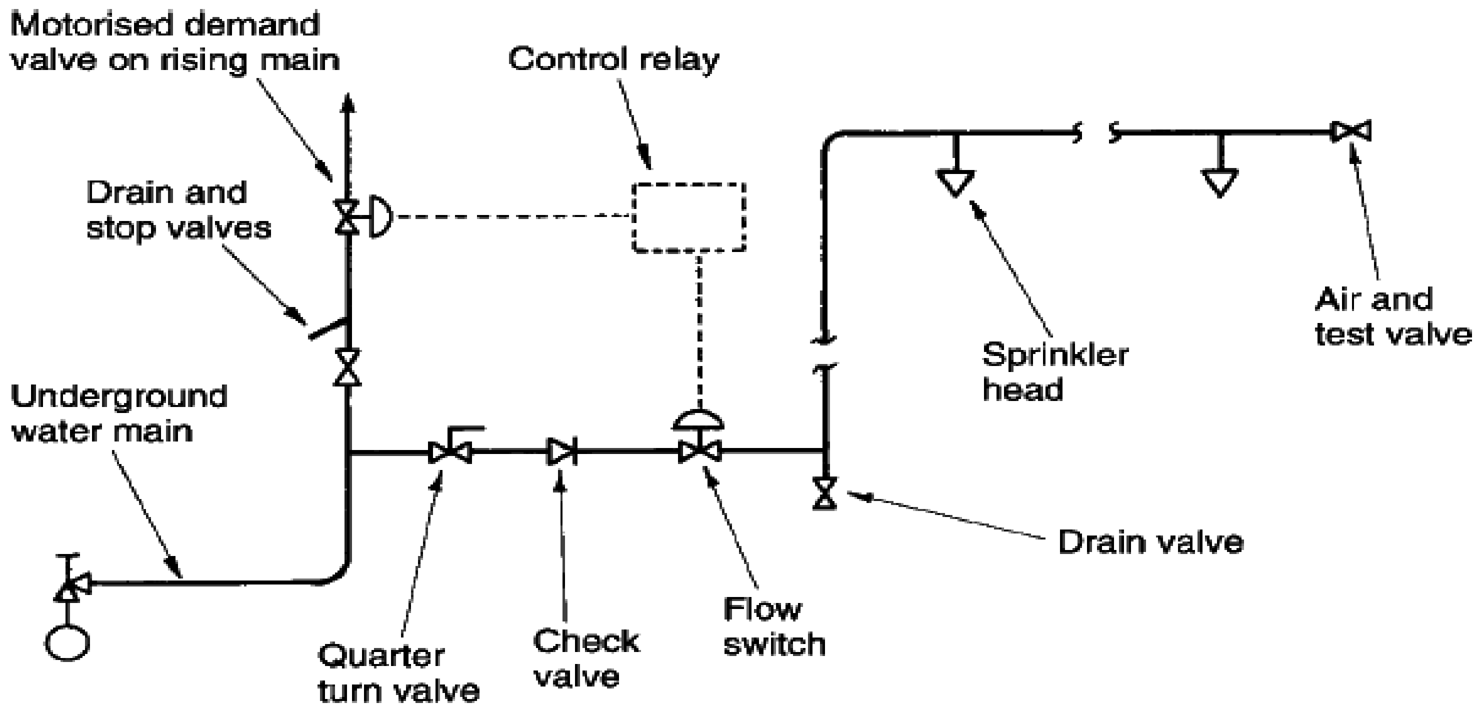
Ch.13
FIRE PREVENTION AND CONTROL SERVICES

Sprinklers – The Principles

Water sprinklers provide an automatic spray dedicated to the area of fire outbreak. Sprinkler heads have temperature sensitive elements that respond immediately to heat, discharging the contents of the water main to which they are attached. In addition to a rapid response which reduces and isolates fire damage, sprinklers use less water to control a fire than the firefighting service, therefore preventing further damage from excess water.

Sprinkler systems were initially credited to an American, Henry Parmalee, following his research during the late 1800s. The idea was developed further by another American, Frederick Grinnell, and the name 'Grinnell' is still associated with the glass-type fusible element sprinkler head.

Domestic pipework – solvent cement bonded, post-chlorinated polyvinyl chloride (CPVC).



Typical domestic sprinkler installation
Note: When flow switch is activated, demand valve closes.

Industrial and commercial pipework – threaded galvanised mild steel.

The simplest application is to attach and suspend sprinkler heads from a water main fixed at ceiling level. However, some means of regulation and control is needed and this is shown in the domestic application indicated below.

Sprinklers – Domestic Installations

Pipe materials – Copper tube – BS EN 1057

Post-chlorinated polyvinylchloride (CPVC)

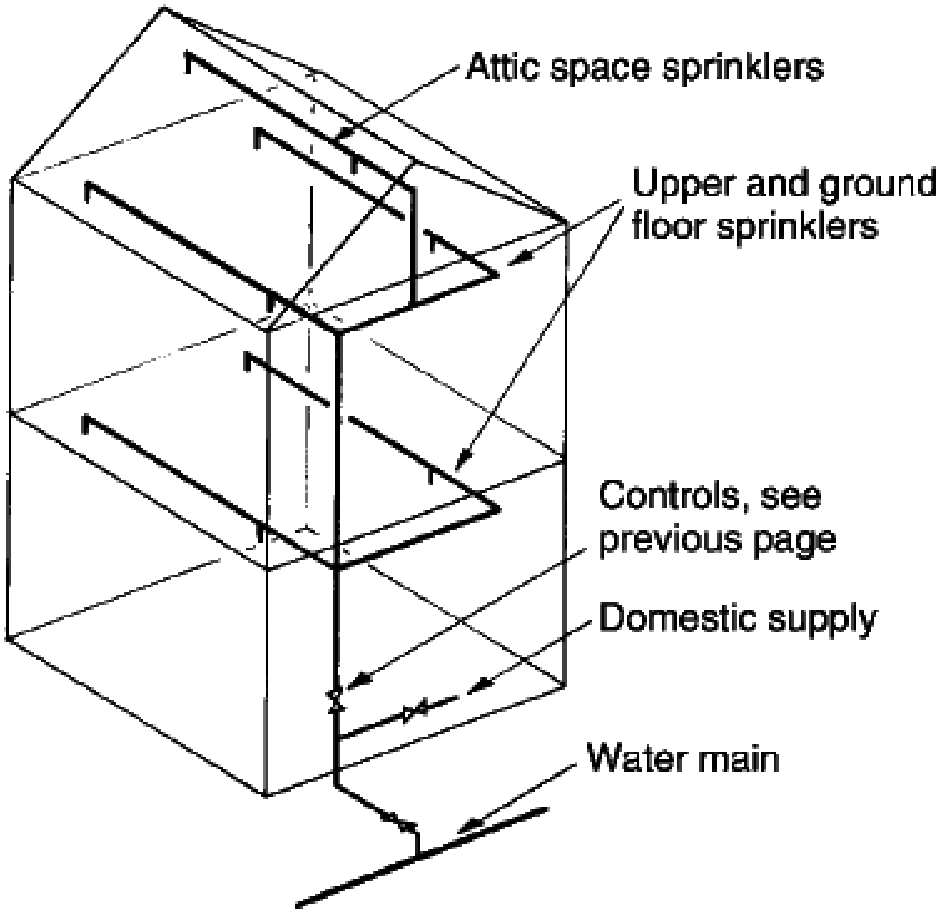
System – mains supplied, wet.

Pipe sizes – 25mm minimum i.d. incoming service to supply at least 60l/min. through any one sprinkler head, or 42l/min. through any two sprinkler heads operating simultaneously in the same room.

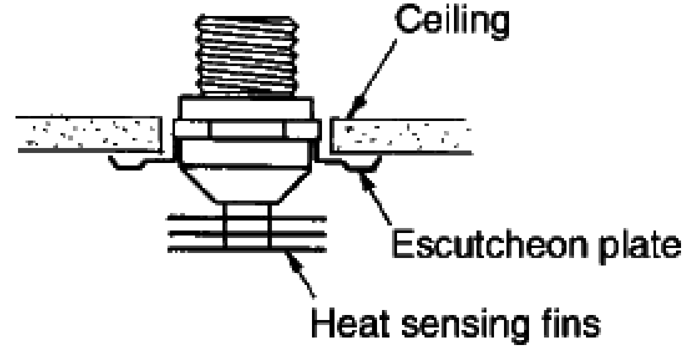
Sprinkler head spacing – area covered by one head, maximum $12m^2$.

Maximum distance between heads – 4m.
Maximum distance from wall to ceiling mounted head – 2m.
Minimum distance between heads in the same room – 2m (only 1 head per room is normal).

Operating pressure – Minimum 0.5 bar (50kPa).



Typical domestic installation

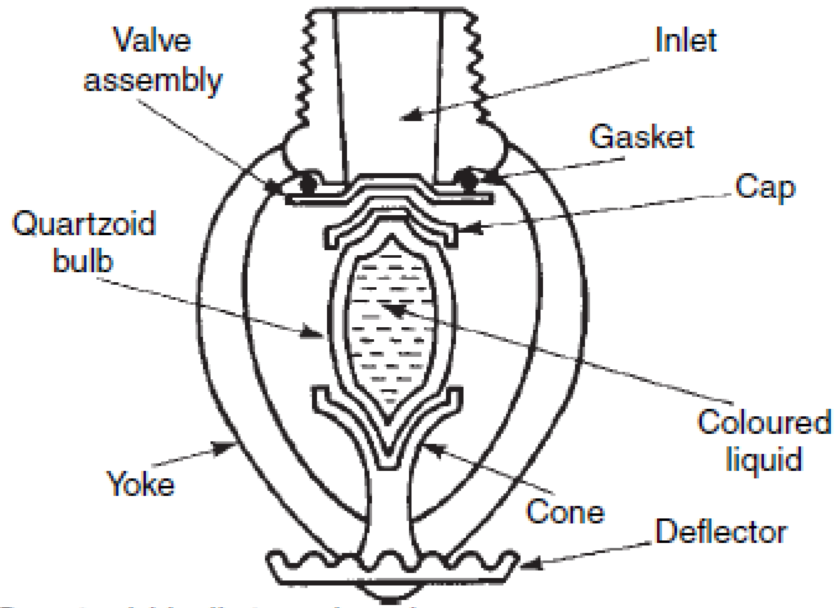


Fusible pellet pendent sprinkler head

Types of Sprinkler Head

Quartzoid bulb – a glass tube is used to retain a water valve on its seating. The bulb or tube contains a coloured volatile fluid, which when heated to a specific temperature expands to shatter the glass and open the valve. Water flows on to a deflector, dispersing as a spray over the source of fire. Operating temperatures vary with a colour coded liquid:

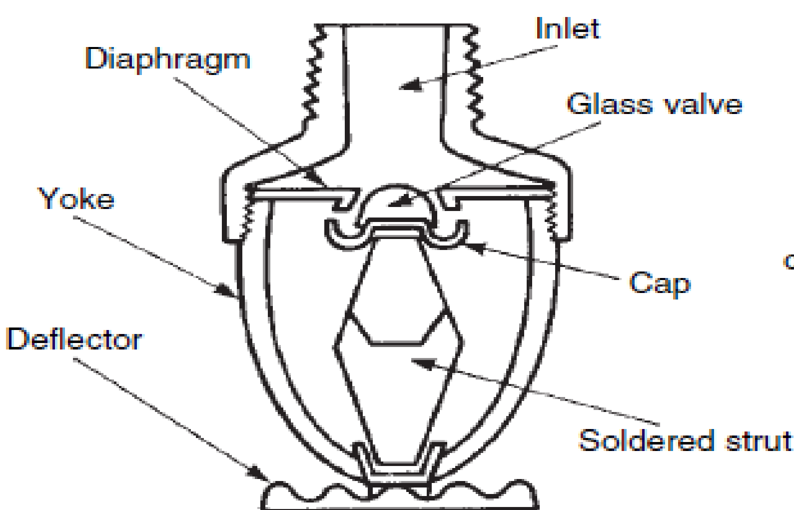
- Orange – 57°C
- Red – 68°C
- Yellow – 79°C
- Green – 93°C
- Blue – 141°C
- Mauve – 182°C
- Black – 204 or 260°C



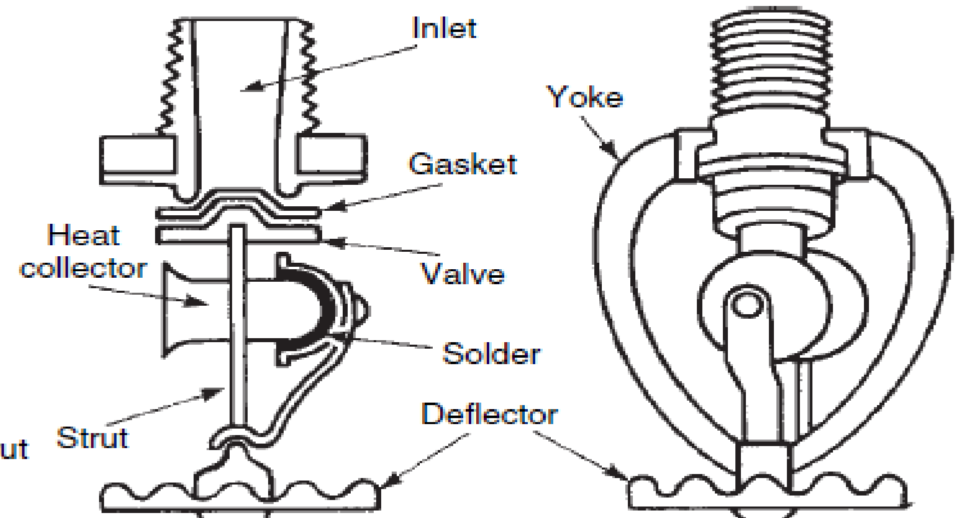
Quartzoid bulb-type head

Fusible strut - has two metal struts soldered together to retain a water valve in place. A range of solder melting temperatures are available to suit various applications. Under heat, the struts part to allow the valve to discharge water on the fire.

Duraspeed solder type - contains a heat collector which has a soldered cap attached. When heat melts the solder, the cap falls away to displace a strut allowing the head to open. Produced in a range of operating temperatures.



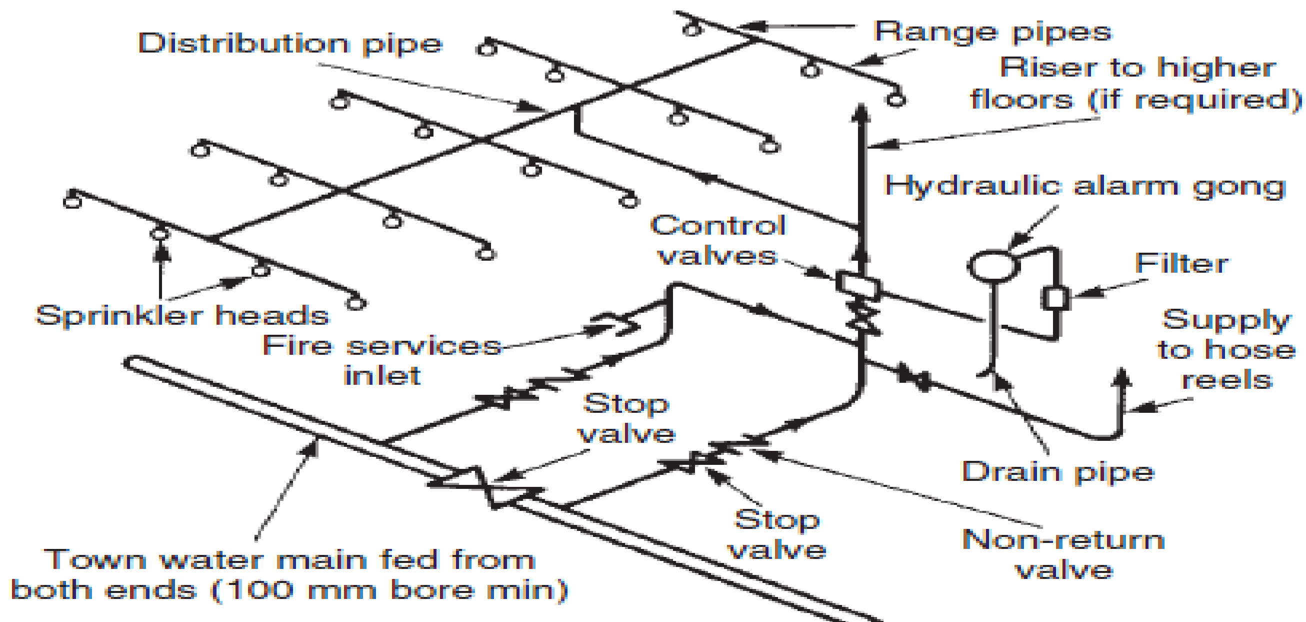
Fusible soldered strut-type head



Duraspeed soldered-type head

The specification of a sprinkler system will depend on the purpose intended for a building, its content, function, occupancy, size and disposition of rooms. Installations to commercial and industrial premises may be of the following type:

- Wet system – the simplest and most widely used application. The pipework is permanently charged with water. It is only suitable in premises, where temperatures remain above zero, although small sections of exposed pipework could be protected by trace element heating. The maximum number of sprinklers on one control valve is 1000. See page 527.



Wet-pipe system

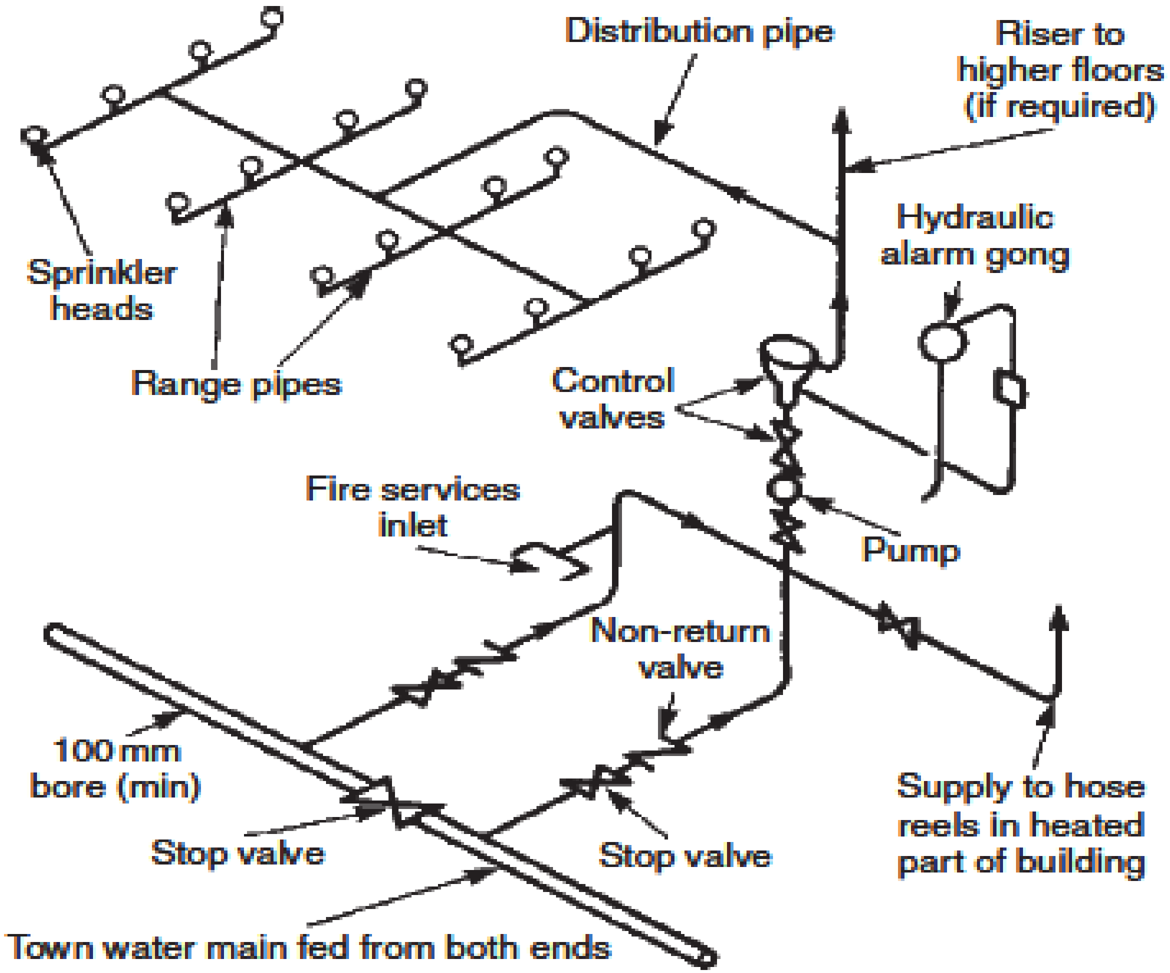
The wet system is used in heated buildings where there is no risk of the water in the pipework freezing. All pipework is permanently pressure charged with water and the sprinkler heads usually attach to the underside of the range pipes. Where water is mains supplied, it should be fed from both ends. If the main is under repair on one side, the stop valve and branch pipe can be closed and the sprinkler system supplied from the other branch pipe.

When a sprinkler head is fractured water is immediately dispersed. Water will also flow through an annular groove in the alarm valve seating to a pipe connected to an alarm gong and turbine. A jet of water propels the turbine blades causing the alarm gong to operate. Pipeline flow switches will alert the local fire service in addition to operating an internal alarm system. Except under supervised maintenance, the main stop valve is padlocked in the open position.

- Dry system – an air charged system applied to unheated premises such as warehousing, where winter temperatures could drop below zero. The maximum number of sprinklers on one control valve is 250, but this may increase to 500 if the air controls include an accelerator. See page 528.
- Alternative wet and dry system – essentially a wet system, but due to the slightly slower response time as air precedes water on discharge, the pipework is charged with water for most of the year and only air charged in winter. The maximum number of sprinklers is the same as a dry system. See page 528.
- Tail end system – used in a building with different internal functions, e.g. a mix of office accommodation with an unheated storage facility. The installation differs from an alternative wet and dry system, as most of the pipework is permanently charged with water. Only those pipes in parts of a building exposed to sub-zero temperatures are charged with air and these are designed as additions (tail ends) to a wet system. The wet and tail end parts are separated by a compressed air control valve. As the system is essentially wet, the maximum number of sprinklers may be 1000. The maximum number after a tail end air control valve is 100, with no more than 250 in total on tail end air valves in one installation.

- Pre-action system – used where there is a possibility that sprinkler heads may be accidently damaged by tall equipment or plant, e.g. a fork-lift truck. To avoid unnecessary water damage, the system is dry. If a sprinkler head is damaged, compressed air discharges and an initial alarm is activated. Water will only be supplied to the damaged sprinkler, if a ceiling mounted heat detector senses a temperature rise. The sensor will open a motorised valve on the water supply and effect another alarm. Detectors have a lower temperature rating than the sprinkler, therefore for a 68°C head, the detector will be set at about 60°C. Max. number of sprinklers is 1000.
- Recycling pre-action system – a variation of the pre-action system, designed as a damage limiting installation. After sprinklers have subdued a fire, a heat detector responds to a lower temperature and disengages the water supply after a 5-min. delay. If the fire restarts and temperature rises, the detector re-engages a motorised valve on the water supply. Maximum number of sprinklers is 1000.
- Cycling wet system-in principle similar to the recycling pre-action system except it is a normal wet system. It functions in conjunction with ceiling heat detectors which will disengage the water supply within a pre-determined time of the temperature dropping. If the temperature rises, the water supply will be automatically turned on again.

Dry system



Dry pipe or alternate wet-and-dry pipe system

Sprinkler Applications

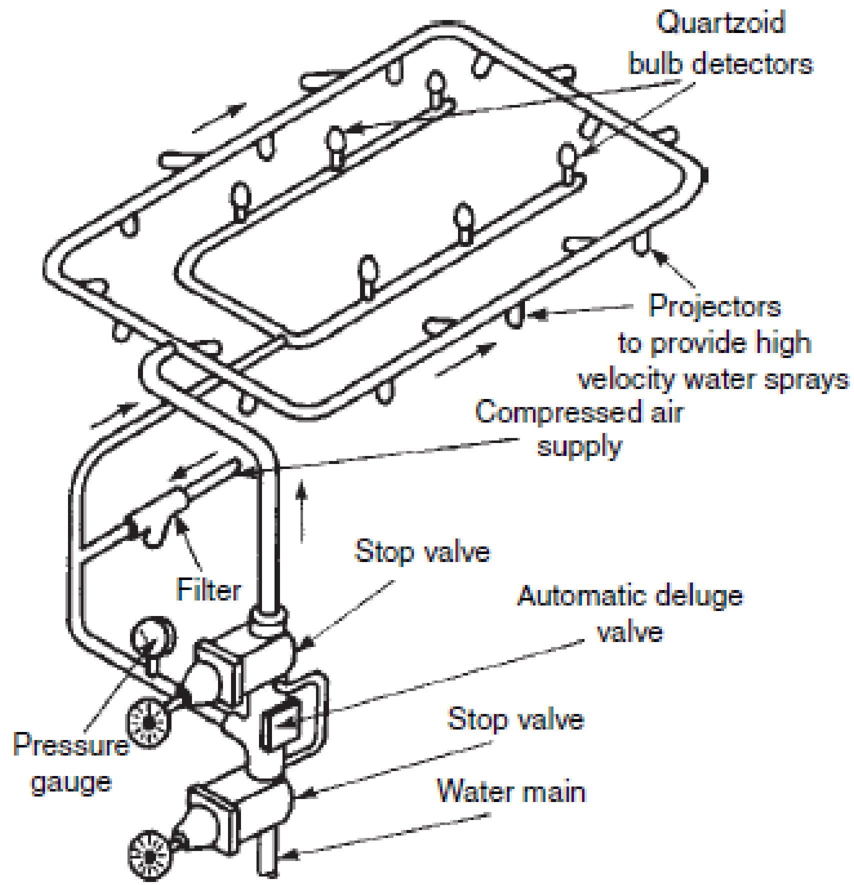
Buildings are assessed by fire risk and categorised by fire load* as a hazard according to their purpose and content:

- Light hazard (LH) – low fire load and containing no single compartment exceeding 126m^2 floor area with fire resistance of at least 30 min. Examples include educational premises, prisons and offices. Maximum protected area is 10 000m^2 per control valve.
- Ordinary hazard (OH 1 to OH 4) – medium fire load category such as process or manufacturing premises.

  OH 1 – cement works, sheet metal processors, dairies, abattoirs, hospitals, hotels, offices, schools and restaurants.
  OH 2 – garages (car workshops), laboratories, bakeries, food processors, breweries, car parks and museums.
  OH 3 and 4 – industrial processors and warehouses with combustible stored products.
- High hazard – high fire load categories typical of warehouses containing combustible products in high racking systems. Fireworks factories and some chemical processes will also be included.

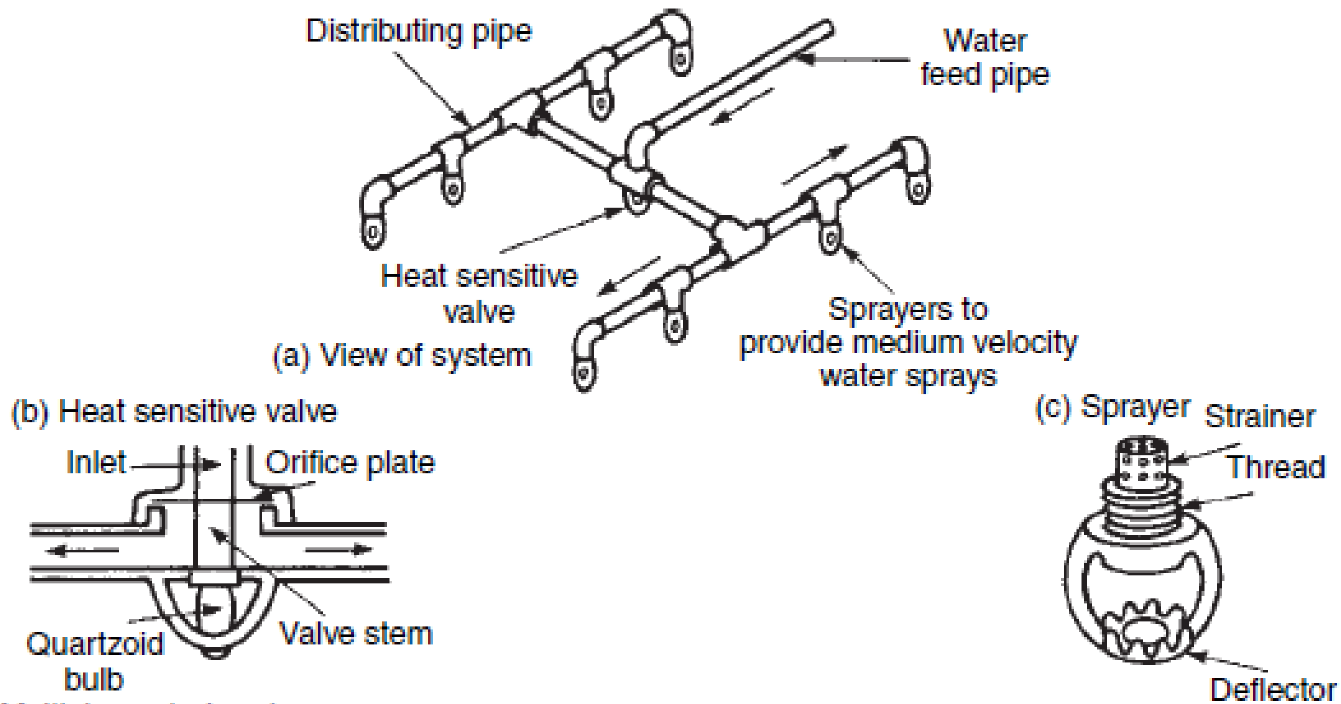
Deluge and Multiple Control Sprinklers

Deluge system – used for specifically high fire hazards such as plastic foam manufacture, fireworks factories, aircraft hangars, etc., where there is a risk of intensive fire with a very fast rate of propagation. The pipework is in two parts, compressed air with quartzoid bulbs attached and a dry pipe with open ended spray projectors. When a fire occurs, the quartzoid bulbs shatter and compressed air in the pipeline is released allowing a diaphragm inside the deluge control valve to open and discharge water through the open pipe to the projectors.



Deluge system

Multiple control system - a heat sensitive sealed valve controls the flow of water to a small group of open sprayers attached to a dry pipe. When a fire occurs, the valve quartzoid bulb shatters allowing the previously retained water to displace the valve stem and flow to the sprayers. An alternative to a heat sensitive valve is a motorised valve activated by a smoke or fire detector.



Multiple control system

Water Supplies for Sprinkler Systems

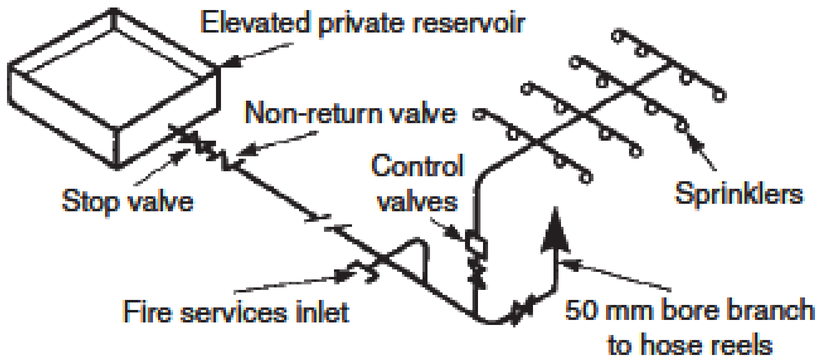
There are various sources of water supply that may be used for sprinkler applications.

Elevated private reservoir – minimum volume varies between $9m^3$ and $875m^3$ depending on the size of installation served.

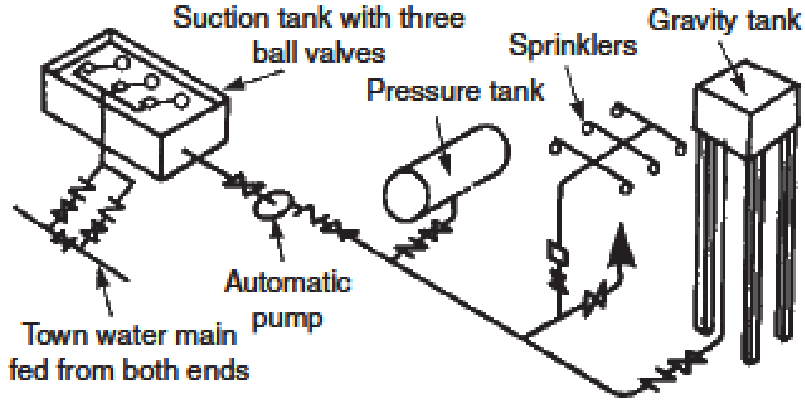
Suction tank – supplied from a water main. Minimum tank volume is between $2.5m^3$ and $585m^3$. A better standard of service may be achieved by combining the suction tank with a pressure tank, a gravity tank or an elevated private reservoir. A pressure tank must have a minimum volume of water between $7m^3$ and $23m^3$. A pressure switch or flow switch automatically engages the pump when the sprinklers open.

Gravity tank – usually located on a tower to provide sufficient head or water pressure above the sprinkler installation.

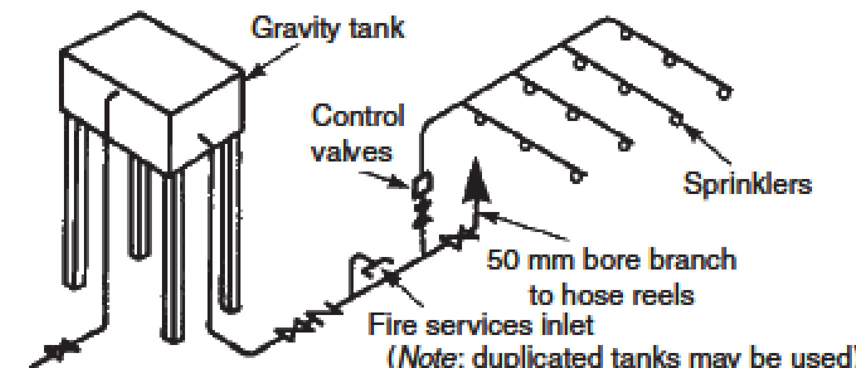
River or canal – strainers must be fitted on the lowest part of the suction pipes corresponding with the lowest water level. Duplicate pumps and pipes are required, one diesel and the other electrically powered.



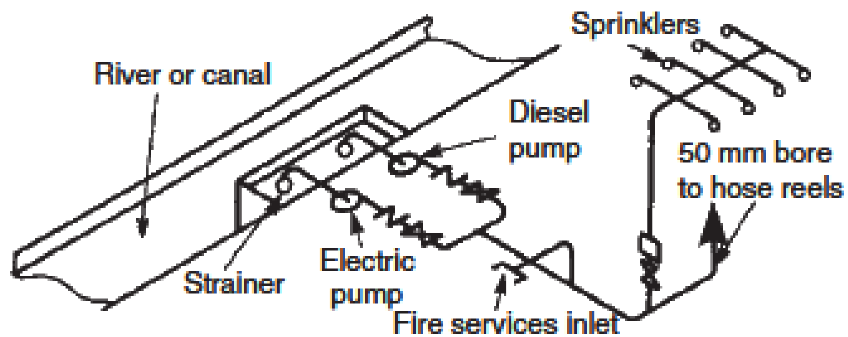
Elevated private reservoir



Town main suction tank automatic pump with pressure tank or gravity tank (if required)



Gravity tank
(containing between 9 m^3 and 875 m^3 of water)



Automatic pumps drawing from river or canal

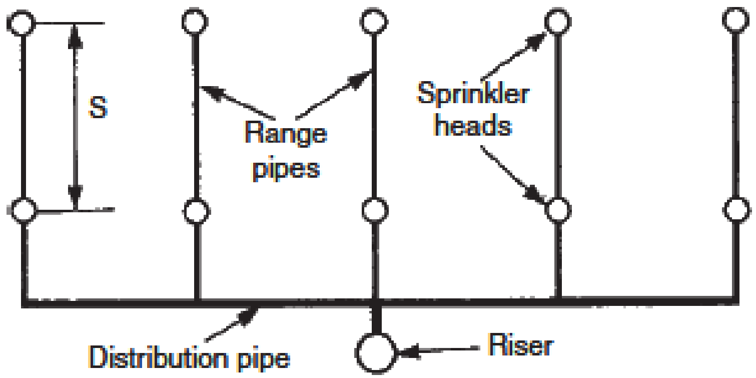
Pipework Distribution to Sprinklers

The arrangement of pipework will depend on the building shape and layout, the position of the riser pipe and the number of sprinkler heads required. To provide a reasonably balanced distribution, it is preferable to have a centre feed pipe. In practice this is not always possible and end feed arrangements are used. The maximum spacing of sprinkler heads (s) on range pipes depends on the fire hazard classification of the building.

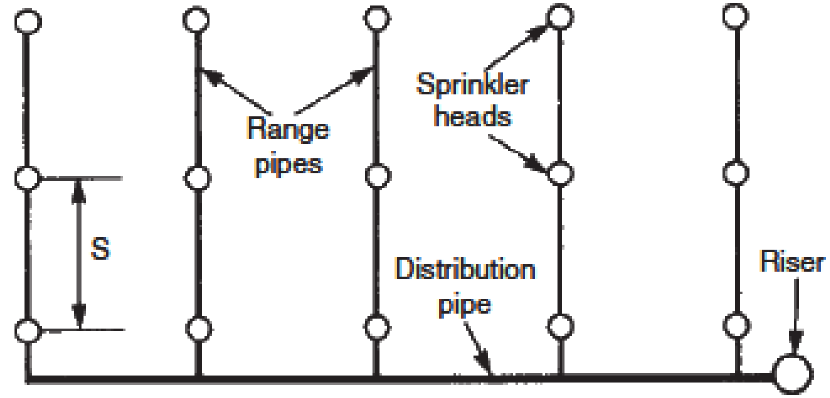
Hazard category	Max. spacing (s) of sprinkler heads (m)	Max. floor area covered by one sprinkler head (m^2)
Light	4·6	21
Ordinary	4·0 (standard)	12
	4·6 (staggered)*	12
High	3·7	9

*See next page

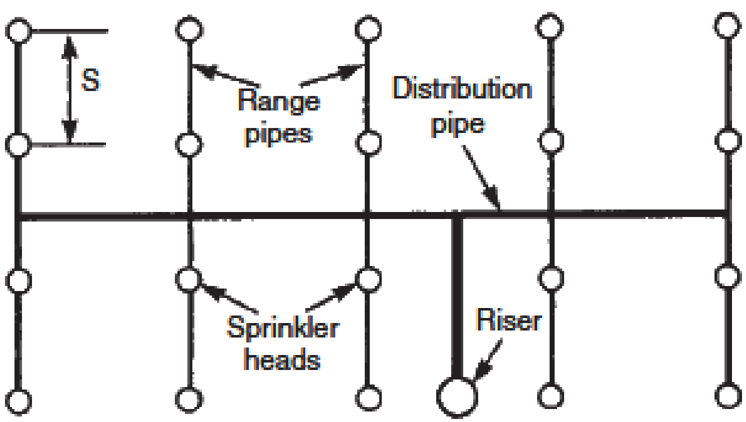
For sidewall-mounted sprinklers, the maximum floor area coverage by one sprinkler head is 17 m^2 for light hazard and 9 m^2 for ordinary hazard.



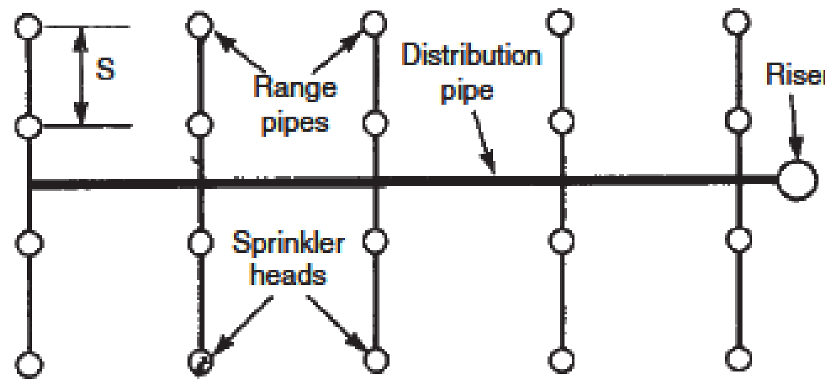
Two-end side with centre feed pipe



Three-end side with end feed pipe



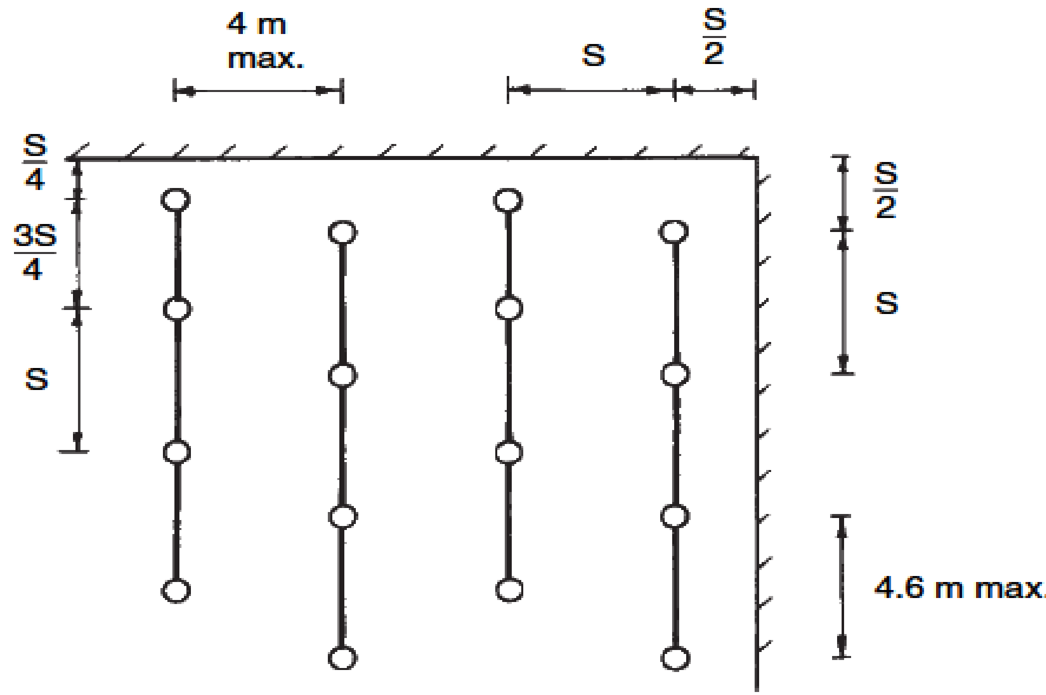
Two-end centre with central feed pipe



Two-end centre with end feed pipe

Further Pipework Distribution and Spacing Calculations

Staggered arrangement of sprinkler heads on an ordinary hazard installation:



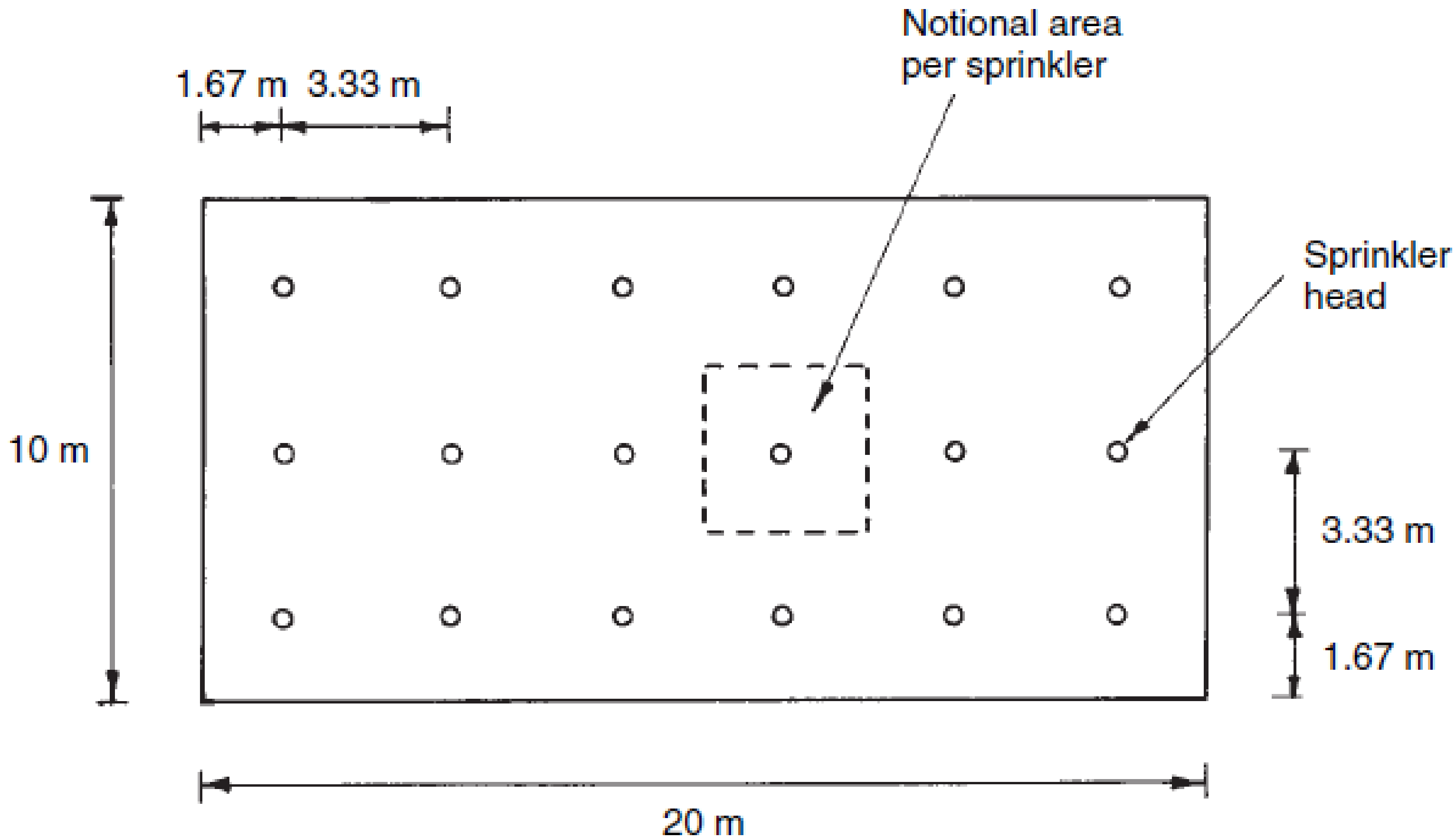
Calculating the number of sprinkler heads: e.g. an ordinary fire hazard category for a factory having a floor area 20 m × 10 m.

$$20 \times 10 = 200 \text{ m}^2$$

Ordinary hazard requires a maximum served floor area of 12 m² per sprinkler head.

Therefore: 200 ÷ 12 = 16·67, i.e. at least 17 sprinkler heads.

For practical purposes, 18 could be installed as shown:



The maximum area served by each sprinkler head = 3·33m × 3·33m = 11·1m².

This is satisfactory, being less than 12m².

Sprinkler Pipe Sizing

Sprinkler pipe installations downstream of the alarm and control valves should be sized by hydraulic calculation, with regard to system pressure and friction losses (see Part 2).

Tabulated data for pipe sizing is available in BS EN 12845 and CIBSE Guide E : Fire engineering. It is also possible to determine pipe diameters from the Hazen–Williams friction loss formula:

$$p = \frac{6.05 \times 10^5 \times L \times Q^{1.85}}{C^{1.85} \times d^{4.87}}$$

Where, p = pressure loss in pipe (bar)

L = equivalent length of pipework plus bends and fittings, i.e. effective pipe length (m)

Q = flow rate through the pipe (minimum 60 litres/minute)

C = constant for pipe material (see table)

d = pipe internal diameter (mm)

Pipe material	Constant (C)
Cast iron	100
Steel	120
Stainless steel	140
Copper	140
CPVC	150

Maximum water velocity through valves is 6m/s. Through any other part of the system, 10m/s.

By determining an acceptable pressure loss as a design prerequisite, the Hazen-Williams formula can be rearranged with the pipe diameter as the subject:

$$d = \sqrt[4.87]{\frac{6.05 \times 10^5 \times L \times Q^{1.85}}{C^{1.85} \times p}}$$

Example

e.g. Calculate the diameter of 30m effective length steel pipe, where the acceptable pressure loss is 0·02 bar with a water flow rate of 60litres/minute.

$$d = \sqrt[4.87]{\frac{6.05 \times 10^5 \times 30 \times 60^{1.85}}{120^{1.85} \times 0.02}}$$

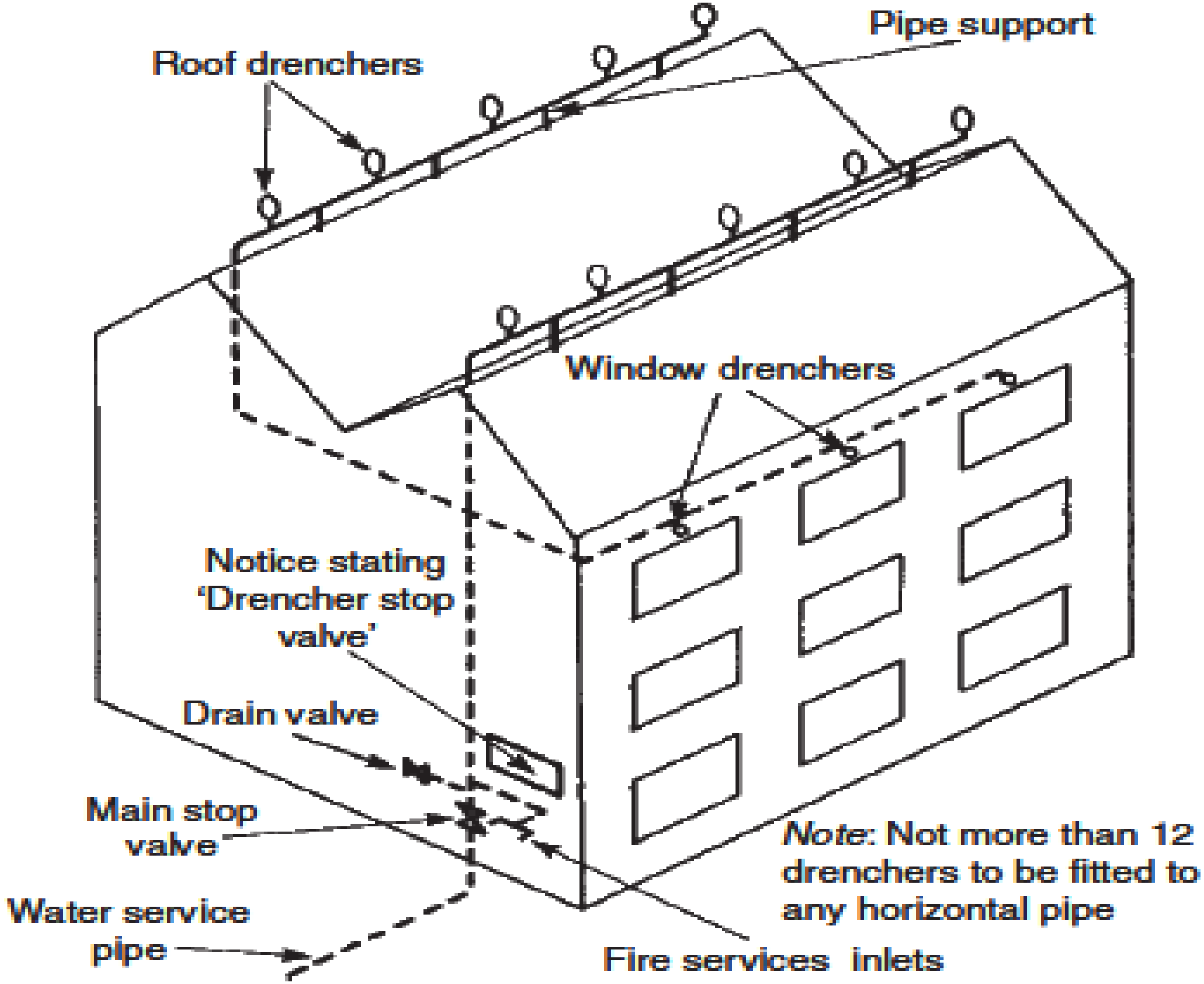
$$d = \sqrt[4.87]{\frac{353554.56 \times 10^5}{140.45}} = 53.09 \text{ mm (i.d.)}$$

50mm nominal inside diameter is just too small, therefore a 65mm nominal inside diameter steel pipe would be selected.

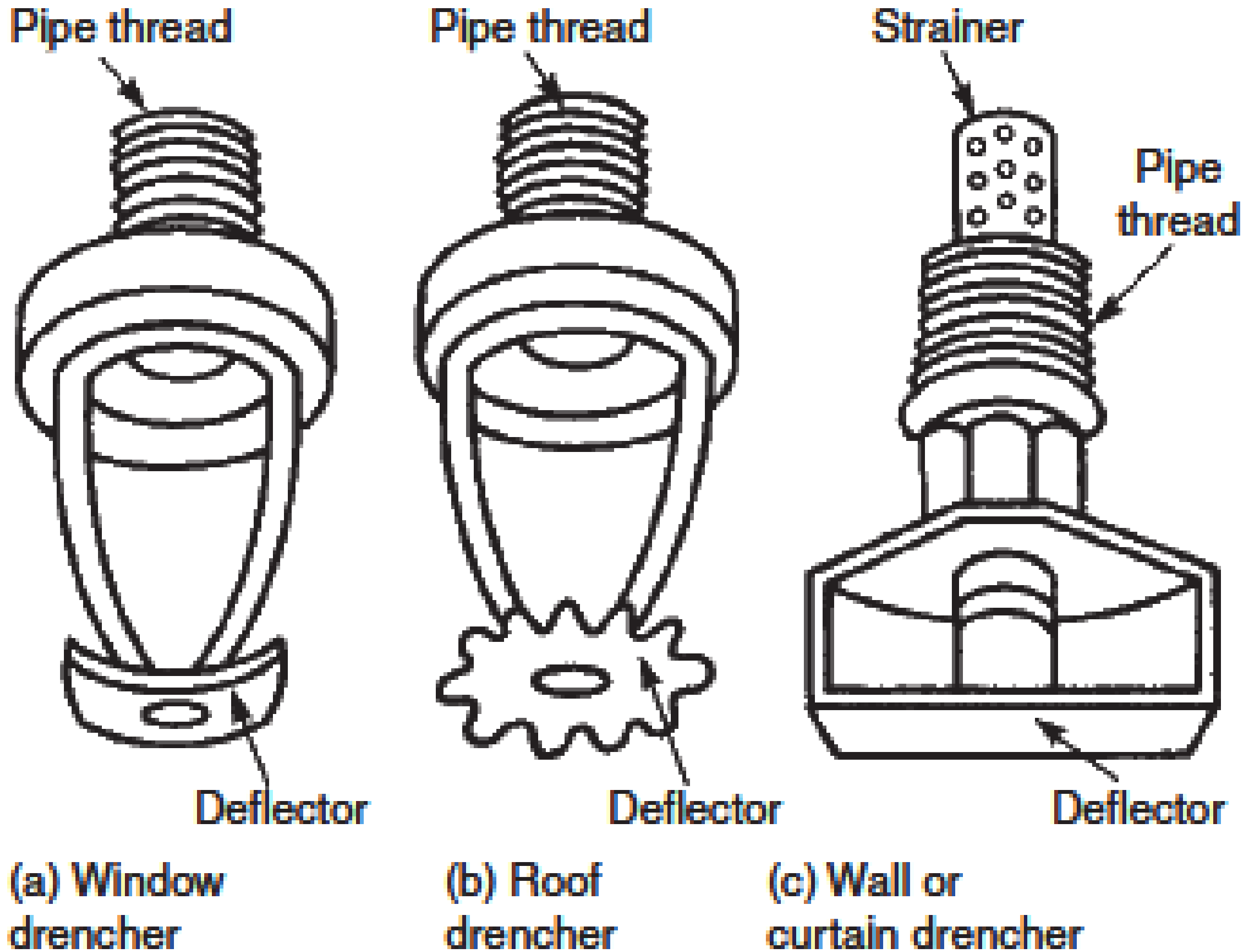
Drenchers

A drencher fire control system provides a discharge of water over

roofs, walls and windows to prevent fire spreading from or to adjacent buildings. Automatic drenchers are similar in operating principle to individual quartzoid bulb sprinkler heads. The number of drencher nozzles per pipe is similar to the arrangements for conventional sprinkler installations as indicated in BS 5306 – 2. For guidance, two drenchers can normally be supplied by a 25 mm i.d. pipe. A 50 mm i.d. pipe can supply ten drenchers, a 75 mm i.d. pipe 36 drenchers and a 150 mm i.d. pipe over 100 drenchers. An example of application is in theatres, where the drenchers may be fitted above the proscenium arch at the stage side to protect the safety curtain.



Typical drencher installation



Types of drencher

Fire Detection

In the UK, the Fire Service attend over half a million fires per year.

These fires result in over 800 deaths and many more injuries. About a tenth of all fires occur in homes and account for some 500 deaths and thousands of injuries. An early warning device to detect smoke and fire could significantly reduce the number of human casualties.

Fire detection

Minimum protection : one detector for every floor level positioned in a central hallway and/or landing. Building Regulation requirements for dwellings are summarized on pages 543 † 544. For other building purposes brief mention only is given on page 544, as different situations have varying requirements. Therefore the Approved

Document should be consulted for specific applications.

Fire alarm

Fire detection and alarm systems may contain:

- system control unit
- primary (mains) electrical supply
- secondary (battery or capacitor stand-by) power supply. An emergency generator could also be used
- alarm activation devices † manual or automatic
- alarm indication devices † audible and/or visual
- remote indication on a building monitoring system
- control relay via a [redacted] to effect fire extinguishers and ventilation [redacted] control actuators.

Fire alarm

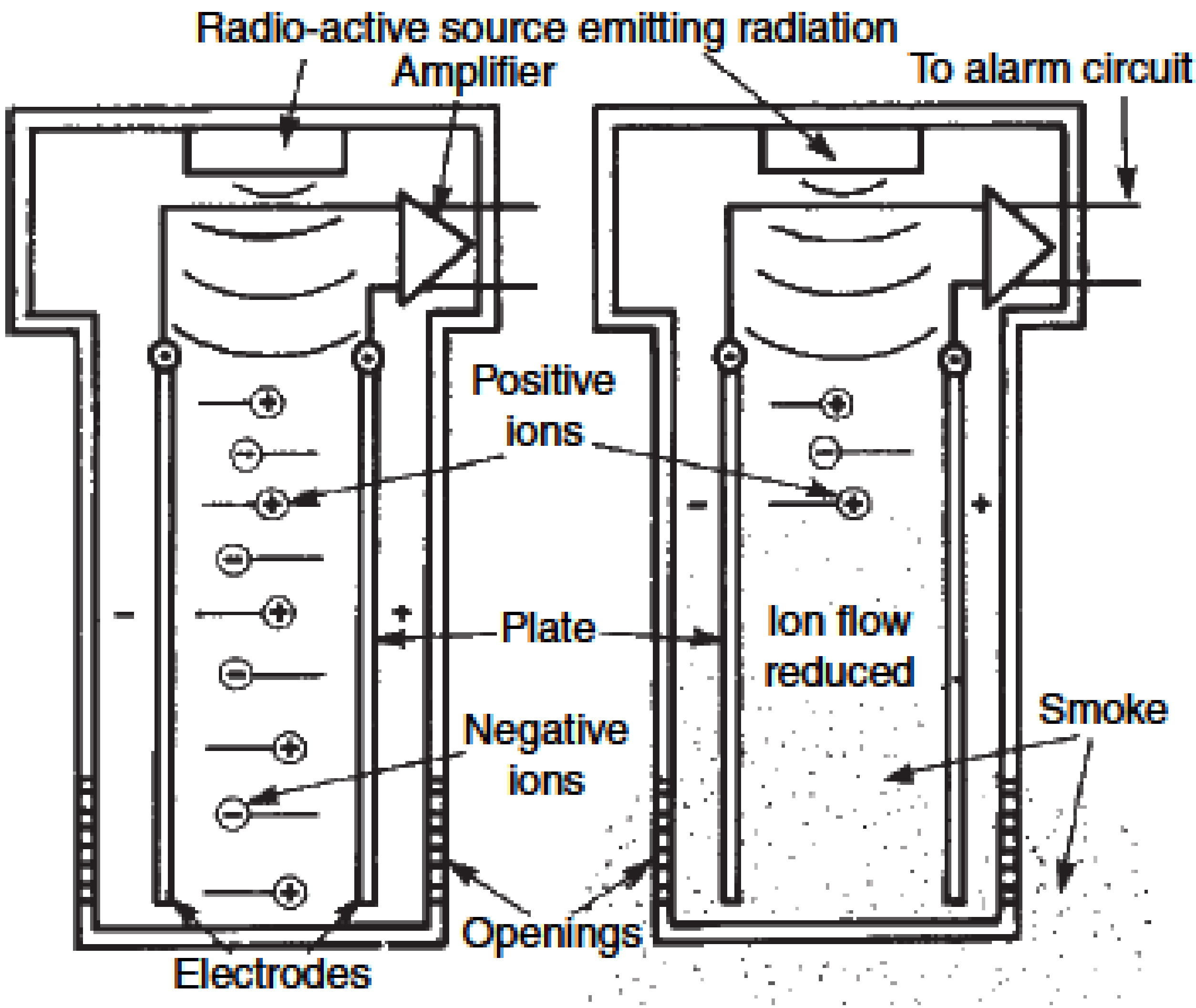
System control unit : an alarm panel which monitors the state of all parts (zones) of the installation. It identifies the point of origin of an alarm, displays this on the panel and communicates this to remote control locations.

Fire alarm

- Zones:
- ● Max. 2000 m^2 floor area in one storey.
- ● No detachment of compartment areas within one floor area zone.
- ● Max. 30 m search distance into a zone.
- ● Single occupancy of a zone where several separate business functions occur in one building.

Smoke Detectors

Ionisation smoke detector † positive and negative charged plate electrodes attract opposingly charged ions. An ion is an atom or a group of atoms which have lost or gained one or more electrons, to carry a predominantly positive or negative charge. The movement of ions between the plates reduces the resistance of air, such that a small electric current is produced. If smoke enters the unit, particles attach to the ions slowing their movement. This reduction in current flow actuates an electronic relay circuit to operate an alarm.



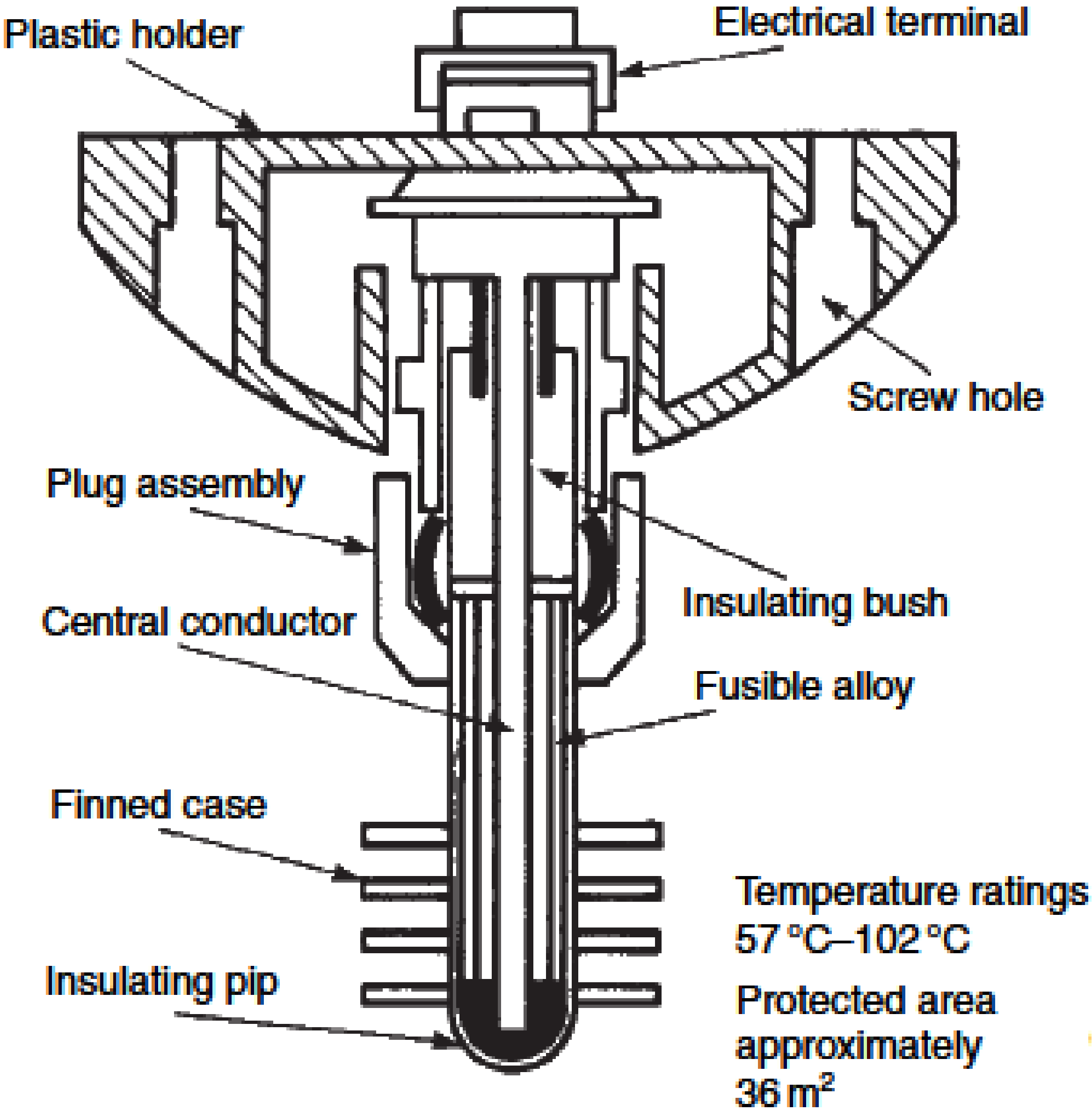
(a) During non-fire period

(b) During fire period

Ionisation smoke detector

Heat Detectors

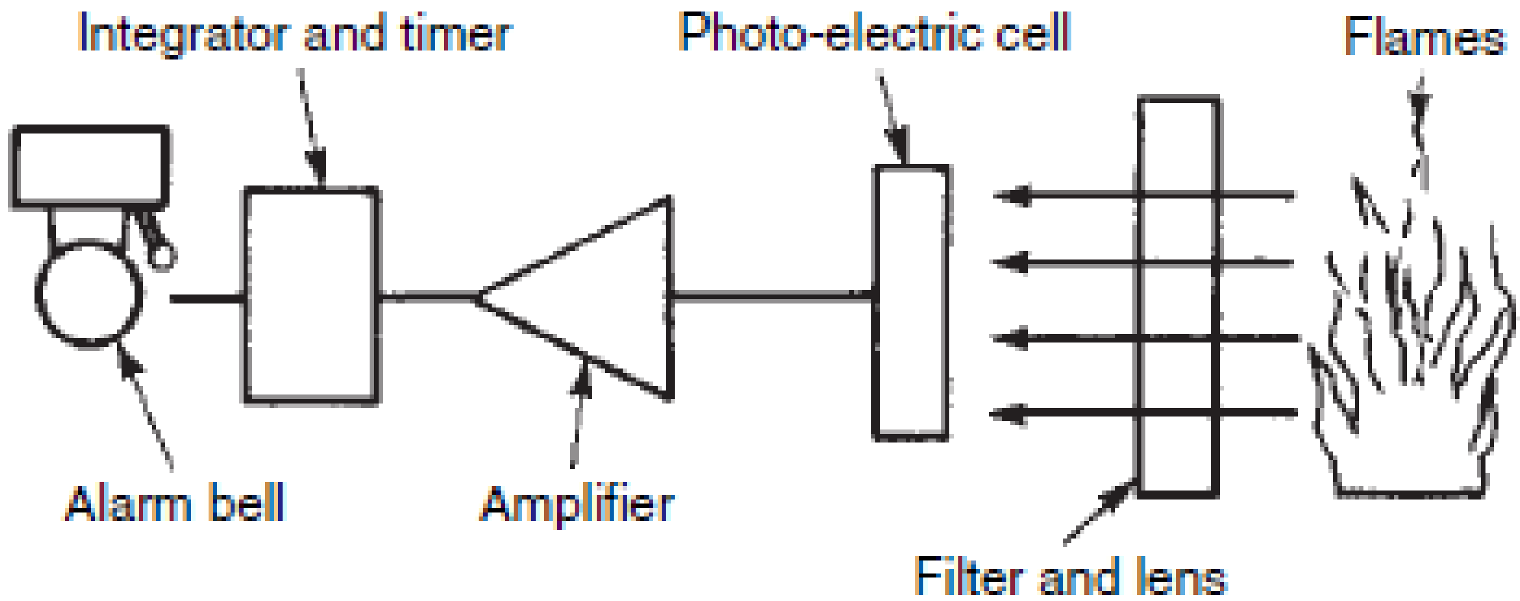
Heat detectors are used where smoking is permitted and in other situations where a smoke detector could be inadvertently actuated by process work in the building, e.g. a factory. Detectors are designed to identify a fire in its more advanced stage, so their response time is longer than smoke detectors.



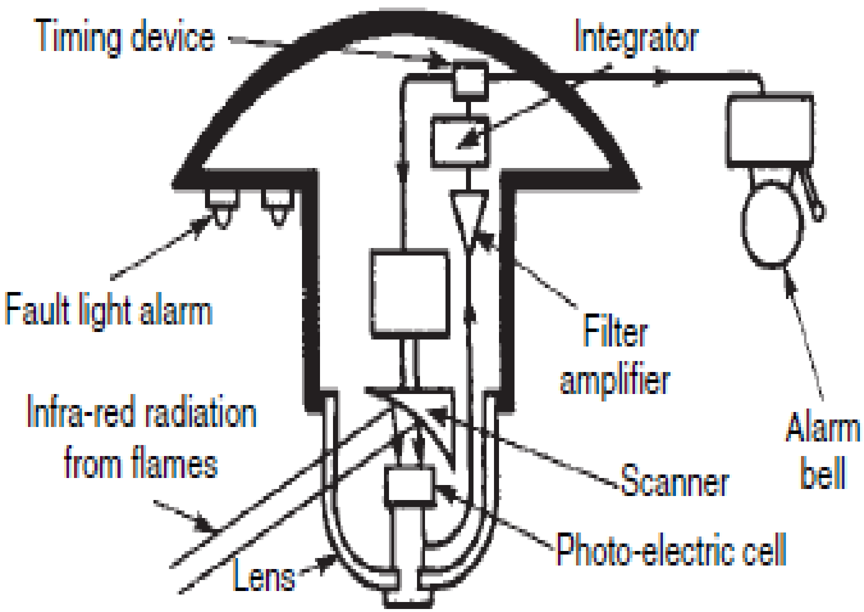
Fusible alloy heat detector

Radiation Fire Detectors

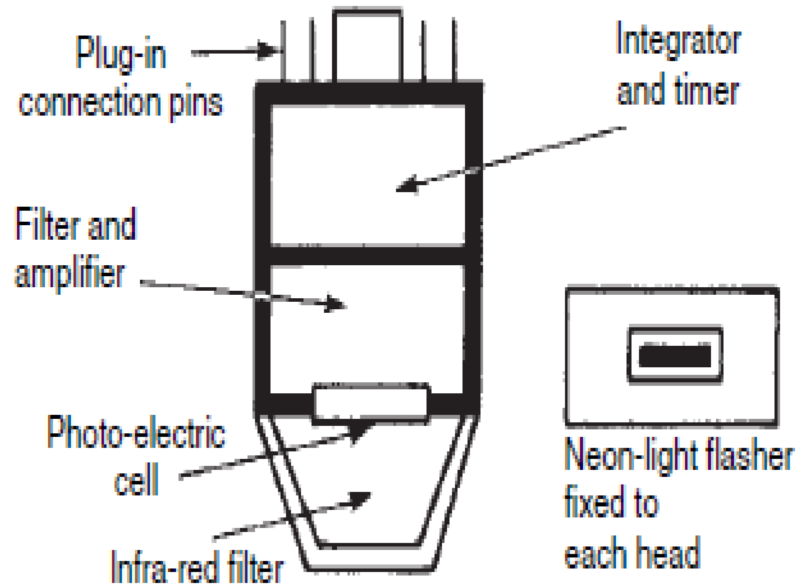
Infra-red detector † detectors have a selective filter and lens to allow only infra-red radiation to fall on a photo-electric cell. Flames have a distinctive flicker, normally in the range of 4 to 15 Hz. The filter is used to exclude signals outside of this range. The amplifier is used to increase the current from the photo-electric cell. To reduce false alarms, a timing device operates the alarm a few seconds after the outbreak of fire.



Components of an infra-red detector



Infra-red detector for large areas



Infra-red detector for small areas

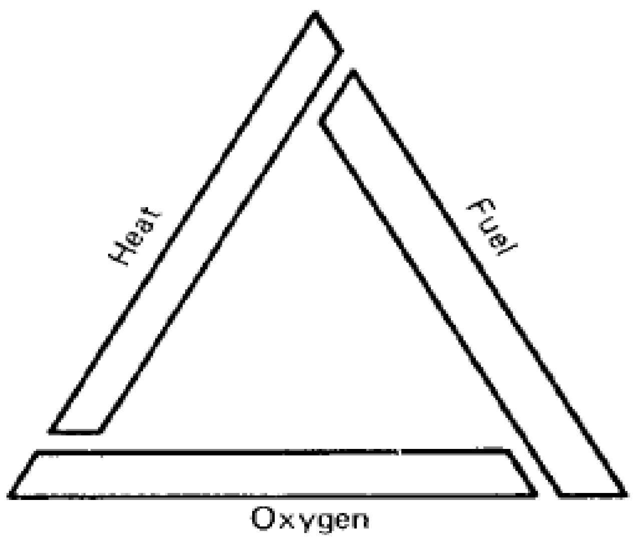
Portable Fire Extinguishers – 1

A portable fire extinguisher must contain the type of fire extinguishing agent suitable for the fire it is required to extinguish. It must also be clearly identifiable by colour coding for its intended purpose.

Fires can be grouped:

- Solid fuels, e.g. wood, paper, cloth, etc.
- Flammable liquids, e.g. petrol, oil, paints, fats, etc.
- Flammable gases, e.g. methane, propane, acetylene, etc.
- Flammable metals, e.g. zinc, aluminium, uranium, etc.
- Electrical.

Extinguishing agent	Extinguisher colour	Application
Water	Red	Carbonaceous fires, paper, wood, etc.
Foam	Red with cream band	Ditto and flammable liquids, oils, fats, etc.
Carbon dioxide	Red with black band	Electrical fires and flammable liquids.
Dry chemicals	Red with blue band	All fires.



Three elements required for a fire. The removal of one element will extinguish the fire

Carbon Monoxide Detectors – 1

Carbon monoxide (CO) gas is colourless, invisible, tasteless and odourless. Where allowed to accumulate it cannot be detected by human perception or senses. With sufficient exposure it can be deadly, hence its common reference as the 'silent killer'. It is the primary cause of death by accidental poisoning in the UK, with estimates in excess of 20 persons per year and some 200 others seriously injured. About half of these incidents are attributed to faulty fuel burning appliances, either incorrectly serviced or improperly installed. It is not easy to determine the total numbers of people affected, as the symptoms and characteristics can be similar to other medical disorders.

Effect on the human body – the body's ability to transport oxygen to vital organs is impaired when exposed to carbon monoxide. Carbon monoxide bonds with the haemoglobin in blood to gradually replace oxygen. This prevents the uptake of oxygen into the blood and the body begins to suffocate.

Types of detector/alarm – mains or battery powered. Audible, also available with a visual facility for people with hearing difficulties. Size and appearance resembles a domestic smoke alarm, but the sensor inside the unit differs being any of the following:

- An electro-chemical type of fuel cell that is energised in the presence of CO.
- Biomimetic – a synthetic haemoglobin that darkens in the presence of CO. The colour change activates a light cell.
- Semi-conductor – an electric circuit of thin tin oxide wires on a ceramic insulator. Presence of CO reduces the electrical resistance allowing greater current flow to activate the alarm.

Carbon Monoxide Detectors – 3

The positioning and number of carbon monoxide detectors depends on the layout of rooms. Several individual battery powered detectors/ alarms is acceptable, but it is preferable to have a system or network of hard-wired mains powered interlinked detectors.

Location –

- In any room containing a fuel burning appliance.
- Bedrooms, positioned at pillow height.
- Remote rooms, 1.5 to 2.0 m above floor level.
- Room adjacent to a dedicated boiler room.
- In bed-sits, close to sleeping area and away from cooking appliance.
- Not in bathrooms or shower rooms.

Positioning –