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Automated Fire Protection

PDH Credits:

6 PDH

Course No.:

AFP101

Publication Source:

Original Courseware

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Release Date:
2017

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Automated Fire Protection

Credits: 6 PDH

Course Description

With a wide diversity of models and manufacturers of fire protection equipment on the market, this course is unable to provide a detailed and comprehensive overview of all of the possible variations involved in designing an automated fire protection system. Instead we will cover the most basic and commonly used systems.

In this course the various piping, mechanical, and electrical components of these systems will be discussed: fire detection, alarming, supervisory, suppression and total extinguishing systems.

Topics

- Wet, Dry, Deluge, Pre-Action, Combined Systems
- Other Common Types of Automated Systems
- Basic Design Approach to System Implementation
- Prescriptive-based Design vs Performance-based Design
- Use of BIM and fire modeling in the design process
- Water supply sources for a sprinkler system
- Characteristics of automatic sprinkler systems
- Basic components of automatic sprinkler systems
- Inspection, testing, and maintenance requirements for fire protection systems
- Some Hydraulic Calculations used in Fire System Design
- Valve Types used in Fire Protection
- Supervisory, Alarming, and Control Devices
- NFPA Code used in design of Fire Protection Systems

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Chapter 1: Introduction to Fire Detection and Suppression Systems

Fire Protection Systems

Chapter Overview

This chapter covers the operation of automated fire protection systems commonly utilized in commercial buildings and industrial facilities.

Also covered is a brief introduction into the non-automated standpipe and hose system, as many times this manually operated system may be incorporated into the total fire suppression and extinguishing system of a building.

Use of Prescriptive and Performance based design approaches are covered, along with a brief explanation of the use of NFPA code.

Finally there will be discussion of past historical and present day reasons for failures within fire protection systems.

Automated and Non-automated

The two main types of fire protection systems used in today's buildings are:

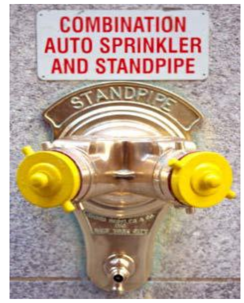
- Standpipe and hose systems (Non-automated firefighting system)
- Automatic sprinkler systems (Automated firefighting system)

Standpipe and Hose System (Non-Automated Fire Protection System)

Standpipe systems consist of a series of pipes which connect a water supply to hose connections (image).

They are basically an extension of the fire hydrant system, designed to provide a pre-piped water supply system for building personnel or the fire department to access for manual firefighting operations.

Standpipe systems provide hose line connections to supply firefighting water, in strategic locations throughout a building or structure. Some older buildings may strictly have a standpipe system alone, while newer buildings tend to have a combination automated sprinkler and standpipe system.



Standpipe Quick-Connect Hose Connection
Image Source: wmsprinkler.com

Classes of Standpipe Systems

Class I

This system provides a 2 1/2 inch hose connection. The fire department will usually carry hose packs to the floor level, typically a stairwell, where they will start their operations and connect to the standpipe system. These connections must match the hose thread utilized by the fire department.

Class II

This system provides a 1 1/2 inch hose connection. These are typically found in cabinets with 100' of hose.

Class III

This system provides a 1 1/2 inch connection, and a 2 1/2 inch hose connection to supply a larger volume of water for use by fire departments and those trained in heavy fire streams. Many times these connections will provide a 2-1/2 inch reducer to a 1-1/2 hose connection.

Automated Sprinkler Systems

Need for Automation in Fire Protection

Imagine the scenario of a fire in an unoccupied or sparsely-occupied building with no one around to notice and report a fire.

The building would likely be a total loss as the fire department would not be contacted until the smoke was visible from the outside, and fully engulfing the structure.

By the time the fire department was able to arrive and connect to the manually operated standpipe and hose system, the degree of damage and possible loss of life could be enormous.

If the building was protected by an automated fire detection, alarm, and suppression system, this same fire could be controlled, and possibly even extinguished by the time the fire department arrives at the scene.

Prescriptive Design vs. Performance-based Design Approaches

Prescriptive and Performance Design

In present day fire protection engineering, the use of Performance Based Design (PBD) is becoming more and more popular.

If used correctly the use of PBD can be an excellent enhancement to the sole use of prescriptive based codes.

- *Prescriptive Design* – step by step design using established code (such as NFPA)
- *Performance Design* – using customized design parameters for a specific application or project

The methodology of PBD is that the FPS designer can establish what the required level of performance will be for the fire protection system, as long as it meets the goals of the performance based design parameters.

The goals of a performance based code are usually in very broad terms, where prescriptive codes specify precisely, the steps to follow to achieve the end results (like following a recipe).

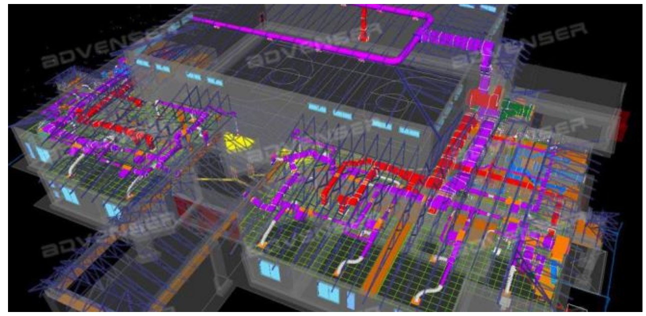
Performance based design parameters can be implemented to add flexibility to existing prescriptive requirements, but are not intended to replace existing prescriptive codes.

PBD is very useful when designing for unique structures since prescriptive codes often do not allow for “out of the box” thinking.

Fire Modeling Programs

Performance design using modeling software

Fire modeling programs are constantly evolving and becoming more popular, especially as (BIM) Building Information Modeling (image) is becoming the standard for integrated architectural design.



BIM Model

Image Source: ablks.eu

3D Model Design of Systems

Fire sprinkler contractors have been using limited, specialized 3-D fire modeling programs for a number of years.

These customized programs allowed sprinkler designers to develop systems in 3-D space, automatically preparing hydraulic calculations, printing BOMs, etc.

With the advent of BIM, the fire protection system can be designed as a part of the whole building. This allows for simultaneous design for structural, electrical, mechanical, and fire system components, helping to isolate potential inter-system conflicts and clearance issues.

Design Considerations

In creating design fire scenarios, all potential outcomes should be considered. This requires knowing as much as possible about the protected structure, the contents, and the occupants.

Building Characteristics Criteria:

- Type of construction
- General layout
- Building’s function (ie. medical, warehouse, manufacturing, etc.)
- Fire resistance ratings
- Fire cutoffs

- Building services (electricity, gas, oil, HVAC, communications)
- Existing or proposed fire protection systems

Building Content Criteria:

- Processes performed within the structure
- Operational characteristics
- Combustible loading
- Hazardous materials used in the processes
- Process energy input and output
- Process material flow

Occupancy Criteria:

- Occupancy numbers
- Where they are located and consolidated
- Their familiarity with the building
- Any potential physical or mental disabilities

Establishing simple "what if?" scenarios, or using more complex failure analysis methods such as event tree analysis, (FTA) fault tree analysis, or (HAZOP) hazard and operability studies enables a performance based design to account for and control the effects of fire events.

Once all possible fire scenarios have been developed, they can be ordered, based on likelihood of outcome.

The next step is then to select a representative fire scenario from each group with risks that exceed the established level of acceptable risk. The filtered set of scenarios form the basis of the design fire scenarios to be used in a performance-based design.

No matter how suitable a performance-based design may be, it can only be implemented if allowed by the applicable codes. The fire protection engineer must be sure that they properly gauge the potential hazards, not having been too lenient or likewise too extreme.

The selected design fire scenarios should reflect the facility's risk from fire as accurately as possible while being realistic and conservative.

PBD is a major part of a broader design methodology, which allows more flexibility within the design and installation codes known as “equivalency methods” or “alternate methods and materials”.

An example of this is the substitution of listed components that are recognized by the prescriptive code with listed components, which have not yet been incorporated into the code.

Prescriptive codes such as NFPA, usually reference “equivalency” or “alternate materials and methods” (AMM) clauses that permit designers to utilize alternative approaches rather than those specifically recognized by the code.

These clauses permit the application of Performance Based Design as a means of rigorously applying engineering principles to provide alternative methods to the “cookbook” approach.

Failure Analysis – Learning from past mistakes in Fire Protection

In reviewing historical sprinkler system statistics, a pattern of common failure modes of sprinkler systems develops. On a frequent basis, the NFPA will publish data outlining sprinkler system performance in the US.

From 1925 through 1969, the reasons for poor sprinkler system performance were:

- Water was shut off (35.4%)
- Inadequate design for required level of system performance (13.5%)
- Insufficient water supplies and reserves (9.9%)
- Poor maintenance practices (8.4%)
- Piping obstructions (debris clogging pipes, valves, devices, and heads) (8.2%)
- Partial sprinkler protection (8.1%)
- Faulty building construction (6.0%)
- System components defective or damaged (5.6 %)
- Exposure fire (1.7 %)
- System was partially or completely frozen (poorly insulated piping, and valves, etc.) (1.4%)
- other (1.9%)

Recent Statistics

Recent statistics offered similar causes for unsatisfactory sprinkler system performance.

The reasons that sprinkler systems failed to operate or were ineffective during a fire were:

- Systems (water supply, detectors, and other) were shut off or inoperable (38%)
- Wrong type of system for the type of fire (18%)
- Water discharge did not target the fire (12%)
- Poor or non-existent maintenance routines (12%)
- Issues with water supply or inadequate water discharge (9%)
- Human intervention defeated the automated systems (8%)
- Damaged system components (3%)

Although the categories used to quantify performance standards have changed and evolved over time, the common overlying causes have remained the same.

Fire Protection Code

NFPA Code

Most fire protection design is governed by the prescriptive codes. In the US, the prescriptive codes most often used in fire protection are the National Fire Protection Association (NFPA) codes or regional building codes.

The regional building codes adopt many NFPA codes through referencing. Prescriptive codes are easy to apply and straightforward, but the design scenarios to which they apply might not be so clearly defined.

Several codes may apply simultaneously, while using some and omitting others may compromise a design.

Fire Protection Code NFPA 13
Image Source: browntechnical.org

The most commonly used code to prescribe a fire protection system design is the NFPA 13 code statute, or the "Standard for the Installation of Sprinkler Systems".

All major U.S. building and fire code departments directly reference NFPA 13. Using an NFPA 13 design does not necessarily ensure an adequately designed fire protection system, however.

The selected design must specifically address the specifications of the particular facility. Code provisions from sources other than NFPA 13 must also be taken into consideration.

NFPA 13 now has more sprinkler design schemes than ever before. Selecting the correct system for a given facility requires regarding all the options, their advantages and disadvantages, applications, and limits.

Caution should be exercised, as some options have very limited and specific applications, yet are sometimes chosen as they appear to be cost effective, without considering if they apply to the design.

Like any other code, NFPA 13 cannot be applied without recognizing design aspects outside of the fire protection system. For example, a sprinkler system should not be designed based on an assumed water flow and pressure without verification that the water supply is adequate.

Is the supply dedicated to fire protection or used for mixed service? Is it from a reliable pressurized municipality source, or from a gravity-fed, or pump-fed reservoir?

Issues can arise if the design specified by NFPA 13 code cannot be satisfied by the available water supply.

Then a choice must be made to add supplemental supply sources, protect the facility by alternate means, reduce the requirements of the facility by changing its design, or use a performance-based design. These are options best addressed early within the designing process.

Chapter 2: Types of Automated Sprinkler Systems

Chapter Overview

Common Types of Systems

There are many different forms of automated fire suppression systems on the market; some used for specific requirements, while others have broad applications.

In this chapter, we will give a brief overview of some of the more broadly used systems, along with overviews of some special application systems.

Also included is the Halon system, which has become obsolete due to its potential for being an environmental hazard.

Types of systems which we will cover:

1) Wet Pipe Sprinkler System
2) Dry Pipe Sprinkler System
3) Water Deluge Sprinkler System
4) Pre-Action Sprinkler System
5) Combined Sprinkler System
6) In-Rack Sprinkler System
7) Quell Fire Suppression System
8) (ESFR) Early Suppression Fast Response systems
9) Gaseous Sprinkler Systems
10) Carbon Dioxide (CO2) Sprinkler Systems
11) Dry Chemical Sprinkler Systems
12) Foam Sprinkler Systems
13) Water Mist/Inert Gas Hybrid Systems
14) Residential Fire Protection Systems
15) Halogenated Gas Systems (Obsolete System)

1.) Wet Pipe System

System Description

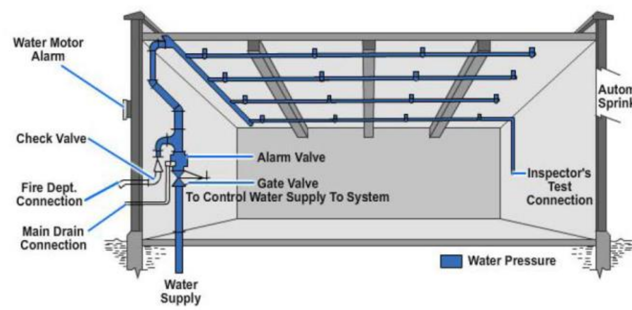
The most commonly found type of sprinkler system is the wet pipe sprinkler system (image). This system consists of heat-activated automatic sprinklers attached to a piping network which is constantly pressurized with water.

Wet pipe systems are usually used when there is no potential for freezing in the pipes, or when there is no other circumstance that might require a special purpose sprinkler system.

These systems are the most reliable, due to their simplicity, with a relatively few number of components.

The system works by delivering water to the targeted areas from automatic sprinkler heads usually installed on the ceiling or walls. The normally closed, heat sensitive, fusible sprinkler heads are used to detect the fire.

Then upon activation, the sprinklers distribute the water over a specified area to control or extinguish the fire. Water is discharged only through those sprinklers that have been activated above or near the fire, thereby minimizing water damage.



Wet Pipe Sprinkler System
Image Source: NAVEDTRA 14259A

Issues with wet pipe systems:

Drainage of Wet Pipe Systems during Freezing Weather

Care should be taken to make sure the piping in a wet pipe system is thoroughly protected against freezing.

Problems with Wet Pipe System Alarms

In wet pipe systems, fluctuating water pressure frequently causes water flow into the sprinkler system, equalizing the sprinkler system pressure with the supply pressure.

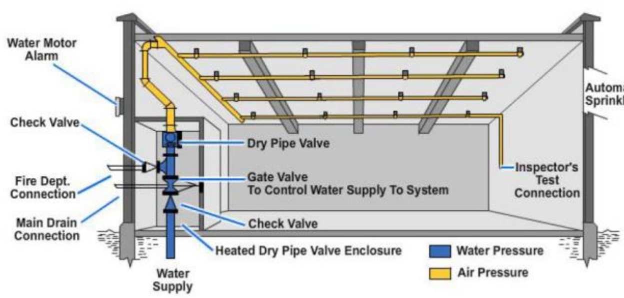
These surges of water or pressure can cause false water flow alarms, without some means of slowing down the switch response to the surge. Various retarding techniques are used, some associated with the sprinkler piping, and some with the water flow detector.

2.) Dry Pipe System

System Description

This system is the second most common type of fire suppression system installed. In a dry pipe system (image), the pipes are typically filled with either pressurized air or nitrogen.

These fire suppression systems are used in fire protected zones where there is the potential for freezing. Air pressure must be lost from the system to trip the ***dry pipe valve***. Then water must travel through the piping network to the sprinklers.



Typical Dry Pipe System
Image Source: NAVEDTRA 14259A

Types of Dry Pipe Valves

A dry pipe valve acts as a control between the water supply and the pressurized air or nitrogen in the piping network.

The dry pipe valve must be contained in a heated enclosure to prevent the valve mechanism from freezing up, as water is on one side of the valve gating mechanism.

A small amount of water, called ***priming water*** is inside the dry pipe valve to ensure a tight seal of the clapper and to keep the rubber gaskets pliable. The valve is designed in a way that a minimal air pressure holds back a much greater water pressure.

Three types of dry pipe valves:

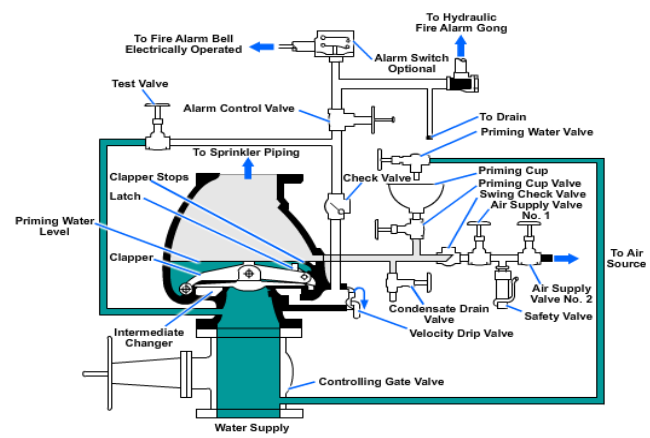
- Differential Dry Pipe Valve
- Low-Differential Dry Pipe Valve
- Mechanical or Latched-Clapper Dry Pipe Valve

Differential Dry Pipe Valve

The differential dry pipe valve (image) has a larger *clapper* on the air side that coincides with a smaller water-side clapper.

The pressure differential between the areas of the two clappers is roughly a 6 to 1 ratio. Therefore, a low air pressure can hold back a much larger water pressure. For example, 20 psi of air pressure can hold back 120 psi of water pressure.

To prevent accidentally tripping the valve, thus causing false alarms, an air or nitrogen pressure is maintained of at least 20 psi above the dry pipe valve's calculated trip pressure setting.



Differential Dry Pipe Valve Assembly
Image Source: Tyco Fire Products

Low-Differential Dry Pipe Valve

Depending on the source of the water supply, dry pipe valves may be subject to debris. With a differential dry pipe valve, there is a high velocity of water entering the system when the valve trips.

This velocity of water can carry debris into the system causing system blockages. If debris from the water source is a potential problem, the low-differential dry pipe valve may be used.

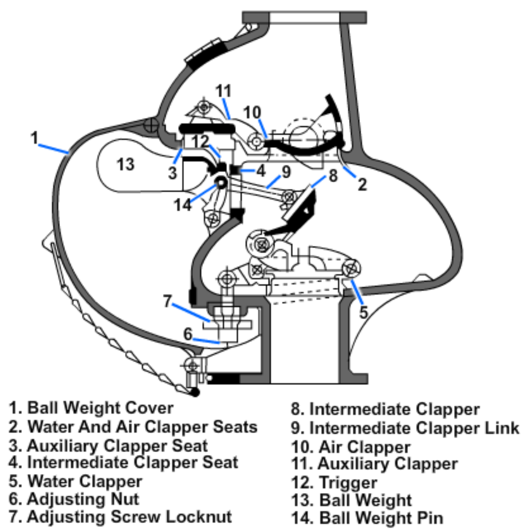
The clapper in the low-differential dry pipe valve is only slightly larger on the air side than on the water side. The air pressure in the system is maintained 15 to 20 psi greater than the water pressure.

Because the sprinkler system piping contains air pressure about equal to the water pressure, the sudden rush of water is slowed and only a slight amount of water is diverted into the branch lines, which do not have operating sprinklers after the valve opens.

Mechanical or Latched-Clapper Dry Pipe Valve

The mechanical or latched-clapper dry pipe valve (image) operates under the same principles as other dry pipe valves. It has a system air pressure which is applied against a small diaphragm, or clapper.

A configuration of levers, links, and latches on the valve clapper provides the leverage for the closing force applied to the water clapper.

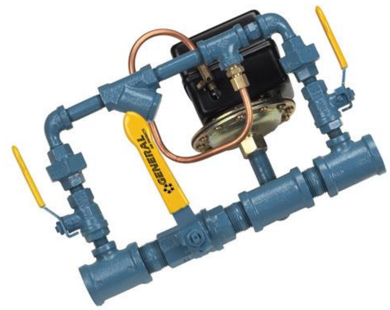


Mechanical or Latched-Clapper Dry Pipe Valve
Image Source: NAVEDTRA 14259A

Automatic Air Pressure Maintenance Device

With either a differential or low-differential dry pipe valve, an *automatic air maintenance device* (image) must be used to maintain air pressure and prevent accidentally tripping the dry pipe valve.

Also, an *automatic drain or high-water level alarm* is required for the priming water level so the water does not accumulate. (If there is too much priming water, the valve cannot operate.)



Automatic Air Maintenance Device
Image Source: generalairproducts.com

Problems with Dry Pipe System Alarms

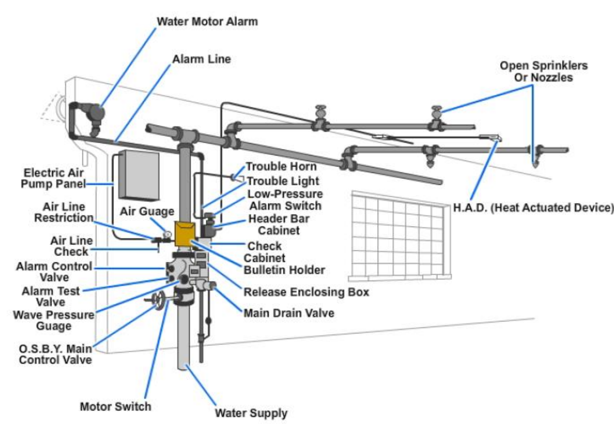
These alarms tend to be slow acting as it takes time to expel sufficient air through a fused sprinkler in order to trip the system.

Various methods are used to speed up dry pipe systems, such as accelerators and exhausters.

3.) Water Deluge System

A water deluge system (image) is used where there are additional hazards, such as areas where flammable liquids or propellants are handled and stored.

With additional hazards, there is the possibility that a fire may grow at a faster rate than an ordinary sprinkler system can control.



Typical Water Deluge System
Image Source: NAVEDTRA 14259A

These systems may also be used in areas such as aircraft hangars, where unusually high ceilings may have strong enough drafts to deflect the direct rise of the heat.

These drafts could prevent the sprinklers directly above the fire from opening but allow others, away from the fire source to open, thus having little effect at the fire's actual location.

In the deluge system, all sprinklers connected to the piping network are normally open, with the supply of water being controlled by a water deluge valve. The water deluge valve remains closed until a fire is detected by a heat-actuated device that controls the opening of the valve.

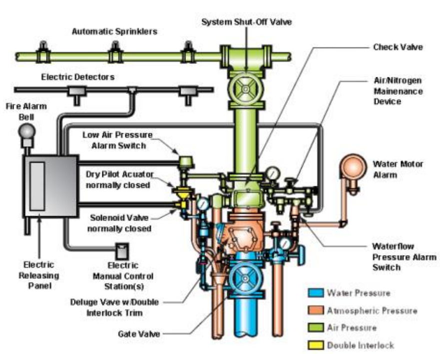
Heat actuated devices (HAD) can be either mechanically or electrically operated.

Time Delay in a Deluge System

The deluge system has a time delay between detecting the fire and discharging water at the sprinkler heads. This delay is due to the valve operation time and filling the piping network with water.
This is similar to the time delay in the dry pipe system. To reduce this delay, the deluge system may be pre-primed by filling the piping network with water downstream from the deluge valve.

4.) Pre Action Systems

The pre-action system (image) utilizes features of both the wet-pipe, and the dry-pipe systems. Similar to the dry-pipe, the pre-action system is initially charged with air under pressure, but basically acts as a wet-pipe system once the specialized valve is opened.



Riser Assembly of a Double Interlock Pre-action System
Image Source: The Code Coach

A pre-action fire sprinkler system is similar in nature to a dry pipe system in that water is not normally contained within the pipes, and similar to a deluge sprinkler system with the exception of closed sprinkler heads.

The two systems differ however, in that water in the pre-action system is held from piping by an electrically operated valve, known as a pre-action valve (image), which is controlled by independent flame, heat, or smoke detection.

This type of system is typically used in areas which are highly sensitive to the effects of accidental sprinkler water discharge.

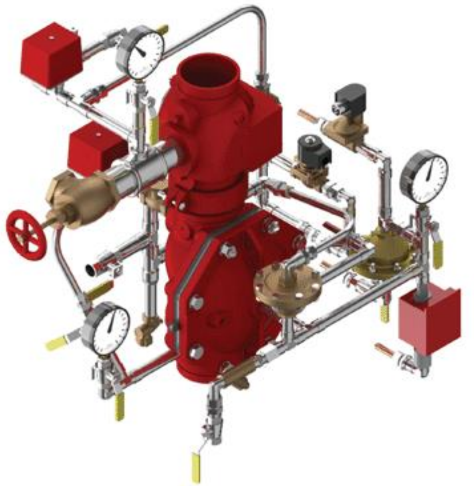
Pre-action systems are typically used when there is a need to delay the introduction of water into the system piping until appropriate signals are received from the detection system or the supervised piping.

Exactly which signals and how many signals have to be received before the valve opens is a function of the type of pre-action system and detection system.

These systems are designed for applications that require maximum protection against inadvertent operation of the sprinkler system.

Typical applications of pre-action systems include:

- High hazard applications which use water as extinguishing agent
- Flammable liquid storage
- Aircraft hangars
- Storage areas for rare and valuable items
- Libraries and archives
- Server rooms
- Refrigerated areas



Pre-action Valve Set
Image Source: Tyco Fire Products

To Initiate a Discharge

In a Pre-action system, two separate events must occur to initiate a sprinkler discharge:

- *Stage One:* The associated detection system must first identify a developing fire, and then open the pre-action valve. Opening this valve allows water to flow into the system piping, effectively creating a wet pipe sprinkler system.
- *Stage Two:* Then the system functions as a wet sprinkler system, with activation of individual sprinkler heads needed to release water flow onto the fire.

Advantage of Pre-action Systems

One advantage is an added level of protection against inadvertent discharge - Dual action is required for water release in a pre-action system, as the pre-action valve must operate and the sprinkler heads must open.

These two levels of activation make the pre-action system well suited for use in water sensitive environments such as archival, fine art, and rare documents storage facilities.

Disadvantages of Pre-action Systems:

- *Higher cost of installation and maintenance* - Pre-action systems are more complex with additional components, such as a fire detection system, adding to the overall system cost, and the need for higher level maintenance skills.
- *Difficult to modify* – The size limitations of a pre-action system may affect future system upgrades, with potential difficulty with modifications to the fire detection and control systems, as well.
- *Potentially less reliability* - The complexity of pre-action systems creates an increased risk of unreliability.

Types of Pre-action Systems

NFPA 13 defines three basic types of pre-action systems:

- *Single Interlocked* – This type admits water to sprinkler piping upon operation of detection devices only.
- *Double Interlocked* - This type admits water to sprinkler piping upon operation of *both* the detection devices and automatic sprinklers.
- *Non-Interlocked* – This type admits water to sprinkler piping upon *either* operation of detection devices or automatic sprinklers.

Standard or Single-interlock System

In this type of pre-action system the water supply is held back by a pre-action valve, which is connected to a supplemental detection system. Water will not enter the pipe until the detection system is activated.

Once activated, the valve is released and allows water into the sprinkler piping. Water will not come from the system, until sufficient heat causes the individual sprinkler head to activate (after the pre-action valve activates, the system functions the same as a wet-pipe system).

Double-interlock System

This type will only operate when both the supplemental detection system and a sprinkler head are activated.

Use of Pressurized Gas

The pre-action system may be set up using a double interlock in which pressurized air or nitrogen is added to system piping.

There are two purposes of this feature:

- to monitor piping for leaks
- to hold water from system piping in the event of inadvertent detector operation

Pre-action systems may be supervised or unsupervised:

Supervised Pre-action System

Has air introduced into the system piping at a pressure of around 5 psi. This air pressure supervises the piping network to detect leaks.

The pressure switches used for detecting low air pressure on the supervised system record in inches of water rather than psi.

In accordance with NFPA 13, a pre-action sprinkler system piping and fire detection devices shall be automatically supervised where there are more than 20 sprinklers on the systems.

Unsupervised Pre-action System

These do not continuously monitor for leaks.

Detection devices for pre-action system

Detection is usually electrically or pneumatically actuated or a combination of both. Detection systems used with electric release systems are commonly actuated by manual pull stations, fixed-temperature heat detectors, rate-of-rise heat detectors, smoke detectors or other means.

The air pressure on the pre-action valve is constantly monitored. If the pressure changes (due to leak in pipe or other issue) an alarm will sound, however, the system will not activate under this condition.

The valve will remain closed, preventing water running into the system until the detection system is activated.

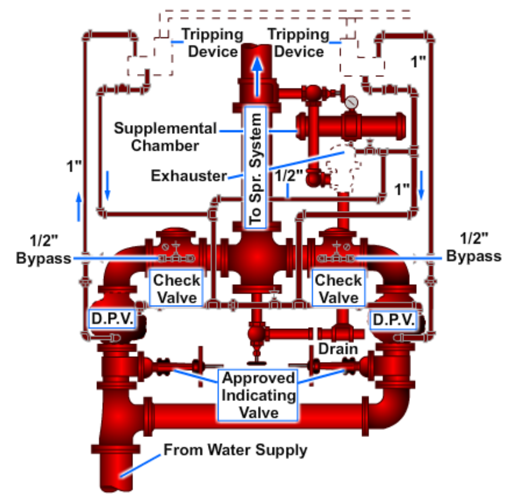
5.) Combined System (Dry Pipe/Pre-action)

Combined System

A combined system (image) has a piping arrangement which uses two modified dry pipe valves connected to tripping devices. The two sections are piped in parallel to supply water to the sprinkler system.

The piping network is filled with air under pressure. When a fire is detected, an exhauster at the end of the system opens, releasing the air within the system. From this point, the system operates the same as a pre-action system.

If the detection system fails, the combined system reverts to acting as a dry pipe system, allowing water to be released to the system when the sprinklers open, discharging the air from the piping network.



Combined System Header Arrangement
Image Source: NAVEDTRA 14259A

6.) In-Rack Sprinkler Systems

In-Rack Sprinkler System

In-rack sprinkler systems (image) are designed specifically to protect racked storage areas. They are integrated with detectors, which trigger the release of water into a targeted area.

Detectors are located close to stored materials and equipment for the quickest possible response, should a fire occur.

These systems are well suited for facilities that use large industrial shelving as it ensures that fires started in the middle of the rack can be extinguished before it spreads to other shelving or adjacent racks.

These types of fire suppression systems are typically found in rack structures that are computer automated, and use mechanized loading equipment.

In Rack Sprinklers
Image Source: vikingsprinkler.com

Advantages of in-rack fire sprinkler systems

- *Modular and easy to expand system* - In-rack fire sprinkler systems are modular and can easily be expanded when more rack units are added.
- *Closer proximity to all racks* - In-rack fire sprinkler systems locate the detectors and sprinklers as close to protected areas as possible, ensuring a quicker and more accurate response to the source of the fire, as opposed to "ceiling-only" sprinkler systems, which can be blocked from lower fire sources.
- *Reduced extinguishing agent requirements* - in-rack fire sprinkler systems only discharge enough for one rack, making system recharging easier and cheaper, following a discharge.
- *Are activated earlier in the fire; less damage* – fires on lower racks can spread considerably before the ceiling-only sprinklers are activated, causing far more damage.
- *Ceiling configuration doesn't impact in-rack sprinklers* - Roofs having slopes greater than 2 in 12, can be challenging to design for, where ESFR sprinklers (covered later in the course), are not permitted. A sloped ceiling changes the dynamics of the fire gases traveling along the ceiling, impacting both the operation of ceiling sprinklers and their spray pattern. In-rack sprinklers are not impacted by ceiling slope.

Disadvantages of In-rack Fire Sprinkler Systems

- *Limited extinguishing capabilities* - Doesn't always extinguish the fire, rather than just controlling it.
- *Water Damage from Human Error* – Having the piping system located where forklift operators are continually loading and unloading pallets of goods, can create a situation of broken pipes, causing water damage to warehoused goods.

7.) Quell™ Fire Suppression Systems (Specialized double interlock pre-action system)

Quell Fire Suppression

The QUELL™ Fire Sprinkler System is a double interlock pre-action system design scenario developed to protect high piled storage.

Its original design purpose was as an alternative means of design for the protection of goods in cold storage environments such as unheated warehouses and frozen food storage facilities; however it may be adapted as an alternative means of design for other high piled storage applications.

The system does not rely on in-rack sprinklers or anti-freeze fluids, allowing for lower installation costs and the ability to cover higher roof and storage heights with a dry sprinkler technological solution.
This system was developed using "performance based design".

While the QUELL™ design is not specifically addressed within the prescriptive requirements of NFPA 13, the equivalency paragraph in the standard (Paragraph 1.5) permits PBD designs that meet or exceed the requirements of that standard.

Fires are controlled quickly using a "surround and drown" method, preventing damage to storage facilities and the materials stored within them.

The design principle is to delay water delivery until an appropriate number of *CMSA* sprinklers* have activated, to provide an optimal number of sprinklers discharging onto the storage area that is burning, as well as pre-wetting the surrounding storage area.

*CMSA Sprinklers

CMSA stands for Control Mode Specific Application. These "high K factor" types of heads are designed to protect storage facilities (with the exception of flammable liquids). They create large droplets, and are designed to control a fire, not to extinguish it.

8.) Early Suppression Fast Response (ESFR)

System Description

ESFR sprinkler systems are designed to completely extinguish a fire, as opposed to just controlling it. This is accomplished by the increased amount of water discharged, compared to control mode systems and in-rack systems.

This increased flow penetrates the fire plume (the area of rising hot gases usually accompanied by smoke) and attacks the fire's fuel source, thus reducing the heat release rate of the fire until it is extinguished.

To Protect Storage Hazards

There are two basic types of sprinkler systems used to protect storage hazards; Control Mode and ESFR-based. These systems are classed based on the type of sprinkler head utilized in the system.

- *Control mode sprinkler heads* - rely on cooling and pre-wetting, allowing the fire to continue to burn in the area of ignition while controlling roof and ceiling temperatures and preventing fire spread until firefighters arrive or the fuel is consumed and the fire goes out. These types of sprinklers are characterized by a relatively large area of operation (15-50 sprinklers).
- *ESFR sprinkler heads* - rely on penetration to stop fire growth quickly and drastically reduce heat release. Usually six or less of this type of sprinkler are required.

Prior to the introduction of ESFR sprinklers (image) in the late 1980s, warehouse storage facilities were protected by "control mode" sprinklers while commodities being stored on racks typically required the installation of in-rack sprinkler systems.

In-rack sprinkler systems are a cause of concern for warehouse administrators, as they add to the cost of the sprinkler installation and require modification if the racking layout is changed; also they are prone to mechanical damage caused by pallet loading and unloading operations.

Warehouse with an ESFR system Installed
Image Source: realestateinspain.wordpress.org

How ESFR systems differ from conventional systems:

- *Speed* - ESFR sprinkler heads sense a fire and begin spraying water quicker than standard response sprinkler heads.
- *High output rate; more volume* – The output rate of conventional sprinkler heads is 25 to 30 gpm, while high output conventional sprinkler heads have an output rate of 60 gpm. ESFR sprinkler heads have an output rate of 100 gpm.
- *Droplet size* - ESFR sprinkler heads release larger droplets of water with greater momentum than conventional heads. This combination of size and momentum allow the sprinkler droplets to penetrate a fire plume, reaching the base of the fire.

ESFR fire suppression systems can be used in warehouses with ceilings as high as 45 feet and storage heights of 40 feet.

The installation and material costs of these systems are more economical than the costs of creating and installing an in-rack fire suppression system, often 30% to 50% less.

In using an ESFR fire suppression system, consideration should be given to the types of products being stored, the storage arrangement, the ceiling height and slope, and construction type of the building.

9.) Gaseous Extinguishing Systems

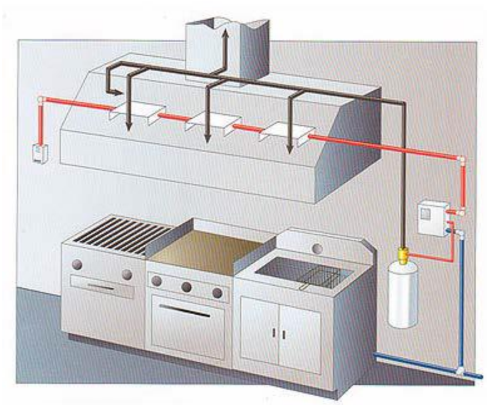
Extinguishing Fire with Inert Gases

Gaseous extinguishing systems are found in areas where sensitive equipment is installed that would be highly vulnerable to destruction from water or dry chemical extinguishing agents.

Computer server rooms, electronic equipment, and power-generating facilities are examples of areas where gaseous extinguishing system installation would be of benefit.

There are three general categories of gaseous extinguishing systems:

- *Local application systems* – This system (image) discharges the gaseous agent directly onto the burning material. They are used for protecting areas such as restaurant range hoods or specialized motors, for example.



Local Gaseous Extinguishing System installed over Griddle, Grill, and Fryer Units
Image Source: gatorfire.net

- *Total flooding systems* - This system (image) discharges the gaseous agent, filling enclosed spaces. They are found in areas such as flammable liquid storage rooms, computer server rooms, or transformer enclosures containing oil-filled equipment.

Total CO_2 Flooding of a Server Room
Image Source: cubefireandsecurity.com

- *Hose line systems* - This system (image) discharges the gaseous agent, through manually-operated nozzles, connected to piping or hoses. Carbon dioxide is the primary gaseous agent used in manual hose line systems.

Hose Reel with Gaseous Nozzle
Image Source: wezna.com

Gaseous Extinguishing System Alarms

There are special considerations for gaseous system alarms (image) because of possible toxic effects on personnel.

This type of fire suppression system requires two clear and distinguishable alarm types. A combination bell alarm and electronic sounder are connected to the fire suppression control panel.

When the fire suppression system detects smoke, it raises the 1st stage alarm. This alarm is considered as a general evacuation alarm. If a further activation is detected via one of the other detectors on the system, the system will raise the alarms of the sounder.

The sounder is the final warning before the fire suppression agent is discharged; this is normally 30 seconds from the 2nd activation.

Combination Bell and Sounder, Fire Alarm
Image Source: firesuppression.co.uk

Cross-zoning of Detectors

Cross-zoning of detector devices is frequently used for gaseous extinguishing systems. Cross-zone detection utilizing multiple detection methods minimizes the potential that a false alarm will result in a discharge of the suppression agent.

A commonly utilized cross-zone detection technique involves using two different fire detection methods with each one assigned to a separate zone. This approach offers an increased assurance that a fire is present before releasing the suppressing agent.

The use of two separate types of spot smoke detection devices such as ionization and photoelectric detectors is a commonly used approach to cross-zoning.

The characteristics of an ionization detector make it ideal for detecting fast flaming fires with smaller particles of combustion.

Photoelectric detectors are suited for slow smoldering fires that tend to produce larger smoke particulate matter.

Depending on the type of fire, the response times for these two types of detectors vary, but eventually both types will detect the fire.

Abort Feature

Some gaseous extinguishing systems, typically those in populated areas, have an abort feature (image) to terminate the unnecessary discharge of an expensive and possibly toxic gaseous agent.

Fire Suppression Abort Switch
Image Source: Kidde

Abort Time Delay

Extinguishing systems with the abort feature have a time delay between actuation of the second (or only) detector and release of the gaseous agent.

The delay is usually set in the range of 15 to 60 seconds, so personnel have the time to evacuate the area before release of the agent or to allow for aborting the release.

If the situation does not warrant a gas discharge, the release can be interrupted by a manual abort switch. When the detectors and control unit have been restored to their normal condition, the abort switch can then be reset.

The abort switch is usually designed to be held in so that the agent discharge cannot be accidentally impaired when the switch is unattended.

Automated Area Segregation

Alarm systems that release a gaseous extinguishing agent use auxiliary alarm outputs to segregate the protected area and reduce dispersion and dilution of the gas.

A typical sequence of alarm system-initiated events in a computer room:

1) Detection of fire by first detector in an area causes local and remote alarm indication, fan shutdown, door and damper closure, and other necessary auxiliary functions.
2) Detection of fire by second detector in the area (cross-zoned with first detector) causes an audible signal and initiates a time delay, during which the time the agent release, and computer power shutdown may be aborted.
3) At the end of the time delay, if release is not aborted, the computer power is shut down and the extinguishing agent is released.

Safety Issues with gaseous systems:

Barotrauma

The sudden positive pressure caused by gas dispersal may be enough to break windows. Personnel and structures need to be protected accordingly, with consideration for ventilation and blow-off in system design.

Suffocation (oxygen displacement)

When an extinguishing agent which is primarily inert gases, is dispersed into an enclosed space the risk of suffocation is a real possibility.

Numerous accidents have occurred where individuals have been killed by inert gas agent releases.

The use of additional life safety systems are typically implemented, with a warning alarm that precedes the gaseous release.

Accidents have also occurred during the maintenance of these systems, so adequate safety precautions are recommended.

10.) Carbon Dioxide (CO2) Based Gaseous Systems

Carbon Dioxide (CO2) Suppression Systems

Carbon dioxide fire suppression systems are an inexpensive and effective option for large unoccupied areas.

This application is well-suited for chemical storage, transformer rooms, power turbines and generators, and contaminant-sensitive manufacturing facilities. The gas is stored in pressurized tanks and delivered to the ignition source through a piping network.

There are two general means of applying carbon dioxide to fire extinguishing:

- *Total flooding* - creates a non-reactive (oxygen depleted) atmosphere in the enclosure or room where the fire is occurring, displacing the oxygen of the room, which feeds the fire.
- *Local application* - discharges carbon dioxide to the surface of liquids or noncombustible surfaces coated with liquid flammables.

Total Flooding Systems

Total flooding systems are used for enclosed spaces which contain materials suitably extinguished by carbon dioxide.

To be effective, the space must be well enclosed so that the gas is allowed to displace the oxygen in the room or enclosure.

Detectors may be needed that can activate the system, then automatically close windows, doors, vents, etc., and set off alarms before the system discharges.

Local Application Systems

Local application systems are used to protect localized hazards, such as oil-filled transformers, chemical tanks, flammable equipment, etc.

Nearby equipment can be linked through the control system to shut down automatically when the protection system activates.

(Nearly any device which is mechanically, electrically, pneumatically, or hydraulically actuated, can be linked with the automated controls of the fire suppression system, to perform shut downs, or slowdowns during a fire event.)

(CO2) Nonconductive Gas

Carbon dioxide is electrically nonconductive. It is used extensively for the protection of electrical equipment.

These properties make it useful as a fire extinguishing agent in all types of computer room applications, where shorted out computer hardware could be disastrous.

There are two general types of carbon dioxide extinguishing systems:

- **High** pressure
- **Low** pressure

High Pressure Carbon Dioxide Systems

In the high-pressure system (image), the CO2 gas is stored in high-pressure cylinders and stored at approximately room temperature.

Normal cylinder pressure is around 600 psi and varies with the ambient temperature of the storage area. Storage area temperatures should not exceed 130°F or drop below 32°F.

As a safety measure, high-pressure cylinders employ a frangible disk that has a burst pressure of 3,000 psi to prevent cylinder rupture as a result of over pressurizing.

Variations in the ambient temperature also tend to affect the discharge rate of the system.

CO2 Tanks
Image Source: gulffiresafety.com

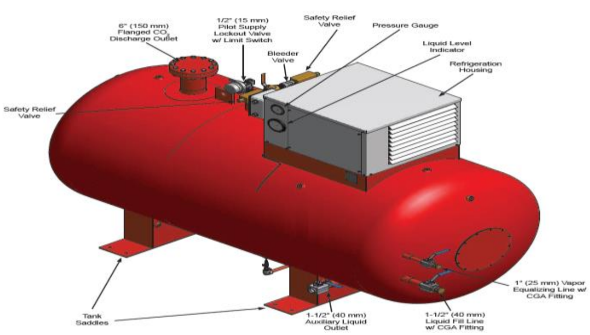
Low Pressure Carbon Dioxide Systems

Low-pressure systems (image) have a pressure vessel which is maintained at 0°F by insulation and refrigeration equipment.

At this temperature, the pressure in the container is approximately 300 psi. Because the container is maintained at a refrigerated temperature, the container can be filled to 90 to 95 percent capacity.

A safety relief valve is installed to bleed off pressure at 341 psi. Another relief valve operates at 357 psi for rapid release of excess pressure. There is also a frangible disk with a burst pressure of 600 psi should the relief valves fail.

Keeping the liquid carbon dioxide at 0°F and 300 psi consistently, assures a uniform discharge rate.



Low Pressure CO2 Tanks
Image Source: dshfiresystems.com

Operating Devices for Carbon Dioxide Systems

As with all systems, carbon dioxide systems must have operating devices for discharge of the extinguishing agent and to activate alarms. Many of the standard operating devices can be used.

Typically used, are the heat-actuated devices (HAD) or smoke detecting devices. Manual controlling devices are also used in carbon dioxide systems.

Whether the agent release is automatic or manual, an alarm at the alarm system control unit should be activated.

Piping for Carbon Dioxide Systems

Carbon dioxide fire protection system piping and associated fittings need to have suitably low temperature characteristics and good corrosion resistance inside and out.

Suitable Metals for Piping

- *Ferrous metals* - such as galvanized steel, copper, brass, and other materials having similar mechanical and physical properties are acceptable
- *Copper tubing* - with suitable flared or brazed connections is acceptable
- *Black steel pipe* - Between the storage tank and selector valves, black steel pipe may be used because of the larger sizes involved and its air tightness

Cast-iron (gray) pipe and fittings are not used in CO2 piping systems

Bursting Pressures for CO2 Piping:

- Pipe and fittings for high-pressure systems need to have a minimum bursting pressure of *5,000 psi*
- For low-pressure systems, a minimum bursting pressure of *1,800 psi*

Avoid Piping Exposure to Heat Sources

Supply pipes are typically routed to avoid exposure to high temperatures from ovens or furnaces or to direct flames.

Hot piping causes excessive vaporization of carbon dioxide and a subsequent delay in effective discharge of CO2.

Pressure Relief Devices or Valves

Devices and valves which prevent entrapment of liquid carbon dioxide may be installed on sections of piping that can be closed off.

Relief Devices usually operate at the following pressures:

- High-pressure systems - 2,400 to 3,000 psi
- Low pressure systems - 450 psi

Nozzle Sizes

CO2 discharge nozzles are manufactured in various designs and discharge patterns. Nozzles are marked with a code number indicating the diameter in 1/32 inch increments of a single orifice standard nozzle having the same flow rate.

Example:

A No. 5 nozzle has the same flow rate as a 5/32 inch diameter standard orifice. A plus sign (+) after the number indicates a 1/64 inch larger size. Decimals are occasionally used to indicate sizes between the whole numbers.

11.) Dry Chemical Extinguishing Systems

Dry chemical extinguishing systems (image) are similar to gaseous extinguishing systems in their construction and operation.

Dry chemical systems are used primarily for extinguishing fires in flammable liquid areas.

Dry Chemical Fire Extinguishing System
Image Source: iafire.com

There are three general categories of dry chemical extinguishing systems (same as gaseous systems):

- *Total flooding*
- *Local application*
- *Hose line systems*

Total Flooding Systems

Total flooding systems discharge the extinguishing agents into enclosed spaces. These systems are used for the protection of flammable liquid or chemical storage areas, and areas similar in nature.

In areas which utilize total flooding systems, the facility should have an evacuation plan implemented, in order to quickly clear the area of all personnel in the event of a fire. In areas using local application systems where the dry chemical is not confined, there is a limited hazard to personnel.

Local Application Systems

Local application systems are configured to discharge the dry chemical directly onto the source of the hazard, without being enclosed.

For both systems, total flooding and local application, the following are some examples of components which may be interconnected with the dry chemical system, and configured for automatic shut down once the system has been completely discharged:

- Ventilating equipment
- Conveyors
- flammable liquid pumps
- Automated industrial equipment such as mixers, roasters, broilers, etc.

Hose Line Systems

Hose line systems discharge dry chemical agents through manually operated nozzles, which are connected by hose or by a combination of piping and hose, to a fixed supply.

Dry Chemical Agents

The dry chemical extinguishing agent typically used is ***sodium bicarbonate (or common baking soda),*** finely ground.

The dry chemicals are mixed with anti-caking additives to prevent clumping and caking, which could prove to be an extremely problematic situation in the event of a fire.

Bicarbonate base dry chemical is especially effective for extinguishing flames in grease-type fires.

Other agents used in dry chemical extinguishing systems include:

- potassium bicarbonate
- potassium chloride
- monoammonium phosphate (multipurpose type)

Dangers of dry chemicals exposure:

- temporary breathing difficulty
- reduced visibility

The Saponification Reaction (Turning Fats to Soap)

The saponification reaction between the dry chemical and fat or grease prevents the fire from reigniting by converting the fats to soap.

Multipurpose dry chemicals will not react with the fat or grease, preventing the saponification reaction from occurring between the fat source and bicarbonate based dry chemical used.

Dry chemical systems are not suitable for use with:

- *Fires in materials that contain their own oxygen supply* - such as nitrocellulose (materials which have been exposed to nitric acid or other powerful nitrating agents, in their manufacture).
- *Fires involving electrical equipment* - such as telephone, computer, and electronic equipment. With these situations, the dry chemical tends to insulate the fine and delicate contacts thus requiring painstaking cleaning.

Problematic Dry Chemical Agents:

- *Monoammonium phosphate and potassium chlorides* - are on the acidic side of the pH scale and when exposed to moisture, can cause corrosion in particular metals. Corrosion can be minimized by promptly cleaning the metallic surfaces which have been contaminated.
- *Monoammonium phosphate* - usually requires scraping and washing of exposed surfaces which were hot, when the agent was dispersed.

Clean up of Dry Chemicals after dispersal

Most dry chemical agents can be cleaned away by wiping with damp cloths, vacuuming, or washing down the exposed materials or surfaces. After a fire event, specialty cleaning services are usually employed by the insurance company to systematically clean the area and return the area to a former condition.

Types of Systems

There are basically two types of dry chemical systems:

- Gas cartridge systems which use a container of expellant gas that, when released by manual or automatic means, pressurize the container of dry chemical, forcing the agent through the piping network or hose lines
- Stored pressure systems that consist of a container of dry chemicals that is constantly pressurized, usually with nitrogen

Use of Expellant Gases for Dry Chemical Dispersal

In order to properly disperse dry chemical agents onto a flame, a pressurized expellant gas is required.

Through the use of various devices, the pressurized expellant gases are released (image) carrying with it the dry chemical powder.

Dry Chemical Dispersal
Image Source: getzfire.com

12.) Foam Water Deluge Systems

Most any fire suppression system, whether wet, dry, deluge or pre-action, can be adapted to disperse pre-engineered foam concentrates.

Foam water systems work by mixing a foam concentrate with water flowing into the piping system.

When a fire is detected, a signal is sent to the releasing panel to open the deluge valve to allow the flow of water. Simultaneously, piping to the bladder tank flows and pressurizes the outer shell of the bladder tank which forces foam concentrate to travel into the system piping, then into the proportioner.

The foam solution produced by water and foam concentrate flows into the system piping and is discharged through the open nozzles or sprinkler heads.

Foam water spray systems can be used for intermittent discharge of: strictly water, then foam for a pre-determined period, and then water, followed by a shut off.

Foam water fire sprinkler systems are used for special applications, such as around flammable liquid storage, and airport hangars (image).

Aircraft Hangar filled with Foaming Agent from a Deluge System
Image Source: sarian.ir

The main components added to a system include:

- bladder tank - to contain the foam concentrate
- concentrate control valves - to isolate the sprinkler system from the concentrate until activated
- proportioners (or controllers) - to mix the proper amount of foam concentrate with the system's supply water

Types of firefighting foam concentrate

The purpose of firefighting foam is to cool the fire and to coat the fuel, preventing its contact with oxygen, resulting in suppression of the combustion.

Common types of foam concentrate:

- *Aqueous Film-Forming Foam Concentrate (AFFF)* – these are water-based, low expansion foams with expansion rates of less than 20 times. They are low-viscosity and spread quickly to cover larger areas.
- *Fluoroprotein Foam Concentrate (FFFP*) - these contain natural proteins as the foaming agents, and unlike synthetic foams, are bio-degradable. They spread slowerproviding a foam blanket that is more heat-resistant and more durable.
- *Alcohol-Resistant Foam Concentrate* - used for fighting fires on materials usually destructive to regular AFFF or FFFP foams as well as fires involving hydrocarbons.
- *Synthetic Foam Concentrate* - are based on synthetic surfactants. Synthetic foams provide better flow and faster knockdown of flames, but limited post-fire security.

(Note: concentrates of varied types should not be combined.)

Foam-Water Sprinklers

Foam discharge heads are specially designed, open-type, air-aspirating sprinklers (ie. - designed to entrain air into the foam/water solution by a modified venturi process), consisting of an open barrel body "foam-maker" that terminates in a deflector, to shape the pattern of the foam or water issuing from the assembly.

Water discharge patterns from these specialty sprinkler heads are similar to those of standard sprinklers.

- *Class A foams* - developed in mid 80s for fighting forest fires, these foams work by lowering the surface tension of the water, assisting in the wetting and saturation of Class A fuels with water. This aids fire suppression and can prevent re-ignition.
- *Class B foams* - designed for class B fires, or flammable liquid fires. Using class A foam on a class B fire may produce unexpected consequences, as class A foams are not designed to contain the explosive vapors produced by flammable liquids. Class B foams consist of two major subtypes, synthetic and protein.

13.) Hybrid Water Mist/Inert Gas System

This fire suppression system is a hybrid system that utilizes a combination of clean agent inert gas (typically nitrogen) and water in its fire protection efforts.

Nitrogen is injected into the water stream at the nozzle, producing microscopic droplets, while acting to reduce the oxygen concentration in the protected area. This creates a mist that is almost dry, making it an ideal system for protecting of computer rooms, data centers, etc.

The mist droplets (image) are up to 100 times smaller than standard water droplets delivered by a traditional water spray system, providing 50% improved heat absorption and a complete extinguishing application.

After the fire is extinguished, there is nearly no water residue, hence no water damage. Hybrid systems work well in extinguishing small fires in large rooms, and perform well in naturally ventilated environments.

The homogeneous mixture of water droplets and inert gas is propelled with enough momentum to overcome the drag effect that has limited the effectiveness of traditional water misting systems.

This prevents dampening of the area and contents, allows the system to be recharged quickly, and minimizes facility downtime.

Providing a high level of fire protection without toxic chemicals or excessive amounts of water, these systems offer a minimal environmental impact and a fast recovery time.

Water Misting Nozzle
Image Source: nfpa.org

Benefits of the hybrid fire suppression system include:

- Nearly no wetting of protected areas
- No expensive clean-up
- No equipment or content loss
- Safe on the environment and personnel
- Qualifies for Green built, LEED "points"
- Quick system recharge
- Minimal downtime for facility
- effective in open, naturally ventilated spaces

4.) Residential Use – NFPA 13D Systems

Fire Suppression systems are not always designed strictly for commercial and industrial applications. NFPA 13D systems are becoming popular in new construction in certain areas of the country.

Though the NFPA 13D Standard for residential fire suppression systems was adopted by the NFPA in 1975, NFPA 13D systems have been slow to catch on.

Recently however, the states of California and Pennsylvania have begun to include sprinklers requirements in at least some new residential construction code.

Whether this catches on and spreads to other states is to be seen, but with insurance discounts of around 10% to 15%, many homeowners may voluntarily install these systems just for the discounted insurance perk.

Stand-alone Residential Fire Protection System
Image Source: aasprink.com

Residential Piping Systems

The NFPA 13D standard lists two broad types of sprinkler systems: stand-alone and multipurpose.

- *Stand-alone systems* - Typically uses orange CPVC pipe that's limited to sprinkler applications and is isolated from the cold water supply by a backflow preventer.
- *Multipurpose systems* - Typically use flexible PEX tubing and are not isolated from the cold water supply, by a backflow preventer.

15.) Halon Gas (Obsolete System)

Phase Out of Halons

Due to the ozone-depleting potential of CFCs, HCFCs, and halon gases, the EPA enacted regulations in the United States to phase out the use of these environmental damaging gases.

This enactment eliminated the production of halons by the year 2000. When maintaining a system that still contains halon gas, a system conversion should be implemented within a reasonable period of time.

Halogenated Systems

Several types of halogenated gas systems were developed for fire protection purposes:

- Halon 104
- Halon 1001
- Halon 1011
- Halon 1202
- Halon 1211
- Halon 1301
- Halon 2402

(Primarily, Halon 1301 and Halon 1211 were in general use in the US.)

Halogenated gas systems were used in the following situations:

- When a clean extinguishing agent is needed
- Energized electrical or electronic circuits are to be protected
- Surface-burning combustible solids are to be protected
- Flammable liquids or flammable gases are present
- Objects or processes have a high value
- The area is occupied by people
- When water availability (or space for water-based systems is limited)

Alternatives to Halon 1301

There are many alternative agents which can now be used in lieu of Halon.

Also, many of the converted halon systems can be now protected with hybrid nitrogen misting systems, depending on the level of damage the equipment in the space will incur by exposure to water vapor.

There are a number of Halon systems still being used as well, many using recycled Halon gases.

Suitable total flooding replacement agents can be used:

- *Normally occupied areas* - alternatives include (PFC-410 or CEA-410), C3F8 (PFC-218 or CEA-308), HCFC Blend A (NAF S-III), HFC-23 (FE 13), HFC-227ea (FM 200), IG-01 (argon), IG-55 (argonite), HFC-125, or HFC-134a.
- *Normally unoccupied areas* - alternatives include carbon dioxide, powdered Aerosol C, CF3I, HCFC-22, HCFC-124, HFC-125, HFC-134a, gelled halocarbon/dry chemical suspension (PGA), blend of inert gas, high expansion foam systems and powdered aerosol (FS 0140), and IG-541 (Inergen).

Unsuitable replacements:

- *Hydrochlorofluorocarbons* - HCFCs (including HCFC with NAF S-III), contain chlorine and are “stratospheric ozone layer depleters”, however less so than Halon 1301. Their choice as a Halon replacement should be discouraged.
- *Perfluorocarbons* **-** PFCs such as C3F8, have very long atmospheric lifetimes and very high global warming potentials.

Chapter 3: Components of an Automatic Sprinkler System

Overview

In this chapter, we will be covering the various components with go into building an automated fire suppression or extinguishing system.

An automated sprinkler system consists of:

- *Water Supply and Reserve Storage* – the water supplied to a fire suppression system can come from a variety of sources such as the public water supply, gravity-fed tanks, pump-fed tanks, ponds, reservoirs, and cisterns.
- *Piping Network and Related Mounting Hardware* – the distribution network of pipes and pipe fittings, such as elbows, tees, clamps, hangers, mounting channel systems.
- *Sprinklers, Nozzles, Riser Assemblies, Control Devices, valves* – sprinkler heads, detectors, alarms, switching devices, etc. Riser assemblies include retard chambers, accelerators, gauges, switches, and valves

Water Supply and Reserve Storage Components

Water Based Systems

For water-based fire suppression systems, having a reliable and readily available source is essential.

In urban and suburban areas, water will primarily come from a municipal water supply, with storage tanks as secondary redundant sources.

In rural areas, water can come from manmade sources such as storage tanks or cisterns. Also natural static sources such as ponds and lakes, or flowing sources such as rivers, streams, canals, etc.

Urban Water Sources:

Pressurized Water Source: Municipal Water Supply

A municipal water source is the most reliable system available to supply a firefighting system. In extreme times of disasters though, these sources may possibly become compromised. In which case, a redundant water supply is always recommended.

Gravity Fed Sources: Elevated or Rooftop Cisterns and Tanks

These are typically situated on the roof of a building, and fed by gravitational force to the firefighting system. Elevated water tank towers, uphill surface-mounted, or even uphill underground tanks are occasional used as well.

Water is usually supplied to the tanks by off peak pumping, or channeling of rainfall. In terms of reliability the systems do not require electricity to feed the system.

In northern regions though, they can become frozen, and thus unavailable, unless adequately insulated, heated, or enclosed.

Care should be given to design for adequate static pressure head, to provide the needed pressure within the piping network.

Prefabricated Sectional Water Tank
Image Source: ParkitThere.com

Pump Fed Sources: Below Grade

These can be underground or located in an area at or below the elevation of the protected facility.

Underground water storage (image) is protected from the effects of freezing, though one drawback is the need for electrical power for the lift pumps during a fire event. To avoid unavailability during periods of power outages, the pump system will require a backup power source.

Underground Storage Tanks *Image Source: xerxes.com*

Rural Water Sources:

Fire Code for Rural Sources

NFPA 1142 (Standard on Water Supplies for Suburban and Rural Fire Fighting) is the standard which identifies a method for determining the minimum water supply necessary for structural firefighting purposes in areas where it has been determined that there is no water or inadequate water for firefighting.

Natural Static Sources:

- Ponds
- Lakes
- Other Impoundments

Natural Flowing Sources:

- Creeks
- Rivers
- Ditches or canals

Manmade Sources:

- Cisterns & Storage Tanks
- Swimming Pools
- Irrigation Systems
- Shuttle Tankers

Ponds – Draft or Dry Hydrant

Farmers and rural property owners often consider their pond to be a ready supply of water in the event of a fire. However, most ponds are not prepared or positioned for adequate fire suppression use.

When a sufficient quantity of water is not available from a public water supply system, a code-conforming source must be developed, which might include a complete pump intake structure and pump house when needed.

A dry hydrant is a non-pressurized, low-cost pipe system installed along the bank of a body of water.

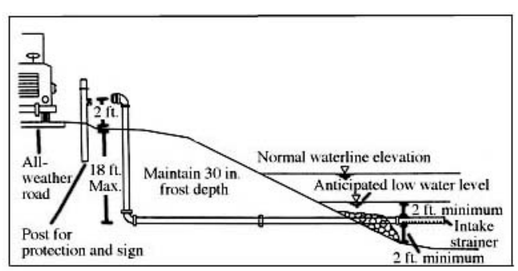
Siphon-based (Non-Pressurized) Dry Hydrant
Image Source: en.wikipedia.org

For code compliance of dry hydrants, the following should be reviewed: "Standard on Water Supplies for Suburban and Rural Fire Fighting" - NFPA 1231.

Local and state code will typically reference this NFPA standard. Another source for installation and construction guidelines is the free USDA, Natural Resources Conservation Service publication, MN-ENG-139.

This publication provides a dry hydrant design sheet for calculating static head loss, minor losses, pipe head loss, intake strainer loss, pipe sizing, and flow capacity.

For construction details, the NRCS documents: Dry Hydrant MN-ENG-306A (Vertical) and 306B (Sloped), and 306C (Combination), provide most of the specifications required for design.



Typical Installation for a Dry Hydrant
Image Source: ohioline.osu.edu

Shuttle Tanker Trucks

These are water tankers (image) which bring the water from the dry hydrants (ponds and rivers) to locations situated away from natural or manmade water storage sources.

Many times temporary fold-up holding tanks are used at the site, so that there is no lull in water supply.

Tanker Truck dumping Firefighting Water into a Fold-up Holding Tank
Image Source: eastbayri.com

Rainfall Reservoirs: Cisterns and Tanks

Gathering of rainfall (image) from the roofing system, or other areas of impervious cover is a very "green" way to store water for firefighting. Cisterns or tanks can be elevated, ground level, or underground.

Ground Level Rainfall Cistern
Image Source: lakecountyil.gov

Groundwater Sources

These are groundwater wells which supply water for fire suppression; typically used for a residential NFPA 13D fire sprinkler system.

They can be a mixed-use well system which supplies domestic water to the residence, or a dedicated system for firefighting use only.

The NFPA 13D fire code states that the well recharge or refill rate can be relied upon to supply a portion of the demand, with the duration demand of 7 or 10 minutes, to be met by the sum of the following three sources.

Water held in three areas in a well-fed fire suppression system:

- in the well casing (above a submersible pump, or below a jet pump)
- the water recharging the well as it is used
- the water supply in a holding tank in the residence

Wells are usually installed along with expansion tanks which are sized to accommodate the difference between the domestic well capacity and the added firefighting demand.

Pumps providing the additional pressure to run the fire sprinkler system may require an additional high flow pump or a booster pump and tank.

Fire Flow Demand

Water supplies that serve sprinkler systems must be sufficient and reliable. In order to determine the quantity of water needed for a sprinkler system, the rate of flow and pressure required for effective performance must be determined.

Long runs of fire hoses should be included within any calculations. The combined water use requirements for all fire-fighting equipment are known as the *fire flow demand*.

Adequately designed systems will be capable of delivering a required fire flow demand for a specified amount of time, water consumption, and maximum rate of flow.

To be more than just adequate, the system must also be capable of delivering the fire flow demand under unforeseen conditions, such as if a supply main or pump is taken out of service.

The 100% reliability of a system depends upon a certain degree of redundancy built in, such as secondary water supply options.

Chapter 4: Some Hydraulic Calculations used for Sprinkler Design

Bernoulli's Theorem

Bernoulli's Equation

This is a method for applying the law of conservation of energy to the flow of fluids. Bernoulli's principle states, in the flow of a fluid, an increase in velocity occurs simultaneously with the decrease in pressure of that fluid.

Meaning, the total energy of the flow at any point along a horizontal pipe is equal to the sum of the pressure head, the velocity head and the elevation in the absence of friction.

This is a principle of major importance in dealing with flow in sprinkler piping networks.

$$z + \frac{p}{\rho g} + \frac{v^2}{2g} = h$$

Bernoulli Equation

where:

- z = Potential head or elevation, ft
- p = Pressure, lb/ft^2
- v = Velocity, ft/sec
- g = Acceleration of gravity, 32.17 ft/sec^2
- ρ = Density of fluid, $slugs/ft^3$
- h = Total head, ft

Ignoring frictional losses and assuming no energy is added or removed from the pipe, the total head h, in the above equation will remain constant at any point within the fluid.

However in practice, the energy will increase and decrease with the effects of pumps and friction loss and this must be included in the equation.

All practical formulas for the flow of fluids originate from the Bernoulli's theorem, with modifications added to account for frictional losses.

Energy Equation for Pipe Flow

Including a term for frictional head loss and a term for pump head input gives the following energy equation for a pipe flow system.

$$z_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_P = z_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_L$$

Energy Equation for Pipe Flow

where:

- the subscript 1 refers to an upstream location in the pipe system
- subscripts 2 refer to a downstream location
- h_L is the frictional head loss between pts 1 - 2
- h_p is the pump head input between pts 1 - 2

K-Factor Formula for Fire Sprinklers

K-Factor

The K-factor formula is one hydraulic calculation which any fire protection engineer should be familiar with, when designing water based fire suppression systems.

It allows us to calculate the discharge rate of flow from any type of nozzle (fire sprinkler, water mist, deluge nozzle, even hydrants) for which we have a k-factor. We can also calculate the k-factor for any discharge device when necessary.

Calculating Discharge

The discharge from a sprinkler head or nozzle can be calculated from the formula below:

$$q = kp^{0.5}$$

Equation for Sprinkler Discharge

where:

- q = flow in gal/min k = nozzle discharge coefficient or k-factor for head in $gpm/psi^{0.5}$ p = pressure in psi

This formula can be rewritten as:

k = q / p0.5 and p = (q / k)2

For standard type sprinkler heads the many design standards specify standard k-factors and minimum pressure, which can be used for different hazard classifications and design densities.

For all other types of sprinkler heads the manufactures data sheet should be referred to for the k-factor and minimum head pressure.

Nominal Size inches (mm)	Name	K (K_M) gpm/(psi)$^{1/2}$ [l/min-(bar)$^{1/2}$]	Flow gpm (l/min)	Pressure psi (bar)
1/2 (13)	Standard	5.6 (80)	85 (300)	230 (16)
17/32 (13.5)	Large	8.0 (110)	85 (300)	113 (7.7)
5/8 (16)	Extra Large	11.2 (160)	85 (300)	58 (3.9)
3/4 (19)	Very Extra Large	14.0 (200)	85 (300)	37 (2.5)
		16.8 (235)	85 (300)	26 (1.8)

Standard K-Factors

Image Source: magazine.sfpe.org

K-factors are also used for many other applications in fire hydraulics such as flow from a fire hydrant, wet riser outlets, and hose reels, for example.

Calculating pressure losses in fire sprinkler systems

Hazen-Williams Formula

Calculating Head Losses

The Hazen Williams formula is a head loss calculation which has long been used for calculating the friction loss in piping networks for water based fire sprinkler protection systems.

The Hazen-Williams formula is empirical but lacks a theoretical basis. This equation uses the coefficient C to specify the pipe interior roughness, which is not based on a function of the Reynolds number, as in other pressure loss equations.

Be aware that the roughness constants are based on "normal" condition with a flow velocity of approx. 1 m/s (3 ft/sec).

This equation can only be used when water is flowing in the 'turbulent' flow range. If the system is outside the normal range of pressure and flow, or the water includes additives, or will be subject to non-ambient temperature conditions then the Darcy-Weisbach equation may be more appropriate. This equation is simple to calculate using a standard scientific calculator.

The Hazen William formula has become a well adopted method for finding pressure losses within fire sprinkler systems, and will usually provide adequate results. The Hazen Williams equation for calculating head losses is shown below.

$$\Delta P_f = 4.53L\,(Q / C)^{1.852} / d^{4.8655}$$

Hazen-Williams Equation

where:

- ΔP_f = frictional pressure drop across pipe length, L (psi)
- C = Hazen-Williams roughness constant
- Q = volume flow (gal/min)
- L = pipe length (ft)
- d = inside pipe diameter (inches)

Relationship between Frictional Pressure Drop and Frictional Head Loss

Calculating Frictional Pressure Drop

If the frictional pressure drop is known, the frictional pressure drop can be calculated and vice versa using the following relationship between these two parameters.

$$\Delta P_f = \rho g h_L$$

Relationship between Frictional Pressure Drop and Frictional Head Loss

where:

- ΔP_f = frictional pressure drop across pipe length, L (lb/ft^2)
- ρ = density of fluid in $slugs/ft^3$
- g = acceleration of gravity, 32.17 ft/sec^2
- h_L = head loss across pipe length, L (ft)

Value of C for use in the Hazen-Williams Formula

Listed in the table below are typical values for the coefficient C, which can be used in the Hazen-Williams formula for different fire sprinkler design standards.

The value of C represents the pipes roughness with higher values of C giving lower friction losses.

Type of pipe	C (NFPA 13)
Cast iron	-
Cement lined cast iron	140
Copper	150
Ductile iron	100
Galvanized steel	120
Mild steel	120
Mild steel (dry and preaction systems)	100
Plastic (CPVC, MDPE)	150
Spun cement	-
Stainless steel	150

Standard C-Coefficients

Image Source: canutesoft.com

The Darcy-Weisbach Equation

Darcy-Weisbach Eq.

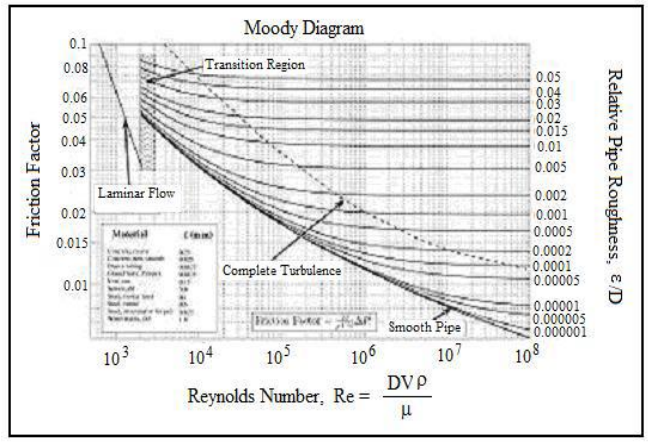
This equation is considered to be the most accurate model for estimating frictional head losses or frictional pressure drop. This equation is only valid for fully developed, steady state, incompressible flow.

Moody Diagram

A value for the Moody friction factor, f, is needed to use this equation. The Moody Diagram, shown in the diagram below, is a tool that has long been used to obtain friction factor values.

- *For laminar flow*, the Moody Diagram gives friction factor, f, as a function of Reynolds number, Re.
- *For laminar flow*, the friction factor can also be calculated as 64/Re.
- *For turbulent flow*, the Moody Diagram gives f as a function of Re and relative pipe roughness, ε/d.
- *For turbulent flow*, the friction factor can be calculated with the Colebrook equation, but this requires an iterative calculation, because the equation is not explicit in f.

An online calculator or an Excel spreadsheet may be used to facilitate the iterative calculation of the friction factor with the Colebrook equation.



Moody Friction Factor Diagram

Image Source: thefullwiki.org

$$\Delta P_f = f(L/d)(\rho v^2/2)$$

Darcy-Weisbach Equation

where

- ΔP_f = pressure loss (lb/ft2)
- f = Moody friction factor
- L = length of duct or pipe (ft)
- d = pipe diameter ft)
- ρ = fluid density (slugs/ft3)

Minor Losses in Pipe Flow Calculations

Frictional losses due to pipe fittings, bends, changes in diameter, etc are typically included in Darcy-Weisbach equation calculations through the use of minor loss coefficients (K values).

The Darcy-Weisbach equation with frictional losses due to pipe fittings included is shown in the equation below:

$$\Delta P_f = [f(L/d) + \Sigma K](\rho v^2/2)$$

Darcy-Weisbach Equation including Minor Losses

where

- ΣK = sum of minor loss coefficients for the pipe fittings, bends, changes in diameter, etc in the pipe system.

Typically used values for some common pipe fittings are shown in the table below.

Fitting	Loss Coefficient, K
Globe valve, fully open	10.0
Angle valve, fully open	5.0
Swing check valve, fully open	2.5
Gate valve, fully open	0.2
Short-radius elbow	0.9
Medium-radius elbow	0.8
Long-radius elbow	0.6
45 degree elbow	0.4
Close return bend	2.2
Standard tee, flow through run	0.6
Standard tee, flow through branch	1.8
Square entrance	0.5
Exit	1.0

Minor Loss Coefficients for Pipe Fittings
Image Source: U.S. EPA, EPANET2 User Manual,epa.gov

Chapter 5 - Piping Network and Related Hardware and Devices

The Piping Network Subsystem

This consists of the pipes, fittings, mounting hardware, valves, and various pressure and flow devices.

Types of Piping:

Steel Pipe (Welded, Threaded, or Roll-Grooved)

Carbon steel pipe (image below) is the most common material used for fire protection systems. However, it's not recommended for use in situations with acidic or corrosive environments.

Steel Piping
Image Source: bullmoosetube.com

Copper Tubing

Copper (image) is a lightweight, long lasting, material which is resistant to corrosion. When in contact with oxygen, copper forms a protective (patina) coating that protects it from corrosive elements, albeit an expensive choice.

Care should be taken, to use only copper hangers and fittings with copper tubing to avoid galvanic corrosion.

Copper Piping
Image Source: opusmcerf.org

Ductile Iron

Ductile iron pipe (image) is made from cast iron that has been treated while molten to increase its malleability, making it less brittle and more resistant to fracture than traditional cast iron.

Iron Piping

PEX (typically used in NFPA 13D applications)

PEX piping (image) is an economical and extremely easy means for installing fire protection piping. This type of piping materials is generally used with multi-purpose residential systems.

Residential Sprinkler with PEX Piping and Fittings
Image Source: Uponor

Chlorinated polyvinyl chloride (CPVC)

CPVC piping (image) is limited in its use for fire protection piping to mainly light hazard and residential applications.

CPVC piping is also highly susceptible to freeze rupturing, and damage from the heat of the fire. This type of piping materials is generally used with stand-alone residential systems.

CPVC Piping
Image Source: opus.mcerf.org

Issues with Obstructed Piping

Sources of obstructions in the piping might include:

- Insufficiently screened water from open bodies of water (ponds, cisterns, rain barrels, etc.)
- Improperly maintained gravity-fed tanks
- Highly acidic, alkaline, or saline water
- Undissolved chemicals in water supply
- Corroded metal particles
- Foreign matter introduced during the frequent operation of the various systems

Types of Pipe and Conduit Hangers

Ring Hangers

Ring hangers are recommended for suspension of non-insulated stationary pipe lines. They come in swivel, split, adjustable, and extendable styles.

Adjustable Swivel Ring-type Pipe Support
Image Source: Anvilproduct.com

Clevis-type Hangers

This type of hanger is recommended for suspension of stationary pipe or conduit. They can be secured or adjusted by turning the lateral running bolt.

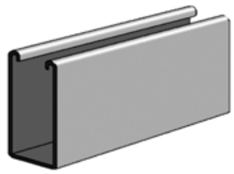
Clevis-type Pipe Support
Image Source: Anvilproduct.com

Uni-strut Channels

Uni-Strut metal framing channels provide dependable and economical performance in a wide variety of applications.

A variety of accessories can be used with these modular support systems, such as: spring nuts, clamps, fittings, pipe and conduit supports, and accessories.

They can be used in a variety of small or large, light or heavy-duty applications, and come in a variety of finishes.



Uni-strut Channel
Image Source: Anvilproduct.com

Clamps

These clamps are suspended and secure the pipe by use of a U-bolt.

Clamp-type Pipe Support
Image Source: Anvilproduct.com

Beam Clamps

These clamps (image) are used to mount piping onto structural beams. They can be mounted by centered (centers the load on beam to prevent distortion), side (for supporting pipe from the bottom flange of beams), or top alignments (for use on top flange of beam and roof trusses).

Centering Standard Beam Clamp
Image Source: Anvilproduct.com

Riser Clamps

These clamps (image) are used for the support of the vertical riser piping. The load is carried by shear lugs, which are welded to the pipe.

Riser Clamp
Image Source: Anvilproduct.com

Sway Bracing

This type of bracing (image) is designed to provide seismic stability on the longitudinal axis as well as providing lateral support.

Longitudinal and Lateral Sway Bracing
Image Source: Erico Products

Issues with Damaged Piping and Hangers

Be sure that piping is not used to support any non-system items such as stock, equipment, or other material.
When inspecting pipes and hangers, look for:

- physical damage
- corroded piping hardware
- bent piping hardware
- loose piping and hardware
- missing piping and hardware
- damaged piping and hardware

Piping System Devices:

Alarm Check Valve

Wet Pipe Systems routinely use these devices to maintain constant pressure and unidirectional flow on the system piping network above the valve.

During a fire, the flowing water will cause the clapper assembly inside the alarm check valve (image) to open, permitting a portion of the water to flow through a port in the valve that's connected to an alarm device.

This valve is typically sold as an assembly, which includes ancillary devices such as: water motor gong, net and main pressure gauges, retard chamber, pressure switch, and a strainer.

Alarm Check Valve Assembly
Image Source – Alibaba.com

Retard Chamber

To prevent a false alarm, a *retard chamber* (image) is placed in the piping, between the alarm check valve and the alarm device. The retarding chamber is a simple reservoir that collects the excess water from a water surge.

If the surge does not exceed the capacity of the reservoir, once the surge stops the water will drain from the retarding chamber and no water flow alarm is triggered.

Retard Chamber
Image Source: hdfire.com

Water Motor Alarm (or Gong)

A water motor alarm (image) is a hydraulically operated outdoor alarm for use with fire protection systems.

It can be used in conjunction with alarm check, dry pipe, deluge, and pre-action valves to sound a local alarm. This water-powered device eliminates the need for an electrical alarm and will operate in situations of power failures.

Water Motor Gong
Image Source: Supplyhouse.com

As water passes through the water motor, the impeller turns, rotating the shaft. The rotating shaft drives a striker assembly, which rings the gong, sounding a continuous alarm as long as the water flow continues.

Accelerators and Exhausters

When there is a fire, the heat opens the sprinkler heads, releasing the air or nitrogen through the sprinkler head from the piping network, thus eliminating the pressure differential.

With no air pressure holding back the clapper, the water pressure below the valve opens the clapper, allowing water to flow through the piping to the opened sprinklers.

This operation has a time delay between the opening of the sprinklers and the application of water to the fire. This delay can be reduced by adding an *accelerator or an exhauster* to the dry pipe system.

The *accelerator* (image) allows air from the system's piping to enter the intermediate chamber area in the dry pipe valve, eliminating the pressure differential, and opening the clapper.

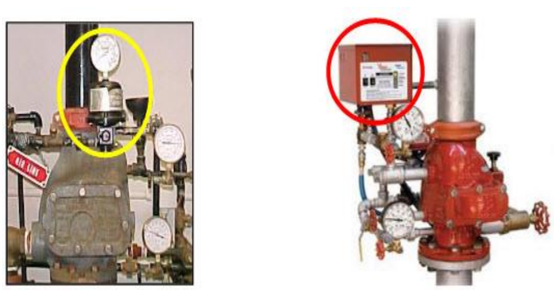


Fig. 1 Mechanically operated **Accelerator** **Fig. 2** Electronically operated **Accelerator**

Mechanical and Electronic Accelerators
Image Source: hfmplanreview.org

The *exhauster* (image) opens and exhausts air from the piping system faster than through the sprinklers, eliminating the pressure differential in lesser time. This greatly decreases the time for water to reach an opened sprinkler. Exhausters are typically used on a dry pipe or a pre-action system.

Dry Pipe System Exhauster (the blue component)
Image Source: dps.mn.gov

(OS&Y) Outside Screw and Yoke Gate Valve

An OS&Y gate valve (image) is a type of "indicator valve" commonly used to control water flow to fire sprinkler systems. OS&Y gate valves operate by opening and closing water flow using a "gate", which lowers into or rises out of the valve.

Raising the gate allows water to flow through the valve while lowering the gate cuts off the water flowing through the valve. When fully open, the typical gate valve has very low friction loss, as there are no obstructions in the flow path, as in some valve designs.

On an OS&Y gate valve, the valve gate is attached to a threaded stem with a handle that connects to the yoke element. As the valve is opened, the stem lifts out of the handle.

A clockwise rotation of the gate moves the stem back into the gate and closes the valve. When the stem is no longer protruding beyond the handle, the gate valve will be closed, providing a visual indication of whether it is open or closed by the position of the stem, thus the use of the term "indicator valve".

Sprinkler control valves are usually designed so that in the event of an emergency, their position, whether opened or closed, may be quickly ascertained either by the:

- **Target** – as on a post indicator valve (PIV)
- **Protruding stem** of an outside screw and yoke (OS&Y) valve

Outside screw and yoke (OS&Y) valve
Image Source: spsvalve

(NRS) Non-Rising Stem Gate Valve

The NRS (image) is a gate valve, similar in nature to the OS&Y type valve. One difference is that with a NRS valve, the screw threads that lift the gate are exposed to the fluid being controlled by the valve.

This can cause problems if the fluid tends to foul the threads, so non rising stem valves are usually used with only clean fluids. Rising stem valves have the threads external to the valve body and are not subject to fouling from the fluid the valve is controlling.

Rising stem valves are usually made from cast or forged steel while non rising stem valves are more typically brass, bronze or cast iron. NRS valves occupy less space, while rising stem valves require more space.

Non-Rising Stem Valve
Image Source: asvvalves

Position Indicator Valves (PIV)

A post indicator valve (PIV) is a valve assembly (image) used to open and close a water supply to fire protection systems in larger buildings.

It's a gate or butterfly valve located on the fire system water main with a raised post that protrudes above ground level or out from a wall. A spring-loaded lever rests against the side of the open/shut indicator, called a *target*.

As the valve is operated, the target moves with the switch following the movement. The position indicating switch is adjusted to trigger a supervisory signal, before the operating nut has rotated two turns or 20 percent of its full travel.

The three main types are installed in different configurations and orientations:

- **Ground-type** - is typically used where the valve is situated outside a building
- **Pedestal-type** - is used inside buildings with underground water mains
- **Wall-type** - is used where the water main passes through a wall cavity

Position Indicator Valve
Image Source: Viking

Sprinklers and Related Devices

Sprinkler Heads

Known as "sprinklers" or "sprinkler heads" (image), these are nozzles spaced at regular intervals along the piping network to distribute a uniform pattern of water into the area of fire protection.

To obtain maximum efficiency, the stream of water coming from the nozzle needs to be dispersed as droplets.

The sprinkler's *deflector* (part of the frame) breaks up the water as droplets, which are more effective in extinguishing the flame.

Sprinkler in Action
Image source:hgi-fire.com

Automatic sprinklers are designed for specific applications based on:

- orifice size
- deflector design
- frame finish
- temperature rating

Deflectors

Deflectors (image) give varied patterns of water distribution, depending upon the shape of the deflector.

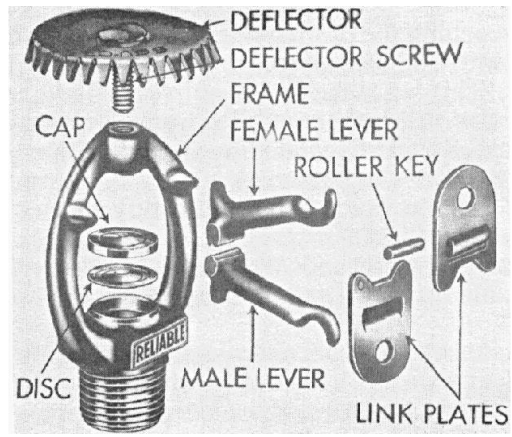
They can be installed in an upright position, a pendent (hanging or suspended) position, or in a sidewall installation. They can be protruding, recessed, or completely concealed.

Types of Sprinklers with Varied Deflector Styles
Image Source: aljasiya.com

Sprinkler Frames

The frame of a sprinkler head (image), can come in many finishes. Those for residential use may be powder coated paint to be aesthetically pleasing, while the frame for others may be copper alloy, or stainless steel for extra life.

The frame of a sprinkler used in certain corrosive environments may be coated for protection with either a lead or wax coating.



Sprinklers Components
Image Source: cool.conservation-us.org

Sprinklers with Release Mechanisms

Use of Release Mechanisms

Automatic sprinklers are normally held closed by *release mechanisms* which are heat sensitive elements that press down on a cap over the sprinkler orifice and are anchored by the frame of the sprinkler.

The heat sensitive element activates by melting or fracturing, to release the water at varying temperatures, depending upon the particular application.

There are four basic types of release mechanisms for automatic sprinklers:

- *Fusible link sprinkler* - is kept closed by a two-piece link, held together by solder with a preset melting point. When the solder melts, the levers pull the two-piece link apart and fly away from the sprinkler. Water pressure in the piping system pushes the cap from the orifice of the sprinkler to discharge water.

- *Frangible bulb sprinkler* - has a small glass bulb located between the orifice cap and the sprinkler frame. The bulb is partially filled with a liquid with air filling the remaining area of the bulb. Heat from the fire causes the liquid to expand into the air, in turn shattering the glass bulb, opening the sprinkler for water discharge.
- *Frangible Pellet Sprinkler* - This type of sprinkler has a rod between the orifice cap and sprinkler frame. The rod is held in place by a compressed pellet of solder. When the solder melts, the rod moves away from the orifice cap. The cap is pushed off by the water pressure in the piping network.
- *Bimetallic Element Sprinkler* - This sprinkler uses a disk made of two distinct types of metal, as the heat-sensitive element. When the sprinkler is off, the disk maintains pressure on a piston assembly.

When a fire occurs and the temperature reaches the sprinkler's rating, the disk flexes open, releasing pressure on the piston assembly, allowing a small amount of water to bleed from the piston chamber faster than it can be replaced through a restrictor.

The water pressure in the piping network pushes the piston down, allowing water to discharge from the sprinkler.

When the temperature is reduced, the element returns to its normal position, allowing water to pass through the restrictor, filling up the piston chamber, forcing the piston into the closed position, and stopping water discharge.

This sprinkler is useful for automatic cycling on and off, such as to put out a rekindled fire.

Sprinklers without Release Mechanisms

Other sprinkler heads that do not include a release mechanism:

Dry Pendent Sprinklers

These are used when pendent sprinklers must be placed on dry pipe systems or wet pipe systems located in areas subject to freezing with the piping network installed in a heated area..

An example being a walk-in refrigerated area or exterior shop area. This sprinkler is fitted with a tube within an attached section of pipe. The tube holds the water-sealing elements in place against a watertight seal at the top of the pipe.

When the sprinkler is activated, the tube drops down releasing the elements through the tube and out the open sprinkler with the discharged water.

Open Sprinklers

These are used on special sprinkler systems, such as deluge or rapid reaction systems, and consist strictly of a sprinkler frame and deflector.

Water Spray Nozzles

These are used for special applications such as wide angle, narrow angle, long throw, or flat spray patterns.

The different patterns may be achieved by either internally or externally deflecting the water stream, dependent upon the type of nozzle used.

Color Coded Fusible Elements

Sprinklers are color coded to identify the temperature rating of the fusible element (image). Color coding is not required for plated sprinklers, ceiling sprinklers, or similar decorative types.

Sprinklers (Color Coded)

- *Orange Sprinklers* **-** These heads have a fusible element designed to trigger at a temperature of **135** degrees F.
- *Red Sprinklers* **-** These heads have a fusible element designed to trigger at a temperature of **155** degrees F.
- *Green Sprinklers* **-** These heads have a fusible element designed to trigger at a temperature of **200** degrees F.

- *Blue Sprinklers* - These heads have a fusible element designed to trigger at a temperature of **286** degrees F.

Water Spray Nozzles

This type of nozzle (image) is used to achieve wide or narrow angle, long throw, or flat spray patterns, which may be created by either an internal or external deflection of the water flow.

Water Spray Nozzles
Image Source: sarian.ir

When inspecting sprinklers (sprinkler heads), check for:

Proper Clearance above Stockpiled Materials

Clearance of a minimum of 18 inches beneath the sprinkler head is required for proper water distribution where sprinklers are installed in areas above stockpiled materials.

Relocation Requirements

In commercial buildings and industrial facilities, walls are frequently moved around to accommodate the needs of new tenants.

Changes to heating, lighting, and air-conditioning systems may require relocation or replacement of sprinklers or additions to the system. Changes of this nature should be based upon a sound engineering review.

Outside Open Sprinklers

When you are servicing outside open sprinklers, visually inspect the general condition of sprinklers, flow testing the control valve, remove and clean any plugged or obstructed sprinklers. Conditions that indicate the need for maintenance include the following.

Occurrence of mechanical injury:
- Bent deflectors
- Loose deflectors
- Bent frames
- Paint overspray or inadvertent painting of heads

Incidents of corrosion:
- Metal discoloration
- Hard water deposits
- Oxidation
- Subsurface flaking

Damage from Temperature Issues:
- Overheating
- Freezing
- Expansion and Contraction

Supervisory Devices

Fire Alarm Control Panels (FACPs)

These are the brains of a fire detection and response communication network. They relay communications between the various detectors, alarms, suppression systems, and monitoring stations within a fire suppression system.

Traditional FACPs are hardwired to each device in the system while wireless panels and accompanying devices are usually linked via (RF) radio frequency.

The panel recognizes when the current or resistance on a circuit increases due to activity from a detection device:
- Smoke detectors
- Heat detectors
- flame detectors
- manual call stations

The FACP will then run a sequence of operations:
1) trigger a visual or auditory signal to alert occupants of an emergency situation, typically prompting a building's evacuation.
2) trigger water sprinklers, dry or wet chemical dispersal systems, or the foam/gas blanketing system
3) Inform a monitoring center of the alarm status (individuals at the receiving location determine a course of action)
4) control HVAC system dampers

5) control building automated controllers
6) control access points, and elevators to isolate the fire or route personnel during an emergency

Supervisory Aalarm Initiating Devices

These devices cause a signal at the supervisory control unit and/or remote receiver when abnormal fire protection system conditions occur. These valves are never closed unless a sprinkler system requires maintenance. Valves that control water flow to a water flow detector or valves in a sprinkler header room or fire pump room that are normally closed may be supervised.

- *Supervisory devices for (NO) normally open valves* signal when the valve is closed no more than two turns or 20 percent of its total travel.
- *Supervisory devices for (NC) normally closed valves* signal when the valve is opened no more than two turns or 20 percent of its total travel.

Smoke Detectors

There are three types of smoke detectors: ionization, photoelectric, and combination.

Ionization

The ionization smoke detector (image) is widely used. It's best used with clean-burning fires that produce small particles. The alpha source causes the air within the smoke chamber to become ionized and conductive.

As smoke particles enter the smoke chamber, the smoke particles attach themselves to the ionized air molecules and the air in the chamber becomes less conductive. When the air conductivity within the chamber drops to a predetermined level, an alarm is triggered.

Spot Type Smoke Detector
Image source: Orr Protection Systems

Photoelectric

A photoelectric smoke detector is the most common smoke detector used today. It detects smoke by using either the principle of light obscuration or light scattering. It's best used with fires which produce large particles during combustion.

- When smoke enters the smoke chamber, it reduces the intensity of light reaching the photosensitive device, which reduces the monitored current.
- When the intensity drops below a certain level, the sensor control circuitry detects a drop in the current produced by the photosensitive device.
- When the current falls below a preset threshold, the smoke alarm is triggered.

Rate-compensated Thermal Detectors

Rate-compensated thermal detectors (image) are devices that are designed to activate at a preset temperature in an area regardless of the rate at which the temperature in the area increases.

This is accomplished by compensating for the thermal lag between the room temperature and the interior of the device.

Rate Compensated Heat Detector
Image source: Gamewell Fire Control Instruments

Water Level and Temperature Indicators / Switches

Pressure-actuated Switch

As the water level changes in a water supply reservoir, the water pressure at this supervisory switch also changes.

This switch is usually installed in the piping near the bottom of the reservoir, and can be adjusted to actuate when the pressure indicates either low or high water levels.

Electronic Water Level Indicators

This type of indicator senses the change in water conductivity to trigger the electrical warning signal. However, they are not commonly found in fire protection systems.

Float-actuated Water Level Switch

This switch is actuated when the float moves outside normal limits. (image) shows a typical high-low water level supervisory device, which would be installed in a water supply reservoir.

High/Low Water Level Float Switch
Image Source: Pottersignal.com

Water Temperature Indicator Switch

These switches (image) are used to prevent water freezing in fire protection systems. Low water temperature indicators are more common. The most common low temperature setting is 40°F.

Tank Temperature Supervisory Switch – High/Low
Image Source: pottersignal.com

Water pressure and flow devices

Sprinkler systems have a variety of controller devices and fittings classified as detecting or initiating. Their purpose is to detect and initiate particular system operations, or alarm systems connected within the sprinkler system.

Pressure and Flow Actuated

Sprinkler water flow detectors are usually pressure-actuated or vane-actuated devices. Pressure switches can be activated by a pressure increase or pressure drop.

Pressure Switches

Pressure actuated switches are designed for the detection of a water flow condition in automatic fire sprinkler systems of particular designs such as wet pipe systems with alarm check valves, dry pipe, pre-action, or deluge valves.

Pressure-Increase Water Flow Detectors

These detectors come in various styles, and can be found in wet or dry pipe sprinkler systems. The switch actuation arrangement involves a sealed, accordion-like bellow that is assembled to a spring and linkage.

The *spring-tension setting* controls the pressure at which the flow detector is activated. It can be adjusted in the field or set in the factory, to the pressure that activates the electrical switch.

When used on a wet pipe system, it is usually mounted at the top of a retarding chamber, which reduces the speed of pressure buildup at the switch.

Other types of this switch may use a *pneumatic retarding mechanism* within the detector housing. Usual settings for retard time are in the range of 20 to 70 seconds.

This retard switch is connected to the alarm port of a wet sprinkler system alarm check valve, and is usually set at a pressure range of 8 to 15 psi.

Pressure Drop Detectors

Pressure drop detectors are similar in design to the pressure increase detectors. These detectors are used where water hammer may cause false alarms to occur with other types of water flow detectors.

These detectors can be used in wet pipe sprinkler systems equipped with check valves that hold excess pressure on the system side of the valve. There is no retarding mechanism or chamber used with this type of detector.

Combination Pressure Increase-Drop Switch
Image Source: pottersignal.com

Pressure Pump/Pressure Drop Type of Water Flow Detector

These detectors are used in large sprinkler systems and in systems with water pressure insufficient to reliably operate one of the other types of water flow detectors.

These detectors are also known as *fixed pressure or water flow detectors with pump*. It is mounted to the sprinkler system riser, using a strap-style connector. This detector consists of a pump, pump motor, and a control unit. The device provides a water flow alarm signal and a low system water pressure supervisory signal.

To compensate for variable water pressure, it will add excess pressure to the system to prevent surges in the supply pressure from opening the alarm check valve and causing operation of the water motor gong or other alarm indicators.

System leak below 1 GPM

Detectors of this type are adjusted to maintain system pressure of 25 to 50 psi above the supply pressure. When a slow leak at the alarm check valve or anywhere in the system occurs, it will cause a slow drop in the system pressure.

When system water pressure decreases to 2 psi below a preset value, a pressure switch will close, causing the pump to start pumping water from the supply side to the system side of the alarm check valve at a rate of about 1 gallon per minute (gpm).

If the total system leak is below 1 gpm, the pressure switch opens and stops the pump when the preset pressure is restored.

System Leak above 1 GPM

If the system leak exceeds 1 gpm, the system pressure will continue to drop, even with the pump running.

In the situation, when system pressure decreases to 4 psi below the preset pressure value, a trouble pressure switch opens to indicate that there is a leak in excess of 1 gpm.

If the water pressure continues to drop to 6 psi below the preset value, an alarm pressure switch will signal a water flow alarm.

Pump Shutdown

Some water flow detectors of this type have an additional switch that disconnects pump power when the supply water pressure drops below 14 psi.

This prevents pump burn up in case of total supply shutdown or a break in the supply line.

Electronic Pressure Drop Detector

For sprinkler systems that must maintain a high excess system pressure over a supply pressure, (that would delay the actuation of a vane type of water flow detector), an *electronic pressure drop detector* is often used.

It is normally mounted to the riser pipe with a flexible hose connection to the system side of the check valve.

This device requires a pressure drop of 5 to 20 ounces per square inch, for a period of at least 3 seconds to signal an alarm. (A pressure drop at a slower rate or of a shorter duration will not cause an alarm).

A slow pressure drop to 15 psi or less causes a trouble signal indicating a system leak and low supply pressure. Pressure increases do not cause an alarm, but an over pressure condition (200psi) will cause a trouble signal.

Trouble signals will also be initiated when:

- The detector's cover is opened
- Supply voltage is outside normal ranges
- An internal circuit fails interfering with detector function

Vane-Type Flow Devices

These types of devices (image) are used strictly on wet pipe sprinkler systems. (They cannot be used on dry pipe systems due to the initial burst of water into the pipe, which may cause damage to the vane and mechanism.)

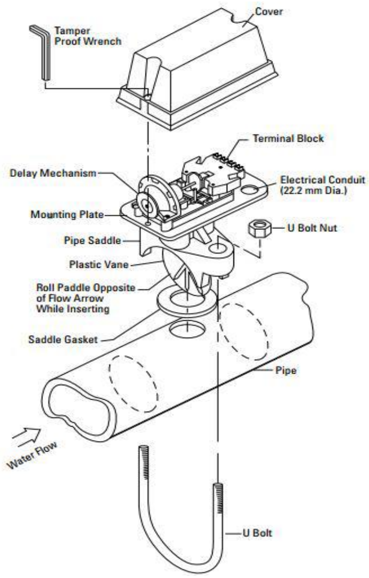


Diagram of Vane-type Water Flow Actuated Detector
Image Source: System Sensor

Vane Type Water Flow Detector

This type of detector (image) is used only in wet pipe sprinkler systems. The detector is inserted in the pipe by drilling a hole in the wall of the sprinkler pipe, and inserting the vane into the pipe.

Then the detector is clamped onto the pipe with a U-bolt, and sealed with a saddle gasket. When the sprinkler system is activated by a fire event, the water flowing through the pipe causes the vane to rotate. The moving vane, in turn, triggers an alarm.

Vane Switch - Water Flow Detectors
Image Source: System Sensor

Chapter 6 - Systems Inspecting, Testing, and Maintenance

Need for Proper System Inspections, Tests, and Maintenance

To make sure automatic sprinkler systems are 100% reliable, periodic inspection and maintaining of system components is essential.

Visual Checks

Many potential issues with automatic systems can be discovered simply by visually inspecting the complete system with a very bright LED light source.

Testing of Components

To be sure of a properly working system, many of the more complex components such as valves, detectors, etc. need to be run through procedural tests. E

ach type of system will require its own specific testing procedures, whether it is a hydraulic, pneumatic, mechanical or electrical device.

Maintenance

During the inspection of systems, certain conditions will indicate maintenance is required. If these conditions are not corrected, they will reduce the total reliability of the system, possibly creating a life threatening condition.

These conditions and some remedial actions are discussed in this chapter.

Human Error

Because of the possibility that valves may have been closed without the knowledge of the plant manager and inadvertently never reopened, frequent periodic checks of all valves is an essential part of industrial fire protection.

Mechanical Failure

As in all mechanical devices, valves are subject to mechanical failure, such as the gate becoming detached from the OS&Y valve's stem showing an inaccurate indication of the gate position.

To insure that the valves are open, the two inch drain is vital.

Silt and debris can block entire sections of sprinkler pipes, reducing or blocking entire sections of piping and sprinklers.

The 2-inch drain test can help by removing the silt and debris at the bottom of the risers that would otherwise end up in the smaller piping.

Simple Systems Tests:

Main Drain Test

(for testing system-wide pressure and flow)

The main drain of an automatic sprinkler system is actually the water flow control valve.

It's important to test the functioning of this value annually to ensure that there is proper water pressure and flow within the sprinkler system.

The main drain test also indicates blockages in the piping network that may risk damage to the system or a reduction of water supply to the system during a fire event.

The Two Inch Drain Test

(for testing valves)

Valves within a sprinkler system which are either closed by accident, or through mechanical failure, are prime contributors to fire disasters due to sprinkler system failures.

The "two inch drain test" or "sprinkler system flowing pressure test" is a fairly simple procedure which tests the functioning of the valves throughout the system.

A portion of the two inch drain test requires fully closing and opening the sprinkler control valves, often called the OS&Y or outside yolk valve or post indicator valve (PIV) located at the bottom of the main sprinkler risers.

This test should be conducted to make sure that the valve is open and fully operational. The OS&Y or PIV valve tests, when are conducted at every sprinkler riser, is one of the most important steps of a facility's self-inspection program.