SKILLED TO BE A **FIRE EXPERT**

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Automatic Fire Suppression System

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1 Introduction to fire suppression systems

Fire prevention, detection and suppression are key factors that should be taken into consideration to guarantee life safety, property, business and environment protection. This requires that appropriate fire safety equipment will be present to protect both people and buildings.

Thus, a major component towards ensuring fire safety in buildings is the design, installation, and maintenance of fire suppression systems. To achieve a successful design and use of those system requires specific knowledge of a number of parameters that are specific to the building and its use. Those mainly include what type of area or object should be protected, what means will be used and what type of fuel will potentially exist in the area that should be protected. After these considerations are taken into account, the type of extinguishing agent and relevant fire suppression system is usually selected taking also into account secondary losses on property after extinguishment or other specific conditions which could affect the design of the fire suppression system. Depending on the circumstances and relevant regulations, a fire suppression system can be applied locally or can accommodate total flooding systems that may include or not relevant accommodation and service spaces, as depicted in Figure 1.

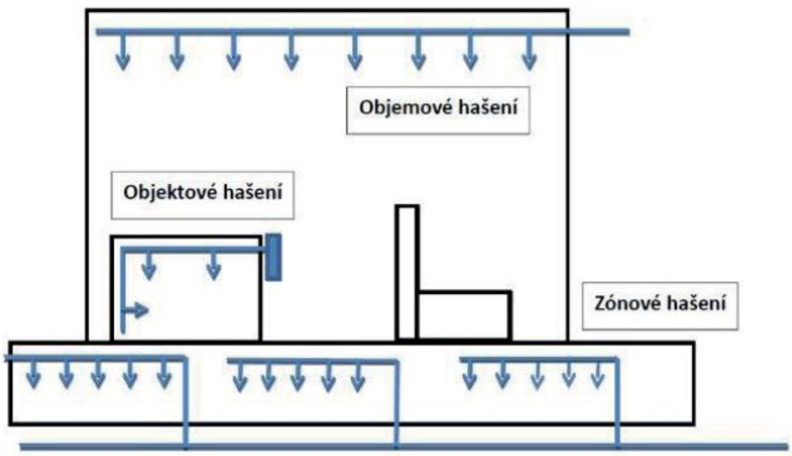

Fig. 1. Possible areas of application of fire suppression systems (Rybar, 2014).

Though water is the most used firefighting agent and has the desirable characteristics to suppress fire (high specific heat and latent heat of vaporisation) it is not always used in fire suppression systems. In cases that certain water reactive materials or liquid hydrocarbon fuels are concerned, wated cannot be effectively used and other types of materials or additives are used instead. For most applications, automatic water sprinkler systems (AES) are considered the most efficient and cost-effective systems. AES are divided in water based and other extinguishing systems based on whether wates is used as the main agents as depicted in Table 1; relevant applications of each system are also tabulated. In water-based systems, there are four basic types of sprinklers that are usually installed and those include wet pipe, dry pipe, deluge and preauction systems. The different systems and their main characteristics are analysed in the following sections.

Table 1. Fire suppression system categories, widely used systems, relevant agents and their application.

Category	System	Applications
Water-based systems	Fire hydrants	Outdoor areas and private premises.
	Wet sprinklers/pipe	Hotels, offices, dormitories, restaurants, clubs, and storages.
	Dry sprinklers/pipe	Outdoor areas with probability of temperature under zero, e.g., cultural heritages.
	Water Mist	Offices, food industry, dormitories, and IT facilities.
	Master Streams	Industrial settings, e.g., flammable liquid storages with liquid hydrocarbons.
	Steam	Waste treatments and mills.
Other extinguishing systems	Foam using polar/ non-polar liquids	Hangars and storages with flammable liquids.
	Gas (CO_2, N_2, gas mixtures)	Archives, server rooms, sensitive electronic, control rooms.
	Powder	Metal fires and electric installations.
	Aerosol	High-voltage switchboards, cable canals and oil storages.
	Dry chemical	Industrial settings, e.g. spray booths and large off-road equipment storage.

2 Water-based extinguishing systems

For the majority of applications, water-based AES are considered to be the most effective and economical way to control, suppress, or extinguish a fire (SFPE Handbook, 2016). Water-based fire suppression systems are proved effective for containing and preventing fire spreading as can be observed in Figure 2 where the effect of those systems in a compartment fire development is illustrated (Hoey, 2021).

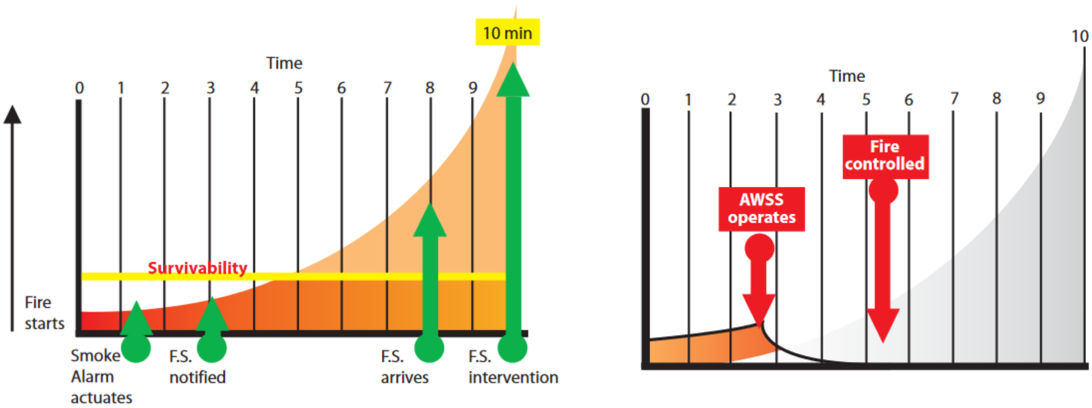

Fig. 2. Effect of fire suppression systems in fire development in a compartment fire, where AWSS is automatic water suppression systems (Hoey, 2021)

2.1 Water mist extinguishing systems

In this type of fixed extinguishing systems water is used in the form of mist. The discharge of a water mist system is very different from a sprinkler or deluge system. The discharge of a single water mist nozzle comprises a small cloud of micro drops of water. The shape of the cloud depends on the design of the nozzle. All active nozzles of a water mist system work in harmony to create a misty area. High pressure water mist extinguishing systems may approach of water drops distribution in dimensions of 0.2 mm to 0.025 mm. This provides highly efficient extinguishing impact with smaller requirements to water distribution and secondary loses which are beneficial especially for fire suppression of enclosure fires. Unlike deluge and dry sprinklers, water mist systems are not suitable for use in windy environments, such as outside.

Water mist systems can remove heat from the fire environment by vaporising mist into steam and wetting or cooling the area. Thus, they are ideal systems for an object protection as they cause limited thermal shock and are quite popular to be used on the bearings in machines with parts rotating at high speeds, e.g. gas- and steam turbines and generators. The requirement in wates is also limited compared to other water-based systems. Water mist systems are divided into three categories depending on the pressure of the systems (Rybar, 2014). Namely, low (max 1.25 MPa), medium (1.25 – 3.5 MPa) and high-pressure systems (higher than 3.5 MPa) can be found.

2.2 Foam extinguishing systems

Foam systems, as depicted in Figure 3, are used in areas where water, gas nor other extinguishing agents would be effective. The most common area of foam application is for combustible and highly flammable liquids. The main extinguishing effect is based on cooling and removing access of flame to oxygen. There are three categories of foam which has different purpose of application.

These categories are based on level of expansion:

Low expansion (expansion ration up to 20) is applied for fire suppression of large flammable liquid fires (storage tanks, manufacturing technologies, docks, storages of tyres and plastic material or storages of flammable materials class A or B).

Medium expansion (expansion ratio 20 - 200) is used for extinguishing flammable liquids or gas liquified gases sumps (LPG).

High expansion (expansion ration higher than 200) is applied at for protection of collection sump of LPG and LNG. It is also commonly used in hangars, storages and warehouses, cable canals, storages of plastic materials, etc.

In outdoor application, it is important to consider wind impact to foam distribution.

Fig. 3. Example of a hangar fire suppression system in action (Global Aerospace Aviation Insurance, 2021)

2.3 Master Streams

This type of fire suppression system is usually used for extinguishing in hangars, heliports, flammable liquids storages. It is also used for cooling of technological objects and constructions or envelopes of flammable liquid tank storages. Master streams can be control manually or remotely (usually in electronically) and they are equipped with water stream, foam-producing nozzle, both or dry chemical. The nozzle flow can be from 3 000 l/min with effective range to 60 m to 60 000 l/min with effective range to 130 m. The application of foam decreases range distance by 30%. An example of application of a Master Streams system with firefighting foam is shown on Figure 4 (Rybar, 2014).

Fig. 4. Foam master stream (Rybar, 2014)

2.4 Steam extinguishing systems

Fire suppression technology using water steam as extinguishing agent is usually used in areas where there is steam distribution. The main benefit of water steam for extinguishing is its capability of oxygen replacement. This system is usually used in petrochemical industry for protection of fractionation towers or in textile industry (Rybar, 2014).

2.5 Gas extinguishing systems

Gas extinguishing systems are used for volumetric extinguishing with application of gas for filling compartment or for local fire suppression of small fires. The main prescribe fire suppression mechanism is prescribed by filling area of defined gas concentration and its still for at least 10 minutes. This system is usually used in electrotechnical systems, server rooms, archives, and area with sensitive electronic or other materials which could be sensitive on secondary losses or residues or where is danger of electrical conductivity.

The main fire extinguishing effect is removing oxygen (inert gases) from the area or cooling effect (CO_2). There are other special mixtures of gases with extinguishing effect without harming people. The most common gaseous agents are CO2 halon alternatives or inert gases including Argon, Nitrogen, and their mixtures or another clean agent such as FK 5-1-12 and other clean agents, see ISO 14520. An example of a gaseous extinguishing system design is illustrated in Figure 5. Next to the volumetric fire extinguishing, there exist also local application of gaseous systems with small cylinder of gases where the agent is applied in place of predicted fire observation for example in boats, vehicles, or electronic systems.

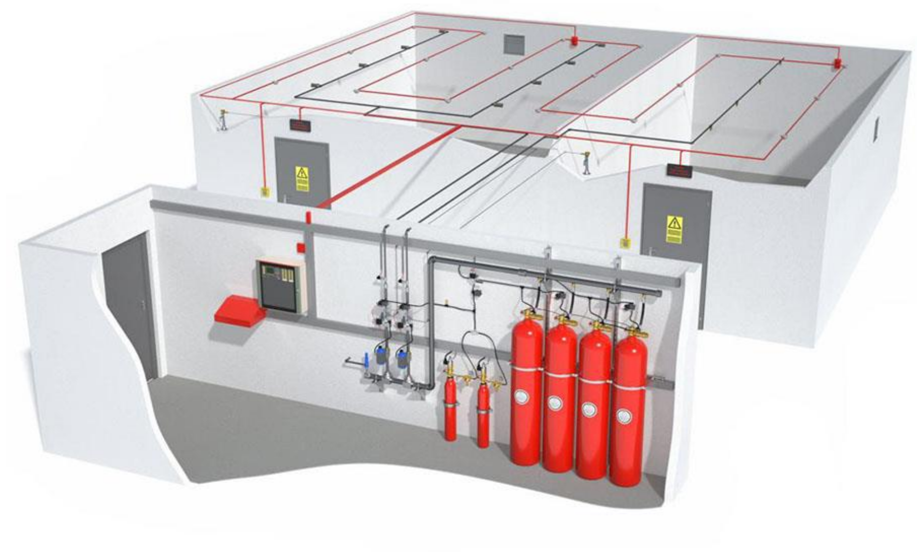

Fig. 5. Example of gaseous fire suppression systems application (Gielles, 2021).

2.6 Dry powder extinguishing systems

Dry powder extinguishing systems are largely used in industrial chemical storages, petrochemical loading and off-loading facilities, auto pain booths, dip tanks, hydraulic or recycling systems. The main extinguishing effect is anticatalytic but this agent missing cooling effect. That required additional cooling of the fire for removing probability of repeated self-ignition. That is made usually by combination with foam systems. This agent is highly effective for extinguishing flammable gases under pressure or flammable liquids.

2.7 Aerosol systems

This extinguishing agent is prepared by burning of solid mixture in generator of aerosol which filling protected area. Burning develop solid and small particles which cause better fire extinguishing efficiency than dry powder. This system is used in objects and area where presence of persons is not expected. The application is for extinguishing of fuels categories A, B or C. The main purpose of this system are oil storages or electrical systems. The main disadvantage of this system is the rest of extinguishing agent and pollution.

3 Water sprinkler systems

Water sprinkler systems are the most widely used automatic fire extinguishing systems. The main extinguishing agent is water which is relatively cheap and non-toxic agent. The main benefits of this automatic fire suppression systems are their ability to work 24/7 365 days a year without needs of action of any person.

As described in *EN 12845 - Fixed Firefighting Systems*, the main design parameters of those fire suppression systems are intensity of water supply, effective area and time of operation. These parameters are influenced by hazard class:

- **(LH) Low Hazard** – non-industrial buildings with low fire load
- **(OH 1, 2, 3, 4) Ordinary Hazard** – medium fire load and medium combustibility
- (**HHP 1, 2, 3, 4) High Hazard Processing** – industrial buildings with processed material
- **(HHS 1, 2, 3, 4) High Hazard Storage** – high hazard object and storages with high fire load

Based on the fire hazard classification there is recommended water supply from 2.5 $l/min.m^2$ to 30 $l/min.m^2$. Another option would be use of early and high-volume suppression fast response (ESFR) systems that can reach ca. 7 - 27 $l/min.m^2$. Main components of sprinkler are water reservoirs or pressured cylinder, pump, connections for firefighter's pumpers, alarm bell, flow meter, dry pipe / wet pipe systems, sprinkler heads, fire alarm system. A connection scheme of a wet and dry pipe water sprinkler system (Minimax, 2021) is illustrated on Figure 6.

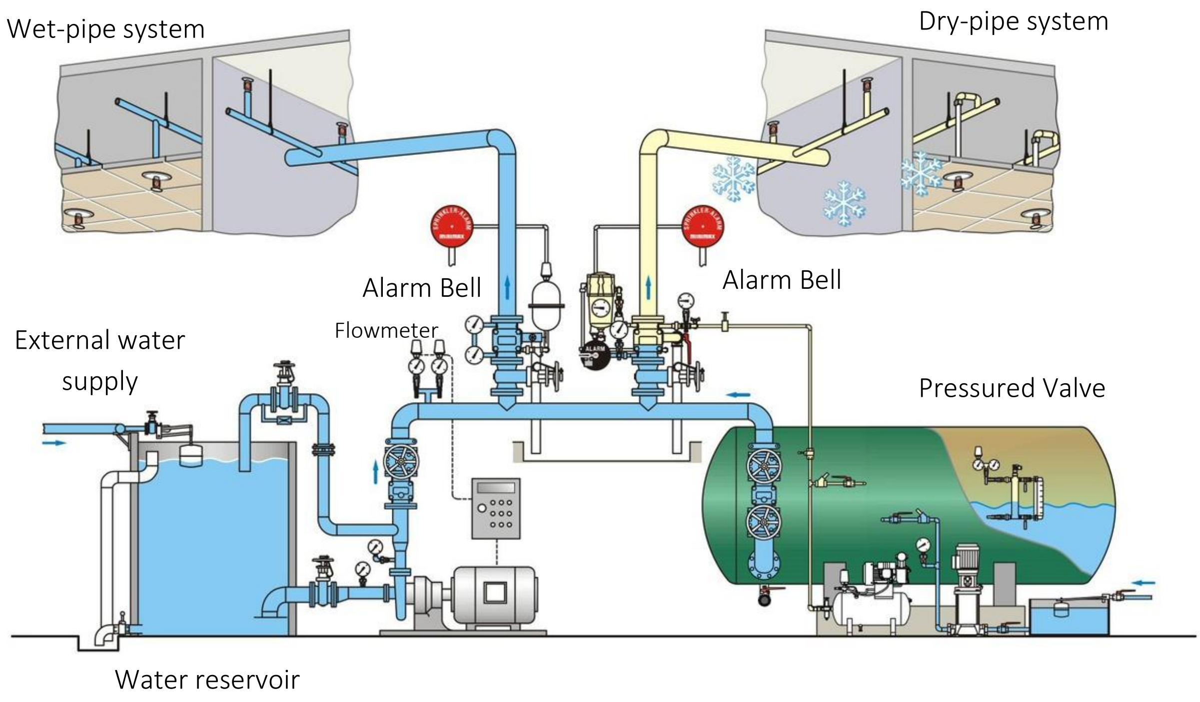

Fig. 6. Scheme of water sprinkler system (Minimax, 2021)

There are four basic types of sprinkler systems:

1. **A wet pipe system** is by far the simplest and most common type of sprinkler system, Figure 7. It consists of a network of piping containing water under pressure. Automatic sprinklers activated by internal heat responsive elements are connected to the piping such that each sprinkler protects an assigned horizontal building area, usually a floor area. The application of heat to any sprinkler will cause that single sprinkler to operate, permitting water to discharge over its area of protection.

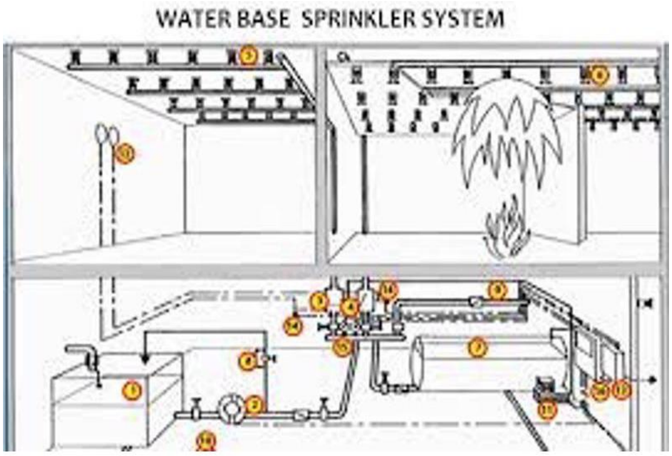

Fig. 7. Scheme of wet pipe water sprinkler system.

2. **A dry pipe system** is like a wet system, except that water is held back from the piping network by a special dry pipe valve, Figure 8. The valve is kept closed by air or nitrogen pressure maintained in the system piping. The operation of one or more sprinklers will allow the air pressure to escape, causing operation of the dry valve, which then permits water to flow into the piping network to control or suppress the fire. Dry systems are used where the water in the piping would be subject to freezing.

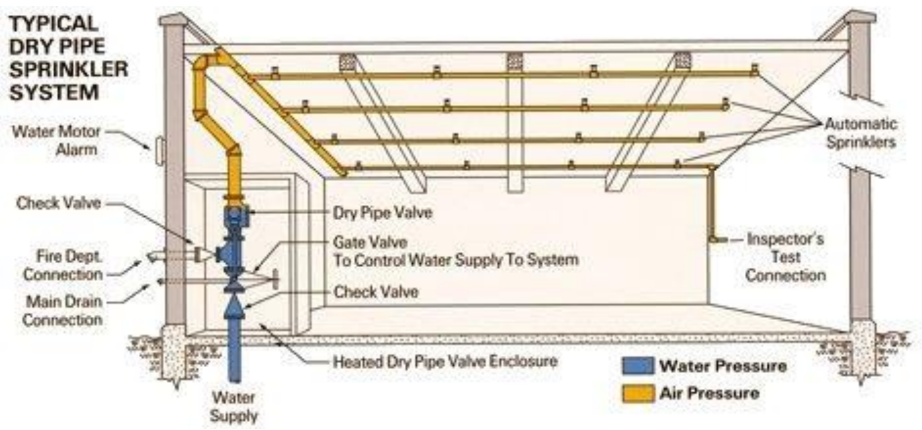

Fig. 8. Scheme of dry pipe water sprinkler system.

3. **A deluge system** is one that does not use automatic sprinklers, but rather open sprinklers. A special deluge valve holds back the water from the piping and is activated by a separate fire detection system. When activated, the deluge valve admits water to the piping network, and water flows simultaneously from all the sprinklers comprising the system. Deluge systems are used for protection against rapidly spreading, high heat release fires.

4. **A preaction system** is like a deluge system except that automatic sprinklers rather than open sprinklers are used. A small amount of air pressure is usually maintained in the piping network to ensure that the system is airtight. As with a deluge system, a separate detection system is used to activate a deluge valve, admitting water into the piping network.

However, because automatic sprinklers are used, the water is only discharged from activated sprinklers, i.e., those that were fused by heat from the fire. Some special arrangements of preaction systems permit variations on detection system interaction with sprinkler operation. Preaction systems are generally used where there is special concern for accidental discharge of water, as in data processing computer rooms or flash freeze warehouses.

3.1 Sprinkler head with glass bulb

Sprinkler is the component of the sprinkler system provides discharging of water when the fire trigger mechanism. The most common trigger is temperature sensitive glass bulb with glycerine-based liquid which expands with heat exposure. The triggering temperature is marked by colour of the fuse, where the red (68°C) is the most common. Another less common activation method is fuse consists of two metal plates soldered together. The other components of the sprinkler head are described on Fig. 9. The liquid is deigned to expand and break the tube in specified temperature. Broken tube cause removing of sealing assembly and opening the sprinkler head and flow of water, which is sprayed by deflector, see Fig. 9.

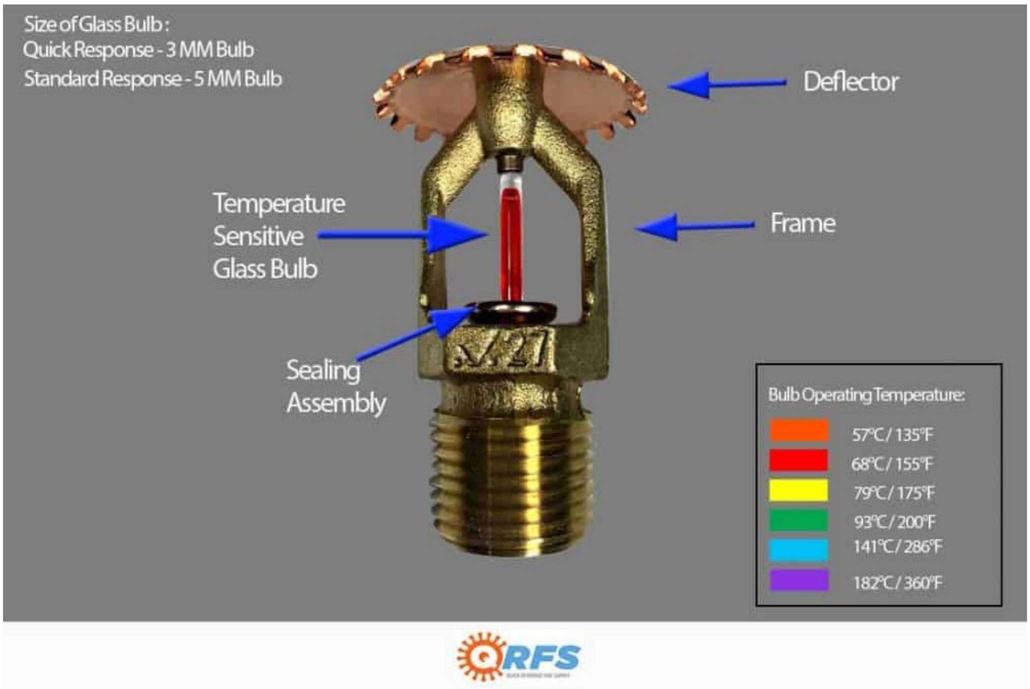

Fig. 9. A glass bulb sprinkler head and the operating temperatres of the bulb.

The decrease of pressure in sprinkler system trigger ventil station and start delivery water in sprinkler system. In the same time the fire alarm is activated as well as alarm bell for signalization of object occupancy. The water supply may be stopped only manually by commander of fire intervention unit (Rybar, 2014).

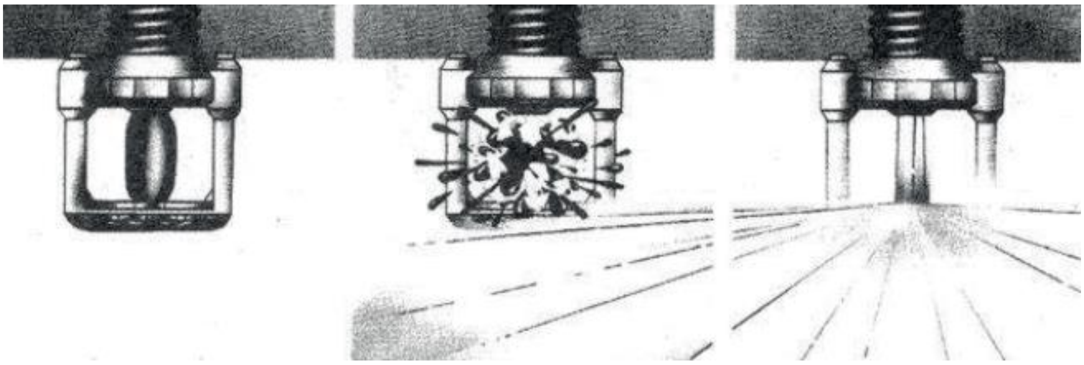

Fig. 10. Activation of sprinkler head (Rybar, 2014)

3.2 Standard vs quick response sprinklers

The biggest difference between standard and quick response sprinkler heads is their activation temperature. The main physical difference between standard and quick response sprinklers is dimension of the bulb, where standard heads equip with 5 mm bulbs and quick response heads are equip with 3 mm bulbs.

Standard response fire sprinklers are usually mounted in warehouses, factories, or other commercial buildings. Quick response fire sprinkler is usually mounted in area with low hazard of fire – e.g., office buildings or schools.

Quick response sprinkler is faster than standard response sprinklers and they are used in area with light hazard. Head discharge the water higher up to ceiling which prevent flashover fire development by cooling ceiling jet.

Fig. 11. Difference between standard and fast response sprinkler head (QRFS, 2021).

3.3 Types of sprinkler heads

There are various types of the sprinkler heads based on their application and orientation. (See Fig. 12). Between main types of the sprinkler heads may be mentioned pendent, upright, sidewall and concealed sprinkler heads.

Pendent head – this type is the most common and it is used in offices, accommodation, and factories. Head is hanged down from ceiling and water covers circular area. Deflector is curved down to direct water in cone shape.

Upright head – this head points upwards to the ceiling. Deflectors are oriented down, and the water spray pattern has hemispherical shape.

Sidewall head – in tight spaces are used sidewall heads. Typical application is in small rooms or hallways (e.g., boats). This head has half deflector in opposite the previous types, which helps to cover entire area.

Concealed head – this sprinkler head has similar properties as the one with the pendant head. The main difference is by equipping by cover plate which fall one temperature is 20°C less than the sprinkler which allows sprinkler activation one the heat exposure reach the activation temperature.

https://www.frontierfireprotection.com/sprinkler-heads-fire-protection/

Fig. 12. Various types of sprinkler heads based on their application.

Spray pattern of selected sprinkler heads are shown on Fig. 13 with various types of spray type. It depends on required environment where the system shou be applied such as technological devices or machinery.

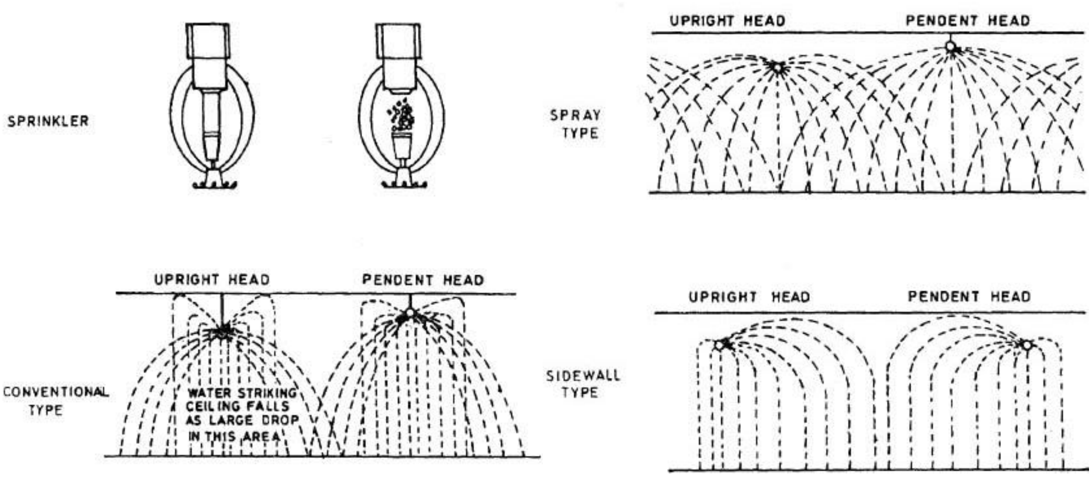

Fig. 13. Different types of sprinkler head spray patterns

4 Interaction with other fire protection systems

The often-designing question in application of fire protection systems is interaction between smoke control / ventilation systems and fire suppression systems. Wrong design and application of these systems may have negative influence on safety of occupants and may cause higher property loss.

The main point for consideration is negative influence between fire suppression systems and smoke extraction systems, where smoke extraction may cause removal of heat which could cause delay in activation of fire suppression system. Based on this it was estimated.

The following tables show the positive contributions of water extinguishing systems and SHEVS to the achievement of specific protection objectives.

Table 2. Property protection (VdS 2815en, 2018)

	Suppression system	**Smoke extraction systems**
Damages caused fire heat	Limitation of fire spread and heat release by dire firefighting after immediate activation of system. Cooling surrounding area of the fire.	Convection heat dissipation and limitation to the smoke compartment.
Damages caused by smoke	Reduction of firefighting and fire gases pollutants.	Exhaust of fire gases and smoke spread limitation by smoke compartmentation.

Table 3. Life protection (VdS 2815en, 2018)

	Suppression system	**Smoke extraction systems**
Fire heat damages	HRR reduction, fire spread reduction in the room	Convection heat dissipation and limitation to the smoke compartment

Evacuation and rescue routes protection	Containment of the fire and fire spread. Reduction of pollutants	Providing a low smoke layer facilitates self-rescue
Secondary fire products	Reduction of pollutants	Indirect support fire brigade intervention
Fire suppression	Containment of the fire and fire spread and support fire brigade measures	Low smoke layer facilitates fire brigade intervention
Pollutant emission	Reduction of fire gases hazardous for occurred persons	Dissipation of fire gases hazardous to occurred persons and provision of low smoke layer

Regarding VdS the Tab. 3 described possible combinations of fire suppression systems and smoke extraction systems together.

Table 4. Possible combination of ventilation and suppression systems regarding VdS

	Sprinkler	**ESFR**	**Water spray**	**Water mist**
Powered SHEVS Automatic activation	Combination possible[1,2]	Combination not permitted	Combination possible[3]	Prove effectiveness by fire tests
Powered SHEVS Manual activation	Combination possible[2]	Combination possible[2] Activation by fire brigade only[4]	Combination possible	Combination possible[2] Activation by fire brigade only[4]
Natural SHEVS Detection by smoke detectors	Combination possible[1]	Combination not permitted	Combination possible[3]	Prove effectiveness by fire tests
Natural SHEVS Activation by thermocouples	Combination possible	Combination possible Coordinate activation characteristics[5]	Combination possible	Prove effectiveness by fire tests
Natural SHEVS Manual activation	Combination possible	Combination possible Activation by fire brigade only[4]	Combination possible	Combination possible Activation by fire brigade only[4]

*ESFR sprinklers (Early Suppression Fast Response) use higher pressures and higher design densities than conventional sprinklers.

*SHEVS - Smoke and Heat Exhaust Ventilation Systems

Basically, there is the rule which recommend decide designing priority, if there is priority of side of occupant protection against toxic gases (e.g., shopping centres), or property protection (storages, warehouses). If the priority on side of protection of occupants, in Czech is generally practice by setting delay in activation of exhaust systems (this is not acceptable for warehouses).

5 Lessons learned - Example of applications

During the fire tests in BRE group, they burned a classical wooden crib to test residential fire test with sprinkler and sprinklered environment using standardized BS 9252 for components for residential sprinkler systems. The difference was obviously significant as unsprinklered test showed known marks of a fire origin, whereas the sprinklered room was extinguished even before the fire could propagate.

Fig. 14. Comparison of sprinkler application impact to fire development and spreading (BRE Group, 2013)

5.1 Failure of sprinkler systems

Failures of the sprinkler systems can be caused by a corrosion, freezing, inadequate parts or importantly, by an improper installation. Alarming examples to can be seen during a revision as fig. 15 shows.

Fig. 15. Typical fault of sprinkler heads (Rybar, 2014)

Fig. 16. Typical pipeline failure of fire suppression system - corrosion (Rybar, 2016)

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