CHAPTER 10.
FIRE PROTECTION EQUIPMENT AND SYSTEMS

10.1 Introduction
10.2 Classification of Fire and Construction Hazards
10.3 Planning for Fire Protection
10.4 Fire Safety Design
10.5 Fire Detection and Signaling Devices
10.6 Fire Alarm Systems
10.7 Fire Suppression Systems
10.8 Automatic Sprinkler Systems
10.9 Smoke Controls
10.1 Introduction

- A fire protection system includes: devices, wiring, piping, equipment, and controls to detect fire or smoke, to actuate signal, and to suppress the fire or smoke.

- Objectives of fire protection:
  1) Primary objectives: to save lives and protect property.
  2) Secondary objective: to minimize interruptions of service due to a fire.
Current trends in building design and modern lifestyles contributing to serious fire hazards:

1) **High-rise buildings**: Buildings become **taller** and more **densely** situated.

2) **Architectural design**: Larger areas and **open spaces**. Less separation walls.

3) **Controlled indoor environment**: Constructed of **fixed glass windows** instead of operable windows in order to **mechanically control** temperature, humidity and air quality and to minimize a **stack effect**.

4) **Increased use of combustible materials**: Furnishings, equipment, and decorative finishes made of materials such as **plastic and synthetics** are a source of **toxic gas** and smoke during a fire.
10.2 Classification of Fire and Construction Hazards

10.2.1 Classification of Fires (according to NFPA, U.S.A.)

- **Class A**
  - Fires of ordinary combustible materials such as wood, cloth, paper, rubber, and many plastics.

- **Class B**
  - Fires in flammable liquids, oils, greases, tar, oil-base paints, lacquers, and flammable gases.

- **Class C**
  - Fires that involve energized electrical equipment. Extinguishing medium must not be a conductor of electricity.

- **Class D**
  - Fires of combustible metals, such as magnesium, titanium, zirconium, sodium, lithium, and potassium.
10.2.2 Classification of Hazards

- **Light (low) hazard**: Locations where the total amount of Class A combustible materials is minor.
- **Ordinary (moderate) hazard**: Locations where Class A combustibles and Class B flammables are present in greater amounts than expected under light hazard occupancies.
- **Extra (high) hazard**: Locations with large quantities of highly combustible materials and conditions are such that fires could develop quickly with high heat release.

10.2.3 Type of Construction

- Building construction is divided into types 1 through 5.
- Type 1 construction is the most fire-resistant. Walls, partitions, ceilings, floors, roofs, structural system, and exit envelopes shall all be constructed of noncombustible material having at least the minimum fire resistance rating specified in the fire code.
10.2.4 Use or Occupancy (Construction Type)

- **Group A**: Assembly. Occupied by more than 1000 people (A-1), less than 1000 people, and other situations (A-3, A-4, and A-5).
- **Group B**: Business. Used for offices, professions or service-type transactions.
- **Group E**: Educational. Elementary schools (E-1, E-2), daycare (E-3).
- **Group F**: Factory. Moderate hazard (F-1), low Hazard (F-2).
- **Group H**: Hazard. Group H-1 through H-7, depending on the hazardous material being handled or stored.
- **Group I**: Institutional. Nurseries, hospital, nursing homes (I-1), others (I-2, I-3).
- **Group M**: Mercantile- display, storage and sale of merchandise.
- **Group R**: Residential
  - Hotels, motels, or boarding houses (R-1)
  - Multifamily dwellings (R-2)
  - One-family or two family dwellings (R-3) child care (R-4)
- **Group S**: Storage
  - Moderate hazard (S-1)
  - Low hazard (S-1)
  - Repair garage(S-3)
  - Open parking garage (S-4)
  - Aircraft (S-5)
- **Group U**: Utility. Buildings not covered by the above groups
10.3 Planning for Fire Protection

▪ Step 1: *Detection*  The presence of a fire is detected manually or automatically.

▪ Step 2: *Signaling*  The building’s management, its occupants and the fire department are notified of the presence of the fire.

▪ Step 3: *Suppression*  Manual or automatic fire suppression equipment and systems are used to extinguish the fire and remove the smoke.

  - 3A *(Initial effort)*: Potable and manual firefighting equipment, such as fire extinguishers, fans, and a first-aid fire hose, are used to extinguish the fire and to remove smoke by dilution or exhaustion.

  - 3B *(Main effort)*: Fire suppression systems, such as automatic sprinklers, fire hoses, and other systems, are used to extinguish the fire. Smoke control systems are activated to remove or confine the spread of smoke.

  - 3C *(Last Effort)*: The fire department takes over the firefighting effort when all previous efforts are ineffective
Fire protection decision tree
10.4 Fire Safety Design

▪ Fire-resistant construction

▪ Smoke controls

▪ Length of travel

▪ Means of egress

▪ Exit enclosures

▪ Adequate lighting

▪ Vertical openings

▪ Vertical transportation

▪ Coordination with mechanical and electrical system

▪ Compliance with code requirements for specific use groups

▪ Coordination with fire department
## Typical building fire protection requirements according to occupancy

<table>
<thead>
<tr>
<th>Typical Occupancies</th>
<th>Required Protection</th>
<th>Maximum Distance to Exit, ft</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fire Alarm</td>
<td>Fire Suppression</td>
</tr>
<tr>
<td>Theaters, TV studios</td>
<td>—</td>
<td>Yes</td>
</tr>
<tr>
<td>Amusement, entertainment</td>
<td>—</td>
<td>Yes</td>
</tr>
<tr>
<td>Churches and religious services</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Business (2 or more stories)</td>
<td>Yes&lt;sup&gt;a&lt;/sup&gt;</td>
<td>—</td>
</tr>
<tr>
<td>Education</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Factories (low hazard)</td>
<td>—</td>
<td>Yes&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Factories (moderate hazard)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Penal or correction institutes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hospitals, child care</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Prisons, detention centers</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mercantile</td>
<td>—</td>
<td>Yes&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hotels, motels</td>
<td>Yes</td>
<td>Yes&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Apartments</td>
<td>Yes</td>
<td>—</td>
</tr>
<tr>
<td>One- or two-family dwellings</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Storage (low hazard)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

(Note: The requirements are based on the interpretation of several prevailing building codes, which vary slightly. In actual building design, the requirements of the prevailing code shall govern.)

<sup>a</sup>Manual boxes are not required for buildings below 75 ft.

<sup>b</sup>Except if the fire area is less than 20,000 sq ft.

<sup>c</sup>Except less than three stories.

<sup>d</sup>Except child care facilities with 100 or fewer children.

<sup>e</sup>Except less than 12,000 sq ft for each fire area or less than 3 stories.
10.5 Fire Detection and Signaling Devices

10.5.1 Manual Alarm Station

- Bells, gongs, and flashing lights are manually activated by a switch.
- To avoid accidental operation of the switch, the station is usually designed so that a person must break a glass panel or glass rod or must perform other preliminary actions before the alarm can be operated.
10.5.2 Thermal Detectors

- Thermal detectors are temperature-activated sensors to initiate an alarm.

  1) **Fixed-temperature type:** This sensor consists of normally open contact held by bimetallic elements that will close the contacts when the ambient temperature reaches a fixed setting. The setting is generally designed for operation at 57 °C, 88 °C, or 94 °C.

  2) **Rate-of-rise (ROR) type:** This sensor reacts to the rate at which the temperature rises. It contains a sealed but slightly vented air chamber which expands quickly when the temperature near the device rises quickly. When the air chamber expands faster than it can be vented, electrical contacts attached to the chamber begin to close and thus initiate an alarm.

  3) **Combination type:** This device reacts to both a fixed temperature and a rate of rise.
10.5.3 Smoke Detectors

- Smoke detectors are quicker to respond than thermal detectors.
  1) Photoelectric type
  2) Ionization type
1) **Photoelectric type**

This type operates on the principle of the scattering of light. Photoelectric detectors detect the presence of visible particles (larger than 3 microns) in the air. Inside the detector, there is a light emitting diode (LED) that directs a narrow beam of infrared light across the detection chamber. When smoke or particles enter the chamber, the infrared light beam is scattered. A photodiode or photo detector, usually placed 90 degrees to the beam, will sense the scattered infrared light and when a preset amount of light is detected, the alarm will sound. Photoelectric detectors are not as sensitive and are designed to detect cool or slow-moving (smoldering) fires that produce a lot of smoke.
2) Ionization type

This type operates on the principle of changing conductivity of air within the detector chamber. The ionization detector uses a small amount of radioactive material to make the air within a sensing chamber conduct electricity. When smoke particles or combustion gases enter the sensing chamber they interfere with the conduction of electricity, reducing the current and triggering an alarm. The ionization detector can detect even invisible combustion gases produced by an open flame and will therefore respond slightly faster to an open flame fire than a photo-electric detector.
10.5.4 Flame Detectors

- Flame detectors are used to detect the direct radiation of a flame in the visible, infrared, and ultraviolet ranges of the spectrum.
- Flame detectors are used mostly in industrial processes for the protection of combustion equipment. Thermal or smoke detectors would be unreliable and generate false alarms in these environments.
- There are four basic types:

  - Infrared detector
  - Ultraviolet detector
  - Photoelectric detector
  - flame flicker detector
10.6 Fire Alarm Systems

- Fire alarm systems are an integral part of a fire protection plan. They are basically electrical systems that are specially designed to announce the presence of fire or smoke. They are not intended to suppress or extinguish a fire.
10.7 Fire Suppression Systems

- Fire suppression is achieved by cooling the combustible material to below its ignition temperature or by preventing oxygen from reacting with the combustible material.

- Fire suppression system must be designed by considering the class of fire and the type of building occupancy.

- Fire suppression system may be classified in several ways.
  1) According to the fire suppression medium – water, foam, chemical, gas, etc.
  2) According to the action of the device – a portable extinguisher, standpipe and hose, automatic sprinkler, etc.
  3) According to the method of operation of the device – manual or automatic.
10.7.1 Water Supply

- Water is the universal firefighting medium.
- It is readily available in large quantities and, in general, is more economical than any other firefighting medium.
- For fire protection purposes, the water supply should be separated from a building’s domestic water system, even though the two are connected to the same public water main.
10.7.2 Portable Fire Extinguishers

- Portable fire extinguishers are used as the first line of fire protection.
- They are normally pre-charged with water or chemicals and are hand-operated.
10.7.3 Standpipe-and– Hose Systems (Standpipe systems)

- Standpipe systems consist of piping, valves, hose connections, and nozzles to provide streams of water for fire suppression.
  
  1) Wet system
  2) Dry system
1) Wet system

- A "wet" standpipe is filled with water and is pressurized at all times.
- Whenever the system is activated, water will charge into the connected hose immediately.
- Wet standpipes can be used by building occupants.
1) **Dry system**

- A “Dry” standpipe is NOT filled with water.
- The intakes of dry standpipes are usually located near a road or driveway so that a fire engine can supply water to the system.
- This system can be used only by firefighters.
- Regulations in many countries require that standpipe systems be charged by hoses from two different pump trucks, which can be accomplished by using both sides of a Siamese connection.
Riser diagram of a three-zone standpipe-and-hose system showing a fire pump for each zone.
10.7.4 Other Fire Suppression Systems

1) Foam systems

- Foam systems are most effective for Class B fires caused by liquid, oil, grease, paint, etc.
- The foam is made by generators, which mix water with detergent or other chemicals to produce as much as 1000 gallons of foam for each gallon of water.
- This systems suppress fire by separating the fuel from the air (oxygen).
10.7.4 Other Fire Suppression Systems

2) Gaseous fire suppression systems

- Gaseous systems are most effective for **Class C fires** caused by electrical equipment.

- All these gases are stored in liquid state under high pressure.

- There are three varieties in agent gases:

  * **The carbon dioxide**: CO₂

  * **Halogenated gas**: fluorine, chlorine, bromine, or iodine

  * **Atmospheric gas**: mixture of argon, carbon dioxide, and nitrogen. The gas mixture is nontoxic, with zero ozone depletion potential (ODP) and zero global-warming potential (GWP).

H-cylinder canisters containing argon gas for use in extinguishing fire in a server room, without damaging equipment.
Gaseous fire suppression system for a building. System may be divided into a number of zones.
3) **Dry Chemicals**

- Dry chemicals are used especially for **Class D fires** caused by combustible metals.

- Examples of such metals include sodium, titanium, magnesium, potassium, uranium, lithium, plutonium, and calcium. Magnesium and titanium fires are common. When one of these combustible metals ignites, it can easily and rapidly spread to surrounding ordinary combustible materials.

- Most of the dry chemicals contain bicarbonates, chlorides, phosphates, and other proprietary compounds.

- The use of water should be avoided on burning metals, since hot metal extracts oxygen from water, promotes combustion, and at the same time liberates hydrogen, which ignites readily.
10.8 Automatic Sprinkler Systems

- Automatic sprinkler systems are integrated fire suppression systems consisting of a water supply and a network of pipes, sprinkler heads, and other components to provide automatic fire suppression in areas of a building.

- This system is the most effective for suppressing a **Class A fires** in buildings containing ordinary combustible materials, such as wood, paper, and plastics.

- The design and installation of the system are strictly regulated by insurance companies and in accordance with fire codes.
10.8.1 Sprinklers

- The major component of an automatic sprinkler system is the sprinkler, which discharge water in specific pattern for extinguishing or controlling a fire.

- A sprinkler head consists of three major components:

  1) Nozzle
  2) Heat detector: Fusible link type / Frangible bulb type
  3) Water spray pattern deflector
- The fusible link type of heat detector is constructed of a “eutectic alloy (용융합금),” which melt at a specific temperature rather than gradually softening. When the link temperature reaches its melting point, the link is pulled apart by the water pressure and opens nozzle.

- The frangible bulb type of detector contains a glass bulb partially filled with a liquid that expands with temperature. At the rated temperature, the liquid will shatter the bulb and open the nozzle.
- The temperature rating of heat detectors is divided into seven groups.

- Sprinklers are color-coded for ease of identification.

<table>
<thead>
<tr>
<th>Maximum Ceiling Temperature</th>
<th>Temperature Rating</th>
<th>Temperature Classification</th>
<th>Color Code (with Fusible Link)</th>
<th>Glass Bulb Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>100°F / 38°C</td>
<td>135-170°F / 57-77°C</td>
<td>Ordinary</td>
<td>Uncolored or Black</td>
<td>Orange (135°F) or Red (155°F)</td>
</tr>
<tr>
<td>150°F / 66°C</td>
<td>175-225°F / 79-107°C</td>
<td>Intermediate</td>
<td>White</td>
<td>Yellow (175°F) or Green (200°F)</td>
</tr>
<tr>
<td>225°F / 107°C</td>
<td>250-300°F / 121-149°C</td>
<td>High</td>
<td>Blue</td>
<td>Blue</td>
</tr>
<tr>
<td>300°F / 149°C</td>
<td>325-375°F / 163-191°C</td>
<td>Extra High</td>
<td>Red</td>
<td>Purple</td>
</tr>
<tr>
<td>375°F / 191°C</td>
<td>400-475°F / 204-245°C</td>
<td>Very Extra High</td>
<td>Green</td>
<td>Black</td>
</tr>
<tr>
<td>475°F / 245°C</td>
<td>500-575°F / 260-302°C</td>
<td>Ultra High</td>
<td>Orange</td>
<td>Black</td>
</tr>
<tr>
<td>625°F / 329°C</td>
<td>650°F / 343°C</td>
<td>Ultra High</td>
<td>Orange</td>
<td>Black</td>
</tr>
</tbody>
</table>
10.8.2 Types of Automatic Sprinkler Systems (Wet-pipe and Dry-pipe)

1) Wet-pipe system

- Wet-pipe sprinkler systems employ automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers opened by a fire.

- This type is the most reliable and simple of all sprinkler systems since no equipment other than the sprinklers themselves need to operate.

- Only those sprinklers which have been operated by heat over the fire will discharge water.
2) **Dry-pipe system**

- Dry-pipe sprinkler systems employ automatic sprinkler attached to a piping system containing air or nitrogen under pressure.

- When sprinklers are open by a fire, the gas is released and the dry pipe valve is open by the water pressure. The water then flows into the piping system and discharges only from those sprinklers which have been open by heat over the fire.

- Dry-pipe systems are installed in lieu of wet-pipe systems where piping is subject to freezing.
10.9 Smoke Controls

- Smoke is always present when there is a building fire.

- The degree of smoke generated depends on the combustible material of the fire.

- Fire from wood and paper generates relatively light smoke, whereas fire from plastic or synthetic materials generates heavy, toxic smoke.

- It has been proved that loss of life due to smoke is considerably higher than from fire alone. Often, smoke spreads out to great distances from the origin of a fire.

- Smoke control has emerged as an important topic in building design.

- It requires close coordination between architectural, structural, HVAC, and fire protection systems.
10.9.1 Stack Effect

- Smoke spreads in a building primarily because of two factors:
  
  1) Hot air: makes the smoke rise owing to its lower density (stack effect).
  
  2) Pressure differences in building: cause air to migrate throughout the building.

- Stack effect is more serious in cold weather than in hot weather, since the temperature differential between the outdoors and the interior of the building is greater.
10.9.2 Pressure Control

- Air flows only when there is a pressure difference between two areas. The flow is from the area of higher pressure to the area of low pressure.

- If the fire area is maintained at a relatively low pressure by exhausting, then air containing smoke will not flow easily to the other areas in the building.

- Some common control practices are as follows:
  
  1) Local exhaust
  2) Pressure sandwich
  3) Compartmentation
  4) Stair pressurization
  5) Sealing of all penetrations
  6) Pressurizing elevator shaft
1) Local Exhaust

- Exhaust by fans or relief by venting at the floor where fire is started will create low pressure in the fire zone, causing air in the other zones to rush in and thus confine the smoke.

2) Pressure Sandwich

- By the proper control of air supply, return, and exhaust, smoke at the fire zone will have less chance to migrate to the other zones.
3) Compartmentation

- The building is divided into two or three vertical compartments as if they were separated buildings stacked on top of each other.

- This practice is used only in buildings taller than about 50 stories.
4) Stair Pressurization

- The stairways are the major means of egress from a building.

- If positive pressure is maintained in stairways by a stair pressurization fan, smoke will not migrate into the stairways.
5) Sealing of All Penetrations

- All openings for piping, ducts, or structural members in or out of the fire partitions, walls, floors, and shafts are paths of smoke.

- These openings should be sealed and caulked.

- Ducts should be equipped with smoke and fire dampers integrated with the fire protection systems.

6) Pressure Control in the Elevator Shaft

- Maintaining a positive pressure in the elevator shaft is particularly important for elevators designed for use by firefighters and the physically disabled people.