Fire Protection Systems

Continuing Education from the
American Society of Plumbing Engineers

CEU 249

July 2017

ASPE.ORG/ReadLearnEarn

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The two main purposes for fire protection systems within built environments are life safety and property protection. Equal consideration must be given to attempting to contain a fire while protecting a building's occupants during their evacuation. Absolute safety from fire is not attainable, but means must be provided to minimize the potential for fire and the damage done by fire.

The systems and methods used today are constantly changing and improving to meet the requirements of project variations and challenges. This chapter provides a basic outline for establishing the needed criteria to ensure fire safety via fire suppression within a building.

FIRE HAZARD EVALUATION

The first step in the design of an automatic sprinkler system is determining the overall fire hazard. The key factors affecting the overall fire hazard are:

- Class of fire
- Classification of occupancy and commodities
- Type of building construction and use
- Fire load and resistance rating

Classes of Fires

A generally accepted method of classification separates combustible materials into the following types:

- Class A fires: Ordinary combustible materials such as wood, cloth, paper, rubber, and many plastics (typical for wet-based sprinkler systems)
- Class B fires: Flammable liquids, combustible liquids, petroleum greases, tars, oils, oil-based paints, solvents, lacquers, alcohols, and flammable gases
- Class C fires: Fires that involve energized electrical equipment
- Class D fires: Combustible metals such as magnesium, titanium, zirconium, sodium, lithium, and potassium
- Class K fires: Fires in cooking appliances that involve cooking oils and fats

Class B, C, D, and K fires require specialized suppression systems based on the material that needs to be extinguished. The correct selection of an extinguishing agent is critical to controlling and extinguishing these types of fires.

Classification of Occupancy and Commodities

The criteria for occupancy classification is defined in NFPA 13: *Standard for the Installation of Sprinkler Systems*. The categories are broken into the following areas based on building use type:

- Light hazard: Low quantity of combustibles with low heat release (e.g., churches, hospitals, museums, offices)
- Ordinary hazard 1: Moderate quantity of combustibles with moderate heat release and 8-foot stockpiles (e.g., mechanical rooms, restaurant kitchens, laundry facilities)
- Ordinary hazard 2: Moderate quantity of combustibles with moderate heat release and 12-foot stockpiles (e.g., stages, large library stack rooms, repair garages)
- Extra hazard 1: High quantity of combustibles with high heat release and no flammable or combustible liquids (e.g., aircraft hangers, saw mills)
- Extra hazard 2: High quantity of combustibles with high heat release and flammable and combustible liquids (e.g., plastics processing, flammable liquids spraying)

If the building includes storage, whether in stockpiles, racks, or pallets, the materials and methods of storage must be known. NFPA 13 provides specific guidelines regarding stored goods within the building environment.

The different building uses and stored materials require different hydraulic demand requirements. It is imperative to obtain this information during the information-gathering process.

Type of Building Construction and Use

The general construction and occupancy use classification of the building must be understood to determine if the building is required to be provided with a sprinkler system by code. In some instances, the model building codes make exceptions to allow an increased building area if the area is fully protected by an automatic sprinkler system (which should be confirmed during code review).

Fire Load and Resistance Ratings

The nature and potential magnitude of a fire in a building are related directly to the amount, composition, and physical arrangement of combustibles, either as contents of the building or as materials used in its construction. The total amount of combustibles is referred to as the fire load of a building and is expressed in pounds per square foot (lb/ft^2), with an assumed calorific value for ordinary cellulosic materials of 7,000 to 8,000 British thermal units per pound (Btu/lb). If this Btu content is applied when organic materials are present in large proportions, the weights must be adjusted accordingly.

The temperatures used in standard fire tests of building components are indicated by the nationally recognized time/temperature curve shown in Figure 1-1. The fire resistance of the construction of building assemblies, such as walls, floors, and ceilings (determined by standard fire tests), is expressed in hours.

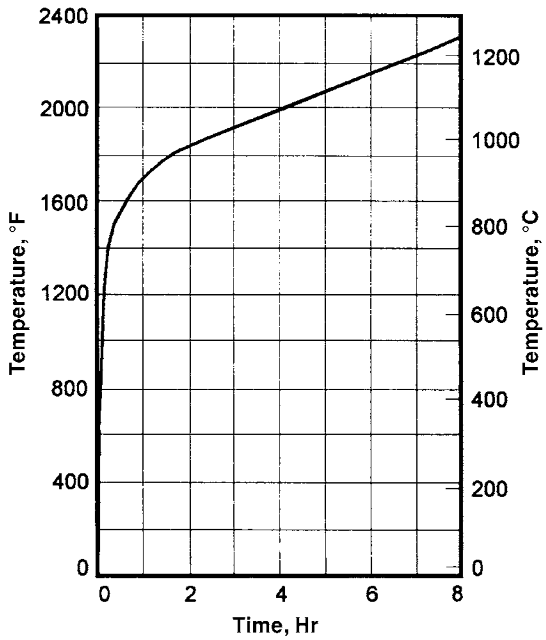


Figure 1-1 Time/Temperature Curve for Standard Fire Test

WATER SOURCE

The primary agent for most fire-extinguishing systems is water. The availability of a municipal water supply of sufficient pressure and quantity to meet the design demands of the fire protection sprinkler system must be addressed. The points to be considered for the water supply include the following:

- Quantity, static pressure at no flow, residual pressure at design flow, and availability of water
- Overall fire demand, including duration of flow
- Makeup and reliability of the source
- Size, material of construction, and age of mains

Refer to NFPA 24: *Standard for the Installation of Private Fire Service Mains and their Appurtenances* for more information.

Quantity and Availability

The amount of water available from a network of underground water mains, whether they be private yard mains or the public water supply, can be determined in several ways. (Refer to NFPA 291: *Recommended Practice for Fire Flow Testing and Marking of Hydrants*.) The simplest method is to consult the history of fire flow tests in the area, available from the local water and fire departments or the plant personnel for private systems. If test results are not current or if the water supply might have changed since the most recent hydrant flow test, a new hydrant flow test should be requested through the local authority (i.e., water department, fire department, or plant management). Many water authorities are now providing a historically low static pressure for a particular area due to the fluctuation in test results that typically depend on the time of day when a particular test was taken. Engineers should consider using this historically low static pressure in their hydraulic calculations, and some municipalities are starting to require its use.

Hydrant Flow Test

To conduct a fire flow test, the following equipment and information are necessary:

- Hydrant butt cap, with dial-spring gauge
- Pitot tube and blade with an attached dial-spring pressure gauge
- Hydrant wrench
- Nozzle pressure flow tables
- Knowledge of the water main's sizing and piping layout

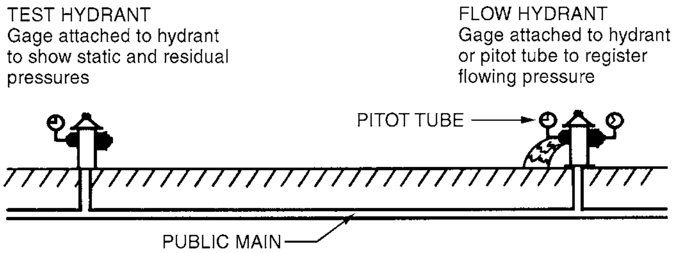


Figure 1-2 Pitot Tube Position

Once all of the necessary equipment is assembled, a minimum of two operable fire hydrants should be selected. It is recommended that the residual pressure hydrant (test hydrant) be as close as possible to the structure under design and downstream of the flow hydrant.

After the hydrants for the test have been selected, the hydrant butt cap with its pressure gauge should be placed on the test hydrant. The water department or maintenance personnel should operate the hydrants to limit the liability for damage. Special provisions might be required to accommodate the large volume of water that will discharge during a test.

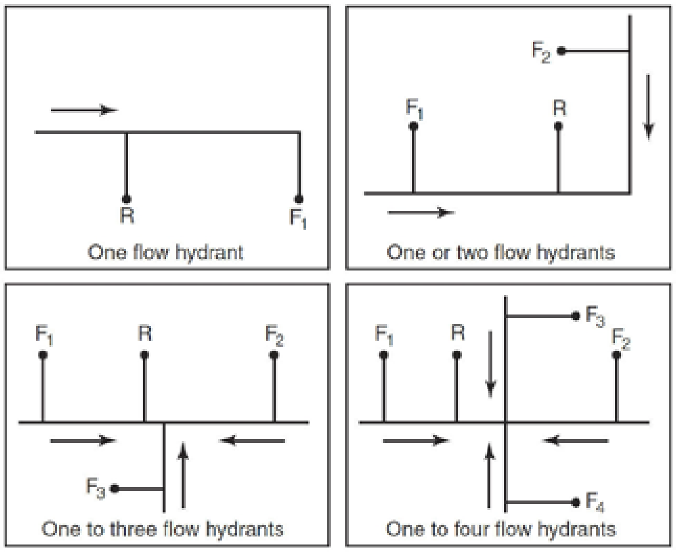
Once the butt cap is in place, the test hydrant should be opened slightly to allow the air in the hydrant barrel to bleed off past the open bleed cock on the hydrant butt. After the air is bled off, the hydrant can be opened fully, and the bleed cock can be closed. The pressure that registers on the gauge at this time is the static pressure (pressure with no flow).

The second hydrant now can be approached. To start the test, one flow hydrant butt should be opened. The coefficient of discharge should be determined by considering the construction and roughness of the inside lip of the hydrant butt. In addition, the actual inside diameter of the butt should be measured to confirm its diameter. After this data has been recorded, the flow hydrant now can be opened fully. Some caution should be exercised when opening the hydrant. It should never be opened rapidly, and the path of discharge should be investigated to ensure that personnel will not be injured and that property will not be damaged by the stream or the residual standing water.

After the flow hydrant has been opened, it should be allowed to flow for two to five minutes to allow debris to clear the hydrant barrel and to stabilize the water flow before the pitot tube is inserted into the stream. When the pitot tube is inserted into the water stream, it should be placed in the centerline of the stream, at approximately one-half of the diameter of the butt opening (see Figure 1-2). The reading on the pressure gauge attached to the pitot tube then can be read. Simultaneously, the residual pressure (flowing pressure) must be read on the test hydrant (see Figure 1-3).

The pitot reading and residual pressure now should be recorded. For best results, the pitot reading should not be less than 10 pounds per square inch (psi) or greater than 30 psi; similarly, the static pressure should drop 25 to 50 percent under the test conditions. In addition, it is a good idea to flow a quantity at least equal to the fire demand.

Now the data gathered during this test can be used to determine the quantity of water flowed and the amount of water available for firefighting operations. First, to determine the quantity of water flowed, the pitot pressure, hydrant butt size, and discharge coefficient are used. Using the pitot pressure and hydrant butt size from a given table (supplied by the manufacturer), a theoretical flow can be found, using the following formula. This formula allows computation of the gallons per minute (gpm) flowing from a nozzle, hydrant outlet, or orifice (see Figure 1-4).



Arrows indicate direction of flow: R – residual hydrant; F – flow hydrant

Figure 1-3 Method of Conducting Flow Tests

Equation 1-1

$$Q = (29.83)\,(c)\,(d^2)\,(\sqrt{p})$$

where

Q = Flow discharge, gpm
c = Coefficient of discharge
d = Diameter of outlet, in.
p = Pitot (velocity) pressure, psi

The flow available at any pressure along the established flow curve can be found using the following equation:

Equation 1-2

$$Q_A = Q_T \left(\frac{P_S - P_A}{P_S - P_R} \right)^{0.54}$$

where

Q_A = Flow available at some residual pressure (P_A), gpm
Q_T = Actual flow measured during the test, gpm
P_S = Measured static pressure, psi
P_R = Measured residual pressure, psi
P_A = Pressure of interest, psi

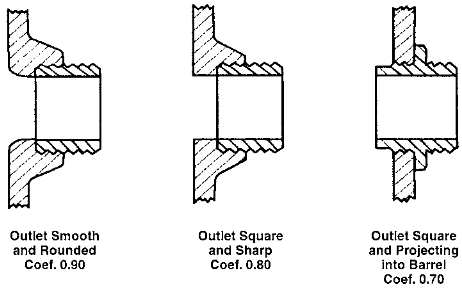


Figure 1-4 Three General Types of Hydrant Outlets and Their Coefficients of Discharge
Source: NFPA 291

The results of a hydrant flow test can be plotted on a graph to develop the characteristic flow curve for the piping network (water supply) for the test location. Either the formula method discussed above or the graph method can be used to determine water availability.

Overall Fire Demand (Flow, Pressure, and Duration)

The overall fire demand is established by hydraulic calculations performed by the engineer, by code, or by the insurance rating organization. The end result is the amount of flow required (gpm) at a calculated pressure (psi). The flow duration requirement is typically mandated by NFPA 13. For example, light hazard occupancies typically require a reliable water supply with a 30-minute duration capability.

Water Supply Makeup and Reliability

A water supply's reliability can be determined by evaluating the method by which the pipe network is fed. Municipal water supplies consist of three types: elevated reservoirs (water towers), direct pump, or combined. The distribution of the water supply can be a dead end, grid, or loop pipe system or a combination of all three.

The elevated reservoir is reliable as it does not depend on electrical power to provide the water pressure. The same reasoning holds true for private supplies. With reliability in mind, an automatic fire protection system should be designed to function properly without the introduction of a booster fire pump. If this cannot be accomplished, then a fire pump will need to be added to provide the water supply. (See the "Fire Pumps" section later in this chapter.)

A water supply piping system that consists of one large supply line feeding a series of dead-ended branch mains is far less efficient than a system of pipes that are looped and gridded together. For example, an 8-inch main flowing 2,000 gpm that is fed from one direction will have a friction loss of 4.62 psi per 1,000 feet of pipe. If that same main were fed from two directions, the flow could be balanced to 1,000 gpm from each side (assuming equivalent pipe characteristics and lengths). The friction loss would then be reduced to 1.128 psi per 1,000 feet, or reduced by a factor of four.

Size and Age of Mains

The size and age of the fire mains play an important part in the ability of the water supply to produce adequate fire flows for fire protection systems. What may not be obvious to the casual observer, however, is how time and the corrosiveness of the water can affect the inside diameter of the supply mains. For example, with moderately corrosive water, a 30-year-old cast iron pipe will have friction factors higher than new cast iron pipe.

AUTOMATIC SPRINKLER SYSTEMS

Once the fire hazard and water supply have been evaluated, the type of sprinkler system to be installed can be selected. The basic types of sprinkler systems are wet pipe, dry pipe, preaction, deluge, combined dry pipe and preaction, and antifreeze.

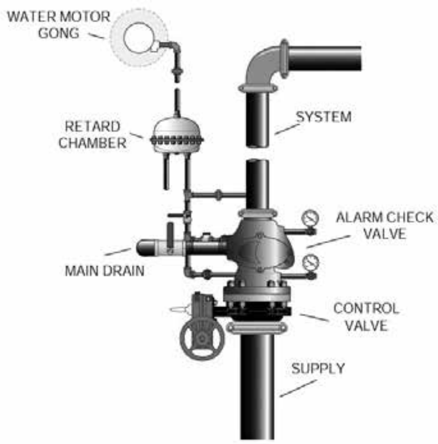


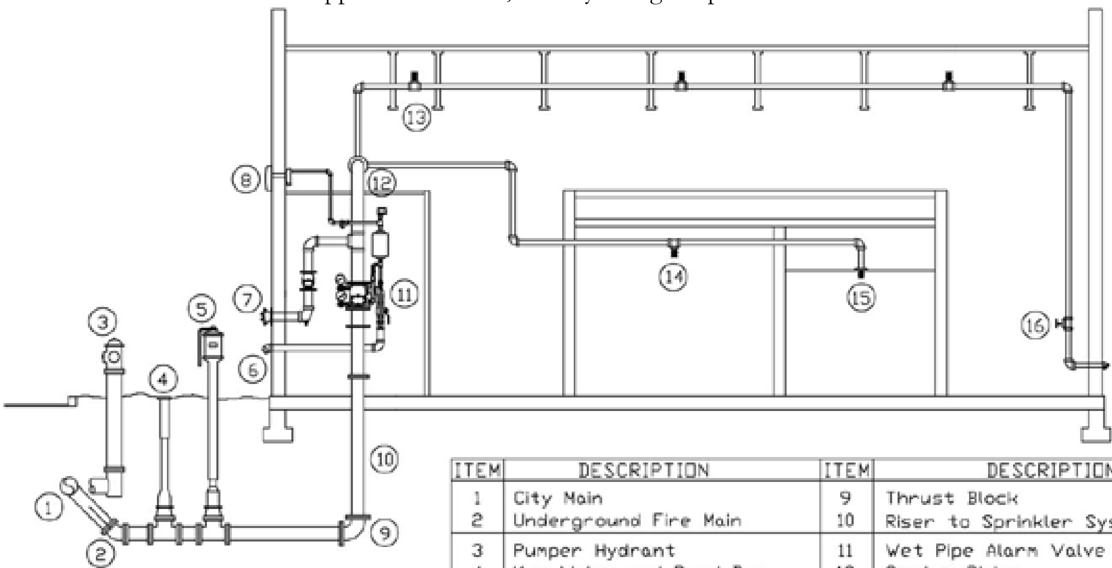
Figure 1-5 Typical Alarm Check Valve Riser
Source: Tyco Fire

Wet Pipe Systems

Wet pipe sprinkler systems are installed more often than all other types by a wide margin. The wet pipe system employs automatic (fusible link, glass bulb, or closed type) sprinklers attached to piping containing water under pressure at all times. When a fire occurs, individual sprinklers are actuated by the heat, and water flows immediately. The starting point for all wet-based sprinkler systems is the water source.

The wet pipe system is controlled by an alarm check valve (see Figure 1-5). When a sprinkler activates, the flow of water raises the alarm valve clapper from its seat, thereby lifting the pilot valve disc from the nozzle. This allows water to enter the alarm line. A water motor gong is actuated by the flow. An optional switch can be attached on the alarm line to provide an electric signal to an outdoor alarm bell or to the building's main fire alarm control panel.

The alarm valve is typically installed vertically in the main water supply to the wet pipe sprinkler system (see Figure 1-6). A variable-pressure water supply, which is the most common type of water supply encountered, requires the use of a retard chamber with the alarm valve to prevent false alarms. Where the water supply has constant pressure, the alarm valve is used without the retard chamber. In cases where a local alarm is adequate, water is admitted directly to a water motor-driven gong. If no water motor gong is required, a vane-type water flow indicator can be inserted in the supply pipe to indicate water flow electrically (see Figure 1-7).



ITEM	DESCRIPTION	ITEM	DESCRIPTION
1	City Main	9	Thrust Block
2	Underground Fire Main	10	Riser to Sprinkler System
3	Pumper Hydrant	11	Wet Pipe Alarm Valve
4	Key Valve and Road Box	12	System Piping
5	Post Indicator Valve	13	Upright Sprinkler
6	Main Alarm Valve Drain	14	Pendent Sprinkler
7	Fire Department Connection	15	Pendent Sprinkler on Drop Nipple
8	Water Motor Alarm	16	Inspector's Test

Figure 1-6 Wet Pipe Sprinkler System

Should a pressure surge occur, which will raise the clapper momentarily and lift the pilot valve disc from the nozzle, a small amount of water will pass into the retard chamber. If only a relatively small amount of water enters the retard chamber, the water will drain off through the retard chamber drain. However, should water escape through a sprinkler or from damaged piping, sustained water flow through the alarm valve will result. The clapper will move from its seat and lift the pilot valve disc, allowing a large volume of water to flow through the nozzle and into the retard chamber. The bleeding capacity through the retard chamber drain cannot keep up with the incoming volume. The retard chamber will fill, and water will flow through the alarm line to actuate the water motor gong and the optional alarm pressure switch, if used.

After a fire operation or test, the water in the alarm line will drain out through the retard chamber drain.

Figure 1-7 Vane-Type Water Flow Indicator

Dry Pipe Systems

Dry pipe systems are used in spaces in which the ambient temperature may be cold enough to freeze the water in a wet pipe system, rendering the system inoperable. This type of system is used most often in unheated buildings, in outside canopies attached to heated buildings (in which a wet pipe system would be provided), or in refrigerated coolers/freezers.

Water is not present in the piping until the system operates. The sprinkler piping is pressurized with air at a maintenance pressure that is relatively low compared to the water supply pressure. To prevent the higher water supply pressure from forcing water into the piping, the design of the dry pipe valve intentionally includes a larger valve clapper sectional area that is exposed to the maintenance air pressure rather than the water pressure. Operation of dry pipe equipment occurs when the fire's temperature fuses a sprinkler, allowing sprinkler piping air pressure to escape. This destroys the pressure differential that normally keeps the dry valve closed and allows water to flow into the sprinkler piping. The air pressure required to keep the clapper in a closed position varies directly with the water supply pressure.

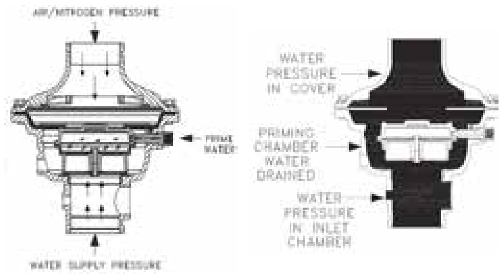


Figure 1-8 Dry Pipe Valve
(left) Air pressure keeps clapper closed; (right) Venting of air allows clapper to open and water to flow

Typically, the dry valve is installed in a heated area or in an insulated, heated valve enclosure protected against any occurrence of freezing temperatures. When one or more of the automatic sprinklers is exposed to sufficient heat, it opens, allowing the maintenance air to vent from that sprinkler. As the air pressure in the piping drops, the pressure differential across the dry pipe valve changes, allowing water to enter the piping system (see Figures 1-8 and 1-9). Water flow from sprinklers needed to control the fire is delayed until the air is vented from those sprinklers. For this reason, dry pipe systems are usually not as effective as wet pipe systems in fire control during the initial stages of a fire. To compensate for the time delay, hydraulic area requirements for dry sprinkler systems are typically greater than those for a traditional wet system.

A hydraulically operated fire alarm is standard; however, many installations also have an electric fire alarm gong that sounds when water flow into the sprinkler piping system actuates the alarm switch. This electric switch can also be used to signal the building's main fire alarm control panel.

Large dry pipe systems are typically installed with an accelerator, a device that accelerates dry valve operation. The accelerator is actuated by a drop in piping pressure. It then functions by applying remaining pressure from the sprinkler piping to the intermediate chamber of the dry valve. Added to the water pressure below the clapper, this quickly eliminates the differential to open the clapper. Exhausters are also available to assist in the quick discharge of air prior to operation.

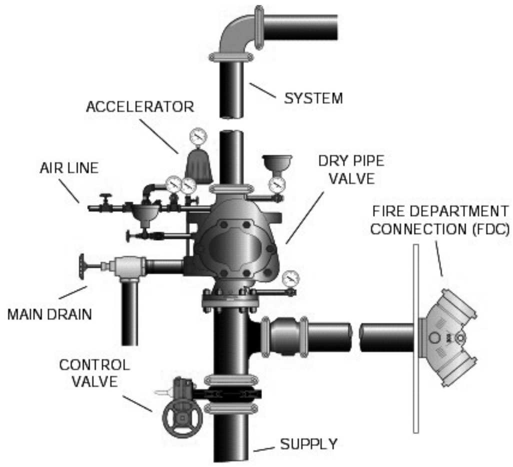


Figure 1-9 Dry Pipe Valve Riser
Source: Tyco Fire

The time of water flow in dry pipe systems is based on system volume, generally not more than 750 gallons for any one dry pipe valve. This volume can be exceeded if water is delivered in 60 seconds or less. (Refer to NFPA 13 for system size and volume limitations.)

Under normal conditions, the dry pipe sprinkler system has sealed automatic sprinklers retaining air pressure in the sprinkler piping. Only after a sprinkler seal fuses and opens to release the air (under pressure) in the sprinkler piping does the dry valve clapper open, and water from the water supply main then flows through it into the sprinkler piping. The dry valve has two functions:

- To keep the clapper closed and withhold water from the sprinkler piping until fire fuses a sprinkler seal
- To trigger a fire alarm when the clapper opens

When set, the rubber-faced dry valve clapper rests with the rubber facing in contact with two concentric seat rings. The annular chamber, or intermediate chamber, is connected to the alarm devices such as the water motor gong and alarm switch. The clapper area against which the water exerts its force is the diameter of the inner seat ring. The clapper area against which the compressed air exerts its force is the diameter of the outer seat ring, which is considerably larger than the inner diameter. This difference in area enables the lesser air pressure (over a greater area) above the clapper to overcome the clapper. Priming water is added to some dry valves to provide a positive system through the intermediate chamber and its alarm outlets.

Electric Air Compressor

For dry pipe systems, the piping's water capacity must be calculated to determine its air capacity, which is used in the selection of the air compressor.

NFPA standards require air compressors to be capable of restoring normal air pressure in a system within 30 minutes. FM Global standards require compressors to be capable of restoring normal air pressure plus 25 percent pressure within 30 minutes.

To calculate a system's capacity in gallons, determine the total pipe footage for each size pipe, and then multiply by the corresponding factor from Table 1-1. When the total capacity in gallons has been determined, multiply by 0.012 to obtain the free air delivery in cubic feet per minute (cfm).

Where one air compressor supplies more than one dry pipe system, the largest-capacity system shall determine the compressor size.

Table 1-1 Capacity and Weight of Water-Filled Pipe

Pipe Size, in.	Schedule 40		Schedule 10	
	Capacity, gal/ft	Weight, lb/ft	Capacity, gal/ft	Weight, lb/ft
1	0.045	2.05	0.049	1.81
1¼	0.078	2.93	0.085	2.52
1½	0.106	3.61	0.115	3.04
2	0.174	5.13	0.190	4.22
2½	0.248	7.89	0.283	5.89
3	0.383	10.82	0.433	7.94
3½	0.513	13.48	0.576	9.78
4	0.660	16.40	0.740	11.78
5	1.040	23.47	1.144	17.30
6	1.501	31.69	1.649	23.03
8	2.660	47.70	2.776	40.08

Accelerator

An accelerator is an accessory device used on large dry pipe systems to hasten dry valve operation. NFPA 13 requires each standard dry valve controlling a system with a capacity of more than 500 gallons to be provided with an accelerator, with the following exception: the 60-second limit does not apply to dry systems with a capacity of 750 gallons or less when equipped with a quick-opening device. An alternate to installing an accelerator is to add another riser and dry valve, although economics may prohibit this.

In a fire condition, the accelerator redirects air pressure from the system piping into the intermediate chamber of the dry pipe valve. This air pressure assists the water pressure differential and opens the dry pipe valve more quickly.

Water Delivery

NFPA 13 requires dry sprinkler systems to deliver water in a prescribed time frame for different hazard applications. For example, a dry system used in a residential application is required to deliver water to the most remote sprinkler initially opened in 15 seconds. This requirement was established to address the time interval between operation of the sprinklers and the heat release and growth of the fire.

Dry Sprinkler System Piping

Dry pipe systems are susceptible to corrosion, which must be taken into consideration when choosing the piping material. Galvanized steel tends to pit when filled with moist air, which can cause leaks. To prevent this, the oxygen in the compressed air system can be replaced with nitrogen.

Refer to NFPA 13 for piping material requirements for dry pipe systems.

Preaction Systems

Preaction sprinkler systems are specialized for use in locations where accidental activation is undesired, such as in museums, data centers, and electrical rooms. A preaction system is installed to eliminate the operational delay of a conventional dry pipe system and the danger of water discharge resulting from accidental damage to automatic sprinklers or piping. In a preaction system, the water supply (deluge) valve is actuated independently of the opening of the sprinklers (i.e., the valve is opened by the operation of an automatic fire detection system and not by the fusing of sprinklers).

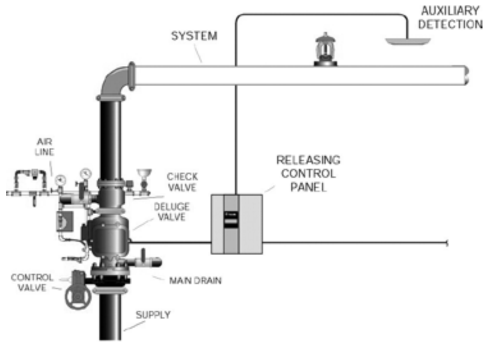


Figure 1-10 Preaction Valve Riser
Source: Tyco Fire

Preaction systems are hybrids of wet, dry, and deluge systems, depending on the exact system goal. The three subtypes of preaction systems are single interlock, double interlock, and non-interlock. The operation of single interlock systems is similar to dry systems, except that these systems require a preceding and supervised event (typically the activation of a heat or smoke detector) to take place prior to the preaction valve (a mechanically latched valve) opening and introducing water into the system's piping. Once the fire is detected by the fire alarm system, the system is essentially converted from a dry system into a wet system. If an automatic sprinkler operated prior to the fire being detected by the fire alarm system, water would be allowed into the piping and discharge through the sprinkler.

Non-interlock systems, much like the single interlock, admit water into sprinkler piping upon operation of either detection devices or automatic sprinklers.

The double interlock system is similar to a deluge system, except that automatic sprinklers are used. These systems require both a preceding and supervised event (typically the activation of a heat or smoke detector) and automatic sprinkler activation to take place prior to water being introduced into the system's piping.

Preaction valves (see Figure 1-10) are typically located near the hazard they serve and are provided with an addressable control panel. Preaction systems operate faster and result in less fire and water damage compared to conventional dry pipe systems. They are limited to 1,000 sprinklers.

Deluge Systems

The purpose of a deluge system is to deliver sprinkler water coverage to the entire area of a fire in the least amount of time possible. It accomplishes this by admitting water to sprinklers or spray nozzles that are open at all times. By using automatic fire detection devices of the type used in preaction systems or controls designed for individual hazards, a deluge system can apply water to a fire more quickly than a system whose operation depends on the opening of sprinklers as the fire spreads. Deluge systems are suitable for extra-hazard occupancies in which flammable liquids are handled or stored and where a fire may flash ahead of the operation of ordinary automatic sprinklers.

Water is not present in the piping until the system operates. Because the sprinkler orifices are open, the piping is at ambient air pressure. To prevent the water supply pressure from forcing water into the piping, a deluge valve, which is a mechanically latched valve, is used in the water supply connection. It is a non-resetting valve and stays open once tripped.

Because the sprinklers are of the open type, the deluge valve must be opened as signaled by a specialized fire alarm system. The type of fire alarm-initiating device (e.g., smoke detector, heat detector, or optical flame detection) is selected mainly based on the hazard. The initiation device signals the fire alarm panel, which in turn signals the deluge valve to open. Activation can also be manual, depending on the system goals. Manual activation is usually via an electric or pneumatic fire alarm pull station.

Activation of a fire alarm-initiating device or a manual pull station signals the fire alarm panel, which in turn signals the deluge valve to open, allowing water to enter the piping system. Water flows from all sprinklers simultaneously. Where large amounts of discharge are involved or where spray nozzles, foam water sprinklers, or other foam applicators are used, the system should be supervised.

Deluge systems are used for fast, total application of water in extra-hazardous areas and in water-spray systems. Deluge valves are essentially check valves with a clapper latched in the closed position (see Figure 1-11). The actuating system unlatches the valve, allowing water to enter the

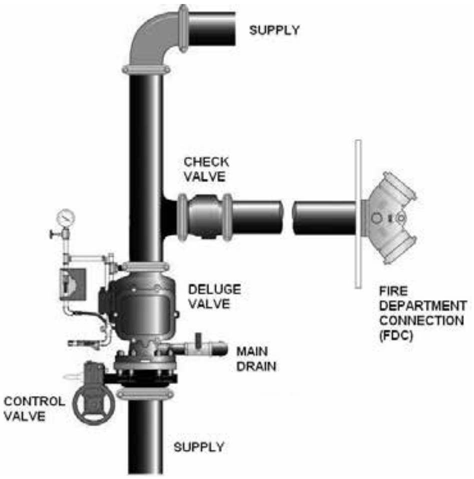


Figure 1-11 Deluge Valve Riser
Source: Tyco Fire

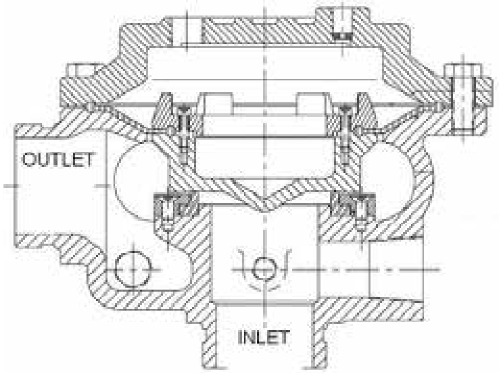


Figure 1-12 Deluge Valve with a Single Differential Diaphragm
Source: Reliable Sprinkler

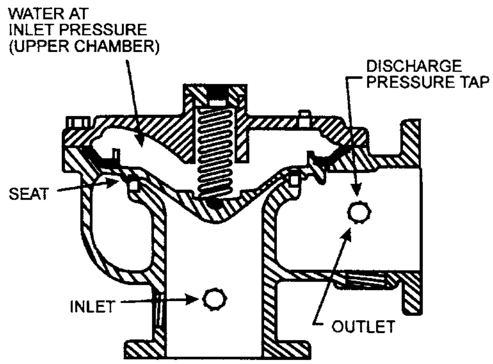


Figure 1-13 Deluge Valve with Outlet Pressure Regulator

piping system and flow out the heads. The more common design of the deluge valve employs a single differential diaphragm in which the water pressure bears on both sides, while the top side adjoins a closed chamber (see Figure 1-12). The actuating system opens the closed chamber, allowing the water to push the diaphragm up and off the water seat, releasing water to the system. A modification of the valve uses a pressure regulator that maintains (on the outlet side) any predetermined pressure less than the available system pressure (see Figure 1-13). This allows the system to discharge at a constant rate.

Combined Dry Pipe and Preaction Systems

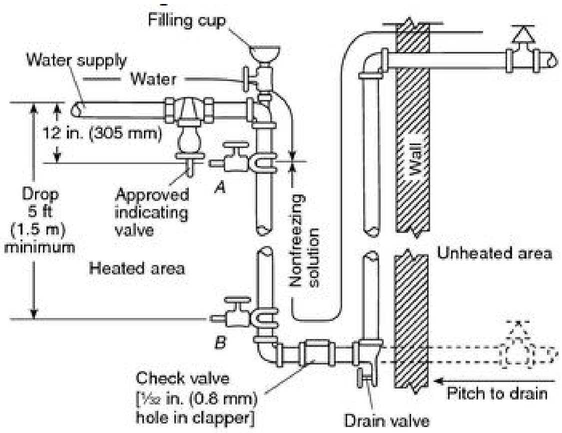
A combined dry pipe and preaction sprinkler system is one that employs automatic sprinklers attached to a piping system containing air under pressure, with a supplemental fire detection system installed in the same areas as the sprinklers. Operation of the fire detection system, as by a fire, actuates tripping devices that open dry pipe valves simultaneously and without loss of air pressure in the system. Operation of the fire detection system also opens approved air-exhaust valves at the end of the feed main, which facilitates water filling the system, usually preceding the opening of sprinklers. The fire detection system also serves as an automatic early-warning fire alarm system. These systems are intended to be applied to unusual structures, such as piers or wharves, that require unusually long runs of pipe.

Antifreeze Systems

Antifreeze systems are typically used as subsystems to wet-based sprinkler systems. These systems are intended to protect small areas that could be exposed to freezing temperatures. Typically, antifreeze systems are used for rooftop cooling tower equipment or, most commonly, residential construction.

The sprinkler distribution piping in an antifreeze system (see Figure 1-14) is filled with a mixed antifreeze solution prepared with a freezing point below the expected minimum temperature for the location. A drain/test connection must be provided at the most remote portion of the antifreeze system.

Confer with the local AHJ and insurer to ensure that they allow the use of antifreeze systems.



Notes:

1. Check valve shall be permitted to be omitted where sprinklers are below the level of valve *A*.
2. The 1/32 in. (0.8 mm) hole in the check valve clapper is needed to allow for expansion of the solution during a temperature rise, thus preventing damage to sprinklers.

Figure 1-14 Antifreeze System Piping Arrangement
Source: NFPA 13

Sprinkler System Hydraulics

Most sprinkler systems installed today are designed using an area and density approach. As described earlier, first the building use and building contents must be analyzed to determine the level of fire hazard. After determining the hazard classification, a design area and density can be found by referencing tables in NFPA 13 (see Figure 1-15). The design area is a theoretical area of the building representing the worst-case area where a fire could burn. The design density is a measurement of how much water in gpm per square foot of floor area should be applied to the design area. Through tests and studies, NFPA, FM Global, Industrial Risk Insurers, and other organizations have established design densities that are appropriate for a wide range of occupancy classifications.

After the design area and density have been determined, fabrication drawings can be developed along with supporting hydraulic calculations, which are generated to prove that the designed pipe system can deliver the required amount of water to the required design area. These calculations account for all of the pressure that is lost or gained between the water supply source and the sprinklers that would operate in the design area. This includes pressure that is lost due to friction inside the piping and pressure that is lost or gained due to elevation differences between the source and the discharging sprinklers.

Another critical concept that must be understood in hydraulic calculations is that all of the sprinklers in the sprinkler system being designed are not expected to discharge simultaneously. Each selected remote area has a calculated number of sprinklers to be included in the hydraulic calculations. The number of sprinklers can be calculated by the following equation:

Equation 1-3

$$\text{Calculated sprinklers} = \frac{\text{Remote area}}{\text{Sprinkler coverage area}}$$

Example 1-1

If the remote area in an ordinary group 1 hazard application is 1,500 square feet, how many sprinklers should be calculated?

Calculated sprinklers = 1,500 ft^2/130 ft^2 = 11.5 sprinklers (12 sprinklers)

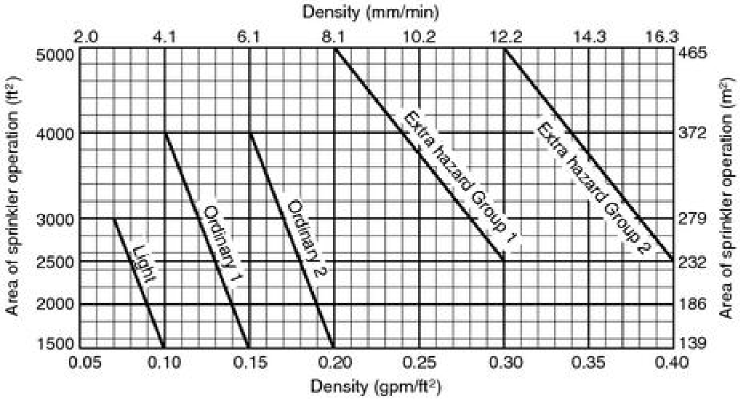


Figure 1-15 Density/Area Curve Example
Source: NFPA 13

The required size of the remote area varies among occupancy classifications. NFPA 13 allows some flexibility in the sizing of the design area, usually allowing an area between 1,500 and 5,000 square feet. Other authorities have different ranges. In many cases, the insurance industry and government authorities require a specific design area based on a specific hazard classification. Otherwise, any area within the acceptable range can be chosen. It must be noted that the required minimum design density will vary with the hazard classification and the size of the design area.

The design area shall be located in the most hydraulically remote part of the fire area. In essence, the design area must be composed of the most demanding portion of the sprinkler system. If the calculations prove that the water supply available is adequate for the most demanding part of the system, then it logically follows that the water supply will be adequate for any part of the system. The most hydraulically remote area is not always easy to identify. In a non-loop and non-grid system (i.e., a conventional tree system), the hydraulically most remote area is usually the area most physically remote from the water supply source. However, it is important to understand that physical remoteness is not a fail-safe criterion for hydraulic remoteness, particularly when dealing with looped or gridded piping systems.

The essential difference between a hydraulically calculated sprinkler system and a pipe schedule sprinkler system lies in the regulation of pipe sizing. For a pipe schedule sprinkler system designed in accordance with NFPA 13, only a limited number of sprinklers may be supplied by a given pipe size. The pipes can become oversized based on the available water supply and pressure, which make the system more costly than necessary. A hydraulically calculated system has no limit to the number of sprinklers that can be supplied by any size pipe; the size is dictated by the rate of flow and pressure loss.

The pipe schedule design method is limited to additions or modifications to existing pipe schedule systems, to new installations of 5,000 square feet or less, or to new installations exceeding 5,000 square feet where the required flows are available with a minimum residual pressure of 50 psi at the highest sprinkler elevation.

System Size

The total square footage covered by a single fire zone is restricted, typically to 52,000 square feet for light and ordinary hazard occupancies and 40,000 square feet for extra hazard and storage occupancies.

Information Required for Hydraulic Calculations

The following information must be obtained before performing hydraulic calculations:

- Water supply information: Static pressure (psi), residual pressure (psi), flow rate (gpm), location and elevation of the flow test, total supply available, date the hydrant flow test was taken (for the AHJ)
- Hazard classification (occupancy): Classification by the insurance company or NFPA standards, density and area requirements, duration of flow requirements, hose stream allowance, pressure allowance
- Piping material: Friction loss for the selected piping type
- Sprinkler heads: Sprinkler head K factor, temperature rating, special coating requirements

Use of Sprinklers

Automatic fire sprinklers operate at a predetermined temperature. These sprinklers utilize a fusible link, a portion of which melts, or a frangible glass bulb containing liquid that breaks, allowing the plug in the sprinkler orifice to be pushed out by the water pressure in the fire sprinkler piping, resulting in water flow. The water stream impacts a deflector, which produces a specific spray pattern designed in support of the goals of the sprinkler type. Most of today's sprinkler heads are designed to direct a spray downward (see Figure 1-16).

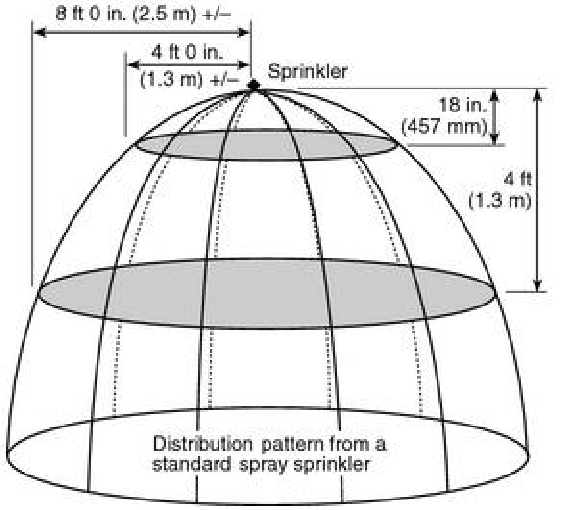


Figure 1-16 Example Sprinkler Flow Pattern
Source: NFPA 13

Many automatic fire sprinklers utilizing glass bulbs follow a standardized color-coding convention indicating their operating temperature as shown in Table 1-2. Activation temperatures correspond to the type of hazard against which the sprinkler system protects. For example, residential occupancies are provided with a special type of fast-response sprinkler with the unique goal of life safety.

The selection of sprinklers will vary by occupancy. The types of sprinklers that may be used are standard spray upright and pendent, sidewall spray, concealed, extended coverage, open, residential, early suppression fast-response, large drop, quick response, and special application sprinklers. Sprinkler spacing is based on the rating and listing of the sprinkler in addition to the requirements set forth in NFPA 13.

Table 1-2 Maximum Sprinkler Temperature Ratings and Temperature Classification Color Code

Maximum Ceiling Temperature	Temperature Rating	Temperature Classification	Color Code (with Fusible Link)	Glass Bulb Color
100°F	135–170°F	Ordinary	Uncolored or Black	Orange (135°) or Red (155°)
150°F	175–225°F	Intermediate	White	Yellow (175°) or Green (200°)
225°F	250–300°F	High	Blue	Blue
300°F	325–375°F	Extra High	Red	Purple
375°F	400–475°F	Very Extra High	Green	Black
475°F	500–575°F	Ultra High	Orange	Black
625°F	650°F	Ultra High	Orange	Black

Source: NFPA 13

Residential Sprinklers

Residential sprinklers, listed by UL, are designed to respond to a fire much faster than currently available standard commercial and industrial sprinklers. Typical residential sprinkler systems are installed in accordance with NFPA 13D: *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes* and NFPA 13R: *Standard for the Installation of Sprinkler Systems in Residential Occupancies Up to and Including Four Stories in Height.* Residential fire sprinkler systems provide coverage throughout the entire house, excluding small bathrooms (less than 55 square feet), small closets (less than 24 square feet), attics, and garages.

Piping System

Sprinkler systems can be made up of many different types of piping. NFPA 13 requires pipe used in sprinkler systems to have chemical properties, physical properties, and dimensions of material at least equivalent to the standards shown in Table 1-3. The pressure limitations of these piping systems and their components must be understood when specifying pipe materials.

Each sprinkler system shall be supported and installed in accordance with the requirements of NFPA 13. Pipe hangers shall be UL listed. Hangers shall be arranged to maintain the required pitch for free expansion and contraction. Sprinkler piping or hangers shall not be used to support non-system components. Each vertical line shall be supported at its base using a hanger placed in the horizontal line near the riser. Hangers shall meet seismic requirements in areas prone to seismic movement.

Table 1-3 Approved Pipe Materials for Sprinkler Systems

Material	Standard
Ferrous piping (welded and seamless), black and hot-dipped zinc-coated (galvanized), welded, and seamless steel pipe for fire protection use	ASTM A795
Welded and seamless steel pipe	ASTM A53
Wrought steel pipe	ASME B36.10M
Electric-resistance-welded steel pipe	ASTM A135
Seamless copper tube	ASTM B75
Seamless copper water tube	ASTM B88
Wrought seamless copper and copper alloy tube	ASTM B251
Fluxes for soldering applications of copper and copper alloy tube	ASTM B813
Brazing filler metal (classification BCuP-3 or BCuP-4)	AWS A5.8
Solder alloys containing less than 0.2% lead and having solidus temperatures greater than 400°F	ASTM B32
Alloy materials	ASTM B446
Special listed chlorinated polyvinyl chloride (CPVC) pipe	ASTM F442

Source: NFPA 13

STANDPIPE SYSTEMS

The purpose of installing a standpipe system is to provide a readily accessible water supply for use by fire department personnel and/or trained occupants during fire situations. A standpipe is a type of rigid water pipe to which firehoses can be connected that is built into multistory buildings in a vertical position. Standpipe systems can be classified into the following system types as defined by NFPA 14: *Standard for the Installation of Standpipe and Hose Systems*:

- Class I: A system that provides 2½-inch hose connections to supply water for use by fire departments and those trained in handling heavy fire streams
- Class II: A system that provides 1½-inch hose connections to supply water for use by trained building personnel or fire departments during initial response
- Class III: A system that provides 1½-inch hose connections to supply water for use by trained personnel and 2½-inch hose connections to supply a larger volume of water for use by fire departments and those trained in handling heavy fire streams

Standpipes may be either wet or dry type, depending on the application. The subtypes of each are as follows:

- Automatic wet standpipe: Contains water at all times, is attached to a water supply capable of providing the system demand (flow and pressure), and requires no action other than opening a hose valve to provide water at hose connections.
- Manual wet standpipe: Contains water at all times but relies exclusively on the fire department connection to supply the system demand.
- Automatic dry standpipe: Contains air or nitrogen at pressure but is attached to a water supply capable of providing the system demand. The water supply is held at a dry pipe valve until a hose valve is opened, releasing the air or nitrogen and allowing water to flow into the standpipe system.

- Semiautomatic dry standpipe: An empty, non-pressurized system attached to a water supply capable of providing the system demand. The water supply is held at a deluge valve and requires the activation of a remote control device to provide water flow into the standpipe system.
- Manual dry standpipe: Has no attached water supply and relies exclusively on the fire department connection to supply the system demand.

Locating and Determining the Number of Standpipe Risers

The model building codes establish whether or not a building is required to be provided with a standpipe system. Typically, standpipes are required in a building where the floor level of the highest story is located more than 30 feet above the lowest level of fire department vehicle access or where the floor level of the lowest story is located more than 30 feet below the highest level of fire department vehicle access. Separate standpipes shall be provided in each required exit stairway where required by code. Additional hose connections may be required where travel distances exceed the code-mandated limits or where identified by the local fire department or authority having jurisdiction.

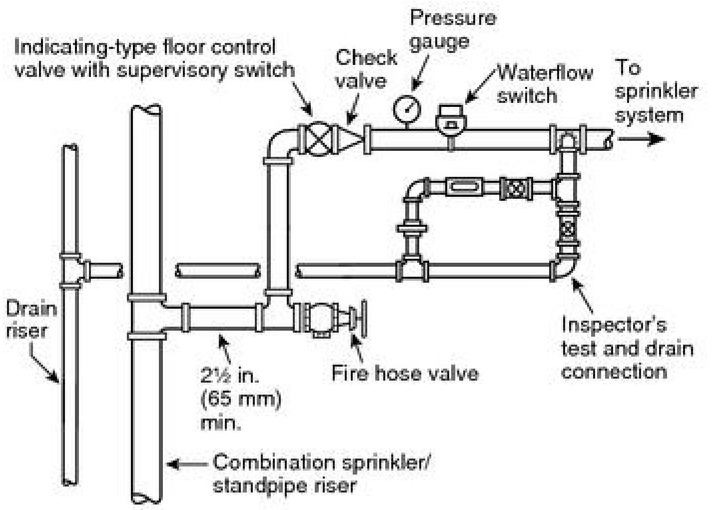


Figure 1-17 Acceptable Piping Arrangement for Combined Sprinkler/ Standpipe Systems
Source: NFPA 14

Most building codes and NFPA require the risers and 2½-inch hose valves for Class I and III standpipe systems to be located inside fire-rated stairs or smoke-proof towers to allow the fire department the opportunity to make its connection to the riser inside a protected area prior to entering the floor under the fire condition.

Standpipe System Design

The design of standpipe risers and branch mains varies according to the system configuration, local and state building code requirements, the building hazard, and the size of the building. Typically, Class I and Class III standpipes shall be at least 4 inches. Standpipes that are part of a combined system (a system that supplies water to both fire department personnel and the building sprinkler system) shall be at least 6 inches (see Figure 1-17). (Exception: Where the building is protected throughout by an approved automatic sprinkler system, the minimum standpipe size may be 4 inches for hydraulically calculated systems.) Since several factors are involved in the standpipe system, it is recommended to check with the local and state codes as well as NFPA standards to ensure that the system will meet local requirements.

Standpipe design flow and pressure requirements from NFPA 14 are as follows:

- For Class I and Class III systems, the minimum flow rate for the hydraulically most remote standpipe shall be 500 gpm.
- Where a horizontal standpipe on a Class I or Class III system supplies three or more hose connections on any floor, the minimum flow rate shall be 750 gpm.
- The minimum flow rate for additional standpipes shall be 250 gpm per standpipe, with the total not to exceed 1,250 gpm or 1,000 gpm for buildings sprinklered throughout.

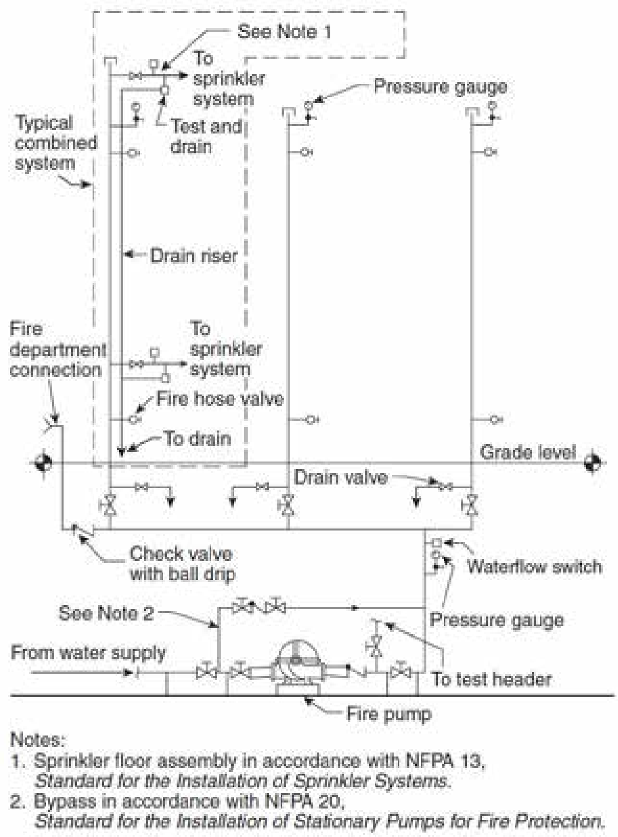


Figure 1-18 Schematic Diagram of Fire Pump with Bypass
Source: NFPA 20

Hydraulically designed standpipe systems shall be designed to provide the water flow rate (see above) at a minimum residual pressure of 100 psi at the outlet of the hydraulically most remote 2½-inch hose connection and 65 psi at the outlet of the hydraulically most remote 1½-inch hose station.

If the water supply to the standpipes cannot provide the required volume and pressure, the system must be upgraded to ensure an adequate supply, or a fire pump must be added to the system (see Figure 1-18).

FIRE PUMP SYSTEMS

A fire pump usually is connected to the municipal or fire protection water supply at the intake and to the building's sprinkler system risers at the discharge (see Figure 1-19). Fire pumps are listed specifically for fire service by a listing agency such as UL and FM Global. The main standard that governs fire pump installations is NFPA 20: *Standard for the Installation of Stationary Fire Pumps for Fire Protection.*

The fire pump becomes active when the pressure in the fire sprinkler system drops below a set threshold. This threshold is typically the performance value of the jockey pump. Once operating, the fire pump provides additional water pressure to the sprinkler system.

The types of pumps used for fire service include horizontal split case, vertical split case, vertical inline, vertical turbine, and end suction. Labeled fire pumps are made in specific sizes ranging from 25 gpm to 5,000 gpm. Pressure selections may range from 40 to 475 psi for fire pumps.

Per NFPA 20, the fire pump must meet the following requirements:

- The net pump shutoff (churn) plus the maximum static suction pressure shall not exceed the pressure for which the system components are rated.
- At 150 percent of the rated capacity, it shall develop at least 65 percent of its rated head and shall not exceed 140 percent of the rated head at zero capacity.
- Components shall be sized per Table 1-4.
- The maximum pump brake horsepower must not exceed the rating of the particular driver.
- Each fire pump must have listed pressure gauges and be fitted with a suitable air relief valve. With certain exceptions, a ¾-inch casing relief valve is required to prevent overheating of the pump when it operates against a closed valve. Where the pump pressure might exceed the safe working pressure of the system, and always when a diesel driver or variable-speed drive is used, a listed main relief valve must be furnished.

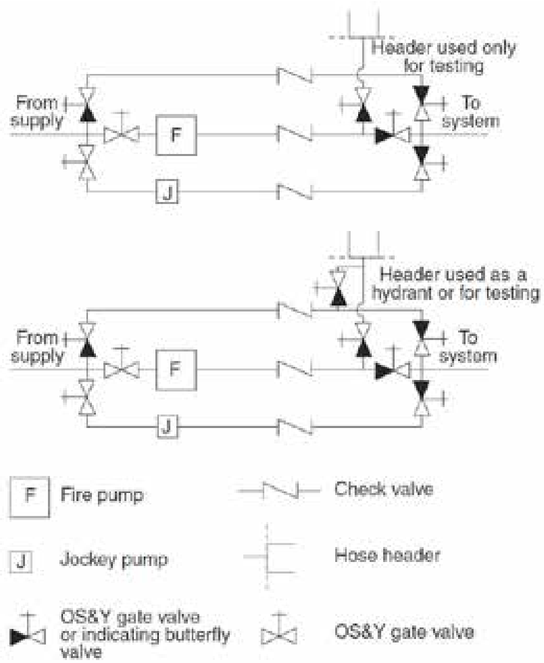


Figure 1-19 Fire Pump System

Table 1-4 Centrifugal Fire Pump Component Sizing Data

Pump Rating, gpm	Suction, in.	Discharge, in.	Relief Valve, in.	Relief Valve Discharge, in.	Meter Device, in.	Number of Hose Valves	Size of Hose Valve, in.	Hose Header Supply, in.
250	3½	3	2	2½	3½	1	2½	3
300	4	4	2½	3½	3½	1	2½	3
400	4	4	3	5	4	2	2½	4
450	5	5	3	5	4	2	2½	4
500	5	5	3	5	5	2	2½	4
750	6	6	4	6	5	3	2½	6
1,000	8	6	4	8	6	4	2½	6
1,250	8	8	6	8	6	6	2½	8
1,500	8	8	6	8	8	6	2½	8
2,000	10	10	6	10	8	6	2½	8

Source: NFPA 20

Fire Pump Drivers

Fire pumps are driven by either electric motors or diesel engines. If the fire pump is electric, power must be uninterruptible with properly protected power cabling and emergency power. Alarms should sound if normal power is interrupted (i.e., loss of phase or phase reversal). All fire pump motor drivers are required to be rated for continuous duty and must not be used at voltages in excess of 110 percent of the rated voltage. At rated voltage and frequency, the full load ampere rating must not be exceeded under any pumping conditions.

If the fire pump is diesel, provisions must be made for a day tank for fuel storage, engine cooling, exhaust pipe discharge location, and sufficient airflow for cooling, combustion, and ventilation.

The performance requirements and accessories for pumps, whether motor or engine driven, are basically the same. The related components of the specific drivers, however, vary in installation, operation, and maintenance.

The motor-control equipment must be factory assembled, wired, and tested, as well as specifically approved for fire service.

Jockey Pump

A jockey pump is typically required in all pressurized systems. This automatic electric pump has a capacity of 5 to 10 gpm or less. The intent is to maintain pressure when it is lost due to minor leaks, not to keep up with sprinkler discharge. Its controller is set to start at about 5 psi above the start signal for the fire pump and to stop at full pressure.

Sizing

Fire pump size can be estimated using the following equations:

Equation 1-4a

$$\text{Brake horsepower (BHP)} = \frac{\text{Head} \times \text{gpm} \times \text{Specific gravity}}{3{,}960 \times \text{Efficiency}}$$

Equation 1-4b

$$\text{BHP} = \frac{(\text{psi} \times 2.13) \times \text{Specific gravity}}{3{,}960 \times \text{Efficiency}}$$

SPECIAL EXTINGUISHING SYSTEMS

Special extinguishing systems focus on the specific elements of a fire: oxygen, heat, and fuel. All three elements must be present at the same time for fire to occur. Oxygen, heat, and fuel are frequently referred to as the fire triangle (see Figure 1-20). Take any of these three things away, and fire will not occur or will be extinguished. Fire suppression systems put out fires by taking away one or more elements of the fire triangle.

Without sufficient heat, a fire cannot begin, and it cannot continue. Heat can be removed by the application of a substance that reduces the amount of heat available to the fire reaction. This is often water. Introducing sufficient quantities and types of powder or gas in the flame reduces the amount of heat available for the fire reaction in the same manner.

Without fuel, a fire will stop. Fuel can be removed naturally, as when the fire has consumed all of the burnable fuel, or manually by mechanically or chemically removing the fuel from the fire.

Without sufficient oxygen, a fire cannot begin, and it cannot continue. With a decreased oxygen concentration, the combustion process slows.

Note: The fire tetrahedron adds another requirement: the presence of a chemical reaction. If the chemical reaction is inhibited, the fire will extinguish.

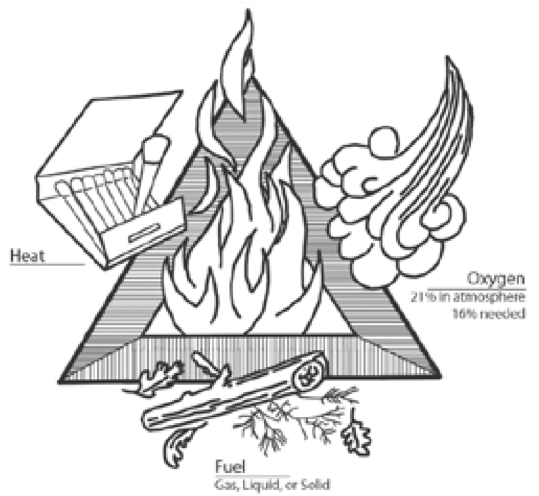


Figure 1-20 The Fire Triangle

Dry Chemical Extinguishing Systems

Dry chemical systems utilize dry powder mixtures as the fire extinguishing agent. They are intended for application by means of portable extinguishers, hand hose-line systems, or fixed systems. The five basic varieties of dry chemical extinguishing agents are borax and sodium bicarbonate, sodium bicarbonate, urea potassium bicarbonate, monoammonium phosphate base, and potassium bicarbonate. When introduced directly into the fire area, dry chemicals cause almost immediate extinguishment. The major effect of dry chemicals is that they break the chain reaction of combustion. The minimum requirements for the design, installation, maintenance, and testing of dry chemical extinguishing systems can be found in NFPA 17: *Standard for Dry Chemical Extinguishing Systems.*

Dry chemical extinguishing systems originally were used to extinguish Class B fires. They consisted of a sodium bicarbonate base with additives to prevent caking and to improve the fluid flow characteristics. Later, multipurpose dry chemicals, effective on Class A, B, and C fires, were developed. When dry chemical systems are specified for use in a Class A fire area, they may not produce a lasting effect on the fire area. Twin-agent units using dry chemicals for early flame knockdown, followed by a foam application to prevent re-flash, are becoming a more common means of fire suppression.

Dry chemicals are most effective and most often used on surface fires, especially on flammable liquids. They can be discharged by handheld extinguishers, wheeled portable equipment, nozzles on fixed piping, or hose lines in local applications where the hazard is not enclosed or where the enclosure does not form an effective fire boundary. Chemical application may be tank side, overhead, or a combination of both.

Dry chemical systems also may be total flooding. The total flooding system consists of a predetermined supply of dry chemical permanently connected to a fixed discharge piping system, with fixed nozzles discharging into an enclosed space or an enclosure around a hazard. Upon actuation of the system by a heat detector, nitrogen is discharged into the storage container, and dry chemical is expelled through the system nozzles. The system may be either of the following:

- Engineered: These systems are based on known factors of chemical flow, pressure, friction losses, and pressure drops. Detection and activation are by automatic operation using electric, electronic, or mechanical detection and discharge. Many authorities require a full discharge test after installation for verification of the effectiveness of such a system or require a room air pressure test.
- Pre-engineered: These systems have been fire tested for a listing with a recognized laboratory. The manufacturer's instructions are specific regarding installation, pipe size, nozzle pressures, and types and quantities of chemicals to be used. Most pre-engineered systems are designed for automatic operation, using electric, electronic, or mechanical detection and discharge. A manual pull station is required to be installed at an exit.

Hand hose-line systems consist of a hose and nozzle connected to a dry chemical supply by direct connection to the storage container or by fixed piping. One or more hose reels can be supplied by the same chemical supply.

Dry Powder Extinguishing Systems

Dry powder extinguishing agents are different from dry chemical extinguishing agents and are effectively used to put out Class D fires, which are metal fires. Certain metals, such as sodium, titanium, magnesium, potassium, uranium, lithium, plutonium, and calcium, are flammable. Magnesium and titanium fires are common. When one of these combustible metals ignites, it can easily and rapidly spread to surrounding Class A materials.

To be effective on any type of Class D fire, the extinguishing agent must suppress the fire without reacting physically or chemically with the combustible materials. Water and other common firefighting materials can excite metal fires and make them worse. Thus, NFPA 484: *Standard for Combustible Metals* recommends that Class D fires be fought with dry powder extinguishing agents, which work by smothering and heat absorption. The two familiar dry powder extinguishing agents for controlling combustible metal fires are graphite and sodium chloride (salt).

Dry powder systems should not be confused with dry chemical systems, which typically are associated with extinguishing agents suitable for use on flammable liquid fires. Some dry chemical agents may create an explosive reaction when applied to combustible metal fires.

Several proprietary dry powders are currently available; however, none should be used without first consulting the manufacturer.

Wet Chemical Extinguishing Systems

Wet chemical extinguishing agents consist of organic or inorganic salts mixed with water to form an alkaline solution that is typically discharged though a piping and nozzle system when activated. The minimum requirements for the design, installation, maintenance, and testing of wet chemical extinguishing systems can be found in NFPA 17A: *Standard for Wet Chemical Extinguishing Systems.*

Wet chemical agents are listed for the suppression of fires in commercial cooking equipment (Class K), such as deep-fat fryers, griddles, range tops, and broilers. These agents are considered to be nontoxic and noncarcinogenic. When wet chemical extinguishing agents are sprayed on a grease fire, they interact immediately with the grease, forming a blanket of foam over the surface on which they are sprayed. This creates a smothering and cooling effect on the fire.

Wet chemical systems typically are pre-engineered systems, defined by predetermined flow rates, nozzle pressures, and quantities of agent required. Wet chemicals are usually stored in cylinders adjacent to the hazard and are activated by either manual or automatic means. Automatic actuation is provided by either a fusible link or heat detector operation. Manual actuation occurs by the use of a pull station. Actuation of the system opens the seal on the gas cylinder, and the gas flows to the agent cylinder and expels the liquid through the distribution piping and nozzles. Once the system is actuated, all sources of fuel and power to the equipment that produce heat are required to be shut down.

Water Spray Fixed Systems

Water spray systems are operationally identical to a deluge system, but the piping and discharge nozzle spray patterns are designed to protect a uniquely configured hazard, usually being three-dimensional components or equipment. Fixed water spray systems are most commonly used to protect equipment from exposure fires such as flammable liquid and gas tanks, piping and equipment, and electrical equipment such as oil-filled transformers. The nozzles used may not be listed fire sprinklers and are usually selected for a specific spray pattern to conform to the three-dimensional nature of the hazard. The minimum requirements for the design, installation, maintenance, and testing of these systems can be found in NFPA 15: *Standard for Water Spray Fixed Systems for Fire Protection.*

Water Mist Systems

Water mist systems utilize water as the extinguishing, suppression, or control medium, but they do so in a nontraditional manner. These systems were introduced in the 1940s and were utilized for maritime applications such as on passenger ferries. The systems were designed to discharge less water using small-diameter piping, thus having less overall weight than a standard sprinkler system. The minimum requirements for the design, installation, maintenance, and testing of these systems can be found in NFPA 750: *Standard on Water Mist Fire Protection Systems.*

When a fire condition is detected in the protected hazard area via a heat or smoke detector, the system control panel sends a signal to the releasing module to operate the water mist suppression system. Small water mist systems contain nitrogen cylinders and a water cylinder, and large systems use pressure pumps. The nitrogen storage cylinder provides pressure to drive the water to the system nozzles. When the system is operated, valves on the nitrogen tanks open, and the resulting air pressure drives the water through the opened water valve and to the system nozzles.

The specifically designed nozzles create distinct water droplet characteristics for the applied hazard, and the resulting water mist contains a variety of droplet sizes. The larger droplets produced by the nozzle provide the necessary energy and momentum to carry the smaller droplets to the base of the fire, where the mist vaporizes and extinguishes the fire. The simple theory behind this is that a large amount of small droplets has a greater surface area than the same volume of large droplets, therefore absorbing more heat.

Water mist systems extinguish fires using the following basic principles:

- Cooling: As the mist is converted into vapor, it removes heat from the fire source.
- Inerting: As the water mist turns to steam, it expands approximately 1,700 times, forcing oxygen away from the flame front, thus denying the fire the oxygen necessary to support combustion.
- Wetting: Primarily for incidental Class A fires, wetting of the surface helps extinguish the fire as well as contain it.

Foam Extinguishing Systems

A foam/water fire sprinkler system is a special application system that discharges a mixture of water and foam concentrate, resulting in a foam spray from the sprinkler. These systems are usually used with special-hazard occupancies associated with high-challenge fires, such as airport hangars and flammable liquids.

Foam, mostly a mass of air- or gas-filled bubbles formed by chemical or mechanical means, is most useful in controlling fires involving flammable liquids with a low flash point and a specific gravity that is lighter than water. The mass of bubbles forms a cohesive blanket that extinguishes the fire by excluding air and cooling the surface and by separating the fuel from the fire.

Foam is not suitable for use on fires involving compressed gases or on live electrical equipment. Because of the water content, 94 to 97 percent, foam cannot be used on fires involving burning metals and is not effective on oxygen-containing materials. For fires involving water-soluble liquids, such as polar solvents, a special alcohol-resistant aqueous film-forming foam (AFFF) concentrate must be used. Foam can be applied to the fire surface or to the subsurface, such as in petrochemical tanks. Polar solvents must be surface applied. Systems can be fixed or semi-fixed.

Foams are defined by their expansion ratio:

- Low-expansion foam: Expansion up to 20:1
- Medium-expansion foam: Expansion from 20 to 200:1
- High-expansion foam: Expansion from 200 to 1,000:1

The minimum requirements for the design, installation, maintenance, and testing of foam extinguishing systems can be found in NFPA 11: *Standard for Low-, Medium-, and High-Expansion Foam* and NFPA 16: *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*.

Mechanical Foam

Many foam concentrates are available, some of which are designed for specific applications. Mechanical foam is made by the mechanical mixing of water and synthetic foam concentrates. Examples include AFFF, fluoroprotein (FP), film-forming fluoroprotein (FFFP), protein (P), low-temperature, alcohol-resistant (AR), and high-expansion foam.

Protein and fluoroprotein foams are the most cost-effective and have excellent burn-back resistance, but they do not knock down the fire as quickly as AFFF, which drains quickly but is not as heat resistant or as stable. Alcohol-resistant foams are somewhere between the two, but cost twice as much as protein foams.

High-expansion foam can be generated in volumes that are 1,000 times that of the water used. The foam is formed by the passage of air through a screen constantly wetted by a solution of chemical concentrate, which usually has a detergent base. The foam can be conducted by ducts, either fixed or portable, and can be manually applied by portable generators. High-expansion foam is useful for extinguishing fires by totally flooding indoor confined spaces, such as mine tunnels, or by local application. It extinguishes by displacing air from the fire and by the heat-absorbing effect of converting the foam water into steam. The foam forms an insulating barrier for exposed equipment or building components. High-expansion foam is generally not reliable when used outdoors, where it is subject to wind currents, and although it is nontoxic, it can have a disorienting effect on people.

Mechanical foam can be conducted through pipelines and discharged through a fixed chamber mounted in a bulk fuel storage tank, or it can be conducted through hoses and discharged manually through special nozzles. This foam can also be distributed through a specially designed sprinkler system.

The type of discharge device (nozzle) that should be used with a specific type of foam is based on the listing from the manufacturer. Foam can be supplied from a diaphragm (bladder) tank using water pressure to make and distribute the foam or from an inline pressure-proportioning system that utilizes an atmospheric tank with a supply pressure pump.

Foam disposal after discharge can cause problems. Although most foams are biodegradable, because their biological oxygen demand (BOD) is high, they cannot be directly discharged into the sewer or stormwater system. A holding tank with a treatment system may be required.

Carbon Dioxide Extinguishing Systems

Carbon dioxide is an effective fire-extinguishing agent that can be used on many types of fires, such as surface fires, flammable liquids, and most solid combustible materials. For fire suppression, the discharge is designed to raise the carbon dioxide concentration in the hazard area. This displaces the air containing oxygen, which results in fire extinguishment. (It should be noted that because of the displacement of oxygen, a carbon dioxide system will fail to support life; thus, care should be exercised in its application.) In addition, carbon dioxide cools fire areas.

Typical applications for a high-pressure carbon dioxide system include spray booths, commercial fryers, dip tanks, dust collectors and bag houses, electrical cabinets, printing presses, and storage vaults. The minimum requirements for the design, installation, maintenance, and testing of these systems can be found in NFPA 12: *Standard on Carbon Dioxide Extinguishing Systems*.

Carbon dioxide is an odorless, colorless gas at ordinary temperatures. Carbon dioxide as used for fire protection systems is available in high-pressure or low-pressure equipment. High-pressure systems (850 psi at 70°F) use gas compressed in standard cylinders. Low-pressure systems use carbon dioxide stored at 300 psi at 0°F in refrigerated, insulated tanks. Low-pressure systems are capable of multiple discharges since the duration of discharge is limited, and several hazards may be simultaneously protected through the use of multidirectional valves.

Under normal conditions, the gas is compressed into a liquid. When a carbon dioxide system is discharged, the pressure in the storage container acts as the propellant, forcing the stored liquid through pipelines to discharge nozzles. Each pound of carbon dioxide will expand to approximately 8 cubic feet of vapor at atmospheric pressure. Most of the liquid expands to a gas, but a portion forms particles of dry ice. This "snow" increases the mass of the discharge, allowing it to be projected for some distance. It absorbs heat and reduces temperature.

A minimum concentration of 34 percent by volume will handle most common materials; others may require an inerting atmosphere up to 100 percent. Some burning materials, such as stacked paper, furs, electrical insulation, and baled cotton, contain so much oxygen in pores or other internal spaces that they must be soaked in a smothering atmosphere for periods ranging from several minutes to several hours.

Carbon dioxide may be applied by either total flooding or local application. Total flooding is used where the hazard is contained in a room, compartment, or other enclosure that will allow the carbon dioxide atmosphere to remain in contact with the burning materials for a sufficient period to extinguish the fire and prevent its reigniting.

Local application is used where a hazard cannot be readily enclosed. The rate and duration of discharge, length of piping, and usable capacity of storage containers are critical factors, as the discharge of carbon dioxide is soon dissipated and has no continuing effect. System design for this type of application is considerably more complex than it is for flooding an enclosure. The types of nozzles to be used and their locations and discharge rates must be determined within accurate limits. Local application is commonly used for the largest and most valuable industrial processes, such as for oil quench tanks, flow-coating paint machines, steel and aluminum mills, printing presses, and power-generating equipment.

Clean Agent Fire Suppression Systems

For many years, halogenated agent (Halon 1211 and Halon 1301) fire suppression systems were utilized to protect high-value equipment, materials, and buildings. However, halons contain chlorofluorocarbons (CFCs), extremely stable compounds that do not break down chemically until reaching the Earth's upper atmosphere, so both Halon 1211 and Halon 1301 were phased out of production in 1994, except for essential uses.

The current replacement fire suppression gases for Halon 1301 are halocarbon clean agents. Halocarbon replacements include compounds containing carbon, hydrogen, bromine, chlorine, fluorine, and iodine. They are grouped into five categories: hydrobromofluorocarbons (HBFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and fluoroiodocarbons (FICs).

The descriptions and design requirements for all of these replacement agents are given in detail in NFPA 2001: *Standard on Clean Agent Fire Extinguishing Systems*. Halon 1301 information may be found in NFPA 12A: *Standard on Halon 1301 Fire Extinguishing Systems*.

Clean agent systems are designed to be chemical inhibitors that react with the transient products of combustion, terminating the combustion chain reaction and thereby stopping flame propagation. They reduce the oxygen content below the point necessary to maintain combustion. Although inert gases have a low level of toxicity, the decomposition products generated by their breaking down in the presence of very high amounts of heat may be dangerous. They may be used in occupied areas if the design concentration does not exceed the "no observed adverse effect level" (NOAEL) of 43 percent.

NFPA 2001 sets exposure limits for inert gases. Unnecessary exposure to inert gas agent systems resulting in low oxygen atmospheres shall be avoided. The maximum exposure in any case shall not exceed five minutes. It is advised that evacuation from the protected areas be done during the countdown period between the verification of a fire and the release of any of these agents.

FIRE EXTINGUISHERS

A fire extinguisher is an active fire protection device used to extinguish or control a fire, typically in emergency situations. A fire extinguisher, in general, consists of a handheld cylindrical pressure vessel containing an agent that can be discharged to extinguish a fire. In selecting a fire extinguisher, consideration should be given to the type of hazard and the potential size of fire involvement. For the proper type, rating, and locations, refer to NFPA 10: *Standard for Portable Fire Extinguishers*.

Fire extinguishers are available to extinguish all Class A, B, C, D, and K fires and are available with specialty extinguishing agents: carbon dioxide, dry chemicals, water, clean agents, foam, and special compounds for use with combustible metals.

Some extinguishers extinguish only one class of fire, and some may be suitable for two or three classes of fire; however, none are suitable for all classes. Rating numerals are used to provide the effectiveness of an extinguisher (i.e., a 4A extinguisher will discharge twice as much extinguishing agent as a 2A unit). The numerical rating for Class B extinguishers is based on the quantity of burning flammable liquid to be extinguished. Class C and D extinguishers do not have numerical ratings.

Class A extinguishers often are used for general building protection (paper, wood, cloth) and use water, AFFF, multipurpose dry chemicals, and clean agents. Class B extinguishers include carbon dioxide, dry chemicals, AFFF, and halogenated types for use on flammable liquid fires (gasoline, grease, oil, paint) and may be located in kitchens, laboratories, and generator rooms. Class C extinguishers include carbon dioxide, dry chemicals, and clean agents for use on electrical equipment fires. Class D extinguishers have special dry powder agents for use on combustible metals. It should be noted that multipurpose dry chemicals leave a residue when used. Delicate electrical or electronic equipment could be damaged if Class A, B, or C dry chemical extinguishing agents are used.

Extinguishers should be mounted with the top no more than 5 feet above the floor, but with the bottom a minimum of 4 inches above the floor. For units in excess of 40 pounds, the top should be 3½ feet above the floor. Extinguishers shall be easily visible and accessible. The actual travel distance to extinguishers, including walking around partitions and equipment, is a critical factor for quick fire control. The maximum distance allowed is listed in NFPA 10. (For example, the maximum distance between extinguishers in a Class A hazard is 75 feet.) It is beneficial to locate extinguishers in normal paths of travel, near exits and entrances, where uniform distribution is possible, and where the units will be readily available. Wheeled extinguishers are usually intended for outdoor placement and use by trained personnel.

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Expiration date: Continuing education credit will be given for this examination through **July 31, 2018**.

CE Questions — "Fire Protection Systems" (CEU 249)

1. Typical residential sprinkler systems are installed in accordance with ________.
   a. NFPA 13D
   b. NFPA 24
   c. NFPA 13R
   d. a or c

2. The fire triangle consists of ________.
   a. oxygen
   b. heat
   c. fuel
   d. all of the above

3. Standpipes that are part of a combined system (a system that supplies water to both fire department personnel and the building sprinkler system) shall be at least ________.
   a. 2½ inches
   b. 3 inches
   c. 4 inches
   d. 6 inches

4. A ________ fire involves energized electrical equipment.
   a. Class A
   b. Class B
   c. Class C
   d. Class D

5. A dry system used in a residential application is required to deliver water to the most remote sprinkler initially opened in ________.
   a. 15 seconds
   b. 20 seconds
   c. 25 seconds
   d. 30 seconds

6. NFPA 484 recommends that Class D fires be fought with ________.
   a. dry chemical extinguishing agents
   b. wet chemical extinguishing agents
   c. dry powder extinguishing agents
   d. carbon dioxide extinguishing agents

7. A ________ standpipe system provides 1½-inch hose connections to supply water for use by trained building personnel or fire departments during initial response.
   a. Class I
   b. Class II
   c. Class III
   d. Class IV

8. What size relief valve is required for a centrifugal fire pump that is rated at 1,250 gpm?
   a. 2½ inches
   b. 3 inches
   c. 4 inches
   d. 6 inches

9. A ________ system is most useful in controlling fires involving flammable liquids with a low flash point and a specific gravity that is lighter than water.
   a. carbon dioxide
   b. foam
   c. clean agent
   d. water mist

10. Which type of system is suitable for extra-hazard occupancies in which flammable liquids are handled or stored and where a fire may flash ahead of the operation of ordinary automatic sprinklers?
    a. dry
    b. preaction
    c. antifreeze
    d. deluge

11. The main standard that governs fire pump installations is ________.
    a. NFPA 20
    b. NFPA 24
    c. NFPA 13
    d. NFPA 291

12. For Class I and Class III systems, the minimum flow rate for the hydraulically most remote standpipe shall be ________.
    a. 500 gpm
    b. 400 gpm
    c. 300 gpm
    d. 250 gpm