15 Fire protection

Learning objectives

Study of this chapter will enable the reader to:

1. classify fire hazards;
2. identify the necessary ingredients for a fire;
3. describe the development of a fire;
4. recognize the hazards of smoke;
5. apply the correct fire-fighting system, or combination of systems, to different fire classifications;
6. understand the principles of portable fire extinguishers;
7. know the criteria for the use of hose reel, dry riser, wet riser, foam, sprinkler, carbon dioxide (CO_2), vaporizing liquid, dry powder and deluge fixed fire-fighting systems;
8. know the sources of water used in fire-fighting;
9. identify how fire development can be detected;
10. recognize the importance of smoke ventilation;
11. identify the locations for fire dampers in air ductwork and know how they operate.

Key terms and concepts

break tank 353; carbon dioxide (CO_2) 351; dry hydrant rise 352; dry powder 351; fire damper 358; fire-fighting system classification 350; fire risk classification 350; foam 351; foam inlet 354; fuel, heat and oxygen 350; hazard, smoke and fire detectors 356; hose reels 352; hydrant valve 353; portable extinguishers 351; smoke 350; smoke ventilator 357; sprinkler systems 354; vaporizing liquid 351; water 351; water pumping 353; water sources 354; water storage 353; wet hydrant riser 353.

Introduction

The systems required to meet the needs of tackling small fires, evacuation and major fire-fighting both by the occupants and then the Fire Service are outlined. Building management systems under

computer monitoring and control will incorporate such systems, together with security functions. Integration of such equipment with the architecture, decor and other services is planned from the earliest design stage.

Fire classification

A building's fire risk is classified according to its occupancy and use. Table 15.1 gives representative information (CIBSE, 1986).

A fire is supported by three essential ingredients: fuel, heat and oxygen. The absence of any one of these causes an established fire to be extinguished. The fire-fighting system must be appropriate to the location of the fire and preferably limited to that area in order to minimize damage to materials, plant and the building structure. Radiation from a fire may provoke damage or combustion of materials at a distance. Structural fire protection can include water sprays onto steelwork to avoid collapse, as used in the Concorde aircraft production hangar.

The system of fire-fighting employed depends upon the total combustible content of the building (fire load), the type of fire risk classification and the degree of involvement by the occupants. Fire escape design where children, the elderly or infirm are present needs particular care so that sufficient time is provided in the fire resistance of doors and partitions for the slower evacuation encountered.

Smoke contains hot and unpleasant fumes, which can be lethal when produced from certain chemicals and plastics. Visual obstruction makes escape hazardous and familiar routes become confused. Packaging materials, timber, plastics, liquefied petroleum gas cylinders and liquid chemicals must not be stacked in passageways or near fire exits in completed or partially completed buildings. Each working site or building needs a safety officer responsible for general oversight.

Fires are classified in Table 15.2.

Table 15.1 Classification of occupancies.

Category	*Group*	*Hazard occupancy*
Extra light	—	Public buildings
Ordinary	1	Restaurant
Ordinary	2	Motor garage
Ordinary	3	Warehouse
Ordinary	3 (special)	Woodwork
Extra high	—	Paint manufacture
Extra high (storage)	1	Electrical appliance
Extra high (storage)	2	Furniture
Extra high (storage)	3	Wood, plastic or rubber
Extra high (storage)	4	Foamed plastics or rubber

Table 15.2 Fire classifications.

Classification	*Fire type*	*Fire-fighting system*
A	Wood and textiles	Water, cools
B	Petroleum	Exclude oxygen
C	Gases	Exclude oxygen
D	Flammable metals	Exclude oxygen
E	Electrical	Exclude oxygen, non-conducting

Regular fire drills are conducted by the safety officer and employees are clearly notified of their responsibilities in an emergency. Staff duties will be to shepherd the public, patients or students out of the building to the rendezvous, while maintenance personnel may be required to operate fire-fighting equipment while awaiting the fire brigade.

Portable extinguishers

Portable extinguishers are manually operated first-aid appliances to stop or limit the growth of small fires. Staff are trained in their use and the appliances are regularly maintained by the suppliers. Table 15.3 summarizes their types and applications. Fire blankets are provided in kitchens where burning pans of oil or fat need to be covered or personnel need to be wrapped to smother ignited clothing.

Water

A 9 l water extinguisher is installed for each 210 m^2 floor area, with a minimum of two extinguishers per floor. A high-pressure CO_2 cartridge is punctured upon use and a 10 m jet of water is produced for 80 s. Water must not be used on petroleum, burning liquids or in kitchens as it could spread the fire.

Dry powder

Dry powder extinguishers contain from 1 to 11 kg of treated bicarbonate of soda powder pressurized with CO_2, nitrogen or dried air. A spray of 2–7 m is produced for 10–24 s depending on size. The powder interrupts the chemical reactions within the flame, producing rapid flame knockdown. The powder is non-conducting and does little damage to electric motors or appliances. A deposit of powder is left on the equipment.

Foam

Portable foam extinguishers may contain foaming chemicals that react upon mixing or a CO_2 pressure-driven foam. They cool the combustion, exclude oxygen and can be applied to wood, paper, textile or liquid fires. Garages are a particular application. Sizes range from 4.5 to 45 l. A 7 m jet is produced for 70 s with a 9 l capacity model.

Vaporizing liquid

Vaporizing liquid extinguishers use bromochlorodifluoromethane (BCF) or bromotrifluoromethane (BTM). These are 1–7 kg extinguishers containing a nitrogen-pressurized liquefied

Table 15.3 Type of portable fire extinguisher.

Group	*Extinguishing agent*	*Fire type*	*Action*	*Colour*
1	Water	Class A	Cools	Red
2	Dry powder	All	Flame interference	Blue
3	Foam	Class B	Excludes oxygen	Cream
4	Carbon dioxide (CO_2)	Classes B, E	Excludes oxygen	Black
5	Vaporizing liquid	Small fires, motor vehicles, class E	Flame interference	Green

halogen gas, which is highly efficient at interrupting the flames of chemical reactions and producing rapid knockdown without leaving any deposit. They are more powerful than CO_2 extinguishers and are used on electrical, electronic and liquid fires. Halogen is used for outdoor fires and motor vehicles, where the toxic vapour given off is adequately ventilated. They are not suitable for enclosed areas because of the danger to occupants. These are CFCs (p. 151) and are part of the international agreement to cease their use. A suitable replacement for fire-fighting is being sought.

Carbon dioxide

Pressurized CO_2 extinguishers leave no deposit and are used on small fires involving solids, liquids or electricity. They are recommended for use on delicate equipment such as electronic components and computers. The CO_2 vapour displaces air around the fire and combustion ceases. There is minimal cooling effect, and the fire may restart if high temperatures have become established. Water-cooling backup is used where appropriate.

Fixed fire-fighting installations

Various fire-fighting systems are employed in a building so that an appropriate response will minimize damage from the fire and the fire-fighting system itself. Backup support for portable extinguishers may be provided by a hose reel installation and this can be used by the staff while the fire brigade is called.

Some public buildings, shops and factories are protected by a sprinkler system, which only operates directly over the source of fire. This localizes the fire to allow evacuation. Where petroleum products are present, a mixture of foam and water is used. The Fire Officers' Committee (FOC) rules should be consulted for further information.

Hose reels

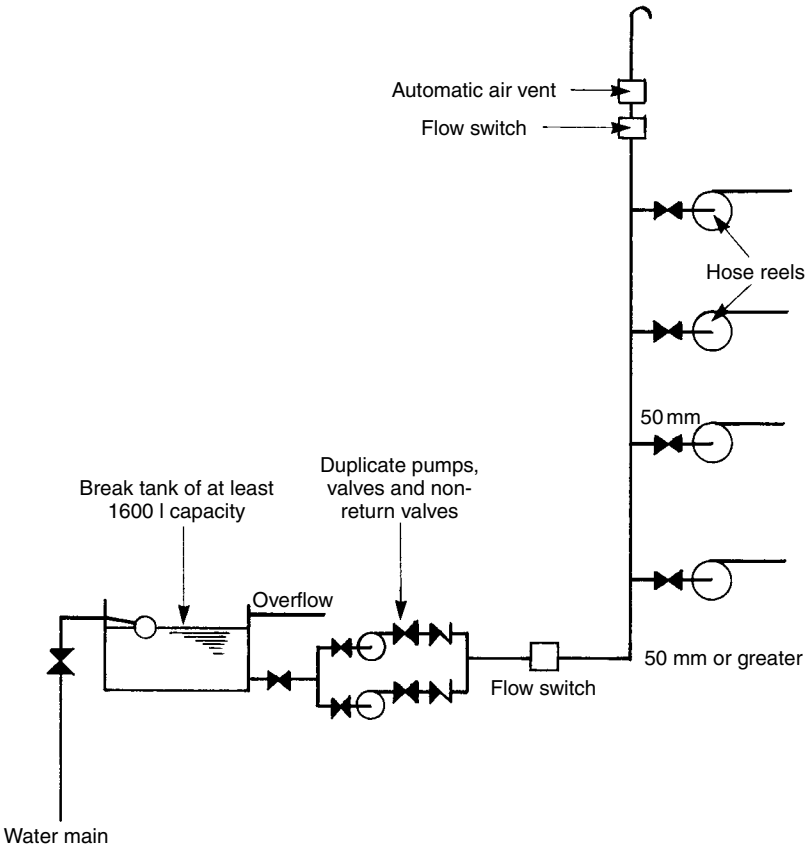
Hose reels are a rapid and easy to use first-aid method, complementary to other systems and used by the building's occupants. They are located in clearly visible recesses in corridors so that no part of the floor is further than 6 m from a nozzle when the 25 mm bore flexible hose is fully extended.

The protected floor area is an arc 18–30 m from the reel, depending on the length of the hose. A minimum water pressure of 200 kPa is available with the 6 mm diameter nozzle. This produces a jet 8 m horizontally or 5 m vertically. Minimum water flow rate at each nozzle is 0.4 l/s, and the installation should be designed to provide not less than three hose reels in simultaneous use: a flow rate of 1.2 l/s. Figure 15.1 shows a typical installation.

The local water supply authority might allow direct connection to the water main, and there may be sufficient main pressure to eliminate the need for pressure boosting. Pump flow capacity must be at least 2.5 l/s. The standby pump can be diesel-driven. Flow switches detect the operation of a hose and switch on the pump.

Dry hydrant riser

A dry hydrant riser is a hydrant installation for buildings 18–40 m high where prompt attendance by the fire brigade is guaranteed. A dry riser pipe 100 or 150 mm in diameter is sited within a staircase enclosure with a 65 mm instantaneous valved outlet terminal at each landing. All parts



15.1 Hose reel installation.

of the building floor are to be within 60 m of the hydrant, measured along the line on which a hose would be laid. A test hydrant is fitted at roof level, and also a 25 mm automatic air vent. A double inlet breeching piece with two 65 mm instantaneous terminals is located in a red-wired glass box in an external wall, 760 mm above ground level and not more than 12 m from the riser.

The inlet point is within 18 m of an access road suitable for the fire brigade pumping appliance. A brass blank cap and chain is fitted to each landing valve. The riser is electrically earthed. Landing valves are 1 m above floor level and are used by the fire brigade for their own hoses.

Wet hydrant riser

A permanently charged rising pipe 100 mm in diameter or greater supplies a 65 mm instantaneous valved outlet terminal at each floor at a pressure of between 410 and 520 kPa. The upper pressure limit is to protect the fire brigade hoses from bursting and is achieved by fitting an orifice plate restriction before the landing valve on the lower floors of a tall building. The maximum static pressure in the system when all the landing valves are shut is limited to 690 kPa by recirculating water to the supply tanks through a 75 mm return pipe.

Each hydrant valve is strapped and padlocked in the closed position. They are 1 m above floor level and are only used by the fire brigade for buildings over 60 m high which extend out of

the reach of turntable ladders. The maximum normally permitted height is 60 m for a low-level break tank and booster set. Higher buildings have separate supply tank and pump sets for each 60 m height.

Pressure boosting of the water supply is provided by a duplicate pump installation capable of delivering at least 23 l/s. Pumps are started automatically on fall of water pressure or water flow commencement. Audible and visual alarms are triggered to indicate booster plant operation.

A break tank capacity of 11.4–45.5 m^3 is required and mains water make-up rate is 27 or 8 l/s for the larger tank. Additionally, four 65 mm instantaneous fire brigade inlet valved terminals are provided at a 150 mm breeching fitting in a red wired-glass box in an external wall, as described for the dry hydrant riser. The box is clearly labelled.

A nearby river, canal or lake may also be used as a water source with a permanently connected pipe from a jack well and duplicate pumps.

Pneumatic pressure boosting is used to maintain system pressure in a similar manner to that shown in Fig. 6.1. The standby pump may be driven by a diesel engine fed from a 3–6 h capacity fuel storage tank providing a gravity feed to the engine.

Foam inlets

Oil-fired boiler plant rooms and storage tank chambers in basements or parts of buildings have fixed foam inlet pipework from a red wired-glass foam inlet box in an outside wall as for the dry hydrant riser.

A 65 or 75 mm pipe runs for up to 18 m from the inlet box into the plant room. The fire brigade connect their foam-making branch pipe to the fixed inlet and pump high-expansion foam onto the fire. The foam inlet pipe terminates above the protected plant with a spreader plate. A short metal duct may be used as a foam inlet to a plant room close to the roadway. Vertical pipes cannot be used and the service is electrically bonded to earth.

On-site foam-generation equipment is available and may be used for oil-filled electrical transformer stations. In the event of a fire, the electricity supply is automatically shut off, a CO_2 cylinder pressurizes a foam and water solution and foam spreaders cover the protected equipment.

Automatic sprinkler

High-fire-risk public and manufacturing buildings are protected by automatic sprinklers. These may be a statutory requirement if the building exceeds a volume of 7000 m^3. Loss of life is very unlikely in a sprinkler-protected building. Sprinkler water outlets are located at about 3 m centres, usually at ceiling level, and spray water in a circular pattern. A deflector plate directs the water jet over the hazard or onto walls or the structure.

Each sprinkler has a frame containing a friable heat-sensing quartz bulb, containing a coloured liquid for leak detection, which seals the water inlet. Upon local overheating, the quartz expands and fractures, releasing the spray. Water flow is detected and starts an alarm, pressure boosting set and automatic link to the fire brigade monitoring station.

Acceptable sources of water for a sprinkler system are as follows:

1. a water main fed by a source of 1000 m^3 capacity where the correct pressure and flow rate can be guaranteed;
2. an elevated private reservoir of 500 m^3 or more depending on the fire risk category;
3. a gravity tank on site, which can be refilled in 6 h, with a capacity of 9–875 m^3 depending on the fire risk category;

4. an automatic pump arranged to draw water from the main or a break tank of 9–875 m^3 capacity;
5. a pressure tank: a pneumatic pressure tank source can be used for certain light fire risk categories or as a backup facility to some other system.

Sprinkler installations are classified under four principal types.

1. Water-filled pipes are permanently charged with water.
2. Dry pipework: pipes are filled with compressed air and used where pipework is exposed to air temperatures below 5°C or above 70°C.
3. Alternate system: pipes are filled with water during the summer and air in the winter.
4. A pre-action system is a dry pipe installation but has additional heat detectors which pre-empt the opening of sprinkler heads and admit water into the pipework, converting it to wet-pipe operation.

Different types of sprinkler head are used depending on the hazard protected, their object being to produce a uniform density of spray.

Fusible link: a soldered link in a system of levers holds the water outlet shut. At a predetermined temperature of 68°C or greater, the solder melts and water flow starts.

Chemical: similar to the fusible link but using a block of chemical, which melts at 71°C or greater, depending on the application.

Glass bulb: a quartz bulb containing a coloured fluid with a high coefficient of expansion, which fractures at 57°C or more.

Open sprinkler heads (deluge system): these are used to combat high-intensity fires and protect storage tanks or structural steelwork. They are controlled by a quick-opening valve actuated from a heat detector or a conventional sprinkler arrangement. A drencher system provides a discharge of water over the external openings of a building to prevent the spread of fire.

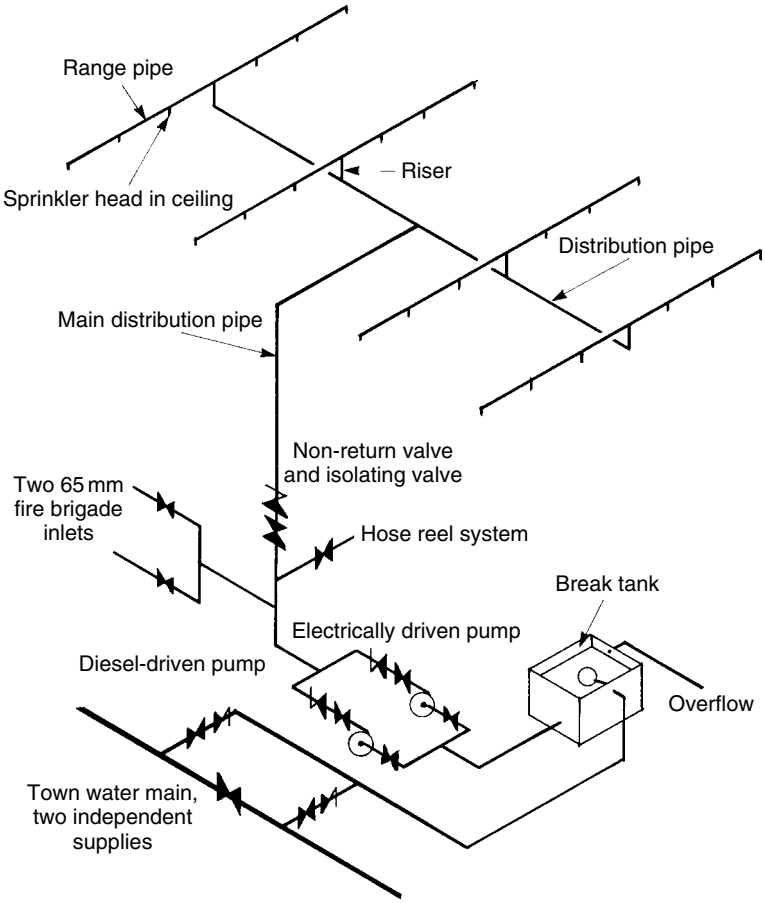
Each sprinkler installation must be provided with the following:

1. main stop valve, which is strapped and padlocked in the open position to enable the water flow to be stopped after the fire is extinguished;
2. alarm valve: differential pressure caused by water flow through the valve opens a branch pipe to the alarm gong motor;
3. water motor alarm and gong: water flow through a turbine motor drives a rotary ball clapper within a domed gong to give audible warning of sprinkler operation and commence evacuation of the building.

A satisfactory pipework installation serving an automatic sprinkler distribution and hose reels is shown in Fig. 15.2. Two 65 mm instantaneous fire brigade inlet pipes are provided at a clearly marked access box.

Carbon dioxide

Carbon dioxide is used in fixed installations protecting electrical equipment such as computer rooms, transformers and switchgear. Heat or smoke detectors sound alarms and CO_2 gas floods the room from high-pressure storage cylinders. Pipework transfers the CO_2 to ceiling and



15.2 Water supply to hose reel and sprinkler installation.

under floor distributors. System initiation can be manual or automatic but complete personnel evacuation is essential before CO_2 flooding is allowed.

Fixed BCF, BTM and dry powder

Extinguishers are installed within rooms or false ceilings and are operated from a manual push-button or automatic fire detector. Personnel evacuation is followed by the release of halogen gas to flood the room with a 5% concentration in air, which is sufficient to inhibit fire.

Fire detectors and alarms

Detection of a potentially dangerous rise in air temperature or pressure or the presence of smoke is required at the earliest possible moment to start an alarm. Evacuation of the building and manual or automatic contact with the fire brigade monitoring switchboard should take place before people are at risk. Means of detection can be combined with security surveillance. Fire detection takes the following forms.

Hazard detectors

Hazard detectors give an early warning of the risk of a fire or explosion.

Temperature rise: a local rise in temperature leads to the melting of a fusible link in a wire holding open a valve on a fuel pipe to a burner, thermal expansion of a fluid-filled bellows or capillary tube or movement of a bimetallic strip to make an alarm circuit.
Flammable vapour detector: gas, oil, petrol or chemical vapour presence is detected by a catalytic chemical reaction.
Diffusion: butane and propane vapour diffusion through membrane is detected.
Explosion: rise of local atmospheric pressure above a set value, or at a fast rate, is detected.

Ionization smoke detector

Ionization smoke detectors contain a radioactive source of around 1 micro curie, typically americium-241, which bombards room air within the detector with alpha particles (ionization). Electrical current consumption is 50 μA. The presence of smoke reduces the flow of alpha ions; the electric current decreases and at a pre-set value an alarm is activated.

Visible smoke detector

A source of light is directed at a receiving photocell. Smoke obscures or scatters the light and an alarm is triggered.

Laser beam

A laser beam is refracted by heat or smoke away from its target photocell and an alarm is initiated. A continuous or pulsed infrared beam can be transmitted up to 100 m and can be computer-controlled to scan the protected area. It can also serve as an intruder alarm.

Closed-circuit television

Manned security monitoring also acts as fire and smoke detection. Infrared imaging cameras reveal overheating of buried pipes and cables and can detect heat sources unseen by visual techniques.

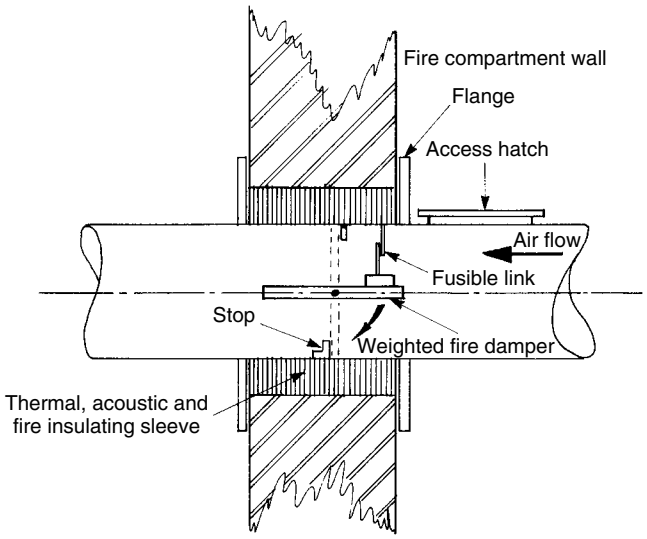
Fire alarms are a statutory requirement. Audible bells, sirens, klaxons, hooters and buzzers are arranged so that they produce a distinctive warning. A visual alarm should also be provided throughout a building. Breakable glass call points are located 1.4 m above floor level within 30 m of any part of the premises.

The electrical system for fire detectors comprises alarms, a central control panel, an incoming supply and distribution board, emergency batteries, a battery charger and fire-resistant cable. A permanent cable or telephone line connection is made to the fire brigade and computer-controlled monitoring indicates any system faults.

Smoke ventilation

Positively removed smoke through automatically opened roof ventilators can greatly aid escape and reduce smoke damage, often localizing a fire that would otherwise spread.

The spread of smoke through ventilation ductwork is arrested by fire dampers where fire compartments within the building are crossed. Fire dampers may be motorized or spring-loaded



15.3 Hinged deadweight single-blade fire damper in a ventilation duct.

multi-leaf, eccentrically pivoted flaps, sliding plate or intumescent paint-coated honeycombs which swell and block on heating. A typical arrangement of a pivoted flap damper is shown in Fig. 15.3.

An air pressurization ductwork and fan system is switched on at the commencement of a fire to inject outdoor air into escape routes, corridors and staircases. The staircase static air pressure is maintained at 50 Pa above that of adjoining areas to overcome the adverse force caused by wind, mechanical ventilation and the fire-produced stack effect ventilation pressure. This ensures that clear air is provided in the escape route and smoke movement is controlled.

Questions

1. List the sources of fire within a building and describe how they may develop into a major conflagration. State how the spread of fire is expected to be limited by good building and services practice.
2. List the ways in which fire and smoke are detected and fire-fighting systems are brought into action.
3. Describe the methods and equipment used to fight fires within buildings in their likely order of use.
4. State the principal hazards faced by the occupants of a building during a fire. How are these hazards overcome? Give examples for housing, shops, cinemas, office blocks, single-storey factories and local government buildings.
5. Sketch and describe the fire-fighting provisions necessary in large industrial oil-fired boiler plant.
6. How are water and foam systems used to protect building structures from fire damage?
7. Compare a fixed sprinkler installation with other methods of fire-fighting. Give three applications for sprinklers.
8. Explain how sprinkler systems function, giving details of the alternative operating modes available. State the suitable sources of water for sprinklers.

9. Tabulate the combinations of fire classification and types of extinguisher to show the correct application for each. State the most appropriate fire-fighting system for each fire classification and show which combinations are not to be used.
10. Which are correct about fire-fighting services? More than one answer is correct.

    1. Primarily are to minimize damage to the building and its services systems.
    2. Primarily to prevent and minimize danger to people.
    3. Secondary purpose is to save the building and its continued use.
    4. Are only used by professional fire fighters.
    5. Have both fixed and portable fire extinguishers.

11. Hose reel fire-fighting systems:

    1. Are not suitable for office buildings.
    2. Never need to be tested.
    3. Should not be intrusively visible.
    4. Are for anyone to use to commence fire-fighting until professionals arrive.
    5. Only used in public buildings.

12. Which are true about fire-fighting systems in large buildings? More than one correct answer.

    1. Never need to be tested after being commissioned.
    2. Have a fire control panel identifying which parts of the system are activated.
    3. Have an indicator board in the entrance to the building advising fire location.
    4. Are all filled with water.
    5. Are always connected to the computer-based building management system.

13. Which are true about sprinkler fire-fighting systems? More than one correct answer.

    1. Have sprinklers located on a 3.0 m grid pattern covering the floors.
    2. Can have sprinklers mounted on a sidewall 150 mm from the ceiling.
    3. Have self-acting outlets heads that fracture on rise of air temperature.
    4. Are part of a fire-fighting strategy.
    5. Provide a high degree of security against fire damage.

14. Which are correct about aerosol chemical gas fire extinguishing? More than one correct answer.

    1. Is a solid aerosol-generating element.
    2. Developed from solid rocket fuel technology.
    3. Is an inert non-toxic solid that can be activated by heat to release a gas.
    4. Aerosol prevents fresh oxygen reaching the combustion zone.
    5. Aerosol is a fast-acting explosive response.

15. Sprinkler fire-fighting systems:

    1. Have sprinklers located on a 6.0 m grid pattern covering the floors.
    2. Must be manually turned on.
    3. Have self-acting outlets heads that fracture on rise of air temperature.
    4. Are the only fire-fighting system a building needs to have.
    5. Creates unnecessary water damage.

16. Which are correct about fire detection and alarm systems? More than one correct answer.

    1. Thermal detectors in office ceilings.
    2. Visible smoke laser light detectors in rooms.
    3. Detailed drawings of detectors wired in series with each other.
    4. Breakable glass alarm call points in all areas.
    5. Automatic connection to the fire brigade call centre.

17. Smoke control during a building fire:

    1. Is not a critical hazard for personnel.
    2. Materials within buildings are sources of toxic chemicals.
    3. Smoke control exhaust fans remove air from the building.
    4. Escape routes are protected with water sprinkler systems.
    5. Air pressure differentials across doorways control smoke movement to aid escape.

18. Identify the essential components of a fire:

    1. Fuel and air.
    2. Source of ignition and combustible material.
    3. Paper, wood, solvents, air and warmth.
    4. Fuel, oxygen and ignition temperature.
    5. Fuel, air and high-temperature radiated heat.

19. How does a fire commence?

    1. A small flame radiates combustibility over a long distance.
    2. Adjacent buildings cannot be set on fire.
    3. Combustible material, liquid or gas becomes raised to its ignition temperature in the presence of oxygen.
    4. Electrical services often start fire.
    5. Any spark from a light switch or plant switch can start a fire.

20. Which is not a means of extinguishing fire?

    1. Deprive the fire of air.
    2. Cool the burning material.
    3. Cease the supply of more fuel.
    4. Calling the fire brigade.
    5. Closing doors and windows and evacuating the building.

21. Which is a means of extinguishing fire?

    1. Disconnect electrical supply from electrical service or item on fire.
    2. Switch lights off and leave that floor level.
    3. Cover burning photocopier with wool blanket and leave that floor.
    4. Spray water onto burning electrical heater and evacuate.
    5. Throw a fireproof blanket over a burning computer.