules when initially planning sprinkler system installation. Sprinkler systems must have the necessary discharge patterns, densities and water flow characteristics for complete coverage of the area serviced. If more than 20 sprinklers are required for an area, an alternate water source is required. Sprinkler systems should be equipped with water flow alarms. Dry systems do not contain water and should be installed so the system can be totally drained. Wet pipe systems react more quickly but are not appropriate in areas with a potential for freezing. Care must be taken to protect sprinkler piping and sprinklers against freezing, corrosion and mechanical damage.

To determine sprinkler requirements, various sources may be consulted. NFPA 13 governs spacing, location and position of sprinklers. NFPA 30 deals with flammable storage warehouses and processing facilities. These resources, along with fire department resources and/or subject-matter experts, should be consulted to determine appropriate piping, sprinkler type, placement, coverage, water-flow and preferred activation modality (NFPA, 2007a).

Fire Extinguishers

Fire extinguishers should be selected based on the hazard class identified in a fire risk assessment. Class A extinguishers contain plain water and are intended for class A fires such as paper and should never be used on class B or class C fires. Class BC fire extinguishers contain sodium bicarbonate or potassium bicarbonate and are intended for class B or C fires. Since the extinguishing agent is mildly corrosive, prompt cleanup is recommended (Fire Extinguisher 101).

Multipurpose ABC extinguishers often are selected since they are appropriate for use on class A, B and/or C fires. These are generally powder extinguishers that leave considerable residue. For this reason, CO_2 extinguishers may be selected for class B and/or class C fires as a way to smother fires in areas such as computer rooms, fur storage areas and computer installations (Klinoff, 2007, p. 372). Halogenated extinguishers (formerly used for computer areas) may still be found in facilities, but agents such as Halon are being phased out due to environmental concerns. For areas where metal fires may be expected, class D extinguishers and/or sand may be selected.

Extinguishers come in different sizes. It is important to select one that is large enough to handle anticipated emergencies but not too heavy to use. OSHA (2002) does not permit chlorobromomethane and carbon tetrachloride extinguishers [1910.157(c)(3)]. Obsolete extinguishers, such as carbon tetrachloride and/or soda ash, should be removed from service (Klinoff, 2007, p. 385).

Extinguisher placement and number must be carefully determined. This determination may be made based on guidance from the fire department or a fire specialist. "Extinguishers must be placed to provide effective fire protection and to meet code requirements" (Schroll, 2002, p. 162). The maximum travel distance to any extinguisher is generally 75 ft. For areas where flammables are used or stored, travel distance is reduced to 50 ft (OSHA, 2002).

Extinguishers must be accessible, visible and secured to a wall or cabinet. "According to NFPA 310 and OSHA regulations, extinguishers weighing 40 lb (18 kilos) or less should be mounted with the top of the extinguisher no more than 5 ft from the floor" (Schroll, 2002, p. 165). A 4-in. clearance from the floor also is required. Placing a fire extinguisher outside the door of a flammable storage area affords prompt access. Signs also promote rapid identification of the nearest fire extinguisher.

The number of extinguishers required for a facility "is dependent on the construction and occupancy hazards" (Haight, 2008, p. 551). The hazard classification (based on occupancy hazards), travel distance and square footage of the area will determine the number of extinguishers required. Schroll (2002) includes a helpful travel distance and coverage chart (p. 163). NFPA 10, Standard for Portable Fire Extinguishers, should be consulted for more detailed information regarding selection and placement. If sand is used as a method of extinguishing fires (e.g., metal fires), placement must be in a location and manner which ensures that the sand remains dry.

Fire Prevention: Risk Assessment

The foundation of a solid fire prevention program is the fire risk assessment. This process begins with the identification of fire hazards in the facility. Once identified, risk (the likelihood and potential severity of injury) is assessed using a quantitative or qualitative approach. If a hazard is not identified, the fire prevention program will not have elements needed to prevent fire associated with that specific risk.

For example, if hot work is performed, it is important to know where the activity is performed.

If hot work is performed outside the maintenance shop, the mechanisms for fire prevention must be clearly defined. This should already be in place in the facility's hot work program.

Fire prevention, like other SH&E areas, should be risk-based with more time and resources directed at high-risk issues. A checklist may be used to identify specific fire hazards. Examples include:

- flammable chemical storage;
- locations where flammable chemicals are used or handled;
- ignition sources in areas where flammables are used, stored or handled;
- location and presence of fired and unfired pressure vessels;
- combustibles (e.g., sawdust);
- electrical equipment.

A chemical inventory may be used to identify where flammable chemicals are used or stored. Liquids, gases and solids also should be evaluated. Determine whether a mechanism is in place to ensure that chemical compatibility is considered when using and storing chemicals. Locate sources of ignition and the proximity to flammable chemical storage and usage. Determine practices for dispensing. Flammable containers that hold 5 gallons or less (safety cans) should be approved by a recognized testing organization (e.g., UL, FM Global); be labeled and leak-proof; automatically vent excessive pressures to avoid container rupture and close automatically; and prevent external flames from coming in contact with liquid contents (Schroll, 2008, p. 489). OSHA 29 CFR 1010.106(a)(29) contains safety can requirements.

Management also should assess the need for flammable cabinets or storage areas. Regulations provide for specific allowances for quantities of flammable/combustible liquids stored in these cabinets, the number of cabinets allowed in any area (hazard class dependent) and grounding (NFPA, 2006). Flammable cabinet construction requirements also are defined by NFPA 30.

In addition, the risk assessment should identify operations or jobs that present a fire risk. Examples include using powered industrial trucks fueled by propane, hot work, welding and cutting. If these activities occur in confined spaces, determine whether the potential exists for flammable atmosphere (ensure that preplanning, permits, an attendant, effective communication, method for rescue and gas monitors are part of the program). If the facility houses compressed gas tanks containing flammable gases, identify low-lying areas where leaked gas could migrate.

Complete a risk assessment for equipment such as furnaces, boilers and crucibles. If smoking is permitted in the facility, ensure that smoking is prohibited near flame sources or potential flammable atmospheres. Identify whether intrinsically safe tools or equipment are required and/or in place. In addition, consider the building's construction and whether risks exist such as overhead heaters located near stacked cardboard boxes (e.g., pallets stored on racking). It also is important to identify potential fire risk from neighboring facilities and any necessary controls. Fire inspection checklists can be used to ensure that significant fire risks are considered.

Finally, determine what controls are already in place and those that should be added. Determine whether sprinklers, fire alarms or other equipment and programs in place adequately mitigate risk. Also, evaluate maintenance records associated with controls to determine whether failure is unlikely, possible or probable.

As part of the risk assessment, management must determine the most appropriate firefighting plan for the facility. If an evacuation-only approach is selected, where everyone evacuates and no one fights fire, no emergency action plan is required (Schroll, 2002, p. 194). However, if the facility decides to train employees to fight incipient-stage fires (referred to as an emergency team) or to train a full fire brigade, OSHA requires specific organizational statements, structure and training (Schroll, 2002). [Refer to Schroll (2002; 2008) and OSHA regulations for specific fire brigade training information.]

Fire Prevention Program: Development & Implementation

A written fire prevention program is an essential element of an effective program. Writing a program

Resources

BOCA Building Officials and Code Administrators—produce model codes for adoption for various U.S. jurisdictions

ICBO International Conference of Building Officials—develop model building codes for adoption

IFCI International Fire Code Institute—provides training and certification; life/safety inspections; targets fire department, architects and building design engineers

NFPA 10 Standards for Portable Fire Extinguishers

NFPA 13 Installation of Sprinkler Systems

NFPA 25 Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems

NFPA 30 Flammable and Combustible Liquids Code

NFPA 51B Standards for Fire Protection During Welding, Cutting and Other Hot Work

NFPA 70 National Electric Code

NFPA 72 National Fire Alarm Code

NFPA 101 Life Safety Code

NFSA National Fire Sprinkler Association

OSHA Code of Federal Regulations

SBCCI Southern Building Code Congress—creators of Southern Building Code

Note: *Adapted from* Introduction to Fire Protection (3rd ed.) *(chapter 5), by R.W. Klinoff, 2007, Clifton Park, NY: Delmar Learning.*

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clearly defines its purpose, scope, responsibilities and essential elements. The program should reflect how the facility plans to address fire risks identified in the facility fire risk assessment.

Written programs often include checklists and reference documents that support specific programs (e.g., hot work, electrical safety, flammable storage and handling) and facilitate inspections to ensure that defined elements are in place. The frequency of fire inspections should be clearly defined and/or included as part of other routine safety inspections. Fire prevention programs should be revisited when new equipment is added or when operations change to ensure that fire risks in those areas are adequately addressed.

As noted, a fire safety program is designed to prevent fires, protect employees and prevent property loss. To accomplish this, facilities should be equipped with adequate fire protection systems and equipment.

A written, site-specific plan describes essential program elements. The program's scope should define the physical location (facility) and delineate responsibility for each program component. Program elements that may need to be addressed include life safety, fire prevention, emergency response/evacuation, fire protection equipment maintenance and inspection, compressed gas cylinders, handling storage and dispensing of flammable chemicals, hot work, training (e.g., evacuation drills) and business continuity.

Life Safety

The first consideration in a fire emergency is life safety. Fire emergencies must be promptly identified to ensure safe evacuation. If occupants must evacuate, a system must be in place to notify them that an evacuation is immediately required.

The fire prevention program should clearly define evacuation procedures. Evacuation locations should be determined before an evacuation occurs. Employees must know where they should report. Evacuation routes/sites should present no additional hazards. If the primary evacuation site is downwind, an alternate upwind site should be selected. Employees should be trained to exit via the nearest exit and not to deviate from the route to retrieve personal items. No one should be allowed to reenter the building.

A system/method should be in place to account for the exit of all building occupants. Companies should conduct annual drills to ensure that the evacuation process and equipment work properly. Observers also should critique evacuation drills and provide insights to improve evacuation procedures.

Maintenance & Inspection

Routine maintenance ensures that fire protection equipment functions properly when needed. Qualified vendors routinely perform annual testing service. Monthly visual inspections should include emergency lighting, exit signs, exit clearance, sprinklers and fire extinguishers.

Standpipe/Sprinkler Systems, Detectors & Alarm Inspections

Water-supply valves should be inspected to ensure that they are locked in the open position. Annual inspection and testing should be scheduled for fixed fire extinguishing systems, alarms, standpipes and sprinklers in accordance with NFPA 25, Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems. A main drain flow test is required annually (Onyx, 2008. p. 567). Hoses must be hydrostatically tested "5 to 8 years after installation and every 2 years thereafter" (Onyx, p. 569). Sprinkler systems should have the inspector test valve opened every 2 years to ensure proper operation. Sprinklers should be assessed periodically to ensure that a vertical distance of at least 18 in. is maintained between sprinkler heads and other objects, such as stored materials, as to ensure adequate water dispersion. Fire and smoke detectors should be checked monthly, have batteries replaced at least annually and be replaced in accordance with manufacturer's instructions.

Manual fire alarms should be tested every other month. For automatic alarms, the "fire-alarm contractor should check the panel" (Onyx, p. 569). Haight (2008) provides a detailed description of fire inspection requirements. Emergency exits should be inspected monthly to verify that exit signs are illuminated, exits are clear and unlocked, and can be readily opened from the inside. Recommendations for maintenance, repair or replacement of equipment should be completed promptly and documented.

Extinguisher Inspections

All fire extinguishers should be serviced annually by a fire-extinguisher service contractor (Onyx, 2008, p. 567). Since time intervals for discharge and hydrostatic testing vary by type, NFPA 10 should be consulted for specific requirements. Monthly visual inspection of fire extinguishers ensures placement and confirms that they are fully charged as required [OSHA 29 CFR 1910.157(e)(2)]. Weight and pressure of extinguishers should be checked every 6 months. Containers with 5% loss should be refilled or replaced (in accordance with manufacturer's instructions). Tags should clearly indicate when inspections are completed.

Fire Inspections: Other

Routine inspections also should include heat-producing equipment. Since the principle hazard of closed container storage of flammable liquids is container fire, safety cans should be inspected to ensure that proper cans with tight-fitting caps or valves that close by springs and that flash arrestors are in place are used. Inspectors also should be familiar with a facility's hot work program and flammable chemical handling and storage procedures.

Facility inspections should include spot-checks to ensure that proper hot work (e.g., permits, barriers) and flammable storage and handling procedures are being followed. Flammable cabinets should be opened and contents evaluated for compatibility. Flammable cabinets should be inspected to ensure that they are grounded. Workers should be observed and/or interviewed to verify that they are following proper procedures. Ask questions to determine whether workers know how to store or transfer flammable liquids, and why bonding and grounding are necessary during transfer.

Training

Training is an essential part of fire prevention. A training plan should be developed. All employees must be trained how to initiate a fire response and/or evacuation. They also must be trained on emergency-escape procedures (e.g., not to use an elevator, to use the nearest exit) and emergency route assignments (OSHA, 1993a).

Workers must know to whom they should report to ensure safe evacuation of all occupants. If employees must remain behind to shut down critical processes, they must be trained in those procedures (OSHA 29 CFR 1926.35). Employees expected to respond to incipient-stage fires also must be trained. Participation in annual evacuation drills should be mandatory. If a fire brigade is established, specific annual training requirements must be completed.

Employees who use flammable chemicals must also receive training on hazards of the chemical, proper procedures for transfer (including grounding and bonding), handling, storage and chemical compatibility. Annual hot work training also is required for authorized employeess. Finally, employees who use compressed gases, equipment that may generate sparks or equipment that has an ignition source should be trained to ensure that proper usage and storage procedures (based on the risk assessment) are followed.

Business Continuity

The fire prevention program should be integrated with the facility's emergency action plan. Emergency action plans generally cover many types of emergencies and integrate with the business continuity plan. Upper management should make decisions in advance regarding notification procedures (e.g., who needs to be notified at what level of the organization). Developing a chart that details the notification requirements categorized by the level of emergency (with up-to-date telephone numbers and call lists) may be useful.

Conclusion

Advance planning prevents fires and reduces property loss and injuries. Appropriate building construction and fire-suppression equipment should be selected to support an operation's fire protection. Fire prevention plans should be written and risk-based, and must consider fire principles, life safety and fire prevention program elements. The fire risk assessment defines the elements of a facility's fire prevention program. Through the development of an effective written program, training, maintenance and inspections, fire risk may be reduced. A strong fire prevention strategy also controls incidents more effectively and supports bottom-line profitability. **PS**

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