

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Introduction

Welcome to Module 2.0 of the Fire Protection for Fuel Cycle Facilities Directed Self-Study Course! This is the second of four modules in this self-study course. The purpose of this module is to identify fire protection features and systems used in fuel cycle facilities and review them for adequacy. This self-study module is designed to assist you in accomplishing the learning objectives listed at the beginning of the module. There are eleven learning objectives in this module. The module has self-check questions and activities to help you assess your understanding of the concepts presented in the module.

### Before You Begin

It is recommended that you have access to the following materials:

- ❑ Trainee Guide
- ❑ NFPA 72, "National Fire Alarm Code"
- ❑ NRC Information Notice 99-07, "Failed Fire Protection Deluge Valves and Potential Testing Deficiencies in Pre-action Sprinkler Systems"
- ❑ NFPA Fire Protection Handbook, Section 6, "Care and Maintenance of Water-based Extinguishing Systems"
- ❑ NFPA 14, "Standard for the Installation of Standpipe and Hose Systems"
- ❑ NFPA 69, "Explosion Prevention Systems"
- ❑ NFPA 780, "Lightning Protection Code"
- ❑ NFPA 70, "National Electrical Code"
- ❑ NFPA 70B, "Electrical Equipment Maintenance"
- ❑ NFPA 70E, "Electrical Safety Requirements"
- ❑ NFPA 79, "Industrial Machinery"
- ❑ NFPA 75, "Electronic Computer/Data Processing Equipment"
- ❑ NFPA 101, "Code for Safety to Life from Fire in Buildings and Structures"
- ❑ NFPA 90A, "Installation of Air Conditioning and Ventilating Systems"
- ❑ Underwriters Laboratories Standard UL-586, also designated ANSI B 132.1, "High Efficiency Air Filtration Units"
- ❑ NFPA 54 (ANSI Z223), "National Fuel Gas Code"
- ❑ NFPA 31, "Oil-Burning Equipment"
- ❑ NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems"

- NFPA 91, “Exhaust Systems for Air Conveying of Materials”
- NFPA 96, “Installation of Equipment for the Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment”
- NFPA 801, “Recommended Fire Protection Practice for Facilities Handling Radioactive Materials”
- NRC Regulatory Guide 3.12, "General Design for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants," July 2008

Complete the following prerequisites:

- Module 1.0    NRC Guidance on Fire Protection for Fuel Cycle Facilities

### **How to Complete this Module**

1. Review the learning objectives.
2. Read each section within the module in sequential order.
3. Complete the self-check questions and activities within this module.
4. Check off the tracking form as you complete each activity within the module.
5. Contact your administrator as prompted for a progress review meeting.
6. Contact your administrator as prompted for any additional materials and/or specific assignments.
7. Complete all assignments related to this module. If no other materials or assignments are given to you by your administrator, you have completed this module.
8. Ensure that you and your administrator have dated and initialed your progress on your tracking form.
9. Go to the next assigned module.

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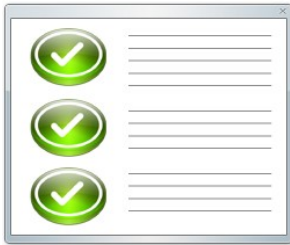
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### LEARNING OBJECTIVES

- 2.1 Upon completion of this module, you will be able to identify fire protection features and systems used in fuel cycle facilities and review them for adequacy. You will be able to:
  - 2.1.1 Identify common fire protection devices and systems features found at fuel cycle facilities.
  - 2.1.2 Describe the key components and requirements of fire alarm systems.
  - 2.1.3 Identify basic types of automatic sprinkler systems.
  - 2.1.4 Discuss considerations for the use and inspection of automatic sprinkler systems.
  - 2.1.5 Determine the appropriate type of portable extinguisher for a specified fire.
  - 2.1.6 Identify potential fire concerns related to machining operations.
  - 2.1.7 Determine the acceptable storage and usage methods for a flammable liquid or gas.
  - 2.1.8 Identify safety equipment and applications related to ovens, boilers, and furnaces by classification.
  - 2.1.9 Identify potential fire concerns related to stationary combustion engines.
  - 2.1.10 Describe the use of compartmentation and isolation as a fire protection feature in building design.
  - 2.1.11 Identify the fire protection function of ventilation systems.

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## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### INTRODUCTION

According to National Fire Protection Association (NFPA) data, losses due to workplace fires in 2007 totaled \$1.85 billion. Of the more than 2,865 persons who lost their lives due to fires in 2007, the NFPA estimates 716 were workplace deaths.

### TWO VIEWPOINTS OF FIRE SAFETY

Fire safety can be considered from two viewpoints:

- Technical and physical aspects
- Procedural and operational aspects

The technical and physical aspects of fire safety address those issues related to what happens in a fire and the physical reasons for the fire events that occur. Generally, this includes the analysis of the dynamics of a fire to yield a description of the fire scenario in a physical sense.

Operational and procedural aspects of fire safety address those issues related to why a fire occurs as it does. For example, some fires are attributed to "poor housekeeping," which indicates that adequate precautions were not taken to prevent a fire. The fire does not ignite simply because of poor housekeeping, but it is a contributing factor from an operational standpoint.

Operational and procedural aspects include an evaluation of potential violations of standards, regulations, and operating sections that address the fire loss scenario. If a fire loss occurs as a result of a recognized hazard, failure to prevent the existence of the hazard can be considered an operational failure. Since the primary purpose of safety standards, regulations, and operating sections is to address unacceptable hazards, failure to comply can be considered an operational failure.

Ultimately, a technical fault must occur for the failure to occur, but the reason for the technical fault may be traced to a decision to use, or not use, the products and materials selected. Consequently, some people feel that all failures ultimately can be considered to be operational or procedural faults.

Identifying the underlying cause of a fire or potential fire is an important consideration when developing documentation [such as a Fire Hazards Analysis (FHA), emergency plans, and operating sections] to identify ways to prevent the occurrence or to mitigate the impact of a fire.

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### Learning Objective

When you finish this section, you will be able to:

- 2.1.1 Identify common fire protection devices and systems features found at fuel cycle facilities.

## TWO TYPES OF FIRE PROTECTION SYSTEMS

Fire protection systems can generally be broken into two types:

1. Active
2. Passive

An **active fire protection system** is defined as a device or action that receives a stimulus before acting in a real or a perceived fire condition.

A **passive fire protection system** is defined as a building component that remains fixed in the building whether or not a fire emergency exists.

### Active Fire Protection System

Traditional active fire protection elements are:

- ☑ Fire detection and alarm notification (manual & automatic)
- ☑ Automatic sprinkler system
- ☑ Portable extinguishers
- ☑ Trained fire brigade (manual fire suppression)
- ☑ Special hazard automatic suppression systems
  - ❑ Halogenated systems
  - ❑ Halon Alternatives
  - ❑ “Clean Agent” systems
  - ❑ Carbon dioxide systems
  - ❑ Dry chemical systems
  - ❑ Water foam systems

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- ☐ Water mist system
- ☐ Water spray systems (deluge)
- ☒ Special features
  - ☐ Emergency lighting and signage
  - ☐ Communication devices
  - ☐ Emergency power

### Passive Fire Protection System

Traditional passive fire protection elements are:

- ☒ Structural fire protection to prevent failure of the building
- ☒ Physical barriers to prevent fire and smoke propagation to limit damage
- ☒ The egress system

### FIRE SUPPRESSION AND DETECTION SYSTEMS

This section describes the fixed and portable equipment that is provided in working areas for fire protection. The fixed equipment includes automatic sprinklers, detectors and alarms. The portable equipment consists of fire extinguishers and hoses to be operated by employees before the arrival of the fire brigade or local fire department.

Fire protection is a broad term that encompasses all aspects of dealing with unexpected fires, including building construction and fixed building fire features, fire suppression and detection systems, fire water supply systems, emergency process safety control systems, emergency fire fighting organizations (fire departments, fire brigades, etc.), fire protection engineering, and fire prevention. Fire protection is concerned with preventing or minimizing the direct and indirect consequences of fire. It also includes aspects of the following perils as they relate to fire protection: explosion, earthquake, lightning, smoke, water damage, life safety, hazardous materials controls, and smoke control.

A **fire suppression system** is one that contains and extinguishes unexpected fires. Most systems are fully automatic, but some may have manual override capabilities or be only manually actuated. Also, most fire suppression systems have fire detection capabilities and provide fire alarm/system actuation notification to the facility's alarm and notification system.

**Fire detection equipment.** Equipment that will automatically detect one or more components directly related to combustion such as heat, smoke, flame, and other fire phenomena.

### FIRE DETECTION AND ALARM SYSTEMS

The best fire prevention measures may occasionally fail, in which case an effective fire detection system should detect the occurrence of fire and activate alarm systems so that personnel evacuation and fire containment and suppression measures may start promptly. The type and location of the detectors depends on the type of hazard.

#### Four Basic Phases of Fire Development

Most fires involving solid combustible materials develop in four basic phases.

1. Incipient:

Invisible products of combustion are being produced with no visible smoke, flame, or noticeable heat.

2. Smoldering:

The combustible products are now visible; however, the flame and noticeable heat are not yet being produced.

3. Flame:

Actual flaming now exists, but significant heat is not present.

4. Heat:

Uncontrolled heat and combustion products are being produced.

Detection systems are designed to detect some phase of activity occurring during one or more of the four phases of fire development.

#### Types of Fire Detectors

The most common elements of a fire that can be detected are heat, smoke (aerosol particulate), and light radiation.

**Note:**

1. Not all fires produce all of the elements.
2. Nonfire conditions can produce similar ambient conditions.

The purpose of automatic fire detectors is to detect one or more of the fire characteristics early enough to allow for evacuation and/or fire extinguishment. There are many different types of detectors available, some of which detect physical changes in the environment and others that detect chemical changes resulting from fires.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

Detectors are classified into two basic categories:

- Spot-type detector
- Line-type or area-type detector

Spot-type detectors are the most commonly used. The spot-detector senses a fire only at the location or spot of the detector. For example, a spot-diaphragm detector is spot-type protection since it alarms when abnormal heat conditions reach the specific detector's location.

Line-type detectors sense a fire at any point along the line of the detector layout. For example, the thermostatic cable detector is considered an line- or area-type detector.

Several types of automatic fire detectors are used throughout fuel cycle facilities according to particular needs and purposes. All of them will detect fire by one of several means and transmit an alarm. In the many buildings equipped with evacuation alarms, the automatic detectors activate those alarms, as do the manual pull boxes. In some cases, fire suppression systems are activated by fire detectors and some alarms are annunciated by fire suppression systems.

### Heat Detectors

Heat detectors are the oldest type of automatic fire detection device. Heat detectors are generally located on or near the ceiling and respond to the convected thermal energy of a fire.

The four general types of heat detectors are: fixed temperature, rate-of-rise, rate compensation (anticipation), and a combination of rate-of-rise and fixed temperature.

When a fire occurs, the operation of any heat-sensitive device is dependent of the transfer of heat from the heated air to the device. The device will only operate when the temperature of the device reaches its operating temperature. As a result, the temperature of the surrounding air will always be higher at alarm than the operating temperature of the device itself. This phenomenon is known as "thermal lag."

In general, heat detectors are designed to operate when heat causes a prescribed change in a physical or electrical property of a material or gas. Although heat detectors are the least expensive fire detector devices, they are most reliable even though they are the slowest in detecting fires. A heat detector is best suited for fire detection in a small confined space where a rapidly building high heat output fire is expected, in areas where ambient conditions would not allow the use of other fire detection devices, or where speed of detection is not a prime consideration.

### Spot Diaphragm Heat Detector

The spot diaphragm detector senses pressure changes in partially trapped air exposed to thermal effects from a fire in the protected area. Heat outside of the chamber causes the air in

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the chamber to expand, and when the expansion exceeds the capacity of the small vent, the diaphragm flexes to close the electrical contact necessary for alarm.

### Fixed Temperature Bimetallic Heat Detector

The most common spot-type of heat detector is the bimetallic type. The principle of unequal expansion in a bimetallic assembly is used to close electrical contacts. The disk in the center of this detector is designed to change from convex to concave at its rated operating temperature. The device has a great operating force available to close the contacts. This feature generally reduces false alarms from vibration and provides a positive closure of contacts. Detection system supervision can be provided by utilizing the same approach on a normally closed circuit that opens when the detector actuates or circuit integrity is interrupted.

Heat detectors using bimetal elements are automatically self-restoring after operation, when the ambient temperature drops below the operating point. See Figure 2-1.

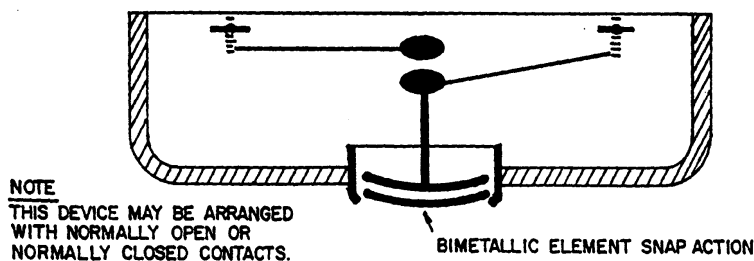
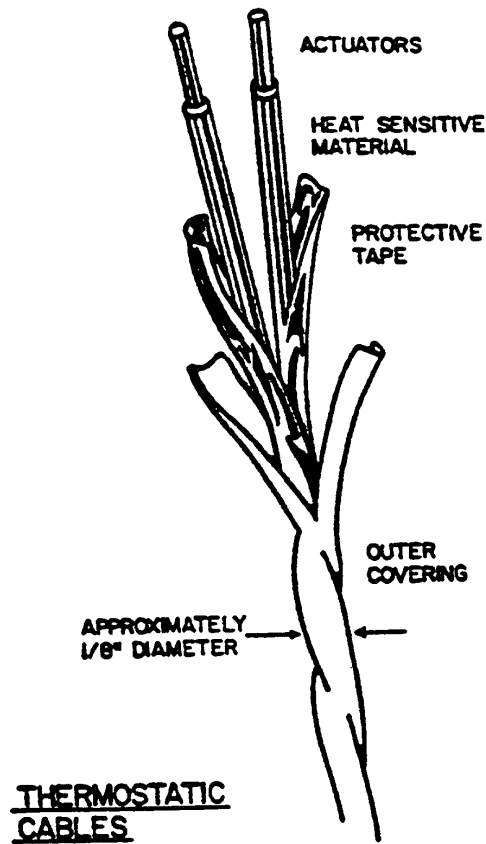


Figure 2-1. Thermostat - Fixed Temperature Bimetallic Type

### Linear Thermostatic Heat Detector

Thermostatic cables are a line type of detector that consists of a pair of tensioned metal conductors separated from each other by a heat-sensitive electrical insulating material applied directly to each wire. A protective covering is used both to hold the wires in proximity to each other and to prevent mechanical damage. At a known temperature, the heat-sensitive covering in the area of the fire melts, permitting the two wires to contact, initiating an alarm. See Figure 2-2.



**Figure 2-2. Thermostatic Cables**

Following an alarm, the fused section of the cable must be replaced to restore the system.

This detection device is often used to trace cable and piping runs since it will detect a fire occurring anywhere along the run of the detector cable.

Flame detectors sense the radiant energy from combustion in the infrared and ultraviolet wavelengths. Flame detectors are used where a fire will develop rapidly into the flaming stage, such as those involving flammable liquids, and are usually used to actuate extinguishing systems. These detectors have a wide angle of view and are extremely fast to respond. Most flame detectors have a few seconds time delay built into them to prevent unwanted alarms. Flame detectors are beneficial in areas where air currents that carry smoke may be unpredictable. Although they operate quickly, flame detectors must actually see the flame or its reflection.

Infrared flame detectors consist of filters, lens assemblies, and a photocell sensitive to infrared radiation. The filters and lenses serve to screen out unwanted wavelengths and to focus the



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resultant energy on the detection cell. To overcome background radiation, most flame detectors of this type use the principle of the flickering flame in the frequency range of 1.5 to 15 Hertz (cycles per second). A time-delay circuit can be included within the detector. See Figure 2-3.

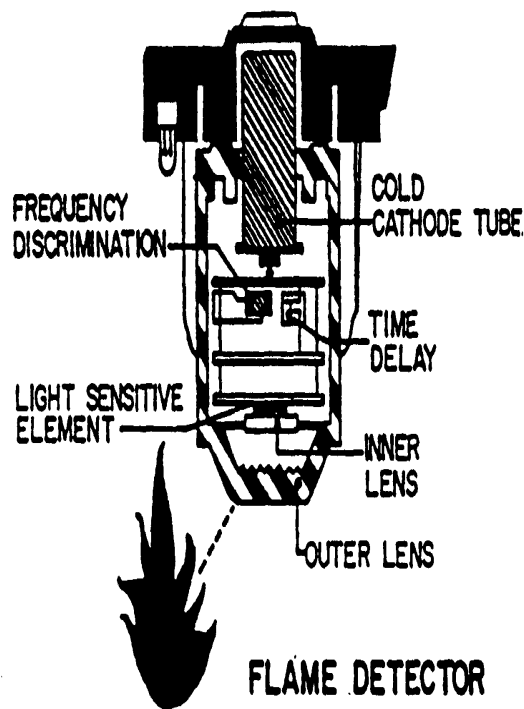


Figure 2-3. Flame Detector

Ultraviolet flame detectors are similar to infrared detectors, but are sensitive only to ultraviolet radiation. The geometry of these devices and spectral response permit them to reject most of the contribution from artificial light and sunlight.

Flame detectors are often used to detect the loss of wanted fire rather than the occurrence of an unwanted fire. A typical installation would include a flame detector in an industrial boiler fuel control system.

### Smoke Detectors

Smoke detectors, generally referred to as early warning detectors, are particularly useful when the type of fire anticipated would produce significant amounts of smoke and combustion products before heat. Smoke detectors are commonly used to protect areas of human occupancy, special high value property, and critical areas, such as computer and control rooms.

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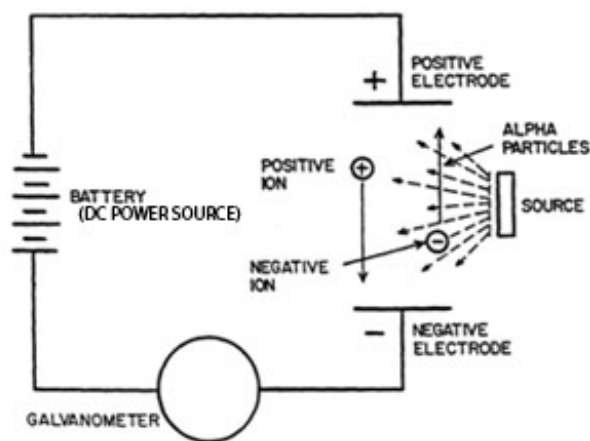
Detectors that are hard-wired into the electrical system should be installed by a qualified electrician. If the detector plugs into a wall socket, it should have a restraining device to keep the plug from being pulled out. Smoke detectors should not be connected to a circuit that could be turned off at a wall switch. Most detectors are battery-powered at the control panel.

Since smoke and deadly gases rise, detectors should be placed on the ceiling at least four inches from the nearest wall, or high on a wall, 4 to 12 inches from the ceiling. This four-inch minimum is important to keep detectors out of possible "dead air" spaces because hot air is turbulent and may bounce so much that it misses spots near a surface. Installing detectors near a window, ventilation supply, door, or heat source is not recommended because drafts could detour smoke away from the unit. In areas where the ceiling has an extremely high point, such as in vaulted ceilings, the smoke detector should be mounted at or near the ceiling's highest point.

### Ionization Smoke Detectors

Smoke detectors utilizing the ionization principle are usually of the spot-type. An ionization detector uses an extremely small quantity of radioactive material to make the air in the detector chamber conduct electricity. Smoke from a fire interferes with the electrical current and triggers the alarm.

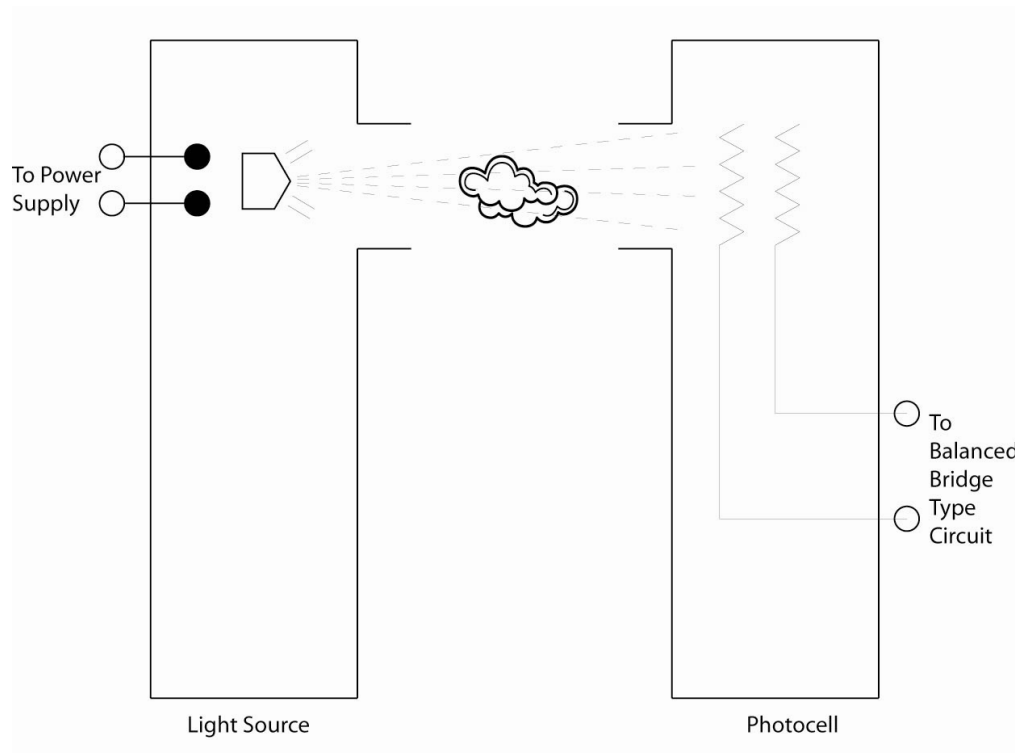
Along with the increased sensitivity, these detectors have a higher frequency of unwanted alarms since air contaminants other than smoke can also activate the ionization type. In order to reduce the susceptibility to false alarms, some ionization detectors use what is commonly referred to as a dual chamber detection method. The second (or inner) chamber is usually arranged similarly to the first, except that it is shielded from the entrance of combustion products. This chamber compensates for the effects of temperature, humidity, and pressure on the first (or outer) chamber. See Figure 2-4.



**Figure 2-4. Ionization Chamber Principle**

### Light Obscuration and Photoelectric Beam Type Smoke Detectors

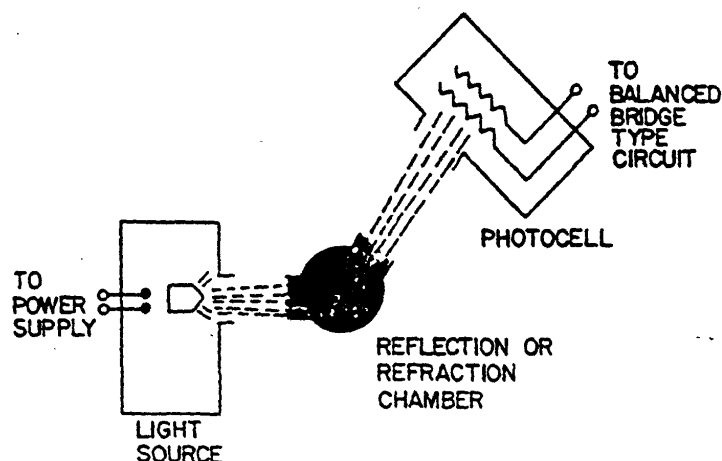
Light obscuration and photoelectric beam type detectors operate when a change in current results from the partial blocking of a light source by particulate matter (visible smoke). This occurs when smoke enters the light source and a separate receiving element at 4% obscuration or less. The alarm is triggered when smoke from a fire interferes with the light. See Figure 2-5.



**Figure 2-5. Smoke Detector Projected Beam Type**

### Light-scattering or Refraction Type Smoke Detectors

Light-scattering or refraction type detectors contain a light source, a reflection chamber for the smoke to enter, and a light sensitive cell. The light, reflected by smoke particles, is used by striking the photocell within a single detector. The alarm is triggered when smoke from a fire interferes with the light. See Figure 2-6.



**Figure 2-6. Smoke Detector Refraction Type**

### **Air Sampling Type Smoke Detection**

Air sampling detection uses a piping or tubing distribution network that runs from the detector to the area(s) to be protected. An aspiration fan in the detector housing draws air from the protected area back to the detector through air sampling ports, piping, or tubing. At the detector, the air is analyzed for fire products. Once the ambient is established and the smoke concentration level is adjusted for the sampling system design, this system can be many times more sensitive than spot-type smoke detection. The sensitivity of the detection software can be adjusted depending on the application. In general, this system is considerably more expensive than a standard smoke detection system.

### **Maintenance of Smoke Detectors**

Maintenance of smoke detectors includes:

- **Testing**

Whether the detectors are hard-wired or battery-operated, the NFPA recommends testing them once a month to make sure they are operating. Testing is the only way to ensure that smoke detectors are working.

Ensure maintenance of smoke detectors is documented.

- **Replacing Batteries**

NFPA recommends replacing batteries at least once a year or when the detector chirps, indicating that the battery power is low.

- **Cleaning**

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### No Substitute for Smoke Detectors

Fire protection in the workplace must start with smoke detectors. There are many other kinds of detectors that may be designed to detect such factors as high temperatures, rapid changes in temperature, and certain gases produced in fires. However, these detectors are not as effective as smoke detectors in giving the first warning when a fire breaks out. NFPA does not require heat detectors in all facilities; however, they may be used for optional extra protection in areas where smoke detectors are susceptible to nuisance alarms.

Tests performed on the speed of warning given by smoke detectors and heat detectors for many types of typical fires showed smoke detectors consistently give first warning—often by enough of a margin to make a major difference in personnel safety. Smoke and deadly gas spread farther and faster than heat.

Contrary to popular belief, the smell of smoke may not alert an individual. Instead, the poisonous gases and smoke produced by a fire can numb the senses and put one into a deep sleep.

### Duct Detectors

Detectors of the early warning type can be used for special applications such as duct detectors. The function of these detectors is to detect smoke so that fans and dampers in air conditioning and ventilation systems can be controlled to prevent distribution of smoke and products of combustion throughout a building.

Duct detectors are made to operate in a higher range of air velocities. It is not recommended that duct detectors be used in lieu of open area detectors. As the smoke-laden air from a fire is drawn into the system, it is diluted by other air sources. As a result, the air may not contain smoke in sufficient quantities to actuate the device when it reaches the detector location.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Summary of Detectors

Table 2-1 provides a brief summary of detectors and their characteristics. An example of each type of detector is also listed.

**Table 2-1. Summary of Detectors and Their Characteristics**

Detector	Characteristics	Example
Spot-type	<ul style="list-style-type: none"><li>Commonly used.</li><li>Senses a fire only at the location or spot of the detector.</li><li>Alarms when abnormal heat conditions reach the specific detector's location.</li></ul>	<ul style="list-style-type: none"><li>Spot diaphragm detector</li><li>Fixed temperature bimetallic</li></ul>
Line-type	<ul style="list-style-type: none"><li>Senses a fire at any point along the line of the detector layout.</li><li>Often used to trace cable and piping runs since it will detect a fire occurring anywhere along the run of the detector cable.</li></ul>	<ul style="list-style-type: none"><li>Thermostatic cable detector</li></ul>
Heat	<ul style="list-style-type: none"><li>Oldest type of automatic fire detection device.</li><li>Designed to operate when heat causes a prescribed change in a physical or electrical property of a material or gas.</li><li>Least expensive and the slowest in detecting fires, least false alarms.</li><li>Best suited for fire detection in a small confined space where a rapidly building high heat output fire is expected, in areas where ambient conditions would not allow the use of other fire detection devices, or where speed of detection is not a prime consideration.</li><li>Generally located on or near the ceiling and respond to the convected thermal energy of a fire.</li></ul>	<ul style="list-style-type: none"><li>Fixed temperature</li><li>Rate-of-rise</li><li>Rate compensation</li><li>Combination of rate-of-rise and fixed temperature</li></ul>

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

**Table 2-1. Summary of Detectors and Their Characteristics**

Detector	Characteristics	Example
Flame	<ul style="list-style-type: none"><li>☐ Sense the radiant energy from combustion in the infrared and ultraviolet wavelengths.</li><li>☐ Expensive.</li><li>☐ Often used to detect the loss of wanted fire rather than the occurrence of an unwanted fire.</li><li>☐ Used where a fire will develop rapidly into the flaming stage, such as those involving flammable liquids, and are usually used to actuate extinguishing systems.</li><li>☐ Have a wide angle of view and are extremely fast to respond.</li><li>☐ Beneficial in areas where air currents that carry smoke may be unpredictable.</li></ul>	<ul style="list-style-type: none"><li>☐ Infrared</li><li>☐ Ultraviolet</li></ul>
Smoke	<ul style="list-style-type: none"><li>☐ Generally referred to as early warning detectors</li><li>☐ Particularly useful when the type of fire anticipated would produce significant amounts of smoke and combustion products before heat.</li></ul>	<ul style="list-style-type: none"><li>☐ Ionization Smoke Detector</li><li>☐ Light Obscuration and Photoelectric Beam Type Smoke Detector</li><li>☐ Light-scattering or Refraction Type Smoke</li><li>☐ Air Sampling Type Smoke Detection</li></ul>
Duct	<ul style="list-style-type: none"><li>☐ Detects smoke so that fans and dampers in air conditioning and ventilation systems can be controlled to prevent distribution of smoke and products of combustion throughout a building.</li><li>☐ Made to operate in a higher range of air velocities.</li></ul>	

## **MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS**

### **DETECTOR SELECTION AND LOCATION, NFPA 72**

The extent and type of combustibles and the goal of the detection system must be evaluated to determine the type of detection devices that are most appropriate. In order to determine which type of detector is most appropriate, an analysis of the normal activities performed in the area must be conducted. Cutting and welding operations, hot surfaces, or lubricant on diesel engines may create conditions that could be detected as "fires" by some types of detectors and therefore warrant consideration.

The designer must determine the importance of the area to be protected as well as the time delay that can be tolerated in the event of a fire. Realistic assessments of fire suppression efforts must be included during this evaluation. Detection systems do not extinguish fires, and if notification of a fire is expected to initiate a manual suppression effort by the fire brigade, a realistic allowance of 10 to 20 minutes must be allotted.



## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-1

INSTRUCTIONS: Answer the following questions. Answers are located in the answer key section of this module.



Match the type of fire protection system in Column A with the appropriate elements from Column B.

#### Column A – Type of Fire Protection System

Active

Passive

#### Column B - Elements

- \_\_\_\_ 1. The egress system
- \_\_\_\_ 2. Portable extinguishers
- \_\_\_\_ 3. Trained fire brigade
- \_\_\_\_ 4. Emergency lighting and signage
- \_\_\_\_ 5. Physical barriers to prevent fire and smoke propagation to limit damage
- \_\_\_\_ 6. Structural fire protection to prevent failure of the building
- \_\_\_\_ 7. Fire detection sprinkler system

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

Fill in the missing words in each statement. Choose from the following words:

activate	batteries	beam	bimetal
combustibles	duct	electrical	fire protection
fires	flame	goal	highest
heat	human	ionization	numb
passive	refraction	sleep	small
smoke	speed	spot diaphragm	stimulus
suppression	thermostatic cable	ultraviolet	air sampling

1. An active fire protection system is defined as a device or action that receives a \_\_\_\_\_ before acting in a real or a perceived fire condition.
2. A \_\_\_\_\_ fire protection system is defined as a building component that remains fixed in the building whether or not a fire emergency exists.
3. \_\_\_\_\_ is a broad term that encompasses all aspects of dealing with unexpected fires, including building construction and fixed building fire features, fire suppression and detection systems, fire water supply systems, emergency process safety control systems, emergency fire fighting organizations, fire protection engineering, and fire prevention.
4. A fire \_\_\_\_\_ system is one that contains and extinguishes unexpected fires.
5. An effective fire detection system should detect the occurrence of fire and \_\_\_\_\_ alarm systems so that personnel evacuation and fire containment and suppression measures may start promptly.
6. The most common elements of a fire that can be detected are \_\_\_\_\_, smoke (aerosol particulate), and light radiation.
7. The four basic phases of fire development are: incipient, smoldering, \_\_\_\_\_, and heat.
8. A \_\_\_\_\_ detector alarms when abnormal heat conditions reach the specific detector's location.
9. A \_\_\_\_\_ detector is considered an line- or area-type detector.
10. In general, heat detectors are designed to operate when heat causes a prescribed change in a physical or \_\_\_\_\_ property of a material or gas.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

11. A heat detector is best suited for fire detection in a \_\_\_\_\_ confined space where a rapidly building high heat output fire is expected, in areas where ambient conditions would not allow the use of other fire detection devices, or where \_\_\_\_\_ of detection is not a prime consideration.
12. Heat detectors using \_\_\_\_\_ elements are automatically self-restoring after operation, when the ambient temperature drops below the operating point.
13. Flame detectors sense the radiant energy from combustion in the infrared and \_\_\_\_\_ wavelengths.
14. Flame detectors are beneficial in areas where air currents that carry \_\_\_\_\_ may be unpredictable.
15. Smoke detectors are commonly used to protect areas of \_\_\_\_\_ occupancy, special high property value, and critical areas, such as computer and control rooms.
16. In areas where the ceiling has an extremely high point, such as in vaulted ceilings, the smoke detector should be mounted at or near the ceiling's \_\_\_\_\_ point.
17. In order to reduce the susceptibility to false alarms, some \_\_\_\_\_ detectors use what is commonly referred to as a dual chamber detection method.
18. Light obscuration and photoelectric \_\_\_\_\_ type detectors operate when a change in current results from the partial blocking of a light source by particulate matter (visible smoke).
19. Light-scattering or \_\_\_\_\_ type detectors contain a light source, a reflection chamber for the smoke to enter, and a light sensitive cell.
20. Maintenance of smoke detectors includes testing, replacing \_\_\_\_\_, and cleaning.
21. Contrary to popular belief, the smell of smoke may not alert an individual. Instead, the poisonous gases and smoke produced by a fire can \_\_\_\_\_ the senses and put one into a deep \_\_\_\_\_.
22. The function of \_\_\_\_\_ detectors is to detect smoke so that fans and dampers in air conditioning and ventilation systems can be controlled to prevent distribution of smoke and products of combustion throughout a building.
23. The extent and type of \_\_\_\_\_ and the \_\_\_\_\_ of the detection system must be evaluated to determine the type of detection devices that are most appropriate.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

24. Detection systems do not extinguish\_\_\_\_\_.
25. \_\_\_\_\_ type smoke detection can be many times more sensitive than spot type smoke detection.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

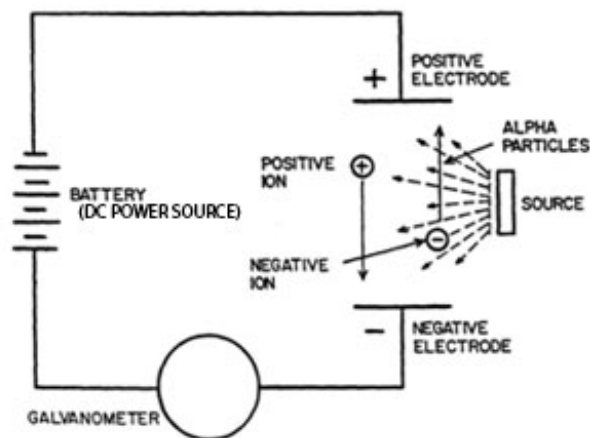
### Activity 1 – Detectors

INSTRUCTIONS: Match each of the following common fire protection devices and automatic fire/chemical detectors with its respective graphic representation. Answers are located in the answer key section of this module.

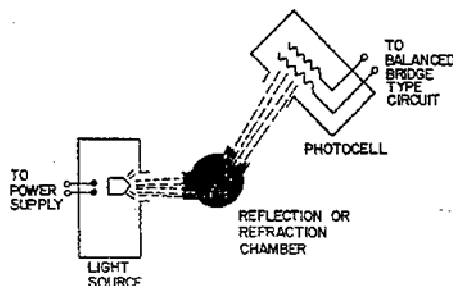


- A. Flame detector
- B. Fixed temperature
- C. Refraction type smoke detector
- D. Linear thermistor heat detector
- E. Ionization smoke detector

1. \_\_\_\_\_

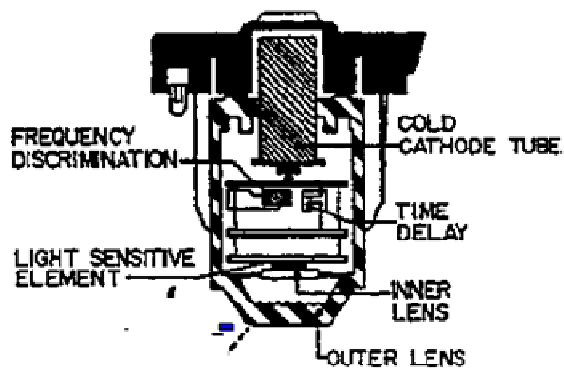


2. \_\_\_\_\_

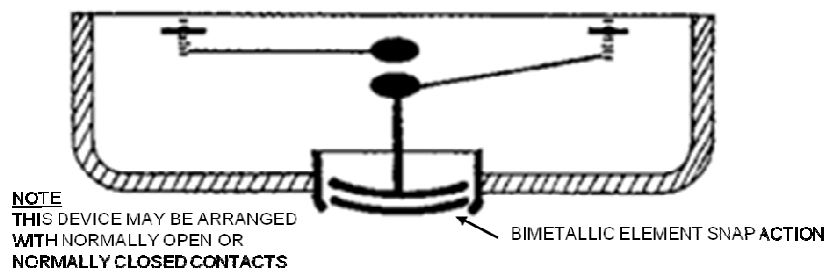


## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

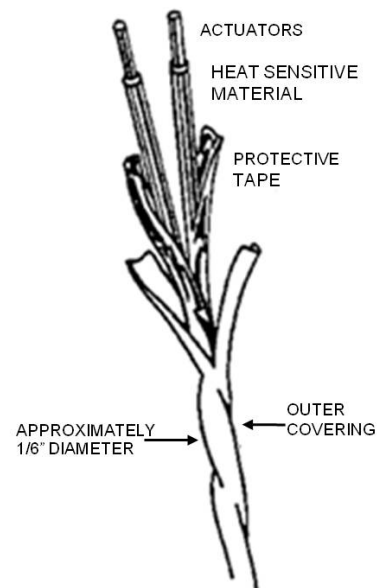
3. \_\_\_\_\_



4. \_\_\_\_\_



5. \_\_\_\_\_





### Learning Objective

When you finish this section, you will be able to:

2.1.2 Describe the key components and requirements of fire alarm systems.

## ALARM SYSTEMS, NFPA 72

NFPA 72, National Fire Alarm Code, provides guidance on the application, installation, performance, and maintenance of fire alarm systems and their components.

### Common Alarm System Fundamentals

The basic functions of a fire alarm system are:

- Provide notification of fire alarm
- Supervisory and trouble conditions
- Alert the occupants
- Summon appropriate aid
- Control fire safety functions.

Fire alarm systems should be provided with at least two independent and reliable power supplies, one primary (main) and one secondary (standby); each of which should be of adequate capacity for the application.

### Primary Power Supply

The primary (main) power supply should have a high degree of reliability, should have adequate capacity for the intended service, and should consist of one of the following:

- Light and power services with the capacity to operate the system under normal conditions. An overcurrent protection device of suitable current-carrying capacity and capable of interrupting the maximum short-circuit current to which it may be subject should be provided in each ungrounded conductor. The overcurrent protective device should be enclosed in a locker or sealed cabinet located immediately adjacent to the point of connection to the light and power conductors.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

- Engine-driven generator or equivalent that has been installed in conformance to NFPA 110, Standard for Emergency and Standby Power Systems, and has the capacity sufficient to operate the system under the maximum normal load conditions in addition to all other demands placed on the unit, such as those of emergency lighting.

### Secondary Power Supply

The secondary power supply should automatically supply energy to the system within 30 seconds and without loss of signals, wherever the primary supply is incapable of providing the minimum voltage required for proper operation. The secondary (standby) power supply should supply energy to the system in the event of total failure of the primary (main) power supply or when the primary voltage drops to a level insufficient to maintain functionality of the control equipment and system components. Under maximum normal load, the secondary power supply should have sufficient capacity to operate a local, central station or proprietary system for 24 hours or an auxiliary or remote station for 60 hours. At the end of that period, the secondary supply should operate all alarm notification appliances used for evacuation or to direct aid to the location of an emergency for 5 minutes. The secondary power supply for emergency voice/alarm communications service should be capable of operating the system under maximum normal load for 24 hours and then be capable of operating the system during a fire or other emergency condition for a period of 2 hours. Fifteen minutes of evacuation alarm operation at maximum connected load should be considered the equivalent of 2 hours of emergency operation.

The secondary power supply should consist of one of the following:

- Storage batteries located so that the fire alarm equipment, including overcurrent devices, are not adversely affected by battery gases. The batteries should be protected against excessive load current by overcurrent devices having a rating of not less than 150 percent and not more than 250 percent of maximum operating load in the alarm condition. The batteries should be protected from excessive charging by overcurrent devices or by automatic current-limiting design of the charging source.
- An automatic starting engine-driven generator as described in the primary power supply section, with an additional requirement of storage batteries having a 4 hour capacity.
- Multiple generators, one of which is arranged for automatic starting capable of supplying the energy required with the largest generator out of service. The second generator may be operated with a pushbutton start.

Operation of the secondary power supply should not affect the required performance of a fire alarm system. The system should produce the same alarm, supervisory, and trouble signals and indications (excluding the alternate current power indicator) when operating from the standby power source as produced when the unit is operating from the primary power source.



## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Signals

Fire is a phenomenon that occurs when a substance reaches a critical temperature and reacts chemically with oxygen, for example, to produce heat, flame, light, smoke, water vapor, carbon monoxide, carbon dioxide, or other products and effects.

An **alert tone** is an attention-getting signal to alert occupants of the pending transmission of a voice message.

An **alarm** is a warning of fire danger.

An **alarm signal** is a signal indicating an emergency requiring immediate action, such as a signal indicative of fire.

Alarms should be established to signal the need for corrective actions whenever necessary to prevent public or environmental exposures from exceeding the limits.

An **evacuation signal** is a distinctive signal intended to be recognized by the building occupants as requiring evacuation of the building or area.

### Distinctive Signals

NFPA 72, National Fire Alarm Code, provides this guidance on the distinction of alarm signals. Audible alarm notification appliances for a fire alarm system should produce signals that are distinctive from other similar appliances used for other purposes in the same area. The distinction among signals should be as follows:

- A fire alarm signal is initiated by a fire alarm initiating device such as a manual fire alarm box, automatic fire detector, waterflow switch in a sprinkler system, automatic fire suppression system, or other device whose activation is indicative of the presence of a fire or fire signature. Fire alarm signals should be distinctive in sound from other signals, and this sound should not be used for any other purpose.
- A supervisory signal indicates the need of action in connection with the supervision of guard tours, fire suppression systems or equipment, or with the maintenance features of related systems. Supervisory signals should be distinctive in sound from other signals. This sound should not be used for any other purpose except that it may be employed to indicate a trouble condition. Where the same sound is used for both supervisory signals and trouble signals, distinction between signals should be made by other appropriate means such as visible annunciation.
- A trouble signal is initiated by the fire alarm system and indicates a fault in a monitored circuit or component.

## **MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS**

In most buildings, evacuation alarm bells are automatically activated when fire is detected. They can also be activated manually at strategically located pull boxes. The emergency actions of personnel and the evacuation procedures for each building or operating area are usually set forth in the operational safety procedures for each building and posted near the main entrance, fire exit, or elevator.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-2

INSTRUCTIONS: Circle the correct response. Answers are located in the answer key section of this module.



1. What term can be described as an attention-getting signal to occupants of a pending transmission?
  - A. Fire alarm/evacuation signal
  - B. Alert tone
  - C. Evacuation signal
  - D. Alarm signal
  
2. What term is defined as "a signal indicating an emergency requiring immediate action"?
  - A. Fire alarm/evacuation signal tone generator
  - B. Alert tone
  - C. Evacuation signal
  - D. Alarm signal

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Activity 2 – Alarm System Fundamentals

INSTRUCTIONS: Complete the sentences below with the correct words and phrases. Answers are located in the answer key section of this module.



1. The four basic functions of a fire alarm system are to
  - 1) \_\_\_\_\_
  - 2) \_\_\_\_\_
  - 3) \_\_\_\_\_
  - 4) \_\_\_\_\_
2. An \_\_\_\_\_ notifies occupants to leave the building or area.
3. The \_\_\_\_\_ operates the fire alarm system under normal conditions.
4. An \_\_\_\_\_ is used to warn building occupants of the pending transmission of a voice message.
5. The \_\_\_\_\_ automatically supplies energy to the fire alarm system within \_\_\_\_\_ when the \_\_\_\_\_ cannot provide the minimum voltage required for fire alarm system operation.
6. An \_\_\_\_\_ is a warning of fire danger.
7. The primary power supply must have an \_\_\_\_\_ in an enclosed locker or sealed cabinet located \_\_\_\_\_ to the light and power conductors.
8. \_\_\_\_\_ are initiated by devices activated by fire; \_\_\_\_\_ indicate the need for actions related to guard tours or maintenance of related fire alarm systems.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

9. The secondary power supply consists of one of the following three options:

- 1) \_\_\_\_\_
- 2) \_\_\_\_\_
- 3) \_\_\_\_\_

10. An \_\_\_\_\_ is a signal indicating an emergency requiring immediate action.

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### Learning Objectives

When you finish this section, you will be able to:

- 2.1.3 Identify basic types of automatic sprinkler systems.
- 2.1.4 Discuss considerations for the use and inspection of automatic sprinkler systems.

### AUTOMATIC SPRINKLER SYSTEM

The term "automatic" means automatically on and automatically off. Semi-automatic means automatically on and manually off. Most automatic sprinkler systems are actually semi-automatic systems.

#### Major Characteristics of Automatic Sprinkler Systems

The major characteristics of automatic sprinkler systems are:

- ❑ Each sprinkler is independent. Only sprinklers fused by the heat release of the fire will operate.
- ❑ Depending upon the fusible link, the fire normally is about 1.5 meters high for ceilings of 3.5 meters or less before the link fuses.
- ❑ Most commonly only one or a few sprinklers open during a fire.

#### General Design Guidance

General design guidance for automatic sprinkler systems is provided in American National Standards Institute (ANSI)/National Fire Protection Association (NFPA) 13, Standard for the Installation of Sprinkler Systems. This standard was first developed in 1896 and has evolved as a consensus standard through numerous revisions as the understanding of fire principles and extinguishment methods have improved. The standard provides the minimum requirements for sprinkler systems including the character and adequacy of water supplies, and the selection of sprinklers, piping, valves, and all materials and accessories.

The automatic sprinkler system may be described as having three major components:

1. The water supply and distribution system to the building.
2. The control system linking the external supply system to the building sprinkler system.
3. The building sprinkler piping distribution system and the sprinklers.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Types of Sprinkler Systems

There are four basic types of automatic sprinkler systems:

1. Wet pipe
2. Dry pipe
3. Pre-action
4. Deluge

### Wet Pipe Sprinkler System

The **wet pipe sprinkler system** is a system employing closed sprinkler heads installed in a piping system containing water and connected to a water supply. Water discharges immediately from sprinklers opened by a fire. See Figure 2-7.

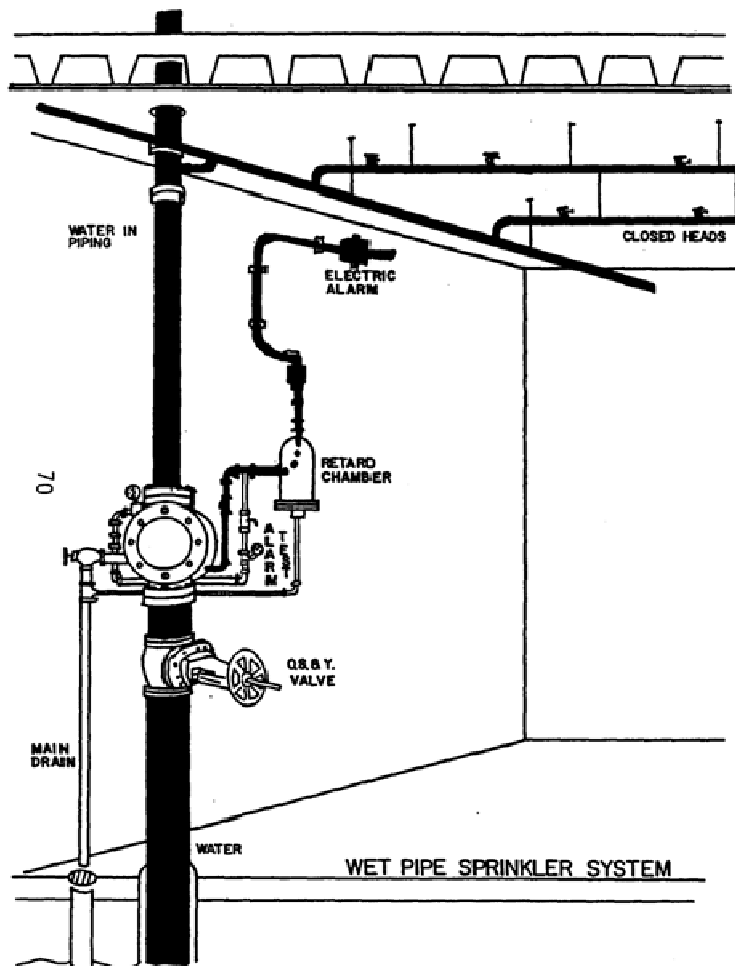


Figure 2-7. Wet Pipe Sprinkler System



## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

The wet pipe sprinkler system is the most common and least complicated of all sprinkler systems. All pipes are normally full of water under pressure. Water is immediately discharged from the sprinkler upon operation of its fusible element. An alarm is initiated by the flowing water to indicate that a sprinkler has operated.

This system is extremely reliable since the only criteria for successful operation are an operating sprinkler and an adequate water supply. The system requires very little maintenance. The only disadvantage of this system is that it is subject to freezing if in an unheated area (like loading docks).

### Example of Wet Pipe Automatic Sprinkler System Water Supply

The following diagram shows how a typical, **wet pipe automatic sprinkler system water supply** might look.

The piping is fitted with water under pressure that is immediately discharged when a sprinkler operates. This water continues to flow, controlling or extinguishing a fire, until it is manually shut off.

In the diagram, a fire has actuated one sprinkler. This sprinkler starts a small flow of water in the piping. The main water supply comes from the public water main (1). From the public main, water flows through a series of valves [which are always open except when shut down for maintenance] to the yard main (2), to the lead-in (3), through the riser (4), into the lead main (5), to the cross main (6), into the branch line (7), and out through the open sprinkler (8).

The fire pump (9), which starts automatically when a flow of water is detected, draws additional water from a stored supply in the suction tank (10) into the yard main. This additional water from the fire pump and suction tank provides a supplementary supply to ensure that enough water at sufficient pressure will be made available to meet the demand of the sprinklers.

Any water flowing through the water-flow alarm valve (11) sounds a local alarm and should send a signal to a central station which may notify the public fire department.

The sprinkler control valve (12), sometimes called the post indicator valve (kPIV), will be used to shut off water to the sprinkler system only after control has been gained over the fire and only when the individual in charge of the fire fighting efforts designates that the valve be shut.

The yard main may be shared with other water needs on the plant or designated for fire suppression only. Fire hydrants and fire hose stations are also usually plumbed separately from potable water systems.

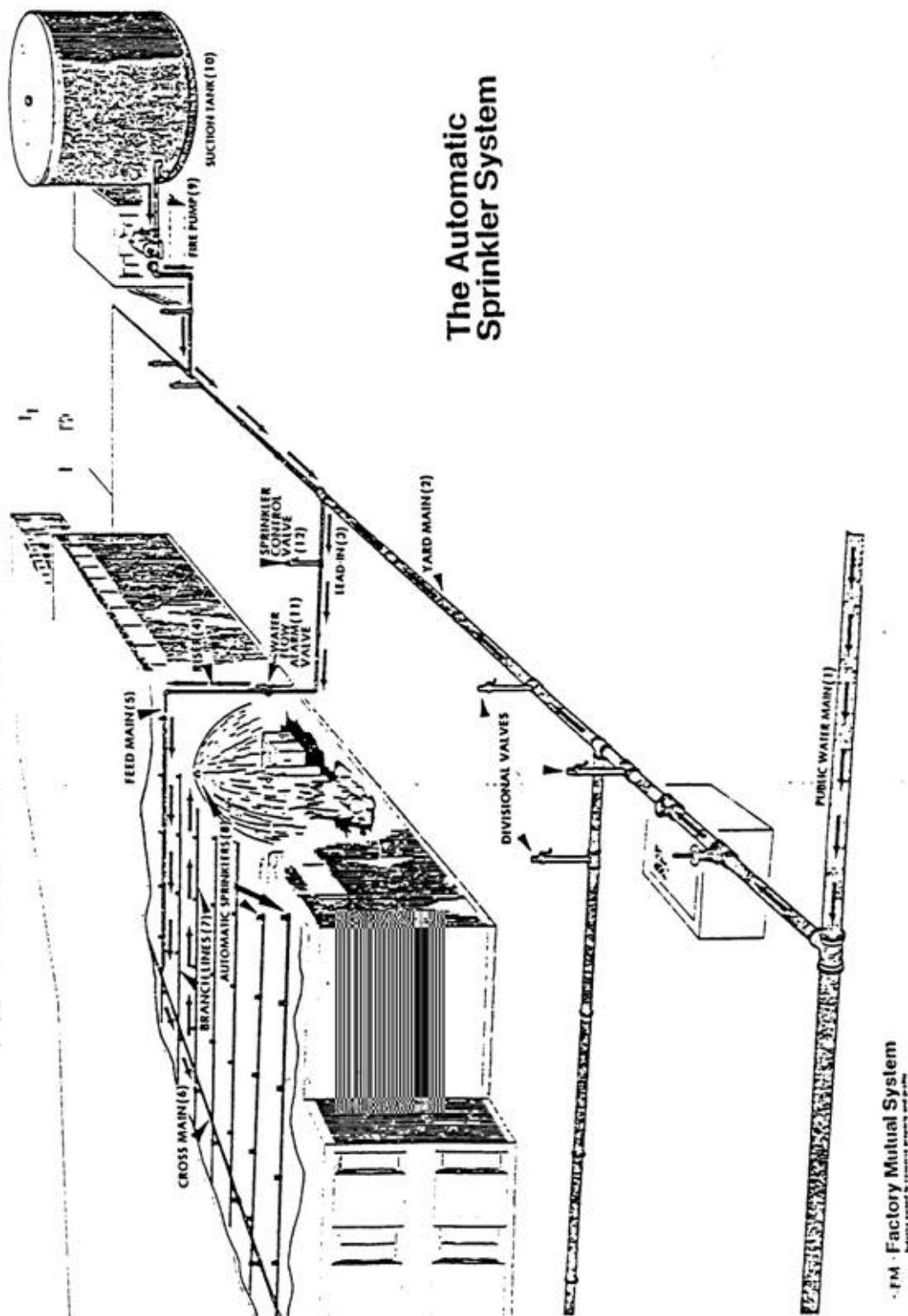


Figure 2-8. The Wet Pipe Automatic Sprinkler System Water Supply

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

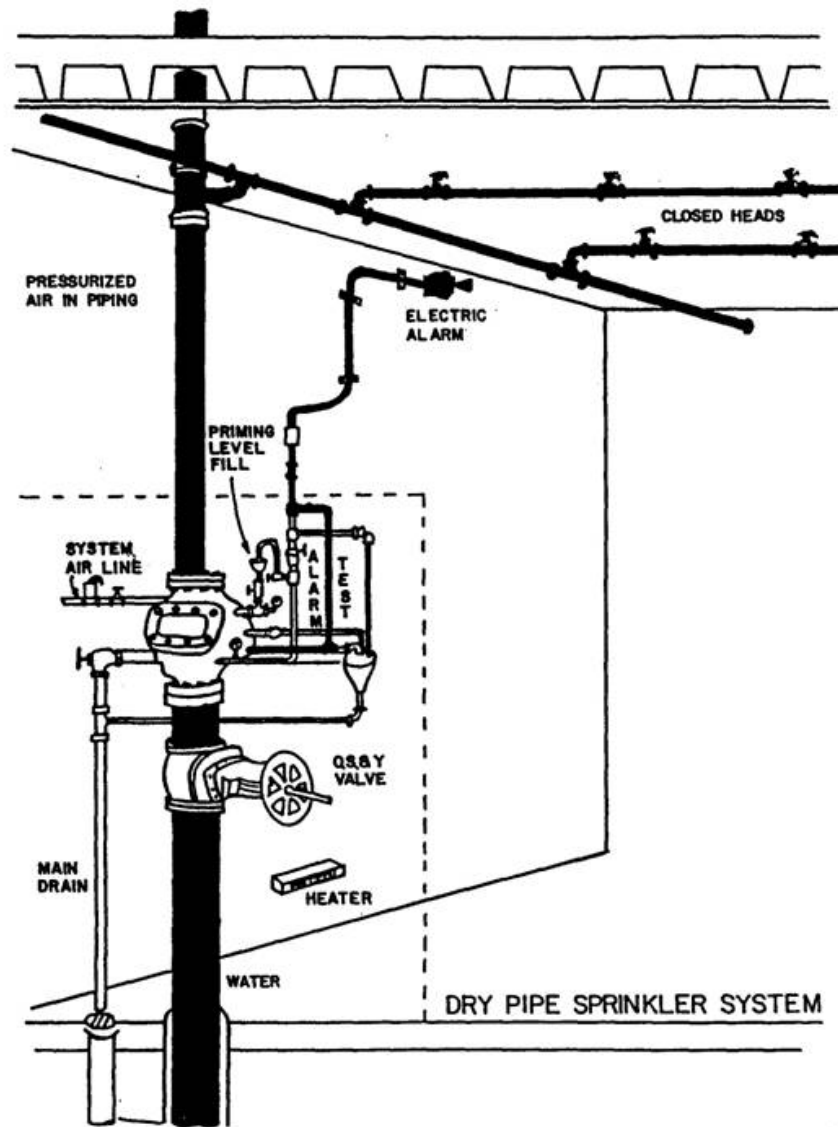
### Dry Pipe Sprinkler System

The **dry pipe sprinkler system** is a system employing automatic sprinklers installed in a piping system containing air or nitrogen under pressure, the release of which, as from the opening of a sprinkler, permits the water pressure to open a valve known as a dry pipe valve. The water then flows into the piping system, pushing out the air, then out the opened sprinklers. See Figure 2-9. The dotted line represents the enclosure which protects the system from freezing.

The dry pipe sprinkler system was developed to provide sprinkler protection for unheated buildings in cold climates. The piping is dry and filled with air under pressure. A differential pressure valve (dry pipe valve) prevents the water from entering the overhead piping system. The valve surface exposed to the compressed air usually has about six times the surface area of that exposed to the water. As a result, it takes only 1/6 as much air pressure as water pressure to prevent the water from entering the system.

Normal closed sprinklers are provided in the overhead piping system just as in the wet pipe system. When the sprinkler fusible element operates, the air in the piping is discharged. As the air discharges, the air pressure decreases, the dry pipe valve operates, and water enters the overhead piping. The water travels to the open orifice and discharges in a uniform fine spray just as in the wet pipe system. Evacuating the compressed air expends valuable time. The fire continues to grow and build in intensity during this time and, as a result, more sprinklers may operate on a dry pipe system than a wet pipe system. If excessive air pressure is maintained in the overhead piping, additional time delays will result as a larger quantity of air will have to be evacuated before the water reaches the sprinkler.

Dry pipe sprinkler systems are difficult to maintain because of the complicated valve arrangement and because moist air in the overhead piping can cause system corrosion.



### Figure 2-9. Dry Pipe Sprinkler System

### Pre-action Sprinkler System

The **pre-action sprinkler system** is a closed head sprinkler system containing air that may or may not be under pressure, with a supplemental fire detection system installed in the same areas as the sprinklers. Actuation of the fire detection system opens a valve that permits water to flow into the sprinkler piping and to be discharged from any sprinklers that may be open. See Figure 2-10.

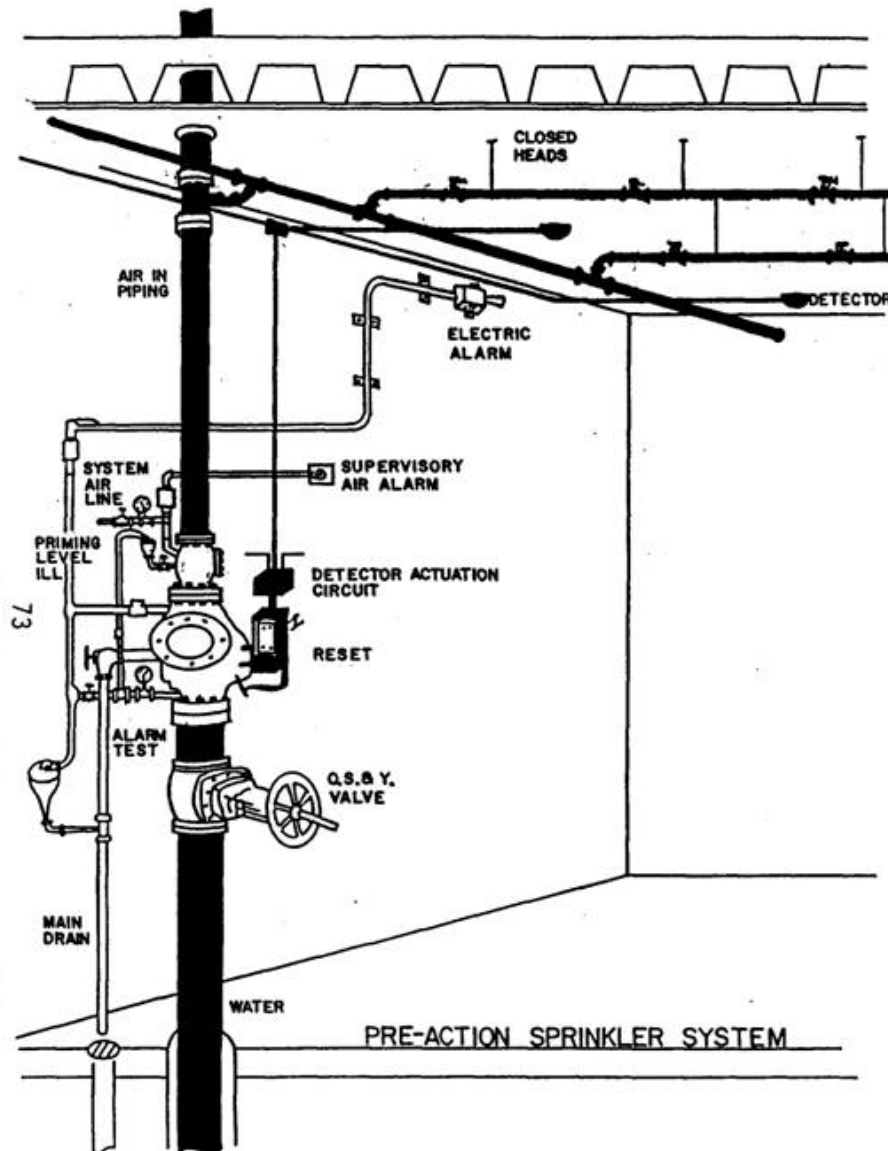


Figure 2-10. Pre-Action Sprinkler System

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

The principal difference between a pre-action system and a standard dry pipe system is that in the pre-action system the water supply valve is actuated independently of the opening of the closed sprinklers installed in the piping. An automatic fire detection system is used to initiate a signal that opens the pre-action valve, permitting water to enter the overhead piping. When the fire generates enough heat to fuse the sprinkler head, water is immediately discharged in the fire as with a wet pipe system.

Any type of fire detector can be utilized with a control panel to send a signal to actuate the control valve. Since any listed fire detector is required to operate faster than a sprinkler head, it is common for water to have reached the sprinkler by the time it fuses, so a pre-action system usually has a similar operating time to a wet pipe system. In addition, this system eliminates the fear of inadvertent water discharges, since work operations must occur for water to be released: (1) detector actuation and (2) sprinkler operation.

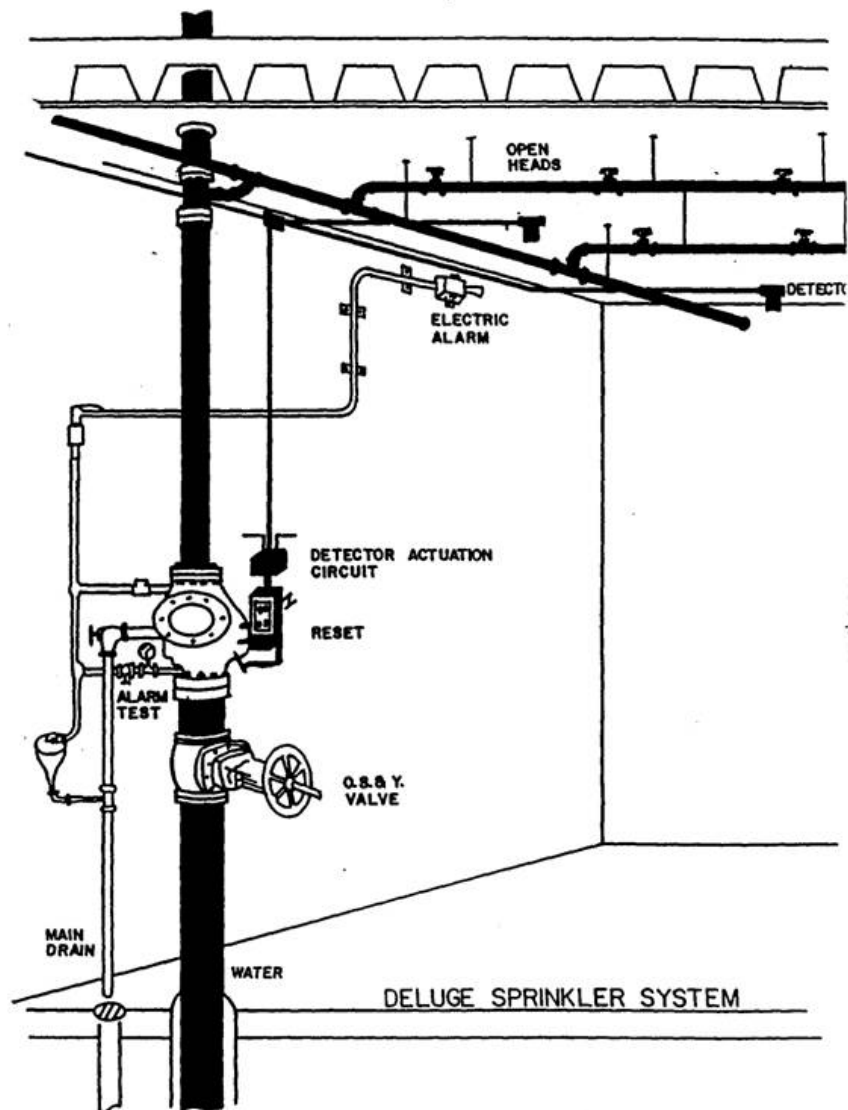
### Deluge Sprinkler System

The **deluge sprinkler system** is a system employing open sprinklers installed in a water supply through a valve that is opened by the operation of a fire detection system installed in the same areas as the sprinklers. When this valve opens, water flows into the piping system and discharges from all attached sprinklers. See Figure 2-11.

The purpose of a deluge sprinkler system is to wet down an entire fire area by supplying water to a network of open sprinklers (sprinklers which have no fusible element) so that all nozzles or sprinkler heads operate simultaneously.

Deluge systems operate on the same principle as pre-action systems in that control valve operation is achieved by actuation of a separate fire detection system.

Deluge systems are used in high hazard occupancies, such as those in which flammable liquids are stored, where there is a possibility that fire may flash ahead of the operation of ordinary automatic sprinklers, or where high explosives are handled. The water supply requirement for deluge systems is typically much greater than for a comparable wet pipe, dry pipe, or pre-action sprinkler system because all the sprinklers on a deluge system must be simultaneously supplied with water.



**Figure 2-11. Deluge Sprinkler System**

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### CONSIDERATIONS FOR SPRINKLER SYSTEMS

Some facilities are equipped with **automatic sprinkler systems**. The sprinkler heads contain a fusible element (most commonly fused between 135°F to 170°F) which, on melting, opens the head and starts a spray of water. The resulting flow of water in the piping activates an alarm.

- Automatic sprinkler heads can be damaged if they are subjected to mechanical abuse, for example, fork lifts. A protective cage should be installed where such damage is possible. Heat inadvertently applied to the sprinkler head can also activate the sprinkler when no actual fire is present. Normal heat sources should, therefore, be kept away from sprinkler heads. To avoid decreasing the flow or spread of water or altering the spray pattern, material or furniture should not be located too close to the sprinkler head.
- At least 18 inches of clearance should be allowed around sprinkler heads. Sprinkler system control valves must be kept accessible for fire department use.
- At least 3 feet of clearance (enough for an individual to pass through easily) should be allowed around such valves.

Sometimes piping systems show significant corrosion pitting due to microbiologically induced corrosion (MIC) after an extended plant outage. MIC is a form of corrosive action that occurs as a result of living organisms coming into contact with the materials of construction, soils, sediment, etc. The metabolic processes of organisms are sustained by chemical reactions and can 1) destroy protective surface films, 2) create corrosive deposits, and 3) alter anodic and cathodic reactions.

MIC has been reported in wet, dry, and deluge fire protection systems composed of cast iron, carbon steel, galvanized steel or stainless steel, as well as copper-based systems. Fire protection system make-up waters are typically stagnant, low in hardness, low in pH, and devoid of anti-microbial compounds (biocides). These characteristics predispose fire protection systems to biological fouling (biofouling) and MIC.

Regulatory requirements that dictate periodic testing can contribute to development of MIC in fire protection systems when make-up waters are replaced with oxygenated and nutrient-rich waters in which microbial communities thrive and form biofilms. The most serious consequence is mechanical blockage of piping and sprinkler heads.



## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### LESSONS LEARNED

#### Oak Ridge Y-12 Plant

On June 26, 1996, a fire protection engineer discovered a paddle-type flow switch installed in a pre-action fire protection system contrary to NFPA Standard 13, Standard for the Installation of Sprinkler Systems. Previous walk-downs of fire systems to designate them as limited condition of operability systems failed to identify this discrepancy because the walk-downs did not include a review for adherence to NFPA code changes. The as-found condition of the paddle-type flow switch resulted in an unreviewed safety question. Reviews of systems should include verification of codes and standards and identification of discrepancies associated with system configuration that could affect system operability.

Engineers initiated an unreviewed safety question determination to address impact of the code violation on the existing authorization basis. They determined an unreviewed safety question existed. Fire protection engineers performed a walk-down of three additional pre-action sprinkler systems and discovered that two of them had at least one paddle-type flow switch installed. They processed a second unreviewed safety question for these flow switches. Facility managers declared the systems were inoperable and initiated compensatory measures (roving fire watches) while the fire protection systems were inoperable. After maintenance personnel removed the flow switches and tested the fire protection systems, the facility managers removed the compensatory measures before they received approval from the Department of Energy (DOE).

Investigators determined the sprinkler systems were installed as wet-pipe systems in the 1970s and were converted to pre-action systems in 1980. Paddle-type flow switches are often installed in large sprinkler systems because they provide a zoned alarm that facilitates emergency response. At the time of the conversion, NFPA Standard 13 stated that paddle-type flow switches "should only be installed in wet systems." The word "should" indicated a recommendation that was advisable but not mandatory. Managers decided to retain the switches, but the decision was not documented.

Revisions to the NFPA Standard after 1980 changed the wording to "shall only be installed in wet systems," making this requirement mandatory. The change in the standard was driven by experience. The sudden surge of water in pre-action sprinkler systems during actuation could damage the flow switch, causing portions to break off and obstruct the piping. This type of failure can happen in any sprinkler system that has a normally empty or air-filled pipe, such as dry-pipe, deluge, or pre-action systems.

Investigators learned that the field walk-downs were limited in scope. The walk-downs were conducted only to support the designation as limited condition of operability systems for restart activities. The review of the pre-action systems did not include adherence to recent code changes and other significant discrepancies associated with system configuration. Although the drawings used in the walk-down process indicated the presence of the paddle-

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

type flow switches, the personnel performing the walk-downs failed to recognize the switches were a significant discrepancy that could impact system operability.

Recommendations from this lesson learned document included the following items.

- Subject matter experts should stay current on revisions to codes and standards and should evaluate changes for impacts on existing systems and facilities.
- Walk-downs, fire protection engineering assessments, and similar activities should incorporate specific instructions to review systems for significant discrepancies associated with system configuration that could affect system operability.
- Paddle-type flow switches should be removed from sprinkler systems that are normally empty or have air-filled piping to eliminate the potential for impact of the system operability. Subject matter experts should examine removed switches for missing parts. If parts are missing, an investigation must be conducted to locate the parts and ensure there are no obstructions.
- Personnel performing walk-downs, fire protection engineering assessments, and similar activities should be trained in and knowledgeable of the unreviewed safety question determination process, including the methodology for determination of an as-found condition.

### Idaho National Engineering and Environmental Laboratory

On June 4, 1998, at the Idaho National Engineering and Environmental Laboratory Central Facilities Area, Fire Protection personnel confirmed the presence of foreign matter inside the fire suppression system piping. Construction workers originally discovered the foreign material when they rerouted the piping system in the fall of 1997. They immediately notified the fire protection engineers. Facility operations personnel and a fire protection engineer removed 10 sprinkler heads for testing and discovered that 8 were partially obstructed and 2 were completely obstructed with a thick, oily substance. Obstructions in fire suppression system piping can render the system inoperable and may allow fires that result in excessive damage to facilities or endanger the lives of building occupants and allow radioactive material to be released into the environment.

Inspection of the foreign matter inside the sprinkler system piping indicated that the blockage might have been caused by cutting oils, sealing compound residue, or microbiological growth. Investigators determined that the sprinkler system was originally installed in the 1960s as a dry-pipe system and was converted to a wet-pipe system in 1978. They also determined that personnel performed periodic system testing as required by NFPA standards. The facility manager implemented 4-hour fire watches until the system was operable and that it was determined that similar conditions did not exist elsewhere on site.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Other Sites

Other occurrences involving fire sprinkler system blockage have been reported.

- On September 29, 1997, at Argonne National Engineering Laboratory-West, maintenance workers performing sprinkler system flow tests discovered that flow was prevented by a blockage caused by a rag left inside piping during construction.
- On March 30, 1995, at the Savannah River Site, fire department personnel determined that a sprinkler system had failed a blockage test. The blockage resulted from a build-up of a "soft mud-like material" in the sprinkler system. Investigators believed that this material was pipe preparation material residues left in the system during installation combined with microorganisms common to stagnant water systems.
- On November 4, 1994, at the Hanford Site, sprinkler system inspectors discovered an obstruction in a section of piping when they performed operability tests following system modifications. They disassembled the section and discovered that it was plugged with grit and scale. They did not identify the source of the grit and scale.
- On October 3, 1994, at the Rocky Flats Plant, fire department personnel discovered blockage in a reducer fitting in a sprinkler system. They cleared the "dirt" causing the blockage and conducted a flow test. They did not identify the source or physical characteristics of the "dirt."
- On April 23, 1993, at the Oak Ridge K-25 Site, fire system inspectors discovered plugged sprinkler system valves. The foreign material plugging the valves consisted of iron oxide and soil. Investigators determined that the iron oxide was the result of oxidation of the inside of the sprinkler pipes; the soil was carried into the sprinkler system by dirty fire water supply.

These occurrences underscores the importance of inspecting and testing fire protection sprinkler systems. NFPA 25, Inspection, Testing, and Maintenance of Water-based Fire Protection Systems, requires examining systems internally for obstructions where conditions exist that could cause obstructed piping, such as when fire pumps take their suction from open bodies of water. Systems should also be examined internally when obstructive materials are observed during maintenance or routine flow testing. Pipe inside diameters may also be reduced by pipe incrustation where the water supply contains lime or magnesia. Deep wells and water containing natural salts tend to corrode pipe interiors.

### DOE Office of Nuclear and Facility Safety

The Department of Energy's Office of Nuclear and Facility Safety (NFS) has reported events in which fire protection systems failed.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

- Weekly Summary 99-02 reported that fire protection engineers at the Argonne National Laboratory East determined that 11 of 12 sprinkler heads failed to operate when tested. The sprinkler heads failed to operate because of an inadequate O-ring seal. This caused a buildup of corrosion products on the exterior of the sprinkler that would render the valves inoperative during a fire or related event. All of the sprinklers exhibited signs of external corrosion. All of the failed sprinkler heads were Reliable Model "A" flush pendant sprinklers.
- Weekly Summaries 98-41, 98-12, and 97-49 reported other problems with malfunctioning sprinklers. These problems involved Omega fire sprinklers manufactured by Central Sprinkler Corporation. The Omegas feature O-rings in their design. The Central Sprinkler Corporation determined that nonactivation of the Omega sprinklers at low pressures is caused by reactions between an internal O-ring and residual hydrocarbons in the sprinkler system water from cutting oils or from improper use of stop-leak products. The Consumer Products Safety Commission required the manufacturer to recall the sprinklers. In June of 1996, Central Sprinkler changed the O-ring material from ethylene propylene diene monomer to silicone, eliminating the hydrocarbon reaction problem.

### **NRC Information Notice 99-07, “Failed Fire Protection Deluge Valves and Potential Testing Deficiencies in Pre-action Sprinkler Systems”**

On March 22, 1999, the NRC issued Information Notice 99-07, “Failed Fire Protection Deluge Valves and Potential Testing Deficiencies in Pre-action Sprinkler Systems.” The notice describes the failure of fire protection systems to perform their design functions at a commercial nuclear power plant. These failures resulted from poorly designed sprinkler system automatic control valves and associated solenoid valves, deficient maintenance, and inadequate valve testing. Since 1996, an NRC commercial nuclear power plant licensee has experienced failures of the Grinnell Model A-4 Multimatic valves. Although the licensee's root cause investigation team was unable to determine the root cause of the valve failures, NRC staff identified several potential problems.

In March 1996, during surveillance testing of pre-action sprinkler systems, the licensee found that 5 of 11 Grinnell Model A-4 valves failed to open when water pressure was vented from the diaphragm chamber. The licensee continued testing and identified more sprinkler system automatic control valves that also failed. A root cause team determined that the valve diaphragm was sticking to its retainer and push rod disk, the push rod showed wear, and the solenoid valves did not bleed water pressure from the diaphragm area, as designed. The team believes that abrasive cleaning of valve push rods and push rod guides inside the diaphragm retainers caused rust to form, which in turn caused the solenoid valve plunger assemblies to stick. Root cause team members also determined that actual fire protection system operating pressures exceeded solenoid valve design pressures and that the higher pressure may have prevented the valves from opening.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

In February 1998, the licensee discovered during surveillance testing that a pre-action sprinkler system valve had failed to trip open. The valve had been left in a tripped condition for approximately nine months. The licensee sampled six more valves that had also been in a tripped condition for long periods. They found that five of the six valves, as well as the original valve, had failed. In June 1998, as it was conducting another testing program, the licensee discovered a deluge valve that failed to open when manually actuated but that successfully operated after adjustments were made to its pull station housing.

NRC staff identified the following potential problems as a result of these failures.

- Valves that are left in a tripped condition for long periods and then reset may experience bonding of the valve diaphragms to the push rod flanges, preventing proper valve operation.
- Plant-supplied or -designed pre-action valve connections (for monitoring diaphragm chamber and main water supply pressures and for providing valve drainage and diaphragm chamber supply water) can result in undersized drains that restrict diaphragm chamber bleed-off and prevent valve actuation.
- High fire protection water supply system pressures may cause valve release mechanisms to jam because of valve indentations. Internal valve component cleaning and inspections should identify these problems.

NRC staff members also believe that valve actuation problems can be masked during full-flow testing if the deluge valves are isolated from the fire protection water supply and the diaphragm is bonded to the flange. This could allow partial blockage of the diaphragm chamber and inhibit valve actuation, even as the valve passes testing. However, if the deluge valves are not isolated from the water supply and the diaphragm is bonded to the flange, the valve would not actuate because of trapped water in the diaphragm chamber, allowing the bonding problem to be identified.

The NRC information notice illustrates the need for personnel to ensure that fire protection system testing methods are adequate to demonstrate system operability. When fire protection systems fail surveillance requirements or systems are not operationally maintained, appropriate compensatory measures must be taken. Facility managers should ensure that fire protection systems are installed, inspected, and maintained using NFPA standards.

**Note:** NFPA 25 states that deluge or pre-action valves shall be trip-tested annually at full flow in warm weather and in accordance with the manufacturer's instructions.

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### NFPA Fire Protection Handbook, Section 6, "Care and Maintenance of Water-based Extinguishing Systems"

The NFPA Fire Protection Handbook, Section 6, "Care and Maintenance of Water-based Extinguishing Systems," contains information on maintaining sprinkler system piping and discusses obstruction identification and system flushing. It also identifies the following eight categories shown in Table 2-2 that should be considered when inspecting sprinkler systems.

**Table 2-2. Considerations for Inspecting Sprinkler Systems**

Category	Consideration
<b>Absence of sprinklers</b>	Observe whether there is any room or building from which sprinklers have been omitted.
<b>Improper location of sprinklers</b>	Observe whether there are sprinklers under air ducts, shelves, benches, tables, overhead storage racks, platforms, or similar obstructions.
<b>Impact of adding pipe to the system with hydraulic calculations</b>	Check the calculations to ensure that current water pressure will suffice.
<b>Proper sprinkler clearance</b>	Ensure that sprinklers are not obstructed by piled-high stock, walls, or partitions (there must be a clear space of 18 inches below the sprinkler deflectors) and that installation guidelines have not been violated (refer to NFPA 13).
<b>Proper position of deflectors</b>	Determine that the distance of the deflectors from the ceiling or bottom of beams or joists conforms to NFPA 13.
<b>Proper pitch of dry-pipe systems</b>	Observe whether all pipes have the proper pitch to prevent collection and freezing of water in low points.
<b>Proper support of piping</b>	Observe whether any hangers are loose, any pipes are not properly supported, and pipes are not being used to support material or other items.
<b>Proper sprinkler installation</b>	Observe whether the sprinklers are installed in the positions for which they were intended. Note the type, design, year of manufacture, and date installed; check for proper temperature rating; check for corrosion and blockage; and check for coatings of paint.

### Building Standpipe Systems, NFPA 14

NFPA 14, Standard for the Installation of Standpipe and Hose Systems, provides the requirements for installing fire hose lines, when fire hose lines are required to meet the fire protection goals of the program.

At many sites, building fire hose lines are not installed because site emergency response personnel and fire departments prefer not to use "in-house" lines but would rather bring their own hoses for use in the fire. Some unique conditions may warrant the installation of hose

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lines, and these cases should be coordinated with the local fire department. Some codes require standpipes and/or hose lines to be installed in selected occupancies. When required, only the fire hose connections (without the hoses) are typically provided for fire department use to aid with manual firefighting efforts.

Management should ensure that the following are accomplished:

- ❑ The class of standpipe service provided for a facility is coordinated with the local fire department.

**Note:** This is a common problem.

- ❑ Standpipe systems are sized in accordance with NFPA 14.
- ❑ Building fire hose connections are conspicuously identified and access to them is maintained clear and unobstructed.
- ❑ Standpipes normally filled with water shall be protected against freezing by ensuring the water in the pipe is at or above 40°F.

### Types of Standpipe Systems

The four generally recognized types of standpipe systems are:

- ❑ A wet standpipe system, having the supply valve open and water pressure maintained at all times. This is the most desirable type of system.
- ❑ A dry standpipe system arranged to admit water to the system through manual operation of approved remote control devices located at each hose station. The water supply control mechanism introduces an inherent question of reliability which must be considered.
- ❑ A dry standpipe system in an unheated building. The system should be arranged to admit water automatically by means of a dry pipe valve or other approved device. The depletion of system air at the time of use introduces a delay in the application of water to the fire and increases the level of competency required to control the pressurized hose and nozzle assembly during the charging period.
- ❑ A dry standpipe system having no permanent water supply. This type would be used for reducing the time required for fire departments to put hose lines into action on upper floors of tall buildings. This type of system might also be used in buildings during construction when allowed in lieu of the wet standpipe system in unheated areas.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-3

INSTRUCTIONS: Answer the following questions. Answers are located in the answer key section of this module.



Match the type of sprinkler system in Column A to its characteristic in Column B.

#### Column A - Sprinkler System

#### Column B - Characteristic

- |                    |  |
|--------------------|--|
| 1. ____ Deluge     | A. A closed sprinkler system containing air that may or may not be under pressure, with a supplemental fire detection system installed in the same areas as the sprinklers. Actuation of the fire detection system opens a valve that permits water to flow into the sprinkler piping and to be discharged from any sprinklers that may be open. |
| 2. ____ Wet pipe   | B. A system employing automatic sprinklers installed in a piping system containing water and connected to a water supply. Water discharges immediately from sprinklers opened by a fire.   |
| 3. ____ Dry pipe   | C. A system employing automatic sprinklers installed in a piping system containing air or nitrogen under pressure, the release of which, as from the opening of a sprinkler, permits the water pressure to open a valve known as a dry-pipe valve. The water then flows into the piping system and out the opened sprinklers.                    |
| 4. ____ Pre-action | D. A system employing open sprinklers installed in a water supply through a valve that is opened by the operation of a fire detection system installed in the same areas as the sprinklers. When this valve opens, water flows into the piping system and discharges from all attached sprinklers.   |



## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

Complete the following questions.

5. What NFPA standard addresses the installation of sprinkler systems?
  
  
  
  
  
  
  
  
  
  
6. In the lessons learned from Y-12, paddle-type flow switches were discussed. What revisions to the NPFA Standard were made after 1980 because of problems with paddle-type flow switches?
  
  
  
  
  
  
  
  
  
  
7. What is a common problem that was found at Idaho National engineering and Environmental Laboratory and other sites in regards to fire sprinkler systems?
  
  
  
  
  
  
  
  
  
  
8. What action did the consumers Products Safety Commission require Central Sprinkler Corporation to do?
  
  
  
  
  
  
  
  
  
  
9. Name at least two potential problems identified by NRC staff in NRC Information Notice 99-07, "Failed Fire Protection Deluge Valves and Potential Testing Deficiencies in Pre-action Sprinklers Systems."

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

10. What does NPFA 25 state about the testing of deluge on pre-action valves?
  
  
  
  
  
  
  
  
  
  
11. List three considerations for inspecting sprinkler systems.
  
  
  
  
  
  
  
  
  
  
12. What is the NFPA Standard for installing fire hose lines?
  
  
  
  
  
  
  
  
  
  
13. The class of standpipe service provided for a facility should be coordinated with what organization?
  
  
  
  
  
  
  
  
  
  
14. How are standpipes normally filled with water protected against freezing?

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

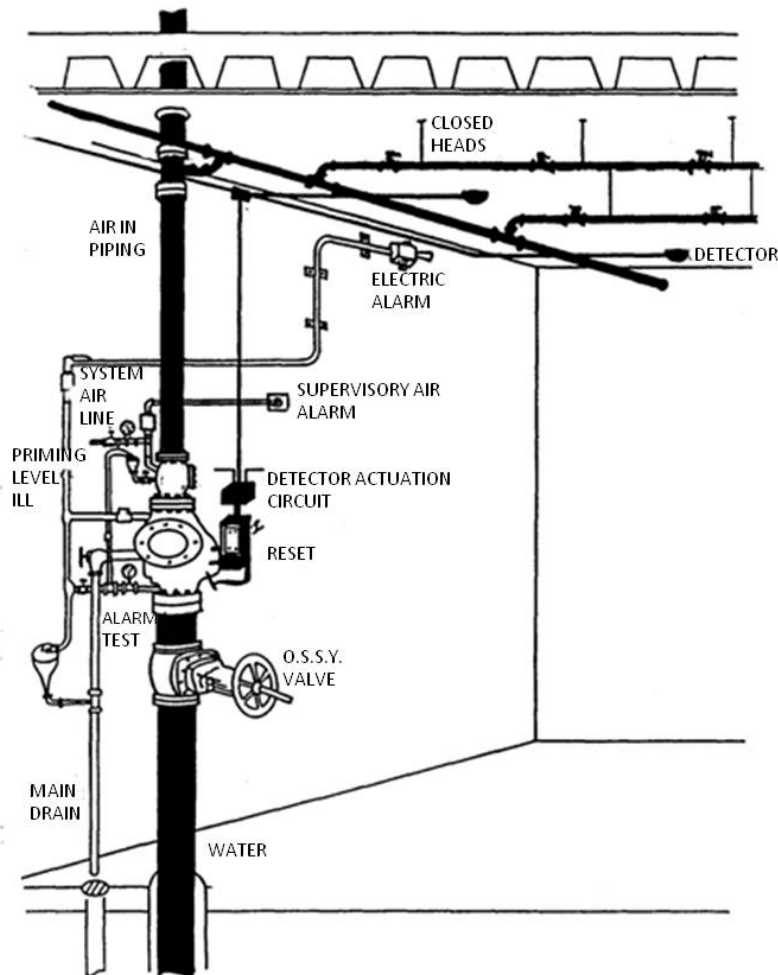
### Activity 3 – Identifying Sprinkler Systems

INSTRUCTIONS: Match the type of automatic sprinkler system with the figure that depicts the respective system. Answers are located in the answer key section for this module.



Match the type of automatic sprinkler system with the figure that depicts the respective system. Answers are located in the answer key section for this module.

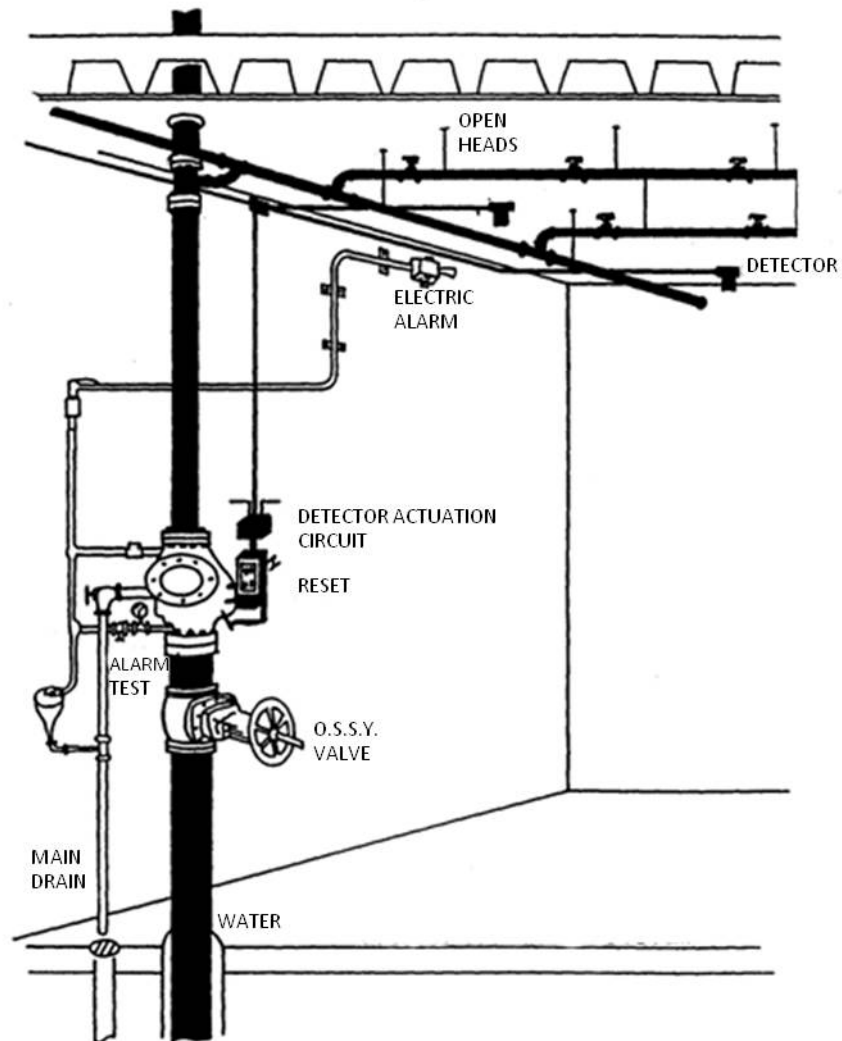
- A. Wet pipe      B. Dry pipe      C. Deluge      D. Pre-action



1. \_\_\_\_\_

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

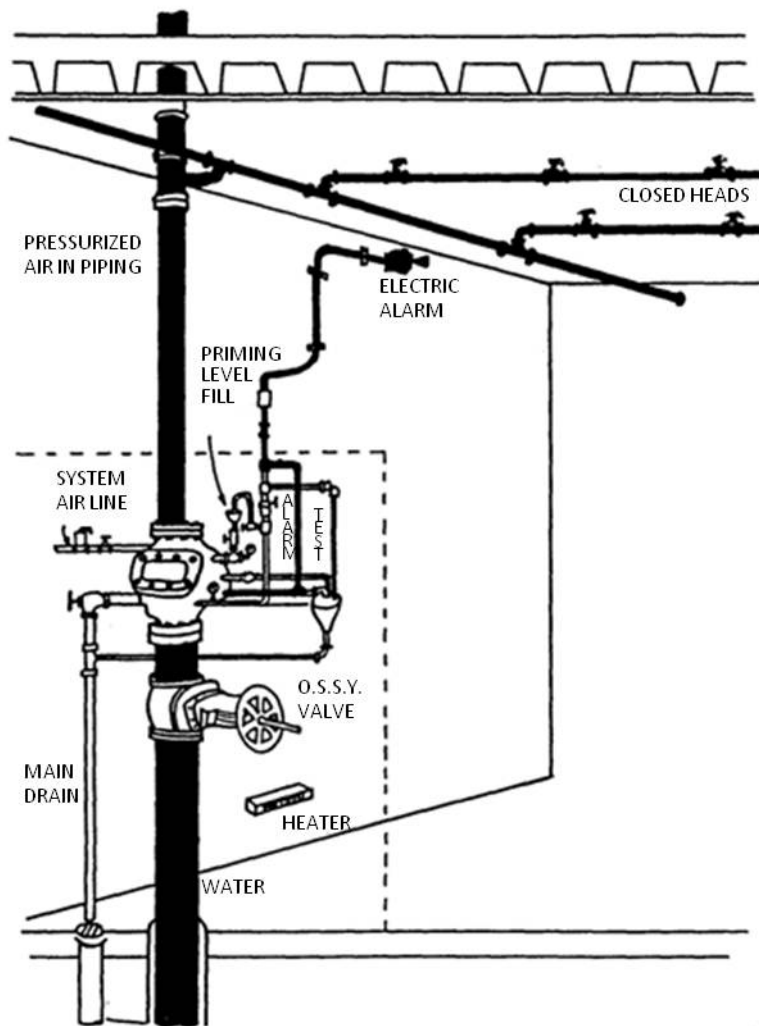
- A. Wet pipe      B. Dry pipe      C. Deluge      D. Pre-action



2. \_\_\_\_\_

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

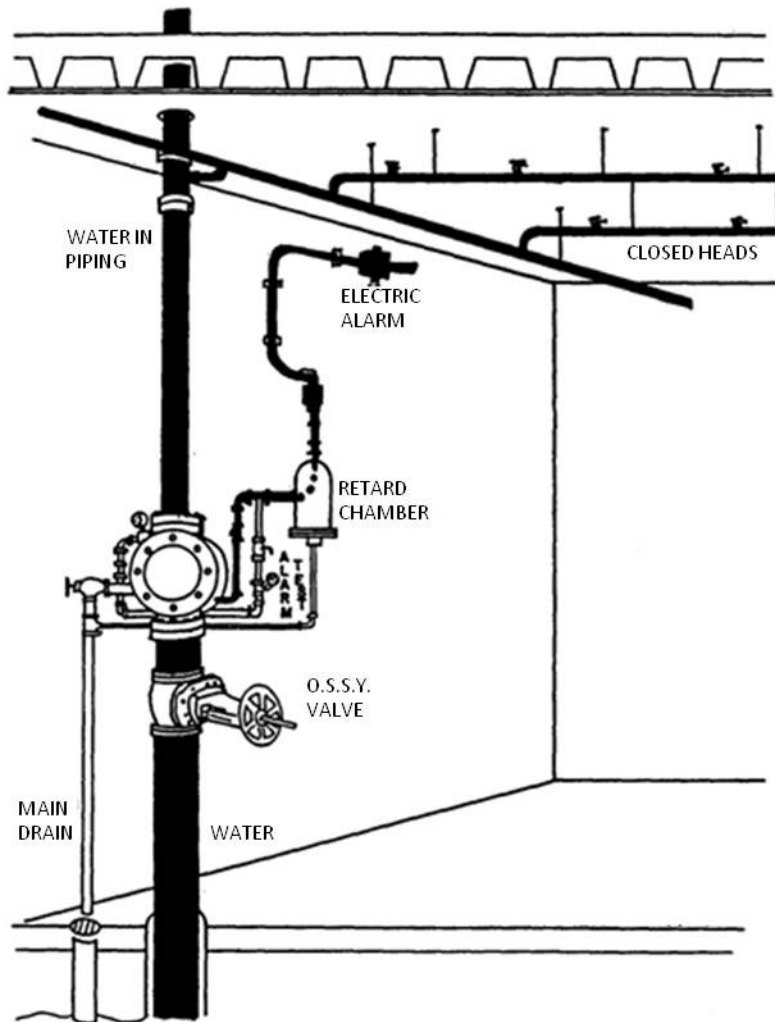
- A. Wet pipe      B. Dry pipe      C. Deluge      D. Pre-action



3. \_\_\_\_\_

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

- A. Wet pipe      B. Dry pipe      C. Deluge      D. Pre-action



4. \_\_\_\_\_



### Learning Objective

When you finish this section, you will be able to:

2.1.5 Determine the appropriate type of portable extinguisher for a specified fire.

## PORTABLE FIRE EXTINGUISHERS

Fire extinguishers are the first line of defense against incipient fires, and should be installed regardless of other fire control measures. Personnel expected to use extinguishers shall be educated annually.

### General Features of Fire Extinguishers

The general features of fire extinguishers are:

- ❑ Carrying handle/operating lever
- ❑ Locking pin
- ❑ Pressure gauge
- ❑ Discharge nozzle or horn
- ❑ Label that identifies the extinguisher type, operating instructions, and classification data

### Methods for Controlling Fires

Fire extinguishers use the following methods to control fires:

- ❑ Removes heat and lowers the temperature (quench).
- ❑ Separates the fuel from the oxygen (smother).
- ❑ Displaces the oxygen with an inert gas (smother).
- ❑ Chemically interrupt the combustion process (halon, dry chemical).

### Classes of Fire

Fire extinguishing agents are identified by the classes of fire that they effectively extinguish.

**Class A** Fire in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics. Water and halon are good agents for this class.

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- Class B** Fires in flammable liquids, oils, greases, tars, oil-base paints, lacquers, and flammable gases. Dry chemical, CO<sub>2</sub>, and halon are good agents for this class.
- Class C** Fires that involve energized electrical equipment where the electrical nonconductivity of the extinguishing media is of importance. Dry chemical, CO<sub>2</sub>, and halon are recommended agents for this class. However, in most cases by simply unplugging the equipment, the fire can be terminated. (When electrical equipment is de-energized, extinguishers for Class A or B fires may be used safely.)

**Note:** For cathode-ray tubes (CRTs) and other computer equipment, it is advisable to utilize a halon extinguisher rather than a CO<sub>2</sub> or dry chemical for the following reasons: CO<sub>2</sub> could cause the cathode ray tube to implode, creating a severe health hazard to the individual, and dry chemical agents will cause the equipment to be out of service for extensive cleaning to remove all traces of the chemical.)

- Class D** These extinguishing agents are for combustible metals such as zircalloy, plutonium magnesium, titanium, and aluminum; metalex is one of the few agents that has any effect on this class.

By knowing the classes of fires, fire extinguishers, and how to operate a fire extinguisher, employees are better prepared to handle fire emergencies that may arise. If a fire does occur, notify the fire department to ensure that it is out, or to provide assistance to determine the cause. Table 2-3 provides a brief description of fire extinguisher classes and their characteristics.

Class of Fire	Characteristics
Class A	Extinguish ordinary combustibles by cooling the material below its ignition temperature and soaking the fibers to prevent reignition. Use pressurized water, foam, or multipurpose (A:B:C-rated) dry chemical extinguishers.
Class B	Extinguish flammable and combustible liquids, greases or gases by depriving the fire of oxygen and inhibiting the chemical chain reaction. Foam, carbon dioxide, ordinary (B:C-rated) dry chemical, multipurpose dry chemical, and halon extinguishers may be used to fight Class B fires.
Class C	Extinguish energized electrical equipment by using an extinguishing agent that is not capable of conducting electrical currents. Carbon dioxide*, ordinary (B:C-rated) dry chemical, multipurpose dry chemical, and halon* fire extinguishers may be used to fight Class C fires.
Class D	Extinguish fires involving combustible metals, such as magnesium, titanium, zirconium, sodium, lithium, and potassium.



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It is not recommended to use water extinguishers on energized electrical equipment or combustible metal fires.

- \* Carbon dioxide or halon extinguishers are preferred in these instances because they leave very little residue. A:B:C dry powder residue is mildly corrosive to many metals. Aqueous film forming foam (AFFF) is recommended for flammable/combustible liquid type fires due to the high flashback properties.

### Fire Extinguisher Markings

Markings should be applied by decals that are durable and color fade resistant. The recommended marking system is a pictorial concept that combines the uses and nonuses of extinguishers on a single label. See Figure 2-12.

**Color Separation Identification** (Picture symbol objects are white; background borders are white.)

Blue	background for "YES" symbols
Black	background for symbols with slash mark ("NO") class of fire symbols and wording
Red	slash mark for black background symbols



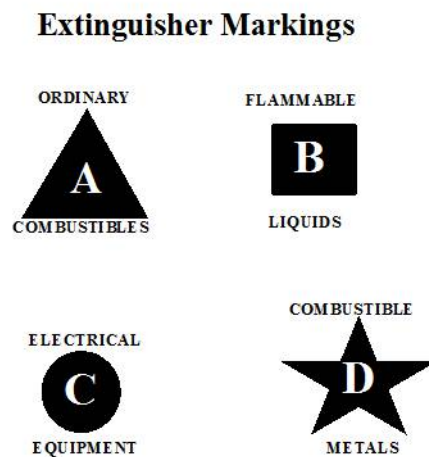
Figure 2-12. Fire Extinguisher Markings

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Letter-shaped Symbol Markings

- ❑ Extinguishers suitable for Class A fires should be identified by a triangle containing the letter "A." If colored, the triangle is colored green.
- ❑ Extinguishers suitable for Class B fires should be identified by a square containing the letter "B." If colored, the square is colored red.
- ❑ Extinguishers suitable for Class C fires should be identified by a circle containing the letter "C." If colored, the circle is colored blue.
- ❑ Extinguishers suitable for fires involving metals should be identified by a five-pointed star containing the letter "D." If colored, the star is colored yellow.

Extinguishers suitable for more than one class of fire should be identified by multiple symbols placed in a horizontal sequence. See Figure 2-13.



**Figure 2-13. Extinguisher Markings**

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### HOW TO IDENTIFY THE PROPER FIRE EXTINGUISHER

All ratings are shown on the extinguisher faceplate. Some extinguishers are marked with multiple ratings such as A:B, B:C, and A:B:C. These extinguishers are capable of putting out more than one class of fire.

Class A and B extinguishers carry a numerical rating that indicates how large a fire an experienced person can safely put out with that extinguisher.

Class C extinguishers have only a letter rating to indicate that the extinguishing agent will not conduct electrical current. Class C extinguishers must also carry a Class A or B rating.

### Types of Extinguishers

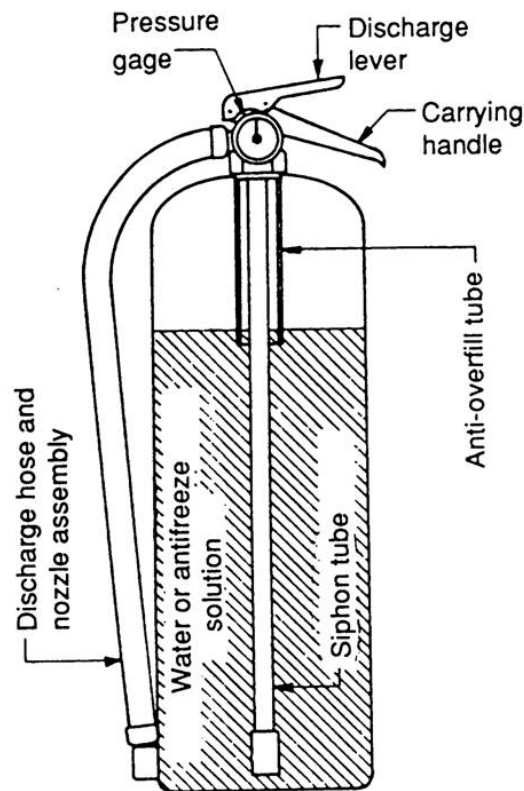
Portable fire extinguishers are classified for use on certain classes of fires and rated for relative extinguishing effectiveness at a temperature of 70°F (21.1°C) by testing laboratories.

The following are five main types of extinguishers and their uses:

1. Water-based
2. Dry chemical
3. Carbon dioxide
4. Halon
5. Dry powder

### Water Based Extinguishers

Water-based extinguishing agents include water, loaded stream, wetting agent, and foam. AFFF are for use on Class A fires only. Antifreeze, loaded stream, AFFF, and wetting agent all use water as a base to which chemicals are added to improve the extinguisher's performance. Both antifreeze and loaded stream models are specially treated to withstand low temperatures; the additive in loaded stream extinguishers is an alkali metal-salt solution. In wetting agents, a material is added to reduce the surface tension of the water so that it will spread and penetrate better. See Figure 2-14.



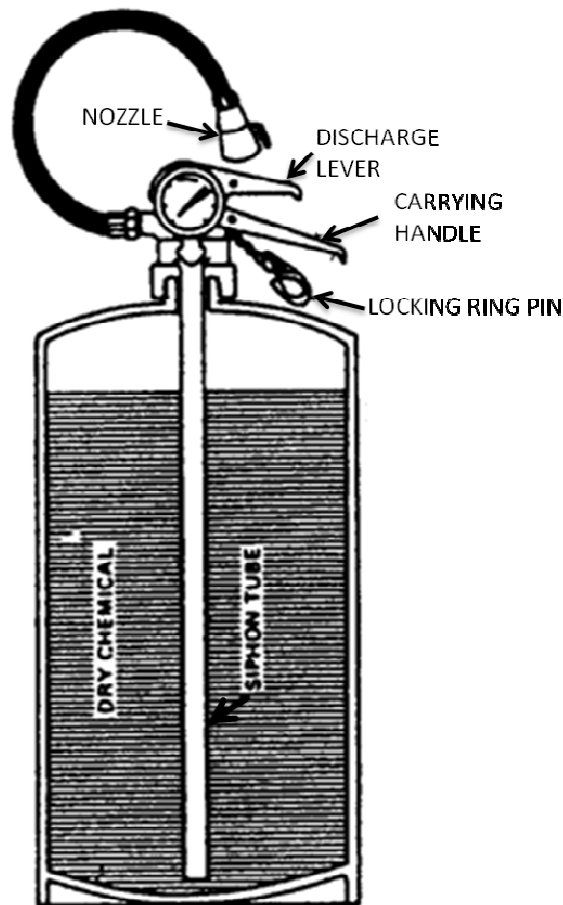
**Figure 2-14. Water Based Extinguishers**

Water-based extinguishers are used mainly on wood, paper, and trash. Do not use on chemicals, grease, electrical wiring, or computers. Never use on flammable liquids, except for AFFF extinguishers. Water extinguishers may spread the fire.

Water-based extinguishers have approximately a 60-second duration, may be used intermittently, and have a maximum range from 30 to 40 feet. Air pressurized water extinguishers work by cooling the fire.

### **Dry Chemical Extinguishers**

In 1961 manufacturers introduced a new kind of agent called "multipurpose dry chemical." It had the advantage of being 50 percent more effective than ordinary dry chemical on flammable liquid and electrical fires and also capable of extinguishing fires in ordinary combustibles. See Figure 2-15.



**Figure 2-15. Dry Chemical Extinguishers**

There are two basic kinds of dry chemical agents. Ordinary dry chemicals may be used on Class B:C fires, and include sodium bicarbonate, potassium bicarbonate, urea potassium bicarbonate, and potassium chloride base agents. Multipurpose dry chemicals may be used on Class A:B:C fires. An ammonium phosphate base agent is the only multipurpose dry chemical currently manufactured.

There are two basic designs of dry chemical extinguishers: one uses a separate pressurized cartridge to expel the agent, and the other pressurizes the agent chamber for the same purpose. The stored-pressure (rechargeable) type is the most widely used. It is best suited where infrequent use is anticipated and where skilled personnel with professional recharge equipment are available. By contrast, the cartridge operated type can be refilled quickly in remote locations without special equipment.

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A:B:C Dry chemical: mono-ammonium phosphate with a nitrogen carrier and other ingredients to keep it flowing.

Used on paper, trash, wood, liquid greases, and electrical wiring; not for computers or radio equipment.

B:C Dry chemical: basically baking soda with nitrogen carrier and other ingredients.

Used for liquid greases and electrical; not for paper, wood, or computers.

Operation is similar to water extinguishers, but technique is more critical because of the shorter range, 12 to 20 feet. Duration of 8 to 25 seconds. Works by blanketing the fire and interrupting the chemical chain reaction at fuel surface. Continue blanketing to prevent reignition after fire appears to be out. Reflash can be a problem.

### Carbon Dioxide Extinguishers

Carbon dioxide ( $\text{CO}_2$ ) is a compressed gas agent. See Figure 2-16. Though intended for use on Class B and C fires, it may be used on Class A fires until water or some other Class A rated agent can be obtained.

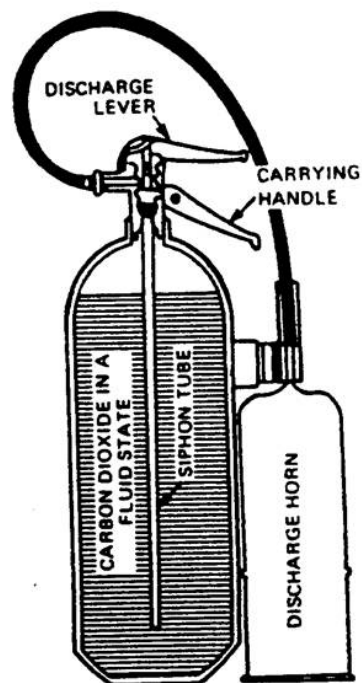


Figure 2-16. Carbon Dioxide Extinguishers

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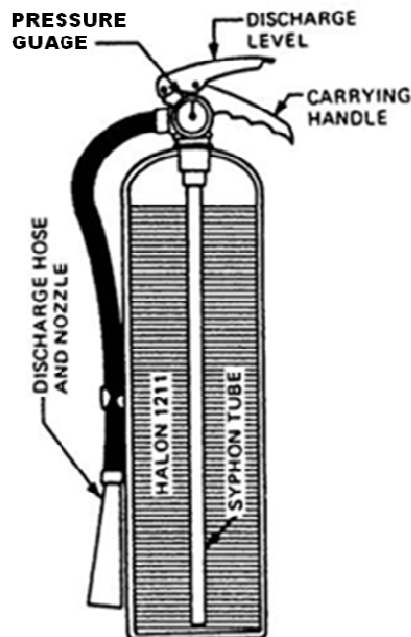
Carbon dioxide prevents combustion by displacing the oxygen in the air surrounding a fire. Its principal advantage is that it does not leave a residue, a consideration that may be important in laboratories, areas where food is prepared, or where there is electronic equipment. It is also very cold and has a refrigerating effect on the area around a fire. However, carbon dioxide extinguishers have a relatively short range because the agent is expelled in the form of a gas/snow cloud; they also are affected by wind or drafts.

If a carbon dioxide extinguisher is used in a confined or unventilated area, precautions should be taken so that people are not overcome from lack of oxygen.

CO<sub>2</sub> Good for chemicals, grease, electrical wiring, and computers, but not for wood, paper, or trash.

### Halon Extinguishers

In general, bromochlorodifluoromethane (Halon 1211) is similar to carbon dioxide by nature of being a "clean agent." Though intended for use mostly on Class B:C fires, Halon 1211 is effective on Class A fires. See Figure 2-17.



**Figure 2-17. Halon Extinguishers**

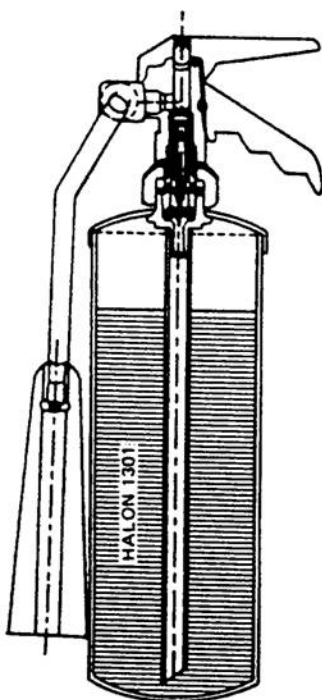
Halon 1211 leaves no residue, is virtually noncorrosive and nonabrasive, and is at least twice as effective on Class B fires as carbon dioxide, compared on a weight of agent basis. It also has about twice the range of carbon dioxide. Like carbon dioxide, it needs no cold weather

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protection. Though Halon 1211 does not have the cooling effect that carbon dioxide has, it is not affected by wind as much as carbon dioxide.

The chief disadvantage of Halon 1211 is its relative toxicity; inhalation of 4 percent to 5 percent for 1 minute is the maximum that can safely be inhaled. When Halon 1211 is used on a fire, the decomposition products include hydrogen chloride, hydrogen fluoride, hydrogen bromide, and traces of free halogens. Normally, only small quantities of these chemicals are formed, and as a warning of their presence, they give off acrid odors.

Halon 1301 extinguishers are rated only for small Class B:C fires and have a significantly less toxicity hazard. They are the preferred agent for total room flooding. Because of its low vapor pressure, the discharge stream of Halon 1301 is principally an invisible gas that may complicate effective application. See Figure 2-18.



**Figure 2-18. Halogenated Agent Extinguishers**

### Halogenated Agent Extinguishers

Halogenated agent extinguishers are also available containing a blend of Halon 1211 and Halon 1301. Halogenated agent extinguishers should be operated and applied to fires in the same general way that carbon dioxide extinguishers are applied. See Figure 2-18.

**Note:** New "clean agents" have been developed and presently being marketed as halon alternatives.



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### Other “Clean Agent” Extinguishers

Alternative fire suppressants to Halon are new generation “clean agent” gaseous suppression systems. These suppression systems offer low-toxicity and provide excellent fire extinguishing capability. NFPA Standard 2001 covers the design and installation of clean agent fire extinguishing systems.

#### Intergen

One of the agents on the market today is Intergen. Intergen is a mixture of three naturally occurring gases: nitrogen (52%), argon (40%), and carbon dioxide (8%). The mixture is slightly heavier than air and does not have a visible discharge. It extinguishes fire by reducing the oxygen level in the area to below 15% - the point at which most combustibles will no longer burn. The patented inclusion of CO<sub>2</sub> in Intergen protects anyone in the area from the effects of reduced oxygen levels. Intergen may be used for Class A surface burning, Class B flammable liquid, and Class C fires occurring within an enclosure by lowering the oxygen content below the level that supports combustion.

#### Argon Gas

Argon gas suppresses a fire similar to Intergen by lowering the oxygen content to about 12.5% . Argon is suitable for Class A, B, and C fires; is colorless and odorless and is electrically non-conductive.

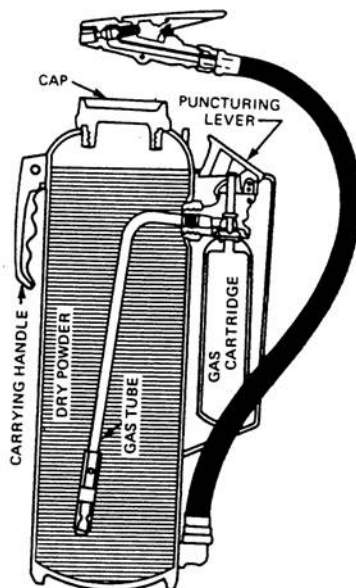
#### FM-200 and FE-227

These two clean agents are chemically known as heptafluoropropane, which are compounds of carbon, fluorine, and hydrogen that are effective on Class A, B, and C fires. They extinguish the fire by cooling at the molecular level and are the same class of compounds used in refrigerants. These agents are odorless, colorless, and electrically non-conductive and are considered safe for total flood applications.

The increased use of combustible metals (magnesium, sodium, lithium, etc.) established the need for a special agent to extinguish fires involving them. The designation "dry powder" was specifically chosen to indicate an agent's suitability for use on Class D (combustible metal) fires; the term "dry chemical" was reserved for agents effective on Class A:B:C or B:C fires.

### Dry Powder Extinguishers

Dry powder extinguishers are intended for use on Class D fires, which involve combustible metals. The agent, extinguisher, and method of application should be chosen according to the manufacturer's recommendations. See Figure 2-19.



**Figure 2-19. Dry Powder Extinguishers**

The agent may be applied to the fire from an extinguisher or with a scoop and shovel, depending on the type of both agent and metal. In any case, the agent should be applied so that it covers the fire and provides a smothering blanket. More agent may be necessary on hot spots. Care should be taken not to scatter the burning material, and it should be left undisturbed until it has cooled.

If there is a fire in finely divided combustible metal or combustible metal alloy scrap that is wet, or if such a fire is wet with water or water soluble machine lubricants, the metal is likely to burn rapidly and violently. Such fires may become so hot that it is impossible to get close enough to apply an extinguishing agent. If burning metal is on a combustible surface, it should be covered with dry powder. Then a 1- or 2- inch (25 or 50 mm) layer of powder should be spread out nearby and the burning metal shoveled into it.

### **Combustible Metal Agents and Application Techniques**

A variety of metals burn, particularly those in finely divided form. Some metals burn when heated to high temperatures by friction or exposure to external heat; others burn from contact with moisture or in reaction with other materials. Because accidental fires may occur during the transportation of these materials, it is important to understand the nature of the various fires and the hazards involved.

The hazards involved in the control or complete extinguishing of metal fires include extremely high temperatures, steam explosions, hydrogen explosions, toxic products of combustion, explosive reaction with some common extinguishing agents, breakdowns of some extinguishing

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agents with the liberation of combustible gases or toxic products of combustion, and, in the case of certain nuclear materials, dangerous radiation. Some agents displace oxygen, especially in confined spaces. Therefore, extinguishing agents and methods for their specific application must be selected with care. Metal fires should not be approached without suitable self-contained breathing apparatus and protective clothing, unless the fire is enclosed in a glovebox.

Numerous agents have been developed to extinguish combustible metal (Class D) fires, but a given agent does not necessarily control or extinguish all metal fires. Although some agents are valuable in working with several metals, other agents are useful in combating only one type of metal fire. Despite their use in industry, some of these agents provide only partial control and cannot be considered actual extinguishing agents. Certain agents that are suitable for other classes of fires should be avoided for metal fires, because violent reactions may result (for example, water on sodium; vaporizing liquids on magnesium fires).

Certain combustible metal extinguishing agents have been used for years, and their success in handling metal fires has led to the designations "approved extinguishing powder" and "dry powder." These designations have appeared in codes and other publications where it was not possible to employ the proprietary names of the powders. These terms have been accepted in describing extinguishing agents for metal fires and should not be confused with the name "dry chemical," which normally applies to an agent suitable for use on flammable liquid (Class B) and live electrical equipment (Class C) fires. Class B extinguishing agents may not be safely applied to some combustible metal (Class D) fires. Other extinguishing agents discussed in this document have been used only experimentally in limited areas or at specific installations, and require much judgment in application.

The successful control or extinguishment of metal fires depends heavily upon the method of application, training, and experience. Practice drills should be held on the particular combustible metals on which the agent is expected to be used. Prior knowledge of the capabilities and limitations of agents and associated equipment is always useful in emergency situations. Fire control or extinguishment will be difficult if the burning metal is in a place or position where the extinguishing agent cannot be applied in the most effective manner. In industrial plant locations where work is performed with combustible metals, public fire departments and industrial fire brigades have the advantage of fire control drills conducted under the guidance of knowledgeable individuals.

### Approved Combustible Metal Fire Extinguishing Agents

A number of proprietary combustible metal extinguishing agents have been submitted to testing agencies for approval or listing. Others have not, particularly those agents developed for special metals in rather limited commercial use. Those extinguishing agents described as follows have been approved or listed for use on fires involving magnesium, aluminum, sodium, potassium, and sodium-potassium alloy. Information on extinguishing agents was obtained from the 20th Edition of the NFPA Handbook.

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### G-1 Powder

"Pyrene" G-1 powder is composed of screened graphitized foundry coke to which an organic phosphate has been added. A combination of particle sizes is used to provide good packing characteristics when applied to a metal fire. The graphite acts as a heat conductor and absorbs heat from the fire to lower the metal temperature below the ignition point, which results in extinguishment. The closely packed graphite also smothers the fire, and the organic material in the agent breaks down with heat to yield a slightly smoky gas that penetrates the spaces between the graphite particles, excluding air. The powder is nontoxic and noncombustible.

G-1 powder is stored in cardboard tubes or metal pails, and can be stored for long periods of time without deterioration or caking. It is applied to the metal fire with a hand scoop or a shovel. The packing characteristics of the powder prevent its discharge from a fire extinguisher.

The powder is applied by spreading it evenly over the surface of the fire to a depth sufficient to smother the fire. A layer at least 12.5 mm (½ in.) deep is recommended for fires involving fines of magnesium and magnesium alloys. Larger chunks of metal require additional powder to cover the burning areas.

Where burning metal is on a combustible surface, the fire should be extinguished by (a) first covering it with powder, (b) shoveling the burning metal onto another 25- or 50-mm (1- or 2-in.) layer of powder that has been spread out on a nearby noncombustible surface, and (c) adding more powder as needed.

G-1 powder is effective for fires in magnesium, sodium, potassium, titanium, lithium, calcium, zirconium, and hafnium, and has been recommended for special applications on powder fires in aluminum, zinc, and iron. It is listed by Underwriters Laboratories Inc. (UL) for use only on magnesium and magnesium alloys (dry fines and moist fines that are not moistened or wetted with water or water soluble cutting oils) and is approved by the Factory Mutual System (FM) for use on fires in magnesium, aluminum, sodium, potassium, and sodium-potassium alloy. When plans call for use of G-1 powder on those metals mentioned, practice fire drills should be held in advance. For fires of thorium, uranium, beryllium, or plutonium, G-1 powder can be effective in covering the fire to prevent its spread but will not extinguish these fires. The products of combustion of thorium, uranium, beryllium, and plutonium can be a health hazard, and precautions should be observed consistent with the usual procedures in combating fires in radioactive material.

### MetalGuard Powder

MetalGuard powder is identical to G-1 powder in composition and is simply a trade name variation.

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### Met-L-X Powder

This dry powder, with its particle size controlled for optimum extinguishing effectiveness, is composed of a sodium chloride base with additives. The additives include tricalcium phosphate to improve flow characteristics and metal stearates for water repellency. A thermoplastic material is added to bind the sodium chloride particles into a solid mass under fire conditions.

Met-L-X powder is noncombustible, and secondary fires do not result from its application to burning metal. No known health hazard results from the use of this agent. It is nonabrasive and nonconductive.

Stored in sealed containers or extinguishers, Met-L-X powder is not subject to decomposition or a change in properties. Periodic replacement of extinguisher charges is unnecessary. Extinguishers range from 14-kg (30-lb) portable hand units (carbon dioxide cartridge propellant), through 68- and 160-kg (150- and 350-lb) wheeled units, to 900 kg (2,000 lb) for stationary or piped systems. The wheeled units and piped systems employ nitrogen as the propellant.

The powder is suitable for fires in solid chunks (such as castings) because of its ability to cling to hot vertical surfaces. To control and then extinguish a metal fire, the nozzle of the extinguisher is fully opened and, from a safe distance (in order to prevent blowing the burning metal into other areas), a thin layer of agent is cautiously applied over the burning mass. Once control is established, the nozzle valve is used to throttle the stream to produce a soft, heavy flow. The metal can then be completely and safely covered from close range with a heavy layer. The heat of the fire causes the powder to cake, forming a crust that excludes air and results in extinguishment.

Met-L-X extinguishers are available for fires involving magnesium, sodium (spills or in depth), potassium, and sodium-potassium alloy (NaK). In addition, Met-L-X has been successfully used where zirconium, uranium, titanium, and powdered aluminum present serious hazards.

### Comparison of G-1 and Met-L-X Powder

Based upon their past usage and known value as extinguishing agents for metal fires, the two agents previously discussed (G-1 and Met-L-X powders) are the most notable.

### Na-X Powder

This powder was developed to satisfy the need for a low chloride content agent that could be used on sodium metal fires. Na-X has a sodium carbonate base with various additives incorporated to render the agent nonhygroscopic (does not absorb moisture) and easily fluidized for use in pressurized extinguishers. It also incorporates an additive that softens and crusts over an exposed surface of burning sodium metal. Na-X is noncombustible and does not cause secondary fires when applied to burning sodium metal above temperatures ranging from 649°C to 816°C (1,200°F to 1,500°F). No known health hazard results from the use of this agent on sodium fires, and it is nonabrasive and nonconductive.

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Stored in 23-kg (50-lb) pails, 14-kg (30-lb) hand portables, and 68- and 160-kg (150- and 350-lb) wheeled and stationary extinguishers, Na-X is listed by UL for fires involving sodium metal up to a temperature of 649°C (1,200°F). Na-X has been tested on sodium metal (spills and in depth) at fuel temperatures as high as 816°C (1,500°F). Stored in the supplier's metal pails and extinguishers, Na-X is not subject to decomposition, so periodic replacement of the agent is unnecessary.

### Training

An integral part of fire prevention training is hands-on fire extinguisher training. This training serves several purposes; it gives the trainee confidence in the ability to operate the extinguisher, it removes some of the fear associated with putting out the fire (the capability of the extinguisher), and it shows the trainee that extinguishers do work in putting out fires.

- ❑ Each workplace building must have a full complement of the proper type of fire extinguisher for the fire hazards present.
- ❑ Employees expected or anticipated to use fire extinguishers must be instructed on the hazards of fighting fire, how to properly operate the fire extinguishers available, and what sections to follow in alerting others to the fire emergency.
- ❑ Only approved fire extinguishers are permitted to be used in workplaces, and they must be kept in good operating condition. Proper maintenance and inspection of this equipment is required of each employer.
- ❑ Where the employer wishes to evacuate employees instead of having them fight small fires, there must be written emergency plans and employee training for proper evacuation.

### Installation and Maintenance

This section provides guidance on the responsibilities for the installation and maintenance of portable fire extinguishers. The scope of this section also requires compliance with NFPA 10, Standard for Portable Fire Extinguishers.

Management should ensure that the following are accomplished:

- ❑ The location and type of portable fire extinguisher are in accordance with the requirements of NFPA 10. The relocation of any portable fire extinguisher must be approved by fire protection engineering, or an appropriate safety reviewer.
- ❑ Portable fire extinguishers are inspected and maintained.
- ❑ Before purchase, portable fire extinguishers are approved by fire protection engineering, or an appropriate safety reviewer.
- ❑ Portable fire extinguishers are inspected monthly. If inspection forms are used, they should be maintained for one year and be available on request.

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- ❑ Portable fire extinguishers are within their hydrostatic test date and maintained in a fully charged and operable condition.
- ❑ Portable fire extinguishers are mounted on hangers or in cabinets, unless they are the wheeled types.
- ❑ Portable fire extinguishers that are provided for vehicles are mounted or secured to prevent physical damage to the extinguisher and injury to passengers.
- ❑ Portable fire extinguishers are conspicuously marked and identified.
- ❑ Portable fire extinguishers are not obstructed or obscured from view, and clear access to the portable fire extinguisher is maintained.
- ❑ Immediate corrective action is taken for portable fire extinguishers identified as having a deficiency (for example, empty, not mounted or missing, broken seal).

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-4

INSTRUCTIONS: Circle the correct response. Answers are located in the answer key section of this module.



1. The extinguishment of which class of fire is complicated by the danger of electrical shock?
  - A. Class A
  - B. Class B
  - C. Class C
  
2. Which type of extinguisher is used for Class A fires only?
  - A. Dry powder
  - B. Water
  - C. Carbon dioxide
  - D. Aqueous film forming foam
  
3. Why is a water extinguisher inappropriate for a flammable liquid fire?
  - A. Its limited range requires you to get too close to the fire.
  - B. Tank capacity is insufficient to put this type of fire out completely.
  - C. It may spread the fire.
  - D. Tank has an air aspirating nozzle.
  
4. Which type of extinguisher is used for metal Class D fires?
  - A. Dry powder
  - B. Water
  - C. Carbon dioxide
  - D. Aqueous film forming foam
  
5. Which of these powders are effective as extinguishing agents for metal fires.
  - A. A-1 and B-1
  - B. Goody's
  - C. Wet
  - D. G-1 and Met-L-X



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### Activity 4 – Type of Extinguishers

INSTRUCTIONS: Match the type of extinguisher in Column A to the class of fire in Column B. Answers are located in the answer key section of this module.



#### Column A - Type of Extinguisher

- \_\_\_ 1. Water-based
- \_\_\_ 2. Dry chemical
- \_\_\_ 3. Carbon dioxide (CO<sub>2</sub>)
- \_\_\_ 4. Halon
- \_\_\_ 5. Dry powder
- \_\_\_ 6. AFFF
- \_\_\_ 7. Multipurpose

#### Column B - Class of Fire

- A. Class A
- B. Class B
- C. Class C
- D. Class D

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**It's time to schedule a progress meeting with your administrator  
before you go any further**

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### Learning Objective

When you finish this section, you will be able to:

2.1.6 Identify potential fire concerns related to machining operations.

## MACHINING OPERATIONS OF COMBUSTIBLE MATERIALS

Machining operations include the methods used to shape, dimension, and finish metals. These methods include tool, electrical discharge, and electromechanical machining.

### Pyrophoric Metals

This section covers the pyrophoricity of combustible metals. Properties of various combustible metals are discussed as well as the conditions in which they become pyrophoric.

Nearly all metals will burn in air under certain conditions. Some are oxidized rapidly in the presence of air or moisture, generating sufficient heat to reach their ignition temperatures. Others oxidize so slowly that heat generated during oxidation is dissipated before the metal becomes hot enough to ignite. Certain metals, notably magnesium, titanium, sodium, potassium, lithium, zirconium, hafnium, calcium, zinc, plutonium, uranium, and thorium, are referred to as combustible metals because of the ease of ignition when they reach a high specific area ratio (thin sections, fine particles, or molten states). However, the same metals in massive solid form are comparatively difficult to ignite.

Some metals, such as aluminum, iron, and steel, that are not normally thought of as combustible, may ignite and burn when in finely divided form. Clean, fine steel wool, for example, may ignite. Particle size, shape, quantity, and alloy are important factors to be considered when evaluating metal combustibility. Combustibility of metallic alloys may differ and vary widely from the combustibility characteristics of the alloys' constituent elements. Metals tend to be most reactive when in finely divided form, and some may require shipment and storage under inert gas or liquid to reduce fire risks.

Hot or burning metals may react violently upon contact with other materials, such as oxidizing agents and extinguishing agents used on fires involving ordinary combustibles or flammable liquids. Temperatures produced by burning metals can be higher than temperatures generated by burning flammable liquids. Some metals can continue to burn in carbon dioxide, nitrogen,

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water, or steam atmospheres in which ordinary combustibles or flammable liquids would be incapable of burning.

Properties of burning metal fires cover a wide range. Burning titanium produces little smoke, while burning lithium smoke is dense and profuse. Some water-moistened metal powders, such as zirconium, burn with near explosive violence, while the same powder wet with oil burns quiescently. Sodium melts and flows while burning; calcium does not. Some metals (for example, uranium) acquire an increased tendency to burn after prolonged exposure to moist air, while prolonged exposure to dry air makes it more difficult to ignite.

The toxicity of certain metals is also an important factor in fire suppression. Some metals (especially heavy metals) can be toxic or fatal if they enter the bloodstream or their smoke fumes are inhaled. Metal fires should never be approached without proper protective equipment (clothing and respirators).

A few metals, such as thorium, uranium, and plutonium, emit ionizing radiation that can complicate fire fighting and introduce a radioactive contamination problem. Where possible, radioactive materials should not be processed or stored with other pyrophoric materials because of the likelihood of widespread radioactive contamination during a fire. Where such combinations are essential to operations, appropriate engineering controls and emergency procedures should be in place to prevent fires or quickly suppress fires in the event the controls fail.

Because extinguishing fires in combustible metals involves techniques not commonly encountered in conventional fire fighting operations, it is necessary for those responsible for controlling combustible metal fires to be thoroughly trained prior to an actual fire emergency.

### DOE and NFPA Standards

NFPA Standards provide design and operating requirements for storing, processing, and handling pyrophoric and combustible materials. The following NFPA Standards apply:

- ❑ NFPA 68, Explosion Venting
- ❑ NFPA 69, Explosion Prevention Systems
- ❑ NFPA 325M, Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids
- ❑ NFPA 480, Storage, Handling and Processing of Magnesium
- ❑ NFPA 481, Production, Processing, Handling and Storage of Tritanium
- ❑ NFPA 482, Production, Processing, Handling and Storage of Zirconium
- ❑ NFPA 651, Manufacture of Aluminum and Magnesium Powder

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In addition to NFPA, DOE Standards for fire protection apply; one of which is STD-1066-99, "Fire Protection Design Criteria." The Standard gives basic criteria for meeting DOE fire and life safety objectives for design and construction, and it contains fire protection guidelines for glovebox fire protection and filter plenum fire protection. Another Standard is DOE-STD-3020-97, "Specification for High Efficiency Particulate Air (HEPA) filters Used by DOE Contractors," which has specifications and testing requirements for HEPA filters used to protect personnel and the environment when installed in DOE nuclear facilities.

The following discusses the properties of various combustible metals, conditions in which they become pyrophoric, storage and handling practices, processing hazards, and methods of extinguishing fires involving these kinds of metals.

### **Zirconium and Hafnium**

#### Zirconium Properties

The combustibility of zirconium increases as the average particle size decreases, but other variables, such as moisture content, also affect its ease of ignition. In massive form, zirconium can withstand extremely high temperatures without igniting, whereas clouds of dust in which the average particle size is three microns have ignited at room temperature. Dust clouds of larger particle size can be readily ignited if an ignition source is present, and such explosions can occur in atmospheres of carbon dioxide or nitrogen as well as in air. Zirconium dust will ignite in carbon dioxide at approximately 621°C (1,150°F) and nitrogen at approximately 788°C (1,450°F). The depth of the dust layer and its moisture content are important variables for ignition. Spontaneous heating and ignition are also possibilities with scrap chips, borings, and turnings if fine dust is present. Layers of six-micron-diameter dust have ignited when heated to 190°C (374°F). Combustion of zirconium dust in air is stimulated by the presence of limited amounts of water (5 to 10 percent). When very finely divided zirconium powder is completely immersed in water, it is difficult to ignite, but once ignited it burns more violently in water than in air.

Massive pieces of zirconium do not ignite spontaneously under ordinary conditions, but ignition will occur when an oxide-free surface is exposed to sufficiently high oxygen concentrations and pressure. The explanation for this reaction is the same as that cited for a similar titanium reaction. Zirconium fires (like fires involving titanium and hafnium) attain very high temperatures but generate very little smoke.

Explosions have occurred while zirconium was being dissolved in a mixture of sulfuric acid and potassium acid sulfate. Zirconium has exploded during and following pickling in nitric acid, and also during treatment with carbon tetrachloride or other halogen-containing materials. Spontaneous explosions have occurred during handling of moist, very finely divided, contaminated zirconium scrap.

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### Hafnium Properties

Hafnium has similar fire properties to zirconium. Hafnium burns with very little flame, but it releases large quantities of heat. Hafnium in sponge form may ignite spontaneously.

Hafnium is generally considered to be somewhat more reactive than titanium or zirconium of similar form. Damp hafnium powder reacts with water to form hydrogen gas, but at ordinary temperatures this reaction is not sufficiently vigorous to cause the hydrogen to ignite. At higher temperatures, however, ignition of the hydrogen may be expected to proceed explosively.

### Storage and Handling

Special storage precautions are not required for zirconium castings because of the very high temperatures that massive pieces of the metal can withstand without igniting. Zirconium powder, on the other hand, is highly combustible; consequently, it is customarily stored and shipped in 3.78-L (one-gallon) containers with at least 25 percent water by volume. For specific details, refer to NFPA 482, Standard for the Production, Processing, Handling, and Storage of Zirconium.

Zirconium powder storerooms should be of fire-resistive construction equipped with explosion vents. Cans should be separated from each other to minimize the possibility of a fire at one can involving others and to permit checking of the cans periodically for corrosion. One plant handling zirconium has established the procedure of disposing of cans containing powder that have been on the shelf for six months.

### Process Hazards

In general, processing recommendations for zirconium and hafnium are the same. Handling of zirconium powder, whenever possible, should be under an inert liquid or in an inert atmosphere. If zirconium or hafnium powder is handled in air, extreme care must be used because the small static charges generated may cause ignition.

To prevent dangerous heating during machining operations, a large flow of mineral oil or water-base coolant is required. In some machining operations, the cutting surface is completely immersed. Turnings should be collected frequently and stored underwater in cans. Where zirconium dust is a byproduct, dust collecting equipment that discharges into a water precipitation type of collector is a necessity.

### Extinguishing Fires in Zirconium and Hafnium

Zirconium and hafnium fires can be extinguished in the same way. Fires exposing massive pieces of zirconium, for example, can be extinguished with water. Limited tests conducted by Industrial Risk Insurers have indicated that the discharge of water in spray form would have no adverse effect on burning zirconium turnings. When a sprinkler opened directly above an open drum of burning zirconium scrap, there was a brief flareup after which the fire continued to

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

burn quietly in the drum. When a straight stream of water at a high rate of flow was discharged into the drum, water overflowed and the fire went out.

Where small quantities of zirconium powder or fines are burning, the fire can be ringed with a Class D extinguishing powder to prevent its spread, after which the fire can be allowed to burn out. Special powders developed for metal fires have been effective in extinguishing zirconium fires. When zirconium dust is present, the extinguishing agent should be applied so that a zirconium dust cloud will not form. If the fire is in an enclosed space, it can be smothered by introducing argon or helium.

### Uranium

#### Properties

Uranium properties are discussed in Module 3.0 of this self-study course.

#### Extinguishing Uranium Fires

Uranium fires should not be approached without protective clothing and respirators unless the fire is enclosed in a glove box. The most effective agent for extinguishing uranium fires has been found to be magnesium oxide sand. Gloveboxes that contain pyrophoric forms of uranium should also contain an amount of magnesium oxide adequate for extinguishment. The burning uranium should be completely covered with the sand to as great a depth as possible. The magnesium oxide extinguishes the fire by providing a heat sink which cools the uranium and by providing a barrier that limits the availability of oxygen.

Argon is a very effective extinguishing agent, providing the oxygen content in the atmosphere is maintained at 4 percent or less. Above 4 percent oxygen, flooding with argon will not extinguish a uranium fire. This is an important point, since it is nearly impossible to reduce the oxygen content to 4 percent or less during argon flooding in most fume hoods. Argon may be used effectively to cool the burning uranium prior to application of the magnesium oxide sand.

Other agents have been tested for use on uranium fires; however, none have proven to be as effective as magnesium oxide. Typical foam or dry chemical agents are not effective extinguishing agents. Fusible salt agents have been shown to be effective on small-scale uranium fires. However, the expansion that accompanies the oxidation of uranium has caused the fusible salt coating to crack, allowing the uranium to reignite.

Water is generally acceptable for use as an extinguishing agent for fires involving uranium. In rare cases where criticality safety considerations preclude the introduction of moderators such as water, suitable alternative fire protection measures need to be incorporated into the facility design. Proper housekeeping that includes removal of combustibles from pyrophoric forms of uranium is the most important aspect of fire loss minimization.

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### Principal Fire Hazards of Machining Operations

The principal hazards common to machining operations are:

- ❑ Chip fires at the machine, where ignition is caused by the heat of metalworking, friction of the chip against the tool, or both.
- ❑ Spontaneous combustion of cuttings.
- ❑ Combustion of oxidizable coolant/lubricants.
- ❑ Fine particles that are either combustible or explosible.
- ❑ Reaction of certain metals with water or other agents that often results in the evolution of heat and explosible hydrogen.
- ❑ Combustion of pressurized hydraulic fluids used for the actuation of machine tools and/or their accessories.
- ❑ Combustion of oil vapors deposited on building structures.
- ❑ Combustion of oil saturated floors.

### Principal Sources of Ignition

During machining activities, the principal sources of ignition are:

- ❑ Smoking materials.
- ❑ Heat of cutting.
- ❑ Spontaneous oxidation.
- ❑ Hot particles from grinding, dressing of grinding wheels, and welding and cutting.
- ❑ Hot surfaces such as furnaces, torches, etc.
- ❑ Electrical sparking or arcing.
- ❑ Impact ignition of certain pyrophoric surface compounds that sometimes form during the earlier stages of fabrication. An example of this is magnesium nitride, which sometimes appears on the surface of castings and can explode under the impulse of a very minor impact.

### Cutting, Welding, and Open Flame Work

A cutting and welding permit program contributes significantly to safe operations and reduced incidents of fire.

Permits are issued for all cutting and welding activities. Appropriate safeguards, such as fire watchers, are in place in conjunction with cutting and welding activities.

Periodic inspections are conducted to verify that permitted activity is being performed in accordance with established procedures.



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### Management Responsibilities Related to Cutting and Welding Activities

This section provides guidance on the responsibilities for cutting and welding with electric arcs, oxygen-fuel gas flames, and other forms of hot work such as open flames, grinding, or brazing activities. This section also provides guidance in compliance with NFPA 51B and the applicable Compressed Gas Association publications.

Management and supervisors should ensure the following are accomplished:

- Cutting and welding are done by authorized personnel in designated cutting and welding areas (shops) to the greatest extent practical.
- Adequate ventilation is provided for all cutting and welding work.
- Torches, regulators, pressure-reducing valves, and manifolds are UL listed or FM approved.
- Oxygen-fuel gas systems (for example, oxygen or acetylene welders) are equipped with listed and/or approved backflow valves and pressure-relief devices.
- Eye protection and protective clothing are worn by all cutters, welders, helpers, and fire watchers, as appropriate. Workers adjacent to arc welding areas are protected from the rays by screens or shields.
- When cutting and welding are done outside of designated areas, the following actions are performed:
  - A permit is completed for each shift.
  - A continuous fire watch is maintained by trained employees. The fire watch should be stationary at the hazard area, and, in addition, a roaming watch should be provided when warranted. A fire is attacked only when obviously within the capability of the portable extinguisher.
  - A supervisor inspects the job site at least once before the start of each job and at least once every 24 hours until the completion of the job.
  - A supervisor determines the best location(s) for the fire watch and verifies that automatic fire protection is in service, that precautions taken are adequate, and that information on the permit is correct.
  - Combustible materials, equipment, or building surfaces within 20 feet of or below the work must be either covered with fire-resistant welding blankets, moved, or wetted down. Openings in ducts, tanks, or other confined spaces within 20 feet of the work are also covered or plugged. Fire-resistant welding blankets are used for electric arc operations instead of wetting the work down.
- Cutting or welding is prohibited in the following situations:
  - In areas while sprinkler protection is out of service.

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- ☐ In explosive atmospheres of gases, vapors, or dusts or where explosive atmospheres could develop from residues or accumulations in confined spaces (see bullet on confined spaces).
- ☐ On metal walls, ceilings, or roofs built of combustible sandwich-type panel construction or having combustible covering.
- ☒ Confined spaces, such as tanks, are tested to ensure that the atmosphere is not in excess of 10 percent of the lower flammable limit before cutting or welding in or on the tank. Tests are repeated as conditions warrant, once each shift as a minimum. Mechanical ventilation is continuous when cutting or welding in or on a confined space.
- ☒ When cutting or welding must be done on small tanks, piping, or containers that cannot be entered, they are cleaned, purged, and tested before starting the work. For work on combustible liquid, gas piping, or tanks, intermittent testing is done during the work and a Job Safety Analysis is provided.

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### Self-Check Questions 2-5

INSTRUCTIONS: Complete the following questions. Answers are located in the answer key section of this module.



1. Machining operations include what methods?
2. List four characteristics that must be considered when machining combustible materials.
3. What is the most effective agent for extinguishing uranium fires?

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4. List principal hazards common to machining operations.
5. What are the principal sources of ignition during machining activities?
6. Under what conditions is cutting or welding prohibited?



### Learning Objective

When you finish this section, you will be able to:

2.1.7 Determine the acceptable storage and usage methods for a flammable liquid or gas.

## PROCESSES INVOLVING FLAMMABLE AND COMBUSTIBLE LIQUIDS AND GASES

There are many combustible materials, including electrical equipment, oxidizing chemicals, fast-reacting or explosive compounds, and combustible liquids and gases, that present specialized fire safety and extinguishing problems.

### Class A Combustibles

Class A combustibles are common materials such as wood, paper, cloth, rubber, plastics, etc. Many fires involve cleaning and construction materials used in process areas.

Fires in any of these fuels can be extinguished with water, as well as other agents specified for Class A fires. They are the most common fuels to be found in nonspecialized operating areas of the workplace such as offices.

### Safe Handling of Class A Combustibles

Safe handling of Class A combustibles means:

- ❑ Disposing of waste daily.
- ❑ Keeping work area clean and free of fuel paths, which can spread a fire once it is started.
- ❑ Keeping combustibles away from accidental ignition sources such as hot plates, soldering irons, or other heat- or spark-producing devices, i.e. furnaces, calciners, column heaters, disolver trays.
- ❑ Keeping all rubbish, trash, or other waste in metal or metal-lined receptacles with tight-fitting covers when in or adjacent to buildings. (Exception: metal wastebaskets approved for such use, which are emptied each day, need not be covered.)

**Note:** Solvents are often used for cleaning contaminated areas and can react with other chemicals in waste bins, i.e. nitric acid, hydrogen peroxide.

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- ❑ Minimize the use of combustibles in any operation so that excessive amounts need not be stored.
- ❑ Management should make frequent inspections and checks for noncompliance with these rules in order to catch fires in the potential stage.

### Control of Combustibles

NFPA 1, Fire Prevention Code, provides the requirements for minimizing and controlling the use of combustible materials.

Management should ensure that the following are accomplished:

- ❑ Housekeeping inspections are performed monthly in their facilities to ensure equipment and materials are maintained in an orderly arrangement at all times.
- ❑ At least 18 inches vertical clearance is maintained between the top of storage and sprinkler head deflectors.
- ❑ Combustible materials are limited to the quantity required for current needs and are separated from ignition sources.
- ❑ Workroom floors are maintained clean and dry to the extent practicable.
- ❑ Noncombustible or fire retardant materials are used whenever possible.
- ❑ Combustible waste is collected in metal containers and provided with lids. (Lids are not required for office waste cans.)
- ❑ Combustible waste does not accumulate inside or adjacent to buildings.
- ❑ In nuclear facilities, wood, plastic, and paper materials are strictly limited for uses that are essential to the facilities operation and to uses that do not have a noncombustible substitute.

### Class B Materials

Class B materials are flammable and combustible liquids (including solvents, oils, greases, tars, paints, lacquers) and flammable gases. Flammable aerosols (spray cans) are also included here.

The use of water to extinguish Class B fires (by other than trained fire fighters) can cause the burning liquid to spread, carrying the fire with it. Liquid fires are usually best extinguished by excluding the air around the burning liquid. Generally, this is accomplished by using one of several approved types of fire-extinguishing agents, such as the following:

- ❑ Carbon dioxide
- ❑ AFFF
- ❑ A:B:C multipurpose dry chemical
- ❑ Halon 1301 (used in built-in, total-flood systems)
- ❑ Halon 1211 (used in portable extinguishers)

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Fires involving flammable gases are usually controlled by eliminating the source of fuel, that is, closing a valve. Extinguishing a flammable gas fire without securing the source may lead to an explosion. Systems should be designed with automatic shutoff or means to secure the supply from a safe distance. As a general rule, the lower the flash point of a liquid, the greater the fire and explosion hazard. It should be noted that many flammable and combustible liquids also pose health hazards.

**Note:** The flash point of a liquid is the minimum temperature at which it gives off sufficient vapor to form an ignitable mixture with the air near the surface of the liquid or within the vessel used.

It is the responsibility of the user to ensure that all Class B material are properly identified, labeled, handled, and stored. If assistance is required, contact the building manager/supervisor.

### Safe Handling of Class B Combustibles

Safe handling of Class B material means to:

- Use only approved containers, tanks, equipment, and apparatus for storage, handling, and use of Class B combustibles.
- Make sure that all containers are conspicuously and accurately labeled as to their use of Class B combustibles.

Class B liquids from tanks, drums, barrels, or similar containers should be dispensed only through approved pumps taking suction from the top or through approved self-closing valves or faucets.

Store, handle, and use Class B combustibles only in approved locations, where vapors cannot reach any source of ignition, such as heating equipment, electrical equipment, oven flame, mechanical, or electrical sparks.

Never clean with flammable liquids within a building except in a closed machine approved for the purpose.

Never store, handle, or use Class B material near exits, stairways, or other areas normally used for egress.

In rooms or buildings, store flammable liquids in excess of 10 gallons in approved storage cabinets or special rooms approved for the purpose.

Know the locations of the nearest portable fire extinguishers rated for Class B fires and how to use them.

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Never smoke, weld, cut, grind, use an open flame or unsafe electrical appliances or equipment, or otherwise create heat that could ignite vapors near any Class B materials.

### Flammable Liquids Cabinet Inspections

A regular program of fire prevention inspections interspersed with comprehensive fire protection engineering evaluations will facilitate the timely identification and mitigation of fire hazards.

Fire prevention inspections must be performed in accordance with established frequencies and scope. Noted deficiencies must either be corrected immediately or a written notice issued to the facility manager to identify required remedial action. Such notices should be tracked until corrective action has been completed.

### Compressed Gas Cylinders

This section provides the requirements for the storage, transportation, identification, and use of compressed gas cylinders. The design, use, and storage of compressed gas cylinders and systems should comply with the following standards as applicable:

- ☐ NFPA 50, Bulk Oxygen Systems at Consumer Sites
- ☐ NFPA 50A, Gaseous Hydrogen Systems at Consumer Sites
- ☐ NFPA 50B, Liquefied Hydrogen Systems at Consumer Sites
- ☐ NFPA 51, Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes
- ☐ NFPA 51A, Acetylene Cylinder Charging Plants
- ☐ NFPA 51B, Cutting and Welding Processes
- ☐ NFPA 52, Compressed Natural Gas Vehicular Fuel Systems
- ☐ NFPA 54, National Fuel Gas Code
- ☐ NFPA 58, Liquefied Petroleum Gas Code
- ☐ NFPA 59, Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants
- ☐ NFPA 59A, Production, Storage, and Handling of Liquefied Natural Gas
- ☐ Compressed Gas Association Publications

Management should ensure that the following are accomplished:

- ☐ Cylinders in transit or storage are provided with protective valve caps and secured in the upright position.
- ☐ All storage areas are clearly identified.



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- ☐ The storage of compressed gas cylinders within buildings should be limited to the quantity required for daily operations unless additional quantities are permitted by the applicable NFPA standard.
- ☐ The storage of compressed gas cylinders outside of buildings should be in accordance with the applicable NFPA standard.
- ☒ Flammable and oxidizing compressed gas cylinders are separated by 20 feet or with a minimum 5-foot-high, 30-minute fire-rated wall.
- ☒ Empty and full gas cylinders are segregated, and empty cylinders are tagged "empty."
- ☒ Compressed gas cylinders are not exposed to temperatures above 125°F and are protected from direct sun and weather elements.
- ☒ Compressed gas cylinders are identified regarding their contents; they are free of defects and are within their hydrostatic test date.
- ☒ Gases are not mixed or transferred from one compressed gas cylinder to another and are refilled only by trained personnel.
- ☒ Cylinders are not lifted by magnetic devices or by their protective caps. They must be secured to a cradle or platform and never dragged, dropped, or struck.
- ☒ Compressed gas cylinders do not come in contact with electrical circuits, open flames, or arcs.
- ☒ Compressed gas cylinders are not used for any purpose other than compressed gas containment.
- ☒ Gas is not used from compressed gas cylinders without approved reducing regulators.
- ☒ Connecting devices are free of oil, grease, and dirt and have threads corresponding to the cylinder valving.
- ☒ Valves must be closed when cylinders are transported, moved at sites, and connected for use.
- ☒ All devices used on compressed gas cylinders comply with the American National Standards Institute and Compressed Gas Association standards.
- ☒ All compressed gas manifolds are designed in accordance with the applicable NFPA standard.s

### Storage of Flammable and Combustible Liquids and Gases

The first requirement for the storage of flammable and combustible liquids is properly designed containers that are liquid-tight and from which release of vapors, if required, is carefully controlled. The containers range from large, upright outdoor storage tanks to millions of gallons (100,000 gallons equals 378 m<sup>3</sup>) capacity down through drums to small cans containing ounces of liquid.

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Tanks may be installed above ground, underground, or under certain conditions, inside buildings. Openings and connections to tanks, for venting, gauging, filling, and withdrawing, can present hazards if they are not properly safeguarded.

### Types of Storage

Storage tanks come in a variety of designs; however, they may be divided into three general categories of pressure design:

- Atmospheric tanks
- Low pressure storage tanks
- Pressure vessels

Pressure tanks and pressure vessels normally are used for vapor conservation purpose, particularly for liquids with high vapor pressures.

Above ground storage tanks are designed with consideration for the weight of the liquid to be contained and also for the added allowance of corrosion.

Underground tanks are designed to safely withstand the service to which they are subjected, including the pressure of the earth, pavement, or possible above ground vehicle traffic. Underground tanks are generally considered the safest form of storage.

Tanks designed for installation in fire resistant enclosures within buildings have the same metal thickness and design features as required for all tanks. Storage tanks inside buildings will vary, depending upon the class of liquid and the occupancy of the building.

Special storage buildings or rooms, and other rooms or portions of buildings where containers may be stored, should be designed to protect the containers from exposure to fires in other portions of the building. Specially designed metal storage cabinets are available for storing up to a total of 60 gallons (227 l) in small containers.

Outdoor drum storage should be located in such a manner as to reduce the spread of fire to other materials in storage or to other property. Areas used for drum storage should be kept free of combustibles and open flames, and smoking should be prohibited.

### **Further Guidance for Flammable and Combustible Liquids**

Guidance is provided in NFPA 30, Flammable and Combustible Liquids Code, NFPA 45, Standard on Fire Protection for Laboratories Using Chemicals, and NFPA 395, Standard for the Storage of Flammable and Combustible Liquids on Farms and Isolated Sites.

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Management should ensure that the following are accomplished:

- Users of flammable and combustible liquids are familiar with the hazard classification for the purpose of complying with this standard.
  - **Flammable Liquid.** A liquid having a closed cup flash point below 100°F (37.8 °C) and having a vapor pressure not exceeding 40 psia (2068 mm Hg) at 100°F (37.8 °C) shall be known as a Class I liquid.

Class I liquids shall be subdivided as follows:

- Class IA shall include those having flash points below 73°F (22.8 °C) and having a boiling point below 100°F (37.8 °C).
  - Class IB shall include those having flash points below 73°F (22.8 °C) and having a boiling point at or above 100°F (37.8 °C).
  - Class IC shall include those having flash points at or above 73°F (22.8 °C) and below 100°F (37.8 °C).
- **Combustible Liquid.** A liquid having a closed cup flash point at or above 100°F (37.8 °C).

Combustible liquids shall be subdivided as follows:

- Class II liquids shall include those having flash points at or above 100°F (37.8 °C) and below 140°F (60 °C).
  - Class IIIA liquids shall include those having flash points at or above 140°F (60 °C) and below 200°F (93 °C).
  - Class IIIB liquids shall include those having flash points at or above 200°F (93 °C).
- The following storage requirements are implemented.
    - In industrial facilities, not more than a 1-day supply of flammable or combustible liquid may be stored in a single fire area outside of an approved flammable liquid storage cabinet, or not more than 25 gallons of Class I liquids in containers and 120 gallons of Class IB, IC, II, or III liquids in containers outside of process equipment.
    - If quantities of liquids exceeding the above limits are required, they must be stored in approved flammable liquid storage cabinets.
  - When flammable liquid storage cabinets are used, not more than 120 gallons of Class I, II, and IIIA liquids are stored in the cabinet. Of this total, not more than 60 gallons may be of Class I and II liquids.

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- ❑ When flammable liquid storage cabinets are used, not more than three cabinets may be stored in a single fire area. In industrial facilities, additional cabinets (limited to a maximum group of three) may be stored in the same fire area, provided the groups of cabinets are separated by 100 feet.
- ❑ According to NFPA 30, paragraph 4-3.2, when flammable liquid storage cabinets are used, the vent openings must be sealed with properly fitted metal bungs; or when the cabinets are required to be vented, they must be vented to the outside.
- ❑ When storage quantities exceed that permitted, the liquids are stored in rooms or facilities complying with NFPA 30, for Flammable and Combustible Liquids Storage.
- ❑ All flammable and combustible liquids (except Class IIIB) in nuclear facilities are stored in approved flammable liquid storage cabinets, rooms, or buildings complying with NFPA 30.

**Note:** This requirement does not apply to laboratories.

- ❑ When dispensing from drums, the drums are equipped with UL-listed or FM-approved dispensing devices.
- ❑ When transferring liquids between conductive containers, the containers are bonded with a wire. The bonding wire or one of the containers must be grounded.
- ❑ Class IA and IB liquids may be stored in glass containers of not more than one gallon, if required for liquid purity or to avoid excessive corrosion of metal containers.
- ❑ Stored liquids should not obstruct corridors, aisles, or exit doors, and should not be stored in exit enclosures (for example, stairwells).
- ❑ When transferring Class I liquids in laboratories from containers of less than 5-gallon capacity, the transfer is made in one of the following manners:
  - ❑ With the use of a laboratory hood
  - ❑ In an area provided with ventilation to prevent the accumulation of a flammable vapor or air mixture exceeding 25 percent of the lower flammable limit
- ❑ When transferring Class I liquids in laboratories from containers of 5-gallon capacity or more, the transfer is made in one of the following manners:
  - ❑ From a separate area outside the building
  - ❑ In a separate, inside storage room that complies with the requirements of NFPA 30

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

- Mechanical ventilation that meets the following criteria is provided when transferring Class I liquids in non-laboratory areas:
  - The ventilation flow rate must be 1 cubic foot/min/square foot of floor area but in no case less than 150 cubic feet/min.
  - The intake and exhaust points must be within 12 inches of the floor and positioned at opposite sides or ends of the room.
  - A flow monitor or equivalent mechanism must be provided so an audible alarm will sound if the ventilation system fails.
- Combustible waste and residue is stored in closed, metal containers for daily disposal.
- Outdoor storage requirements comply with NFPA 30.

**Note:** Contact fire protection engineering for assistance.

- Inside storage rooms comply with NFPA 30.

**Note:** Contact fire protection engineering for assistance.

### HYDROGEN SYSTEMS

This section provides the design and operation requirements and responsibilities for the prevention of hydrogen fires where hydrogen is handled, stored, used in piping or in a process, discharged through valves into pressure containers, or flowing out of containers through nozzles. This section also provides guidance from the following standards:

- NFPA 50A, Gaseous Hydrogen Systems at Consumer Sites
- NFPA 50B, Liquefied Hydrogen Systems at Consumer Sites
- NFPA 77, Static Electricity
- 49 CFR 100-199, Transportation
- Compressed Gas Association Publications

Management should ensure that the following are accomplished:

- Gas or liquid hydrogen is stored in approved containers equipped with pressure relief devices.
- Piping, tubing, fittings, valves, gauges, and regulators in hydrogen systems are suitable for hydrogen service.

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- According to NFPA 50B, hydrogen storage of less than 50 gallons (3,000 cubic feet for gaseous H<sub>2</sub>) is permitted inside buildings other than in separate, specially designed buildings or rooms, but restrictions regarding flammable objects, electrical equipment, etc., in the vicinity apply.
- Storage containers, piping, valving, regulating equipment, and other accessories are readily accessible to authorized personnel and emergency fire department apparatus, and are protected against physical damage.
- Hydrogen systems are electrically bonded or grounded before discharging hydrogen.
- Legible instructions are maintained at locations that require operation of hydrogen equipment by the user.
- A qualified person is in attendance at all times when mobile hydrogen supply equipment is unloading hydrogen.
- Each hydrogen system installed is inspected annually and maintained by qualified personnel.
- Weeds or similar combustibles are not permitted within 15 feet of gaseous hydrogen system equipment or within 25 feet of liquefied hydrogen system equipment.
- Personnel using hydrogen and hydrogen equipment are provided documented training on the fire hazards associated with hydrogen; for example, the flames are practically invisible.

### BOILING LIQUID EXPANDING VAPOR EXPLOSION (BLEVE)

The phenomenon known as a Boiling Liquid Expanding Vapor Explosion (BLEVE) is the result of a liquid within a container reaching a temperature well above its boiling point at atmospheric temperature, causing a vessel to rupture into two or more pieces.

As an example, under a rapid heating, a tank containing pressurized liquid may fail, suddenly producing an explosive effect. The liquid in the tank absorbs energy from the surrounding fire and heats up rapidly. The resulting increased rate of vaporization produced increases the ullage pressure, and when this pressure exceeds a certain limit (characteristic of the material properties of the tank wall, wall thickness and temperature), the tank fails. The liquid released from the tank boils rapidly and expands. The resulting explosion may fragment the tank into pieces and propel them over large distances. If the material is flammable, it may ignite and form a fireball posing additional hazard.

Most liquefied gas BLEVEs that involve container failure result from fire exposure. A few BLEVEs have occurred due to container failures from other causes, such as corrosion or impact from an outside force.

The size of a BLEVE basically depends upon the weight of the container pieces and upon how much liquid vaporizes when the container fails. Most liquefied gas BLEVEs occur when

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containers are from slightly less than 1/2 to about 3/4-full of liquid. Fireballs several hundred feet in diameter are not uncommon. A basic BLEVE safeguard is to reduce the chances of fire exposure to the container. This safety measure applies to containers of liquefied and nonliquefied gases (compressed gases). Even though by definition nonliquefied gases are not subject to a BLEVE, they can still result in explosion due to fire exposure.

See photo below of a transportation accident involving hazardous substances (Figure 2-20).



Figure 2-20. BLEVE

### EXPLOSION PREVENTION SYSTEMS, NFPA 69

NFPA 69, Explosion Prevention Systems, provides standards to be applied to the design, construction, operation, maintenance, and testing of systems for the prevention of deflagration explosions by means of the following methods:

- ☐ Control of oxidant concentration
- ☐ Control of combustible concentration
- ☐ Explosion suppression
- ☐ Deflagration pressure containment
- ☐ Spark extinguishing systems

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**Combustion** is the chemical process of oxidation that occurs at a rate fast enough to produce heat and usually light in the form either of a flame or glow.

**Deflagration** is the propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium.

**Detonation** is the propagation of a combustion zone at a velocity that is greater than the speed of sound in the unreacted medium.

**Explosion** is the bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration.

### Explosion Prevention Techniques

NFPA 69 recognizes five explosion prevention techniques that are grouped into two classes. One class is based on preventing combustion; the other is based on preventing or limiting damage after combustion occurs.

#### Methods Based on Preventing Combustion

- ☐ Oxidant concentration reduction
- ☐ Combustible concentration reduction

#### Methods Based on Limiting or Preventing Damage

- ☐ Explosion suppression
- ☐ Deflagration pressure containment
- ☐ Spark extinguishment systems

In general, explosion prevention systems are used to protect processing, storage, and materials handling equipment. When explosion prevention techniques are applied to rooms, buildings, or other enclosures where personnel may be present, consideration should be given to the safety of the personnel.

Furnaces use flame curtains and flames to burn off excess H<sub>2</sub>. Calciners use nitrogen or air to prevent H<sub>2</sub> from being released. Flame is not used to burn off H<sub>2</sub> releases. A common fire safety feature is a H<sub>2</sub> detector.

### LIGHTNING PROTECTION, NFPA 780

NFPA 780, Lightning Protection Code, provides guidance on the lightning protection requirements for ordinary structures; miscellaneous structures and special occupancies; heavy-duty stacks; and structures containing flammable vapors, flammable gases, or liquids that can give off flammable vapors.



### Fundamental Principles of Lightning Protection

The fundamental principle in the protection of life and property against lightning is to provide a means by which a lightning discharge can enter or reach the earth without resulting damage or loss.

Parts of structures most likely to be struck by lightning are those that project above surrounding parts such as lighting and meteorological stations, chimneys, ventilators, flagpoles, towers, water tanks, spires, steeples, deck railings, shafthouses, gables, skylights, dormers, ridges, and parapets. The edge of the roof is the part most likely to be struck on flat-roofed buildings.

### Lightning Protection Systems

Lightning protection systems consist of three basic parts that provide the low impedance metal path required:

1. A system of air terminals on the roof and other elevated locations
2. A system of ground terminals
3. A conductor system connecting the air terminals to the ground terminals

Properly located and installed, these basic components assure that the lightning discharge will be conducted harmlessly between the air terminals and the ground terminals.

The best time to design a lightning protection system for a structure is during the planning phase, and the best time to install the system may be during construction. System components may be built in so as to be protected from mechanical displacement and environmental effects. In addition, aesthetic advantages may be gained by such concealment. It is generally less expensive to meet lightning protection requirements during construction.

**Note:** Periodic grounding maintenance should also occur.

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### Protection for Structures Containing Flammable Vapors, Flammable Gases, or Liquids That Can Give off Flammable Vapors

Certain types of structures used for the storage of liquids that can produce flammable gases are essentially self-protecting against damage from lightning strikes and need no additional protection. Metallic structures that are electrically continuous, tightly sealed to prevent the escape of liquids, vapors, or gases, and of adequate thickness to withstand lightning strikes are inherently self-protecting if grounded. Protection of other structures may be achieved by the use of air terminals, masts, overhead ground wires, or other types of protective devices.

The principles of lightning protection for structures containing flammable vapors and/or gases or liquids that can give off flammable vapors are:

- ☐ Liquids that can give off flammable vapors should be in essentially gas-tight containers.
- ☐ Openings where flammable concentrations of vapor or gas can escape to the atmosphere should be closed or otherwise protected against the entrance of flame.
- ☐ Structures and all appurtenances (for example, gauge hatches and vent valves) should be maintained in good operating condition.
- ☐ Flammable air-vapor mixtures should be prevented, to the greatest possible extent, from accumulating outside of such structures.
- ☐ Potential spark gaps between metallic conductors should be avoided at points where flammable vapors may escape or accumulate.
- ☐ Alarm systems and electronics should be suitably isolated for protection.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-6

INSTRUCTIONS: Match the terms in Column A to the definitions in Column B. Answers are located in the answer key section of this module.



#### Column A

#### Column B

- |  |  |
|--|--|
| 1. ____ Class A combustibles   | A. A liquid having a closed cup flash point at or above 100° F (37.8 °C).  |
| 2. ____ Class B combustibles   | B. The propagation of combustion zone at a velocity that is less than the speed of sound in the unreacted medium.  |
| 3. ____ Flammable liquid   | C. The bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration.   |
| 4. ____ Combustible liquid   | D. Common materials such as wood, paper, cloth, rubber and plastics.   |
| 5. ____ Deflagration   | E. A liquid having a closed cup flash point below 100° F (37.8 °C) and having a vapor pressure not exceeding 40 psia (2068 mm Hg) at 100°F (37.8 °C) shall be known as a Class I liquid. |
| 6. ____ Explosion  | F. Flammable and combustible liquids (including oils, greases, tars, paints, lacquers) and flammable gases.  |
| 7. List the three general categories of pressure designed storage tanks. |  |

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

8. In industrial facilities, how much supply of flammable or combustible liquid may be stored in a single fire area outside of an approved flammable liquid storage cabinet?
9. All flammable and combustible liquids (except Class IIIB) in nuclear facilities are stored in what?
10. How should gas or liquid hydrogen be stored?
11. List the explosion prevention methods based on preventing combustion.
12. List the explosion prevention methods based on limiting or preventing damage.



### Learning Objectives

When you finish this section, you will be able to:

- 2.1.8 Identify safety equipment and applications related to ovens, boilers, and furnaces by classification.
- 2.1.9 Identify potential fire concerns related to stationary combustion engines.

### BOILERS, OVENS, AND FURNACES

Explosion and fire are the principal hazards of boilers, ovens, and furnaces, and their associated fuel supplies, pipes, ducts, and fans. Explosions are the result of the ignition of combustible mixtures of fuel and air that have accumulated in the confined spaces of the equipment. Generally such accumulations are the result of a malfunction or operator error associated with an inadequate or improper purge or incorrect operation of the burner equipment.

Combustion controls are part of the fire protection requirements for boilers, ovens, and furnaces.

Management should ensure that the following are accomplished:

- ☐ Boilers, ovens, and furnaces are designed in accordance with the applicable NFPA standards.
- ☐ The equipment is started using only the igniters designed for the equipment.
- ☐ All systems are provided with basic interlock systems to prevent improper operation of the equipment and to limit actions to those prescribed for the proper operating sequence.
- ☐ All systems are provided with automatic safety features that prevent the systems from approaching an undesirable or unstable operating condition.
- ☐ All interlock and automatic safety systems have audible and/or visual annunciation to indicate abnormal conditions.
- ☐ All interlock and automatic safety systems are placed on a regular testing schedule to ensure they function as intended. Report and correct any defects identified and document the repairs.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

- ☐ All equipment has normal and emergency operating sections in place, and the sections are reviewed regularly to ensure they are current.
- ☐ All operators receive formal training so they are prepared to operate the equipment safely and efficiently.

### Ovens and Furnaces Classifications

The standard for ovens and furnaces is identified in the following classification descriptions:

- ☐ Class A ovens or furnaces are heat utilization equipment operating at approximately atmospheric pressure, wherein there is a potential explosion and/or fire hazard that may be occasioned by the presence of flammable volatiles or combustible material processed or heated in the oven. Such flammable volatiles and/or combustible materials may, for instance, originate from paints, powder, or finishing processes, including dipped, coated, sprayed, impregnated materials, or wood, paper and plastic pallets, spacers, or packaging materials. Polymerization or similar molecular rearrangements and resin curing are processes that may produce flammable residues and/or volatiles. Potentially flammable materials, such as quench oil, waterborne finishes, cooling oil, etc., in sufficient quantities to present a hazard are ventilated according to Class A standards. Ovens may also utilize low-oxygen atmosphere to evaporate solvent.
- ☐ Class B ovens or furnaces are heat utilization equipment operating at approximately atmospheric pressure wherein there are no flammable volatiles or combustible material being heated.
- ☐ Class C furnaces are those in which there is a potential hazard due to a flammable or other special atmosphere being used for treatment of material in process. This type furnace may use any type of heating system and includes the special atmosphere supply systems. Also included in the Class C standard are integral quench and molten salt bath furnaces.
- ☐ Class D furnaces are vacuum furnaces that operate at temperatures above ambient to over 5000 F (2760 C) and at pressures below atmospheric using any type of heating system. These furnaces may include the use of special processing atmospheres.

The fuel gas or oil safety shutoff valve should be the "key unit" of all safety controls used to protect against the explosion or fire hazards that could result from accidental interruption to various services or operations, such as flame failure, failure of fuel pressure, failure of combustion air pressure, failure of exhaust or recirculation fans, excessive temperatures, or power failure.

Safety shutoff valves should automatically shut off the fuel to the burner system after interruption of the holding medium by any one of the interlocking safety devices. They should

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

be self-closing and not readily bypassed or blocked open. Safety shutoff valves should not be used as modulating temperature control valves.

### Cracked Ammonia Process Fire Concerns

Most NRC licensee furnaces use cracked ammonia ( $\text{NH}_3$ ) which produces high amounts of  $\text{H}_2$  during burning. The cracked ammonia process requires a high heat. The upper flammable limit of  $\text{H}_2$  is 74%, while the lower flammable limit is 4%. Most fire danger is where flammable gas is burning.

**Lower Flammable Limit (LFL).** The lowest percent concentration (by volume) of a flammable vapor or gas mixed in air that will ignite and burn with a flame. Lower flammable limit percentages of flammable liquids and gases can be found in NFPA 325M.

**Upper Flammable Limit (UFL).** The highest concentration (expressed in percentage of vapor or gas in the air by volume) of a substance that will burn or explode, when an ignition source is present. Theoretically, above this limit, the mixture is said to be too "rich" to support combustion. The range between the LFL and the UFL constitutes the flammable range or explosive range of a substance.

Proportions of air (oxygen) to hydrogen must not exceed 74% hydrogen and 26% oxygen. Flame is used to burn off the  $\text{H}_2$  released. If the  $\text{H}_2$  is not burned (that is, the flame is out), then the possibility of an explosion increases. A flame supervision system is needed to ensure the flame is burning.

### Classifications of Ovens and Furnaces

#### Incinerators

Incinerators should be separated from the remainder of the facility by fire barriers having a minimum 1-hour fire resistance rating.

Where the incinerator is required to burn radioactive contaminated waste, its exhaust should be ducted to a filtration system before release to the environment. The exhaust may also be ducted to the facility off-gas system. Such ducts should be designed to minimize deposition of particulate effluent and to facilitate cleaning.

Depending on the temperature of the exhaust, a cooling water spray or passage through a liquid precipitation separator may be required for both cooling and dust separation.

### Boilers and Boiler Furnaces

Boilers for the supply of steam for process operation and boiler furnaces should be separated from the remainder of the facility by fire barriers having a minimum 1-hour fire resistance rating.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

The construction and operation of the boiler furnaces should comply with the relevant standards in the NFPA 85 series, depending on the type of furnace and the fuel used.

The fuel storage tanks should be separated from the furnace area by fire barriers having a minimum 1-hour fire resistance rating. The fuel lines should be laid out to minimize possibility of damage.

### Stationary Combustion Engines

Stationary combustion engines, if located in part of a structure housing fuel processes, should be in enclosures having a fire resistance rating of at least one hour. These engines are often used to power generators and fire pumps.

Fuel storage tanks, except for day tanks, should be located outside the room and be constructed in accordance with NFPA 30, Flammable and Combustible Liquids Code. Unenclosed day tanks should be constructed and have capacities limited according to NFPA 37, Stationary Combustion Engines and Gas Turbines.

The engine exhaust system should be designed to prevent ignition of any combustible materials by contact with hot metal surfaces or by leaking exhaust gases or sparks.

The stationary combustion engine room should be ventilated effectively to minimize accumulation of combustible vapor and possibility of explosion. NFPA 37 provides guidance.

### Fire and Explosion Protection

The foundation of fire and explosion protection is prevention. Reliable equipment, good facility design, system monitoring and malfunction alarm instrumentation, operator training, and maintenance are key elements in preventing fires and explosions in burners, ovens, and furnaces.

Good facility design requires that the boiler be installed in a separate room or structure, preferably of noncombustible construction. Boilers and furnaces should be set on concrete floors or platforms that extend beyond the equipment for a distance of at least four feet (1.2 meter) in each direction. If they must be set on combustible floors, there should be sufficient air circulation beneath the furnace to keep the temperature of the combustible floor below 160° F (71 C).

Cleanliness and good housekeeping will also contribute to the prevention of fire and explosion. Automatic sprinkler or water spray systems are practical forms of fire protection in all boiler rooms.



## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-7

INSTRUCTIONS: Circle the correct answer to each of the questions below. Answers are located in the Answer Key section of this module.



1. All interlock and automatic safety systems for boilers, ovens, and furnaces should have to indicate abnormal conditions.
  - A. Trained operators
  - B. Adequate ducts
  - C. Audible and or visual communication
  - D. Testing twice a year
2. What is the "key unit" of all safety controls used to protect against the explosion or fire hazards resulting from accidental interruption of various services or operations?
  - A. Safety fuel shutoff valve
  - B. Fuel pressure switch
  - C. Ventilation safety device
  - D. Combustion air safety device
3. The fuel storage tanks should be separated from the furnace area by fire barriers having a minimum \_\_\_\_\_ fire resistance rating.

A. 1-hour	C. 3-hour
B. 2-hour	D. 4-hour
4. The stationary combustion engine room should be ventilated effectively to \_\_\_\_\_ the accumulation of combustable vapor and mitigate the possibility of explosion.
  - A. Cool
  - B. Prevent
  - C. Prohibit
  - D. Minimize

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

Match each oven and furnace classification in Column A to its respective characteristic in Column B.

### Column A - Classification

### Column B - Characteristic

- |                  |   |
|------------------|---|
| _____ 5. Class A | A. Vacuum furnace   |
| _____ 6. Class B | B. No flammable volatile or combustible material being heated   |
| _____ 7. Class C | C. Explosion-potential exists; ventilation and supervisory controls required to maintain flammable vapor content well below the lower flammable limit |
| _____ 8. Class D | D. Uses special processing atmospheres  |



### Learning Objective

When you finish this section, you will be able to:

2.1.10 Describe the use of compartmentation and isolation as a fire protection feature in building design.

### STRUCTURAL FIRE PROTECTION CRITERIA

Any materials with unusual fire characteristics, such as urethane foams, and any materials that develop significant quantities of toxic or harmful products of combustion, should not be used as interior finishes or other interior applications without the approval of the fire protection authority.

#### Type I Construction

The process buildings should be designed and constructed to qualify as Type I construction, as classified by NFPA 220, Types of Building Construction. This requires that the structural members of the buildings, including walls, columns, beams, girders, trusses, floors, and roofs, are constructed of approved noncombustible or limited combustible materials and have specified minimum fire resistant ratings. If nonprocess areas are housed in the same or adjoining buildings, the entire building complex should be of Type I construction.

To confine fire to its area of origin and prevent its spread, areas containing processes or materials involving fire hazards should be separated by structural barriers into fire areas. Structural barriers include walls, floors, ceilings, and roofs that bound fire areas and should have a minimum of 2-hour fire resistance rating, except for roof.

Openings in the barriers comprising boundaries of fire areas should have doors or fire stops installed. Such devices should have at least the same fire resistance rating as the barriers in which they are installed.

The building design should provide for safe means of egress for personnel in the event of a fire emergency. Egress routes should be clearly marked. NFPA 101, Life Safety Code, provides guidance on egress design and the requirements for protection of egress routes.

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### Electrical Wiring and Installations, NFPA 70

Electricity may cause a fire if it arcs or overheats electrical equipment. An electric arc may not only ignite combustible material in its vicinity; it may also fuse the metal of the conductor. Hot sparks from burning combustible materials and hot metal may be thrown about or fall, setting fire to other combustible materials. One common method of reducing the degree of hazard is to provide sufficient air circulation to prevent unsafe temperatures and premature breakdown of electrical insulation.

All electrical wiring and installations should be made, used, and maintained in accordance with NFPA 70, National Electrical Code, and other standards that apply to special situations, such as NFPA 70B, Electrical Equipment Maintenance; NFPA 70E, Electrical Safety Requirements for Employee Workplaces; NFPA 79, Industrial Machinery; and NFPA 75, Electronic Computer/Data Processing Equipment. Cable insulation is a primary fuel for fire propagation in a control room.

### Hazardous (Classified) Locations

Locations should be classified depending on the properties of the flammable vapors, liquids or gases, or combustible dusts or fibers that may be present, and the likelihood that a flammable or combustible concentration or quantity is present. (Where pyrophoric materials are the only materials used or handled, these locations should not be classified.)

NFPA 70, National Electrical Code, contains guidelines that are appropriate for determining the type and design of equipment and installation which provide protection from the hazards arising from the combustibility and flammability of vapors, liquids, gases, dusts, or fibers.

### Flame Spread

Exposed interior wall or roof installations, and any factory-installed facing material, should have a UL-listed/FM-approved flame spread rating of 25 or less.

Heating, ventilating, and air conditioning (HVAC) ducts should be noncombustible construction. Combustible ductwork carrying contaminants should not travel to clean areas. Fiberglass reinforced plastic (FRP) ducts may be acceptable in special situations; for example, in existing exhaust duct installations on a case-by-case basis.

### Compartmentation

Compartmentation is a design method for confining the effects of a fire to one area. The goals of compartmentation in confining a fire to the area of origin and are generally the following:

- Segregate a process with a higher level of fire hazard than that of the surrounding process. This is commonly found around rooms or suites used for storage, trash, flammable liquids, furnaces, laboratories, maintenance, painting, and other potential fire hazard areas; solvent extraction processes should be segregated.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

- ❑ Compartmentation also limits the size of the fire, which limits the amount of smoke that will be generated and facilitates fire suppression. When a single room is compartmented, there may be insufficient ventilation for a fire to fully develop.
- ❑ Compartmentation is also used to protect locations of high value or critical operations from a fire in the surrounding areas. Computer rooms, some control rooms, vaults, and record storage are often protected from a fire involving the rest of the building.

### Fire Barriers

A fire barrier is any surface that will delay or prevent an ignition into an adjacent space.

Barriers, such as partitions and floors, separate building spaces. These barriers also delay or prevent fire from propagating from one space to another. The major function of barriers is to prevent an ignition in the adjacent room. NFPA 101, Life Safety Code, and NFPA 90A, Installation of Air Conditioning and Ventilating Systems, provide best industry practices for building fire barriers.

Management should ensure that the following are accomplished:

- ❑ All modifications or additions that affect new or existing fire barriers are reviewed and approved by the appropriate safety reviewer.
- ❑ All fire barrier penetrations are provided with approved, through-penetration firestops and/or are protected by approved operable fire door(s), fire damper(s), or fire window(s) having the appropriate fire-resistance rating(s).
- ❑ Drawings are prepared for each building provided with fire barriers that show the location of all fire barriers.
- ❑ Changes or modifications to installed fire barriers should be controlled by administrative sections.
- ❑ Fire doors are identified and numbered.
- ❑ Fire doors are not chocked or blocked open.
- ❑ Security systems should not interfere with or affect the operation or integrity of fire doors (for example, latch mechanisms), fire dampers, fire windows, or other fire protection system components.
- ❑ Fire or smoke dampers are identified and numbered.
- ❑ Fire or smoke dampers are not blocked open.
- ❑ Inspection records of fire barrier penetration devices (fire doors and fire or smoke dampers) are maintained by the building administrator for auditing purposes.
- ❑ Immediate attention is taken to resolve any deficiencies that involve fire barrier impairments.

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Wall, floor and ceiling, and roof and ceiling assemblies should be tested and rated for their fire resistance by UL or similar nationally accredited testing laboratories, or should be listed for their fire resistance as approved by FM or similar organizations.

### Mechanical Equipment Rooms

Rooms used for storing mechanical equipment, filters, electrical equipment, and other sensitive equipment must be separated from other area of the building by fire-rated walls and doors. To maintain the integrity of these separations, the fire doors must never be left open.

Fan rooms house ventilation equipment that often includes automatic shut down and dampers activated by interlocking with the building smoke and fire detectors.

Fire dampers and other automatic shut-down provisions must not be disabled without proper approval. Mechanical equipment rooms and fan rooms must not be used for storage of any kind.

### Building Fire Exits

Each workplace building must have at least two means of escape, remote from each other, to be used in a fire emergency.

Exit routes from buildings must be clear and free of obstructions and properly marked with signs designating exits from the building.

The requirements and responsibilities for maintaining safe building exits are provided and are in compliance with NFPA 101.

Management should ensure that the following are accomplished:

- ❑ Every building exit and path to an exit is kept clear and unobstructed.
- ❑ Building exit doors are not locked and do not require more than one action to open.
- ❑ Exit doors are maintained in good operating condition.
- ❑ Material is not stored in stairwells or corridors of buildings.
- ❑ Emergency lights, exit signs, and other exit marking systems are maintained in good operating condition.
- ❑ Fire doors are not blocked open.
- ❑ Exit discharges including exterior building stairs are kept clean and unobstructed.
- ❑ Radiation barriers (for example, roped areas) do not affect egress routes.
- ❑ Security features are in compliance with NFPA 101.

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### Building Emergency Lights

The requirements and responsibilities for battery-operated and emergency-generator-operated emergency lighting systems are found in sections of NFPA 101, NFPA 70, and NFPA 110.

Management should ensure that the following are accomplished:

- All emergency light tests are documented and written records maintained.
- Emergency lights that are found deficient are repaired within 24 hours, or portable emergency lights are provided at the affected area(s) until the permanent lights are restored to service.
- Emergency lights are inspected during emergency light tests to verify the following:
  - Electrical cords are not damaged or frayed.
  - Lamps are not cracked or damaged.
  - Units are securely mounted.
  - Lamps illuminate within 10 seconds of switching to the backup power supply.

### Exit Corridors

Exit corridors must not be used for storage. The Life Safety Code, NFPA 101, requires that buildings designed for human occupancy must have continuous and unobstructed exits to permit prompt evacuation of the occupants and allow necessary access for responding emergency personnel. The intent of the code is to keep exits free from obstructions and clear of combustible materials. Attention to housekeeping, therefore, is very important.

"Temporary" storage of furniture, equipment, supplies, or anything else is not permitted in exit ways. Combustibles, including recyclable waste paper, are not permitted in exit ways. The code also requires that emergency lighting be provided for means of egress in certain areas.

Metal lockers with ends and tops ferried to the walls and that do not interfere with minimum exit-width requirements may be installed in exit corridors when approved by the fire department and the building manager/supervisor.

### Fire Doors and Fire Stops

Fire doors must not be blocked or locked to prevent emergency use when employees are within the buildings. Delayed opening of fire doors is permitted when an approved alarm system is integrated into the fire door design.

Automatic fire doors and dampers are provided at strategic points to close and block the spread of smoke and fire when these are sensed by automatic detectors.

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Automatic fire doors must never be blocked or left in disrepair so that they cannot close and latch automatically as intended in the event of a fire.

Self-closing fire doors are those doors designed and installed to close each time after being opened. They too must never be blocked, wedged, or tied open. If such doors must be kept open, the self-closers must be replaced with approved automatic smoke-activated release hold-open devices.

Fire spreads only rarely by breaching walls or floors. Usually it bypasses these physical barriers through openings created for people or utilities or through concealed spaces in walls, ceilings, attics, or under floors. These concealed spaces or voids are particularly dangerous, as they can act as flues through which a fire can burn or smoke can spread undetected.

Normal construction framing methods leave voids between members and membranes on each side of a wall. If these voids run the height of the building or connect with similar horizontal voids between floor and ceiling, hot gases and flames can spread to areas far from the area of origin. Firestops are blocks of solid construction at regular intervals in concealed spaces to restrict passage of fire and smoke.

### **Fire Hydrants**

Fire hydrants are maintained for emergency use. They must be kept accessible and in good working condition and an adequate number of hydrants must be provided.



## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-8

INSTRUCTIONS: Complete the following questions. Answers are located in the answer key section of this module.



1. Identify the fire protection standard for Type I construction that requires beams, girders, and trusses to be constructed of noncombustible or limited combustible materials.
  
  
  
  
  
  
  
  
  
  
2. To confine fire to its area of origin and prevent its spread, areas containing processes or materials involving fire hazards should be separated into \_\_\_\_\_.
  
  
  
  
  
  
  
  
  
  
3. Define compartmentation.
  
  
  
  
  
  
  
  
  
  
4. What are the goals of compartmentation?
  
  
  
  
  
  
  
  
  
  
5. Define fire barrier.
  
  
  
  
  
  
  
  
  
  
6. Storage of furniture, equipment, or supplies is permitted in exit corridors as long as it is temporary. True or False

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### Learning Objective

When you finish this section, you will be able to:

2.1.11 Identify the fire protection function of ventilation systems.

## VENTILATION SYSTEMS

Ventilation is an important fire fighting operation. It involves the removal of smoke, gases, and heat from building spaces.

Ventilation is the process of supplying or removing an atmosphere to or from any space by natural or mechanical means.

### Functions of Ventilation

Ventilation of building spaces performs the following functions:

- ❑ Contain airborne radioactive material inside the building.
- ❑ Protection of life by removing or diverting toxic gases and smoke from locations where building occupants must find temporary refuge.
- ❑ Improvement of the environment in the vicinity of the fire by removal of smoke and heat. This enables firefighters to advance close to the fire to extinguish it with a minimum of time, water, and damage.
- ❑ Supplies oxygen to the fire. Most of the time vent systems are automatically shut down.
- ❑ Control of the spread or direction of the fire by setting up air currents that cause the fire to move in a desired direction. In this way occupants or valuable property can be more readily protected.
- ❑ Provision of a release for unburned, combustible gases before they acquire a flammable mixture, thus avoiding a backdraft or smoke explosion.

### Ventilation Design

The ventilation system should be designed to isolate affected areas during fire accidents and to provide channels for exhausting fire products, through filters if necessary, to outside the plant. NFPA 90A, Installation of Air Conditioning and Ventilating Systems, provides guidance on ventilation design for fire protection. Design may involve access panels, moveable windows,

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skylights, or other means of readily opening spaces in case of a fire emergency.

Where a ventilation system is required to prevent the release of radioactive material to the atmosphere, all materials of construction and all filters for the system should be fire resistant. High efficiency particulate air (HEPA) filters should conform with Underwriters Laboratories Standard UL-586, also designated ANSI B 132.1, High Efficiency Air Filtration Units.

### Heat Removal

If a heat removal system such as a water spray system is required for the final filter plenum, it should operate automatically (with manual override) upon abnormal rise of the effluent temperature or at a set temperature.

### Heating Furnaces, NFPA 54 and NFPA 31

Heating furnaces should be installed in accordance with NFPA 54 (ANSI Z223), National Fuel Gas Code, if gas-fired, or NFPA 31, Oil-Burning Equipment, if oil-fired. The installation of electrical duct heaters should comply with NFPA 70, National Electrical Code.

### Maintenance for Ventilation, Exhaust, and Blower Systems

Routine maintenance through periodically inspecting and cleaning building ventilation, exhaust, and blower systems is needed to mitigate potential fire hazards. Maintenance should be identified and applied to ventilation systems (including intake and exhaust openings, plenums, etc.) for change rooms, exhaust and blower systems in laboratories, paint booths, metal and woodworking areas, and other similar areas where flammable or combustible vapors, residues, lint, and/or fibers accumulate. The applicable sections of the following NFPA standards provide guidance that addresses the maintenance of ventilation, exhaust, and blower systems:

- NFPA 90A, Installation of Air Conditioning and Ventilating Systems
- NFPA 90B, Installation of Warm Air Heating and Air Conditioning Systems
- NFPA 91, Exhaust Systems for Air Conveying of Materials
- NFPA 96, Installation of Equipment for the Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment
- NFPA 801, Recommended Fire Protection Practice for Facilities Handling Radioactive Materials

**Note:** Ducts with known radiological contamination are excluded from this standard, except where the potential fire hazard is severe.

See also the NRC Regulatory Guide 3.12, "General Design for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants," July 2008.

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### Glovebox Ventilation

Glovebox ventilation systems should be protected against fire. The glovebox ventilation should incorporate a downdraft design, that is, the ventilation inlet opening should be near the top of the box and the exhaust opening should be near the bottom of the box. The downdraft design should be used unless operational features dictate otherwise.

Glovebox primary exhaust openings should be provided with prefilters and fire screens to reduce vapor mist and fire propagation. The fire screens should be stainless steel screens (8 to 16 mesh) or a perforated stainless steel plate using the same mesh sizes. The screens should be installed at the primary exhaust openings.

Glovebox exhaust ventilation lines should be designed so each box has its own exhaust port that minimizes exposure to adjacent boxes during a fire. Single exhaust manifolds that connect an entire glovebox line should not be used.

Noncombustible materials should not be used for glovebox ventilation ducts (rigid and flexible) and insulation.

In addition, the following conditions help to prevent fires from spreading:

- Any fire door that is a part of the glovebox processes is normally closed. When the fire detection system on either side of the door senses a fire condition and the safety control system senses an object within the collision zone of fire door, closing of the door is prohibited by the safety control system until the collision zone is clear. Otherwise, the control system stops the process operations and ensures that the fire doors are closed.
- The fire dampers located in the ventilation exhaust of process rooms are capable of being manually closed, and ventilation supply is either automatic or manual.
- Process room ventilation exhaust will normally remain open during a fire, and confinement system (in the form of the High Depressurization Exhaust System) ensures that any potential releases caused by a fire are filtered. Filters with fire screens are provided at each exhaust outlet from process rooms containing gloveboxes to protect the final HEPA filters.
- Glovebox ventilation ducting should have with separation/isolation dampers or doors to minimize fire propagation.

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### LIFE SAFETY CRITERIA, NFPA 101

NFPA 101, Life Safety Code, provides guidance for ensuring the safety of personnel. Any security, radiological control, or other physical restrictions to prevent access to or egress from an area should not prevent emergency egress in the event of a fire or related condition. Size and arrangement of interior corridors should accommodate the following:

- Personnel traffic flow patterns
- Safety of building occupants
- Movement of equipment (including initial equipment installations, facility operations, and future replacement or removal)
- Ultimate decontamination and decommissioning of the facility including equipment required during decontamination

In those areas where an accidental breach of a primary confinement system could expose personnel to radioactive material, a distance of 75 feet, as measured by the method in the NFPA 101, should be the maximum travel distance to ensure that personnel can exit through the next confinement.

Doors that serve as exits from security areas should comply with NFPA 101 requirements. When security-related hardware is installed on a fire door, the modifications should not adversely affect the fire rating of the door.

### Hazardous Areas

When exemptions are granted to specific facility fire protection standards for reasons unique to the facility, as in the case of some containment structures, fire protection features should be provided so as to assure the life safety of facility occupants as required by the cognizant fire protection authority.

Hazardous areas, such as radioactive spaces or spaces with inert atmospheres, should have sufficient alarms and interlocks to assure that access by emergency personnel will not endanger such personnel or result in a public hazard.

Exit requirements for toxic and explosive environments should be as determined by the designated official. In addition, for explosive environments, exits should reflect the criteria consistent with the security of the facility.

A control room emergency lighting system should be automatically activated and immediately available for a stated minimum length of time on failure of the normal lighting system. The emergency lighting system for vital areas should be an electrically independent system that is not degraded by failure of the normal lighting system.

## **MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS**

### **Life Safety Inspections**

Employers need to provide an acceptable degree of life safety to personnel.

Periodic inspections are necessary to provide a comprehensive and technically valid assessment of the fire risks to a facility as well as an indication of existing deficiencies that would degrade life safety below acceptable levels. Periodic assessments are critical toward ensuring that existing fire safety features remain effective as facility occupancy changes occur.

Comprehensive fire protection assessments should be performed for all site facilities.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-9

INSTRUCTIONS: Complete the following questions. Answers are located in the answer key section of this module.



1. What is ventilation?
2. What are four functions of ventilation?
3. What is the primary characteristic required for ventilation systems used to prevent the release of radioactive material to the atmosphere?
4. Where a heat removal system such as a water spray system is required for the final filter plenum, when should it operate?
5. What is needed to mitigate potential fire hazards for ventilation, exhaust, and blower systems?



## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

6. Which design is needed for glovebox ventilation: updraft or downdraft?
  
  
  
  
  
  
  
  
  
  
7. According to NFPA 101 measurements, when in areas where an accidental breach of a primary confinement system could expose personnel to radioactive material, what should be the maximum travel distance to ensure that personnel can exit through the next confinement?
  
  
  
  
  
  
  
  
  
  
8. Why should hazardous areas, such as radioactive spaces or spaces with inert atmospheres, have sufficient alarms and interlocks?
  
  
  
  
  
  
  
  
  
  
9. What should be automatically activated and immediately available for a stated minimum length of time on failure of the normal lighting system?
  
  
  
  
  
  
  
  
  
  
10. What should be performed to ensure that existing fire safety features remain effective as facility occupancy changes occur?

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### SUMMARY

There are many concerns related to fire safety and fire protection. This lesson provides only an overview of some of the issues with which an inspector needs to become familiar. Some of the topics covered in the lesson are:

- ☐ Fire Detection and Alarm Systems
- ☐ Sprinkler Systems
- ☐ Portable Extinguishers
- ☐ Machining Operations of Combustible Metals
- ☐ Processes Involving Flammable and Combustible Liquids and Gases
- ☐ Boilers, Ovens, and Furnaces
- ☐ Structural Fire Protection Criteria
- ☐ Lightning Protection
- ☐ Ventilation Systems
- ☐ Life Safety

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**Schedule an appointment with your administrator before you go any further.**

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## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### ANSWER KEY

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## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-1

#### Column A - Type of Fire Defense System

- A. Active
- B. Passive

#### Column B - Elements

- 1. B
- 2. A
- 3. A
- 4. A
- 5. B
- 6. B
- 7. A

Fill in the blank answers.

- 1. An active fire defense system is defined as a device or action that receives a stimulus before acting in a real or a perceived fire condition.
- 2. A passive fire defense system is defined as a building component that remains fixed in the building whether or not a fire emergency exists.
- 3. Fire protection is a broad term that encompasses all aspects of dealing with unexpected fires, including building construction and fixed building fire features, fire suppression and detection systems, fire water supply systems, emergency process safety control systems, emergency fire fighting organizations, fire protection engineering, and fire prevention.
- 4. A fire suppression system is one that contains and extinguishes unexpected fires.
- 5. An effective fire detection system should detect the occurrence of fire and activate alarm systems so that personnel evacuation and fire containment and suppression measures may start promptly.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

6. The most common elements of a fire that can be detected are heat, smoke (aerosol particulate), and light radiation.
7. The four basic phases of fire development are: incipient, smoldering, flame, and heat.
8. A spot-diaphragm detector alarms when abnormal heat conditions reach the specific detector's location.
9. A thermostatic cable detector is considered an line- or area-type detector.
10. In general, heat detectors are designed to operate when heat causes a prescribed change in a physical or electrical property of a material or gas.
11. A heat detector is best suited for fire detection in a small confined space where a rapidly building high heat output fire is expected, in areas where ambient conditions would not allow the use of other fire detection devices, or where speed of detection is not a prime consideration.
12. All heat detectors using bimetal elements are automatically self-restoring after operation, when the ambient temperature drops below the operating point.
13. Flame detectors sense the radiant energy from combustion in the infrared and ultraviolet wavelengths.
14. Flame detectors are beneficial in areas where air currents that carry smoke may be unpredictable.
15. Smoke detectors are commonly used to protect areas of human occupancy, special high property value, and critical areas, such as computer and control rooms.
16. In areas where the ceiling has an extremely high point, such as in vaulted ceilings, the smoke detector should be mounted at or near the ceiling's highest point.
17. In order to reduce the susceptibility to false alarms, some ionization detectors use what is commonly referred to as a dual chamber detection method.
18. Light obscuration and photoelectric beam type detectors operate when a change in current results from the partial blocking of a light source by particulate matter (visible smoke).
19. Light-scattering or refraction type detectors contain a light source, a reflection chamber for the smoke to enter, and a light sensitive cell.
20. Maintenance of smoke detectors includes testing, replacing batteries, and cleaning.

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

21. Contrary to popular belief, the smell of smoke may not alert an individual. Instead, the poisonous gases and smoke produced by a fire can numb the senses and put one into a deep sleep.
22. The function of duct detectors is to detect smoke so that fans and dampers in air conditioning and ventilation systems can be controlled to prevent distribution of smoke and products of combustion throughout a building.
23. The extent and type of combustibles and the goal of the detection system must be evaluated to determine the type of detection devices that are most appropriate.
24. Detection systems do not extinguish fires.
25. Air sampling type smoke detection can be many times more sensitive than spot-type smoke detection.

### Activity 1: Detectors

1. E
2. C
3. A
4. B
5. D

### Self-Check Questions 2-2

1. B
2. D

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Activity 2: Alarm System Fundamentals

1. The four basic functions of a fire alarm system are to
  - 1) provide notification of fire alarm, supervisory, and trouble conditions;
  - 2) alert the occupants;
  - 3) summon appropriate aid; and
  - 4) control fire safety functions.
2. An evacuation signal notifies occupants to leave the building or area.
3. The primary power supply operates the fire alarm system under normal conditions.
4. An alert tone is used to warn building occupants of the pending transmission of a voice message.
5. The secondary power supply automatically supplies energy to the fire alarm system within 30 seconds when the primary power supply cannot provide the minimum voltage required for fire alarm system operation.
6. An alarm is a warning of fire danger.
7. The primary power supply must have an overcurrent protective device in an enclosed locker or sealed cabinet located immediately adjacent to the point of connection to the light and power conductors.
8. Fire alarm signals are initiated by devices activated by fire; supervisory signals indicate the need for actions related to guard tours or maintenance of related fire alarm systems.
9. The secondary power supply consists of one of the following three options:
  - 1) storage batteries;
  - 2) an automatic starting engine-driven generator with 4-hour capacity storage batteries;
  - 3) at least two generators, one with automatic start and one with pushbutton start.
10. An alarm signal is a signal indicating an emergency requiring immediate action.

### Self-Check Questions 2-3

#### Column A - Sprinkler System

  D   Deluge

#### Column B - Characteristic

A. A closed sprinkler system containing air that may or

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

  B   Wet pipe

  C   Dry pipe

  D   Pre-action

may not be under pressure, with a supplemental fire detection system installed in the same areas as the sprinklers. Actuation of the fire detection system opens a valve that permits water to flow into the sprinkler piping and to be discharged from any sprinklers that may be open.

- B. A system employing automatic sprinklers installed in a piping system containing water and connected to a water supply. Water discharges immediately from sprinklers opened by a fire.
  - C. A system employing automatic sprinklers installed in a piping system containing air or nitrogen under pressure, the release of which, as from the opening of a sprinkler, permits the water pressure to open a valve known as a dry-pipe valve. The water then flows into the piping system and out the opened sprinklers.
  - D. A system employing open sprinklers installed in a water supply through a valve that is opened by the operation of a fire detection system installed in the same areas as the sprinklers. When this valve opens, water flows into the piping system and discharges from all attached sprinklers.
- 5. NFPA Standard 13
  - 6. Don't install in dry systems.
  - 7. Obstructed pipes
  - 8. Recall millions of sprinklers
  - 9.
    - Valves that are left in a tripped condition for long periods and then reset may experience bonding of the valve diaphragms to the push rod flanges, preventing proper valve operation.
    - Plant-supplied or -designed pre-action valve connections (for monitoring diaphragm chamber and main water supply pressures and for providing valve drainage and diaphragm chamber supply water) can result in undersized drains that restrict diaphragm chamber bleed-off and prevent valve actuation.



## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

- High fire protection water supply system pressures may cause valve release mechanisms to jam because of valve indentations. Internal valve component cleaning and inspections should identify these problems.
10. NFPA 25 states that deluge or pre-action valves shall be trip-tested annually at full flow in warm weather and in accordance with the manufacturer's instructions.
  11. Any three of the following:
    - Absence of sprinklers
    - Improper location of sprinklers
    - Impact of adding pipe to the system with hydraulic calculations
    - Proper sprinkler clearance
    - Proper position of deflectors
    - Proper pitch of dry-pipe systems
    - Proper support of piping
    - Proper sprinkler installation
  12. NFPA 14, Standard for the Installation of Standpipe and the Systems
  13. The local fire department and fire brigade.
  14. By ensuring the water in the pipe is at or above 40°F.

### Activity 3: Identifying Sprinkler Systems

1. D
2. C
3. B
4. A

### Self-Check Questions 2-4

1. C
2. B
3. C
4. A
5. D

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Activity 4: Type of Extinguishers

1. A
2. A:B:C or B:C
3. B:C or A:B:C
4. B:C or A:B:C
5. D
6. A:B
7. A:B:C

### Self-Check Questions 2-5

1. The methods used to shape, dimension, and finish metals. These methods include tool, electrical charge, and electromechanical machining.
2. ANY 4 OF THE FOLLOWING:
  - Properties of the combustible metal
  - Conditions in which the metal becomes pyrophoric
  - Storage and handling practices of the combustible metal
  - Processing hazards related to the combustible metal
  - Methods of extinguishing fires involving the combustible metal
3. Magnesium oxide sand
4.
  - In areas while sprinkler protection is out of service
  - In explosive atmospheres of gases, vapors, or dusts or where explosive atmospheres could develop from residues or accumulations in confined spaces
  - On metal walls, ceilings, or roofs built of combustible sandwich-type panel construction or having combustible covering
5.
  - Chip fires at the machine, where ignition is caused by the heat of metalworking, friction of the chip against the tool, or both
  - Spontaneous combustion of cuttings
  - Combustion of oxidizable coolant/lubricants
  - Fine particles that are either combustible or explosible
  - Reaction of certain metals with water or other agents that often results in the evolution of heat and explosible hydrogen
  - Combustion of pressurized hydraulic fluids used for the actuation of machine tools and/or their accessories
  - Combustion of oil vapors deposited on building structures
  - Combustion of oil saturated floors

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

6.
  - Smoking materials
  - Heat of cutting
  - Spontaneous oxidation
  - Hot particles from grinding, dressing of grinding wheels, and welding and cutting
  - Hot surfaces such as furnaces, torches, etc.
  - Electrical sparking or arcing
  - Impact ignition of certain pyrophoric surface compounds that sometimes form during the earlier stages of fabrication

### Self-Check Questions 2-6

1. D
  2. F
  3. E
  4. A
  5. B
  6. C
- 
7.
    - Atmospheric tanks
    - Low pressure storage tanks
    - Pressure vessels
  8. Not more than a one-day supply, or not more than 25 gallons of Class I liquids in containers and 120 gallons of Class IB, IC, II, III liquids in containers.
  9. Approved flammable liquid storage cabinets, rooms, or buildings complying with NFPA 30.
  10. Gas or liquid hydrogen should be stored in approved containers equipped with pressure relief devices.
  11.
    - Oxidant concentration reduction
    - Combustible concentration reduction
  12.
    - Explosion suppression
    - Deflagration pressure containment
    - Spark extinguishment systems

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-7

1. C
2. A
3. A
4. D
5. C
6. B
7. D
8. A

### Self-Check Questions 2-8

1. NFPA 220, Types of Building Construction
2. Fire areas
3. A design method for confining the effects of a fire to one area.
4. Segregate a space with a higher level of fire hazard than the surrounding area. This is commonly found around rooms or suites used for storage, trash, flammable liquids, furnaces, laboratories, maintenance, painting, and other fire hazard areas.
5. Any surface that will delay or prevent an ignition into an adjacent space.
6. FALSE

## MODULE 2.0: FIRE PROTECTION FEATURES AND SYSTEMS

### Self-Check Questions 2-9

1. Ventilation is the process of supplying or removing an atmosphere to or from any space by natural or mechanical means.
2.
  - Protection of life by removing or diverting toxic gases and smoke from locations where building occupants must find temporary refuge. Low pressure storage tanks
  - Improvement of the environment in the vicinity of the fire by removal of smoke and heat. This enables firefighters to advance close to the fire to extinguish it with a minimum of time, water, and damage.
  - Control of the spread or direction of the fire by setting up air currents that cause the fire to move in a desired direction. In this way occupants or valuable property can be more readily protected.
  - Provision of a release for unburned, combustible gases before they acquire a flammable mixture, thus avoiding a backdraft or smoke explosion.
3. Fire resistant.
4. It should operate automatically (with manual override) upon abnormal rise of the effluent temperature.
5. Routine maintenance through periodically inspecting and cleaning is needed.
6. The glovebox ventilation should incorporate a downdraft design, that is, the ventilation inlet opening should be near the top of the box and the exhaust opening should be near the bottom of the box. The downdraft design should be used unless operational features dictate otherwise.
7. A distance of 75 feet.
8. To assure that access by emergency personnel will not endanger such personnel or result in a public hazard.
9. An emergency lighting system.
10. Periodic assessments.

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