Application of Fixed Water Spray Systems for Fire Protection in the Petroleum and Petrochemical Industries

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Application of Fixed Water Spray Systems for Fire Protection in the Petroleum and Petrochemical Industries

1 Scope

1.1 General

When addressing loss prevention, an organization should consider the use of fixed fire protection systems, one of which is water spray systems. *Water spray systems* appear similar to *sprinkler* systems in some respects; however, the intended uses, applicable Fire Codes and design criteria differ. This publication provides guidance for the petroleum industry and some petrochemical industry applications (for non-water-reactive petrochemicals with physical and combustion characteristics comparable to hydrocarbons) in determining where water spray systems might be used to provide protection from fire damage for equipment and structures.

Damage to process equipment and structural steel also can be limited by fireproofing, applying water through manual hose streams or applying water from fixed or mobile monitor nozzles; these methods are covered in API Recommended Practice 2218 *Fireproofing Practices in Petroleum and Petrochemical Processing Plants*, API Recommended Practice 2001 *Fire Protection in Refineries* and other referenced documents such as the National Fire Protection Association (NFPA) *Fire Protection Handbook and various NFPA Codes*.

The specifics of water spray system design, installation and component types are covered in the publications referenced in Section 2, principally NFPA 15, and are not duplicated in this publication.

The following other special applications of water spray are outside the scope of this publication:

— foam sprinkler systems used to supplement water spray systems and extinguish flammable liquid fires (see NFPA 16 for details);

— vapor mitigation systems [which have been used successfully by several major corporations to reduce the potential effects of releases of hazardous materials such as HF acid (see API Recommended Practice 751 for additional information)];

— water curtains used in special situations to minimize radiant heat or disperse hydrocarbon vapors before ignition;

— traditional applications of sprinklers in non-process buildings;

— water mist systems as described in NFPA 750.

1.2 Concept of Hazard vs. Risk

Hazards are conditions, or properties of materials, with the inherent ability to cause harm. Risk involves the potential for *exposure* to hazards that will result in harm or damage. For example, a hot surface or material can cause thermal skin burns or a corrosive acid can cause chemical skin burns, but these injuries can occur only if there is contact exposure to skin. A person working at an elevated height has “stored energy” and a fall from a height can cause injury—but there is no risk unless a person is working at heights and is thus exposed to the hazard. There is no risk when there is no potential for exposure.

Determining the level of risk for any activity involves understanding hazards and estimating the probability and consequences of exposures that could lead to harm or damage. While the preceding examples relate hazards to the risk to people, the same principles apply to property risk. For instance, hydrocarbon vapors in a flammable mixture with air can ignite if exposed to a source of ignition resulting in a fire which could cause injury and damage property. Water spray systems do not change the probability of a flammable material release. Proper application of water spray systems can reduce the consequences (damage) and thus reduce risk to people, property, or the environment.

1.3 Retroactivity

The provisions of this publication are intended for use when designing new facilities or when considering major expansions. It is not intended that the recommendations in this publication be applied retroactively to existing facilities. This publication can be used as guidance when there is a need or desire to review existing capability or provide additional fire protection.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Recommended Practice 751, *Safe Operation of Hydrofluoric Acid Alkylation Units*

API Recommended Practice 2001, *Fire Protection in Refineries*

API Recommended Practice 2021, *Management of Atmospheric Storage Tank Fires*

API Recommended Practice 2218**,** *Fireproofing Practices in Petroleum and Petrochemical Processing Plants*

API Standard 2510, *Design and Construction of Liquefied Petroleum Gas (LPG) Installations*

API Publication 2510A*, Fire Protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage Facilities*

NFPA [1], *Fire Protection Handbook, 20h Edition*

NFPA 11**,** *Standard for Low-, Medium-, and High-Expansion Foam Systems*

NFPA 13*, Installation of Sprinkler Systems*

NFPA 15*, Water Spray Fixed Systems for Fire Protection*

NFPA 16*, Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 20*, Installation of Stationary Fire Pumps for Fire Protection*

NFPA 24*, Installation of Private Fire Service Mains and their Appurtenances*

NFPA 25*, Inspection, Testing and Maintenance of Water Based Fire Protection Systems*

NFPA 72*, National Fire Alarm Code*

NFPA 214*, Water-Cooling Towers*

NFPA 750*, Water Mist Fire Protection Systems*

NFPA *850, Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*

FM [2], *Global Property Loss Prevention Data Sheets # 7-14*

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[1] National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.
[2] FM Global Corporate Headquarters, 270 Central Avenue, P.O. Box 7500, Johnston, RI 02919-4923, www.fmglobal.com.

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1
automatic spray systems
Spray systems designed to actuate when a sensor detects a fire; no action by personnel is required.

3.2
control of burning
A reduction in the rate of burning and heat release from a fire through application of water spray to the source of the fire or fuel surface until the source of fuel can be shut off, the fire can be extinguished or the fuel is all consumed.

3.3
deluge system
As defined by NFPA is an installation equipped with multiple open nozzles connected to a water supply by means of a deluge valve which allows water to flow from all nozzles simultaneously. This is similar to a water spray system, but does not use directional water spray nozzles to achieve a specific water discharge and distribution. In the refining and petrochemical industries the term deluge system is generally a system without nozzles in which all the water is applied from an open pipe. API 2510 and API 2510A describe such a system at the top of a vessel which allows water to run down the sides in a thin film, frequently using a weir to improve distribution and assist the even flow of water over the protected vessel.

3.4
deluge valve
A system actuation valve which allows water to flow into a piping system to discharge from all open pipes or spray nozzles. A deluge valve can be opened automatically in response to a detection system installed in the area being protected or by manual operation in an area remote from the fire area.

3.5
envelope
The three-dimensional space enclosing the fire.

3.6
exposed equipment
Equipment subject to fire damage, usually from a source other than the equipment being protected.

3.7
exposure protection
The absorption of heat through application of water spray to structures or equipment exposed to a fire (directly or by radiant convective heat from a fire), to limit surface temperature to a level that will minimize damage and prevent failure.

3.8
extinguishment
Occurs when combustion is no longer present.

3.9
fireproofing
A systematic process, including materials and the application of materials, that provides a degree of fire resistance for protected substrates and assemblies

3.10
hazard
A condition or inherent physical or chemical characteristic (flammability, toxicity, corrosivity, stored chemical, electrical, hydraulic, pressurized or mechanical energy) that has the potential for causing harm or damage to people, property, or the environment.

3.11
manual spray systems
Spray systems that by design must be actuated by a person.

3.12
may
Indicates provisions which are optional.

3.13
risk
The probability of exposure to a hazard, hazardous environment or situation which could result in harm or damage

3.14
risk assessment
The identification and analysis, either qualitative or quantitative, of the likelihood and outcome of specific events or scenarios that result in harm or damage with judgments of probability and consequences.

3.15
risk-based analysis
A review of potential hazards and needs to eliminate or control such hazards based on a formalized risk assessment

3.16
rundown coverage
A protective water film flowing by gravity onto lower portions of equipment (such as vessels or towers) from water applied to higher portions.

3.17
shall
Indicates provisions required for conformance to provisions of this standard or which are mandatory for conformance to other Standards or Codes.

3.18
should
Indicates provisions which are recommended but not mandatory.

3.19
water spray system
An automatic or manually actuated fixed pipe system connected to a water supply and equipped with water spray nozzles designed to provide a specific water flow rate and particle size discharge and distribution over the protected surfaces or area.

3.20
water spray nozzle
An open or automatic (self-actuating) device that, when discharging water under pressure, will distribute the water in a specific, directional pattern.

4 Analysis of Protection Needs

4.1 General

When the installation of fixed water spray protection is contemplated, various features and components of the facility should be evaluated using sound engineering judgment while considering the factors found in this document (see 4.2 through 4.9). After evaluation of facility hazards and risks, these considerations may be used as a basis for determining the proper and desirable location of fixed protection systems. The evaluation should include consideration of the need for protection and alternate protection provided.

4.2 Fire Protection

A risk-based assessment and analysis can determine the need for water spray protection at various locations in a petroleum or petrochemical facility. This analysis should include evaluation of the extent and capabilities of other types of fire protection. A variety of fire protection options are available to protect equipment. All should be explored to determine the most suitable approach for reduction of risk associated with a specific hazard or area. Exposure, consequence and risk reduction factors to be evaluated include, but are not limited to, the following:

a) equipment, building and unit spacing;

b) fireproofing (compatibility with water spray);

c) manual and automatic shutdown systems;

d) isolation and de-inventory systems, emergency depressuring;

e) response times and capabilities of plant and other fire brigades;

f) firewater coverage capability from fixed monitors, portable monitors, and hose streams;

g) the availability of portable and mobile fire-fighting equipment and personnel to operate it;

h) drainage of hydrocarbon from a spill area;

i) fuel load (hydrocarbon hold-up capacity, temperature, volatility);

j) the availability, flow capacity, quality, and duration of an uninterrupted water supply;

k) criticality and value of equipment;

l) special hazards or vulnerability of equipment (such as radioactive sources or internal grout/cement lined equipment);

m) potential community or environmental impact.

4.3 Access to Equipment

Access for fire protection or suppression can be a problem if physical obstructions, radiant heat or obscured visibility due to combustion by-products prevent adequate coverage using monitors or hose streams. Intervening equipment, structural members, piping or plant layout (roads, ditches, canals) can limit access. Consideration of the accessibility for mobile equipment or hand-held hose streams during a potential fire emergency will help determine the need for fixed fire protection.

4.4 Frequency of Fire

Experience can indicate that certain types of equipment have higher frequency rates or potential for fire. Typically this might include certain pumps, compressors, and fired heaters. Such fires might expose and damage other nearby equipment and potentially spread the fire. After evaluating other factors (see Section 4.2), designers may choose fixed water systems directed toward the potentially higher rate equipment as a preferred option for limiting the amount of damage and preventing the spread of fire.

4.5 Unit Value

Technological growth has made possible construction of larger, more sophisticated and progressively more expensive process units. In some areas these more automated process units require fewer personnel to operate. The use of more sophisticated instrumentation for overseeing operations can result in less on-site field surveillance and fewer people available to respond to fires using manually actuated monitors or hose streams. More expensive facilities have an inherent potential for a higher financial loss if a fire occurs. This potential for greater loss may justify the additional cost of water spray systems to reduce risk and protect company assets.

4.6 Critical Equipment and Interruption of Operations

When a water spray system is used for protection of safety- or life-critical equipment, the protection should take into account the hazard to which the equipment may be exposed and the time required for the equipment to complete its function.

When equipment which is critical for continued operation is involved in a fire, the loss due to downtime for repairs or replacement can exceed the loss due to physical damage. Such equipment is usually large and has a high value or long replacement time. Provision of water spray systems in addition to passive protection should be considered for critical equipment items.

4.7 De-Inventory and Isolation

Emergency shutdown provisions and isolation of process equipment may, to a great extent, determine the type and duration of the fire protection appropriate for a facility. The design and installation of water spray systems in process areas can be based on the potential fire exposure, the expected fire duration and drainage capacity. If process equipment cannot be isolated and de-inventoried or depressured in a timely manner, a fire can have a duration longer than the protection that passive fireproofing can reasonably provide. Application of cooling water from spray systems (or firewater monitors or hand lines) should be given consideration in such cases since this can provide continuing protection for as long as the water supply lasts.

4.8 Unusual Products, Chemicals, or Service

In facilities that handle unusual products or chemicals, the physical and chemical compatibility of water with these substances shall be evaluated. Some materials (such as certain metal alkyl catalysts) react violently with water, while fires involving water soluble fuels (such as alcohols and some ethers) are often difficult to extinguish with water. Special consideration should be given to the water compatibility and extinguishment needs for special products and to the appropriate response for materials, which are handled or stored at very high temperature or pressure.

4.9 Community and Environmental Impact

In some situations a potential fire location is close to off-site occupancies or environmentally sensitive sites. The possible impact on the community and environment may justify installation and use of water spray systems, where they may not appear needed based on economics or equipment criticality. Alternate scenario analyses should include potential off-site impact of fuel and water run-off.

5 Description of Water Spray Systems

5.1 General

A water spray system is a fixed-piping system connected to a reliable source of firewater. Such a system is hydraulically designed with water spray nozzles to achieve specific water discharge and distribution on the surface or area to be covered. The piping system is connected to the water supply through a manually or automatically actuated valve that initiates the flow of water. An automatic valve is actuated by a detection system installed in the same area as the water spray nozzles. NFPA 15 provides detailed descriptions of water spray systems.

Fixed water spray systems are designed to provide fire exposure protection, control of burning, extinguishment, or egress protection. They can be independent of other forms of protection, or they may supplement them. Gas fires should be extinguished by isolation. Water spray systems are neither intended nor suitable for extinguishment of pressurized jet fires. (See API 2218, Annex C for further discussion on jet fire considerations.)

Some system components in water spray systems perform critical functions. These components include nozzles, pilot sprinklers, fire detectors, strainers, fire pumps, deluge valves, indicating isolation valves, and signaling devices. Components that have been tested and approved for use in water spray system applications are available and should be used in accordance with the limitations of the approval and manufacturer's installation instructions.

5.2 Nozzles

Nozzles should be of a type that has been tested and listed for use in water spray systems. The selection of specific spray involves consideration of the following factors:

a) characteristics of the equipment to be protected;

b) purpose of the system;

c) the discharge characteristics of the nozzle;

d) possible wind or thermal draft conditions;

e) equipment configuration and spacing requirements;

f) corrosive water or atmospheric conditions;

g) water flow rate requirements versus availability;

h) drainage;

i) potential solids in water supply capable of obstructing spray nozzles.

The effective range of the spray is determined by the velocity and the size of the water droplets. Because of differences in orifice size, nozzle characteristics, and discharge pattern, one type of nozzle cannot ordinarily be substituted for another without proper analysis.

5.3 Piping and Fittings

Water spray system pipe, pipe fittings, hangers and other pipe support methods should be as recommended by NFPA 15. Pipe support and hanger design should consider the potential for damage from impact or over-pressure events. The water spray system piping shall be mechanically designed for the maximum operating pressure that the water supply system can provide, but not less than 175 psig (1207 kilopascals).

NFPA 15 requires that outdoor installations of pipe, fittings, and hangers be corrosion resistant. As a minimum, steel pipe and fittings shall be galvanized inside and out. Where the galvanizing is removed by cutting and threading, the exposed steel shall be protected from corrosion by application of a corrosion resistant coating or paint.

Where severe corrosion conditions exist such as inside cooling towers, in salty marine atmospheres, or where salt or brackish water is used, the use of more highly resistant piping systems should be considered. This might include the use of epoxy lined steel pipe, fire rated glass reinforced plastic, cupro-nickel, stainless steel pipe or tubing, or fire resistant synthetic rubber. Although the initial material costs can be higher, the long term maintenance cost saving and longer system life can warrant the additional investment. The strategy for testing water spray systems, the test medium used (e.g., salt water, treated water, etc.), frequency of testing, and the testing procedures should be considered for the material selection and design. Any materials selected shall have a fire resistance rating suitable for the location for which it will be installed.

5.4 System Actuation Valves

Each water spray system should be provided with a spray system actuation valve, which controls the flow of water to the spray nozzles. This valve may be of a type which is intended for local manual operation only, or for automatic operation.

System actuation valves, which are intended only for local manual operation, shall be located where they are easily identified and accessible during a fire. The valves shall be of a type which can be opened easily and quickly by one person. Valves larger than 6 inches in diameter may need to be equipped with a gear or power operator to facilitate opening.

System actuation valves, which are intended for remote manual or automatic actuation of open flow systems, are referred to as deluge valves. These valves may be mechanically, hydraulically, pneumatically, or electrically operated to open and begin water flow. Deluge valves shall be of a type which has been specifically tested, approved, or otherwise demonstrated suitable for use in water spray systems. Automatically or remotely actuated deluge valves shall have a means of manual operation at the valve, which bypasses the remote or automatic control. Deluge valves should not be located within the area being protected when this reasonably can be avoided.

System actuation valves should be located and installed where they will be protected from mechanical damage or explosion damage if that potential exists. Water spray systems, which include a deluge system, should be provided with a normally open isolation valve between the deluge valve and the water supply, of a type which gives a positive indication of its open or closed position.

5.5 Strainers

Strainers shall be provided for any system or group of systems that uses nozzles with waterways less than $^{3}/_{8}$-in. (9.5-mm) in diameter and/or for any system in which the water is likely to contain obstructive material. The strainer is normally located just upstream of the system actuation valve(s) and shall be downstream of the fire water supply system isolation valve, if any.

Strainers should be capable of removing all solids of a size that would obstruct the spray nozzles. Normally, $^{1}/_{8}$ in. (3.2 mm) perforations are suitable. Strainers shall also be capable of allowing continued operation without seriously increasing the head loss, for a period estimated to be ample considering the type of protection provided, the condition of the water, and other local circumstances. Refer to UL 321 or FM 5551 Approval Standard, or equivalent standard for guidance.

Strainer designs should incorporate a flush-out connection that can be used without shutting down the system and which is accessible during an emergency. In some cases, a bypass may be warranted to facilitate periodic cleaning of the strainer at intervals based on water quality and strainer obstruction experience. Consider equipping bypass with strainer to avoid fouling components while operating on bypass.

Individual or integral strainers for spray nozzles shall not be used in substitution for in-line strainers when potential for solids in water supply capable of obstructing spray nozzles exists.

5.6 Pressure Gauges

Pressure gauges are generally provided to indicate the status of the system, and are utilized to monitor functionality during system operation and testing.

5.7 Alarm, Control, and Detection

Water spray systems (manual or automatic) may be provided with an audible alarm at the protected premises to indicate that the system has been actuated. Where a water spray system is in a remote area, a system for monitoring the alarm should be in place. This monitoring should be at an attended location such as a control room or accomplished using alternate alert systems, such as automated personal paging.

Automatically operated systems can help minimize damage by providing faster operation of the system, as well as provide an alarm for quicker response action by facility personnel. Automatic operation can be accomplished by the use of fire and/or gas detection systems installed within the protected area.

Fire detection can include various types of systems:

— electronic (such as those described in NFPA 72);

— pneumatic (such as those described in API RP 14C);

— fixed temperature pilot sprinkler (such as those described in NFPA 15).

Where detection systems have been provided for actuation of water spray systems, the system should provide an alarm which is separate from the system actuation (water flow) alarm.

Automatic systems can provide faster response than manual systems, but generally have greater life-cycle costs because they usually require more maintenance; and, unless properly maintained, they may be less reliable because of their complexity. Nevertheless, automatic actuation is generally considered a preferred approach for remote or unstaffed locations needing fire protection.

6 Water Spray Design Objectives

6.1 General

Three specific objectives of water spray systems can include exposure protection, control of burning, and extinguishment. While water spray has been proven effective in achieving these objectives, water spray is not intended to provide protection from pressurized (jet) impingement fire exposure. The force of a jet fire can separate water from the surface it is intended to protect, making the water spray ineffective, or provide more heat input than the water density can absorb. Protection from the effects of the high heat flux caused by jet impingement requires the use of jet fire rated fireproofing (refer to API 2218 for more details) or by large (one or two orders of magnitude higher than water spray) localized firewater application from monitor nozzles or hose streams directed to reach the point of impingement.

6.2 Exposure Protection

The most common objective of a water spray system is exposure protection; protecting equipment and structures from heat stress caused by exposure to radiant and convective heat, and preventing ignition of combustible components. One factor to consider when designing a system for exposure protection is the allowable temperature a structure could safely sustain before significant damage or failure occurs. The purpose of these systems is to absorb heat and reduce

temperatures. A continuous water film from sprays will theoretically limit the surface temperature to the boiling point of water, 212 °F (100 °C). Much heat can be absorbed and damage can be reduced through exposure protection; however, systems designed for exposure control are not intended to extinguish fires or protect against direct jet fire impingement.

6.3 Control of Burning

Water spray systems can be used to control the rate of burning. This is achieved by applying water to the flame, or burning surface, to absorb heat near its source, reduce vapor generation and flame intensity, and limit the amount of heat released to expose the surrounding environment while the fuel is consumed.

6.4 Extinguishment

The physical properties of the fuel involved in a fire will determine whether extinguishment by water spray is possible. In some scenarios, extinguishment can be accomplished by surface cooling, emulsification, or dilution (all of which reduce vapor release) or smothering by the steam produced. Extinguishment by water spray is generally most effective where the fuel is a combustible solid, water soluble liquid, or high flash point liquid. However, the risks associated with extinguishing certain fires should be carefully evaluated. If significant quantities of flammable gases or vapors are released, a more hazardous condition with potential for explosive re-ignition can be created by extinguishing such fires instead of allowing them to burn at a controlled rate with appropriate surveillance and protection of surrounding equipment.

6.5 Hot Equipment

Other than for cast iron equipment, thermal shock caused by the application of water spray on hot equipment during fire situations generally is not a problem, despite some historical concerns.

7 Water Application Rates

7.1 General

The appropriate application rates for fire protection water spray systems depend upon the design objectives for the application, the type and nature of the equipment or structure to be protected, and the characteristics of the probable fuel involved. A single large water spray system may use several different application rates within the same system. For example, a system could provide protection for a group of process pumps (at an application rate intended for control of burning), as well as providing direct spray for exposure protection of adjacent cable trays and structures at the appropriate application rates for exposure protection for those elements.

The actual application rate used should be selected based on available reference data, judgment, experience, and (in some cases) testing. A hazards assessment with pre-incident scenario analyses can be useful in determining the probable nature of a potential fire, the consequences of unabated burning, and the appropriate water application rates.

Section 7.2 and Section 7.3 below, as well as NFPA 15, provide guidance and suggested application rates for some of the more common uses of water spray systems. Experience or testing can indicate that application rates other than those suggested here may provide the desired protection.

7.2 General Area Coverage

7.2.1 General

Section 7.2.2, Section 7.2.3, and Section 7.2.4 provide general information and application rate ranges based on the intended objective—exposure protection, control of burning, or extinguishment.

Section 7.3 provides more specific guidance based on the actual equipment or structure being protected. Table 1summarizes some of the application rates discussed for specific objectives and equipment.

For each application, the water flow rates chosen should consider heat generation potential and be sized accordingly.

7.2.2 Exposure Protection

Exposure protection involves spraying water directly onto an equipment item or structure to prevent failure due to heat or to prevent ignition of combustible components. The required application rate depends upon the rate of heat transfer, the maximum allowable temperature, and the efficiency of heat absorption by the water. In general, suggested application rates are between 0.10 and 0.25 gpm/ft^2 (4.1 and 10.2 lpm/m^2). These suggested rates are experience-based and include a safety factor of at least 0.05 gpm/ft^2 (2.0 lpm/m^2).

The higher application rate of 0.25 gpm/ft^2 (10.2 lpm/m^2) is recommended for protecting steel surfaces that are stressed such as pressure vessels and load-bearing structural members such as vessel legs, pipe rack supports, and vessel skirts. Rates between 0.15 and 0.25 gpm/ft^2 [10.2 and 6.1 lpm/m^2] may be used where supported by relevant engineering data, documented experience, or where other protective measures have been taken.

This application rate is good for moderately severe heat inputs, including direct, non-pressured, flame contact. However, as mentioned in Section 6.1, it is not sufficient for protection from flame impingement from a pressurized jet fire.

The lower application rate of 0.10 gpm/ft^2 (4.1 lpm/m^2) is recommended for protecting non-load bearing steel surfaces including such items as non-load bearing structural members and atmospheric storage tanks and vessels. It may also be used at this rate for radiant heat absorption.

7.2.3 Control of Burning

Fire intensity can be effectively controlled with water spray application into the flame or onto the burning liquid.

Water applied into the flame reduces the amount of radiant and convective heat released to the surroundings, as well as slowing the reaction rate through heat absorption. This is typically the objective when water spray is installed for protection where three dimensional fires are expected, such as at pumps, compressors, or well heads. An application rate of 0.50 gpm/ft^2 (20.4 lpm/m^2) or higher is typically recommended. In certain cases, scenario-specific engineering studies have shown that water application rates in the range between 0.20 to 0.50 gpm/ft^2 (8.2 to 20.4 lpm/m^2) can be effective.

Water applied to the burning surface of flammable or combustible liquids is even more effective in controlling fire intensity. The water droplets that reach the surface can reduce the temperature of the burning liquid, thereby reducing the rate of vaporization and burning. Application rates recommended for typical hydrocarbon spill fires are in the range of 0.30 to 0.35 gpm/ft^2 (12.2 to 14.6 lpm/m^2). In some cases, rates as low as 0.20 gpm/ft^2 (8.2 lpm/m^2) may be effective. Proper choice of spray equipment is necessary to balance two objectives:

a) provide droplet size with large enough size and high enough velocity to reach the fuel surface through a fire's convective air currents;

b) deliver the water spray without transferring so much energy to the fuel surface that agitation increases vapor release and fire intensity.

7.2.4 Extinguishment

Extinguishment is seldom the primary purpose of water spray system installations in the petroleum industry. Where extinguishment is the design objective, the potential fire most commonly involves combustible solid materials, such as a conveyor belt system with combustible belts. The application rate depends on the nature of the fuel involved and the configuration of the application and could range from 0.15 to 0.30 gpm/ft^2 (6.1 to 12.5 lpm/m^2).

Water spray can also be used to extinguish some types of combustible (and in some cases flammable) liquids. Immiscible combustible hydrocarbons, in which water is not soluble, with flash points of 140 °F (60 °C) or greater (such as diesel fuel) can sometimes be extinguished by cooling the liquid below its flash point. Application rates between 0.25 and 0.50 gpm/ft^2 (10.2 and 20.4 lpm/m^2) can be effective, depending on the liquid. Water miscible liquids (such as alcohols and glycols) which will absorb water can sometimes be extinguished by dilution, but the high vapor pressure and low miscibility of certain ethers (for instance, MTBE) presents a difficult challenge.

It should be noted that extinguishment of low flash point hydrocarbon liquids with water spray is seldom possible and not necessarily desirable. A key question during hazard analysis is, "If the material is extinguished while still generating vapor, is there a risk of vapor cloud re-ignition?" If the answer is "yes" and extinguishment is still desired, special agents (such as foam) that have the ability to secure the liquid surface from re-ignition should be considered.

7.3 Application Rates for Equipment and Structure Protection

7.3.1 General

As discussed in the preceding sections, when fixed water spray systems are provided to protect equipment or control fires, the application rate will vary based on several considerations:

a) type of equipment being protected;

b) potential heat generation capability; and

c) fire protection or control objective.

The following sections address specific applications of fixed water spray systems.

7.3.2 Pumps

Some form of fire protection should be considered for pumps when there is a significant potential for fire and there is a risk of significant damage beyond the pump involved. This generally applies to large pumps handling flammable liquids or combustible liquids at temperatures elevated above their flash points, and which are located within process structures—or in large pump rows where access for conventional fire suppression using fixed monitor nozzles or hose streams would be difficult.

Based on the above, a fixed water spray system should be considered when all three of the following conditions exist:

a) the fluid being handled is at a temperature that is significantly (e.g. 22 °C or more 40 °F or more) above its flash point; and

b) the considered pump is in close proximity to other equipment (including adjacent pumps) or structures that could be quickly damaged by the pump fire; and

c) the pump is located where protection by monitor nozzles or hose streams would be difficult or impractical.

The water spray system should be designed to envelope, as a minimum, the entire pump including the shaft, seals, and other critical parts. Optionally, the spray envelope may be extended 2 ft (0.6 m) beyond the pump periphery and include suction and discharge parting flanges, check valves, gauge connections, block valves, balance lines, and lubrication connections within the spray envelope. The application rate should be not less than 0.50 gpm/ft^2 (20.4 lpm/m^2) of the projected envelope area at grade level. NFPA 15 should be consulted for other design requirements.

The values shown in Table 1 are intended for fire protection engineering personnel to use in conjunction with the explanatory material in the text and related references.

Table 1—Water Spray Application Rates for Exposed Surface Area

Consult the indicated section in text or reference for more detailed information to expand on summary data in table.

Item	Section in API 2030 or Other Indicated Reference	Application Rate: Gallons per Minute per Square Foot	Application Rate: Liters per minute per Square Meter
Application Rates for General Exposure Protection			
General Exposure Protection	7.2.2	0.10 to 0.25	4.1 to 10.2
Application Rates for Control of Burning			
Control of Burning *Varies with Application Scenario*	7.2.3	0.50	20.4
Application Rates for Extinguishment– *(see note 4)*			
Extinguishment			
Combustible Solid	7.2.4	0.15 to 0.30	6.1 to 12.2
Combustible Liquid	7.2.4	0.25 to 0.50	10.2 to 20.4
Flammable Liquid	7.2.4	(May not be desirable or possible; see text)	
Exposure Protection Application Rates for Specific Equipment and Structures			
Air-fin coolers - *(see note 1)*	7.3.5	0.25	0.2
Atmospheric Storage Tanks	7.3.14	0.10	4.1
Compressors			
– General	7.3.7	0.25	10.2
– Buildings	7.3.7	0.30	12.2
Cooling Towers	7.3.11; NFPA 214	0.15 to 0.50	6.1 to 20.4
Fired heater supports	7.3.10	0.25	10.2
LPG loading racks	7.3.12	0.25	10.2
Motors	7.3.9	0.25	10.2
Pipe Racks *(see note 2)*	7.3.3	0.25	10.2
Open Cable Trays/Conduit Banks	7.3.16	0.30	12.5
Exposure Protection Application Rates for Specific Scenarios, continued			
Pressurized storage tanks	7.3.6: API Std 2510 and Publ 2510A		
Radiant Exposure	7.3.6 (distance related)	0 to 0.10	0 to 4.1
Non-pressure Impingement	7.3.6 (design related)	0.25 to 0.15 (*see note 3)*	10.2 to 6.1 (*see note 3)*
Pressure Impingement	7.3.6; prefer direct 250 to 500 gpm fire water stream at point of impingement	0.50 minimum	20.4 minimum

Table 1—Water Spray Application Rates for Exposed Surface Area (Continued)

Consult the indicated section in text or reference for more detailed information to expand on summary data in table.

Item	Section in API 2030 or Other Indicated Reference	Application Rate: Gallons per Minute per Square Foot	Application Rate: Liters per minute per Square Meter
Process Buildings & Structures	7.3.15; NFPA 13		
Primary		0.30	12.2
Supplemental		0.15	6.1
Pressure Vessels, Exchangers and Towers (*see note 3)*	7.3.6	0.25	10.2
Pumps	7.3.2	0.50	20.4
Transformers	7.3.4	0.25	10.2
Turbines			
– General	7.3.8 (7.3.7)	0.25	10.2
– In Buildings		0.30	12.2
Well Heads	7.3.13	0.50	20.4

Values from Table 1 are intended for use by fire protection engineering personnel in conjunction with the explanatory material in the text and references.

NOTE 1 *While NFPA 15 does not specifically address air-fin heat exchangers it recommends a minimum of 0.25 gpm/ft^2 (10.2 lpm/m^2) for protection of vessels and piping. Where the temperature of the of the vessel or its contents should be limited, higher application rates may be required [NFPA 15].*

NOTE 2 *Water spray density for the upper level of multilevel pipe racks can be reduced in accordance with NFPA* 15.

NOTE 3 Rates between 0.15 and 0.25 gpm/ft^2 [6.1 and 10.2 lpm/m^2] may be used where supported by relevant engineering data, or documented experience, or where other protective measures have been taken.

NOTE 4 Rates should be established by review of relevant test data for the specific materials [NFPA 15].

NOTE 5 In some cases, rates as low as 0.20 gpm/ft^2 (8.2 lpm/m^2) may be effective.

7.3.3 Pipe Racks and Piping

Failure of a pipe rack from the heat of a fire can cause failure of the lines within that rack and release of additional fuel to the fire. Provision of water spray protection for pipe racks is appropriate for consideration where the potential exists for a liquid pool fire or other severe exposing fire below the rack and access for application of water from hose streams and monitors is limited. Good drainage with the ability to remove potential fuel from beneath the pipe rack can lessen the need for water spray. Pipe racks that are near ground level (on sleepers) seldom require fixed water spray. Where exposure potential suggests a need for protection, general industry practice is to fireproof pipe racks (per the requirements of API 2218) rather than install water spray systems.

Where water spray systems are used to protect piping and conduit in exposed major pipe racks, they shall be designed in accordance with NFPA 15. In addition, non-fire proofed vertical pipe rack supports may be protected by water spray at a rate of 0.25 gpm/ft^2 (10.2 lpm/m^2). Protection for control valve stations should be considered if the stations have potential for significant fire exposure.

7.3.4 Transformers

Large oil-filled transformers are typically installed where they are separated from process equipment, buildings, structures, or other transformers by distance or masonry walls. Water spray protection is seldom justified unless there is a significant potential fire exposure to (or from) the transformer. For new construction, the spacing guidelines in NFPA 850, should be followed to reduce the need for water spray protection.

Where water spray systems are deemed necessary, the systems should be designed and installed in accordance with NFPA 15 using an application rate of 0.25 gpm/ft^2 (10.2 lpm/m^2) on all exposed surfaces.

7.3.5 Air-Fin Coolers

A tube failure within an air-fin cooler used to condense or cool flammable liquids can result in a liquid spill to grade and effectively provide its own fuel for an exposure fire. Such a fire could damage the leaking cooler, adjacent cooler banks, the support structure, and equipment under the cooler.

Consideration should be given to providing water spray protection for large or critical banks of liquid filled air-fin coolers or where there might be a significant exposure to or from process equipment below the coolers. Gas-filled air-fin coolers seldom warrant water spray protection unless exposed to a potential fire from adjacent process equipment. Where protection is provided for incidents originating at process equipment (such as pumps) control of exposure may be achieved more cost effectively by using water sprays for intensity control at the fire source.

Where water spray at air-fin coolers is provided, the system should be designed such that the nozzles are below the cooler and spraying upward against the bottom of the fin tubes. The water spray system should provide an application rate of 0.25 gpm/ft^2 (10.2 lpm/m^2) of horizontal projected surface. For forced draft (fan below) type coolers, nozzles should be placed inside the plenum, between the fan and the tubes and at the air inlet to the fan. For both forced draft and induced draft coolers, water spray protection has significantly greater value when the power to the fan motors is shut off. Flame or temperature detectors or an interlock may be provided to shut down the fan on activation of the water spray.

Where water sprays are provided for non-fireproofed, vertical steel supports for air-fin coolers, they shall be designed for a direct water spray at a rate of 0.25 gpm/ft^2 (10.2 lpm/m^2) of surface, one side. Up to 12 ft (3.7 m) of rundown coverage is acceptable.

7.3.6 Pressure Vessels, Exchangers, and Towers

Pressure vessels are of concern when exposed to a fire, including storage vessels and spheres, process vessels, process towers, and certain heat exchangers. Potentially damaging heat exposure can be from thermal radiation, non-pressurized direct fire exposure, or intense pressurized jet-fire exposure. Concentrated heat from a fire can raise the temperature of steel and reduce its strength to a point where it can fail catastrophically at its normal safe operating pressure unless there is a mechanism to remove or dissipate the heat. Liquid filled pressure vessels can withstand heat inputs since the liquid inside absorbs the majority of the heat by temperature rise and vaporization, helping to keep the steel shell at a safe temperature. Gas filled vessels (or the vapor space above the liquid in a partially filled vessel) can withstand much less fire exposure since the vapor or gas absorbs very little heat. In addition, non-fireproofed steel supports for vessels can fail as a result of direct fire exposure, allowing the vessel to topple or fall.

Consideration should be given to providing fixed water spray systems to protect pressure vessels which might be exposed to a significant fire and which are located where adequate cooling cannot be provided from hose streams and monitor nozzles. [Recommendations specific to LPG spheres are discussed in the following paragraph.] Where water spray is provided on vessels, the entire vessel surface should be covered. Where only radiant exposure is of concern, 0.10 gpm/ft^2 (4.1 lpm/m^2) or lower may be acceptable based on distance from hazards; however, for non-pressure fire impingement exposure of pressure vessels, the basic minimum application rate is 0.25 gpm/ft^2 (10.2 lpm/m^2) of vessel surface. Vertical vessels and towers may need to be protected only to a height of 40 ft (12.2 m) above the level at which a liquid pool fire could form. Up to 12 ft (3.6 m) of cooling water rundown is allowed on vertical and inclined surfaces. However, direct spray coverage of the bottom surfaces is usually required to ensure coverage. Additionally, where projections (manways, flanges, etc.) interfere with the water coverage, supplemental spray nozzles might be necessary. NFPA 15 should be consulted for additional requirements.

Alternative designs for protection of LPG storage spheres are common and are generally acceptable. As discussed in API 2510 and 2510A, these designs can involve one or more very large discharge nozzles at the top of the sphere along with some type of distribution device, such as a weir. The design objective is to create a uniform film of water

that covers the critical portions of the sphere's surface. [In the petroleum industry this configuration is often called a "drenching" or "deluge" system and should be recognized as different from the definition of deluge systems described in NFPA 15.] The film provided by these systems may not cover the very bottom of the sphere where the fill and withdrawal line connections are located and can leave dry spots at the point of connection of the vessel to the support legs. These areas may require supplemental water spray nozzles or fixed monitor nozzle coverage to assure that all critical surfaces are covered by water. The total water flow for the entire sphere surface for non-pressure flame impingement scenarios should be the equivalent of 0.10 to 0.25 gpm/ft^2 (4.1 to 10.2 lpm/m^2).

Emergency response plans should recognize that intense pressurized jet-fire exposure will require additional cooling and application of a monitor or hose fire water stream on the order of 250 to 500 gpm (1000 to 2000 lpm) applied at the point of flame impingement is recommended in API 2510A. This is particularly significant where impingement contacts the vessel vapor space. The vapor space is more vulnerable because even without the benefit of liquid vaporization the unit thermal capacity of propane liquid is 30 times that of propane vapor at a typical LPG pressure vessel pressure relief valve (PRV) setting of 250 psig (1725 kilopascals).

Non-fireproofed vessel supports should also be protected by water spray, including legs and skirts plus steel saddles greater than 12 in. (300 mm) high at their lowest point. The application rate should be 0.25 gpm/ft^2 (10.2 lpm/m^2) of protected surface, one side only. Rates between 0.25 and 0.15 gpm/ft^2 [10.2 and 6.1 lpm/m^2] may be used where supported by relevant engineering data, or documented experience, or where other protective measures have been taken. For protection only against radiation from pool fires without aggressive flame contact, the minimum flow should be 0.10 gpm/ft^2 (4.1 lpm/m^2) as noted in API 2510.

Tube and shell type heat exchangers greater than 3 ft (1 m) in diameter should be considered as liquid filled pressure vessels when operated with flammable liquid on the shell side. If water spray protection is provided, it should be designed as above for pressure vessels. Consult NFPA 15 and FM 7-14 for additional information.

7.3.7 Compressors

Small motor driven compressors [typically less than 200 to 300 horsepower] handling flammable gases present the same fire concerns as discussed in Section 7.3.2 for pumps handling flammable liquids, and the same decision criteria should be used for evaluating the need for water spray protection. Where water spray protection is provided, the coverage and application rate should be the same as for a pump.

Large engine or turbine driven compressors provide an added fire concern because of the large volumes of hot lubricating oils being handled under pressure in the driver, transmission, and lubrication systems. Even though these lubricants are high flash point materials, a leak of lubricant in the vicinity of hot metal surfaces could produce flammable vapors resulting in the potential for a fire exposing an expensive compressor and driver. It may be desirable to provide water spray to protect this equipment. Where water spray is provided, it should be designed to directly spray all exposed equipment surfaces, including auxiliary equipment such as lube oil consoles and lube oil pumps, at an application rate of 0.25 gpm/ft^2 (10.2 lpm/m^2) of projected equipment surface.

Where large compressors are located within buildings or under weather canopies additional concerns arise. A fire associated with the compressor or driver could cause structural failure of the building or canopy or expose other adjacent equipment. Instead of providing direct water spray on each equipment or structural item, the general area within the building or canopy can be provided with overall water spray protection to reduce the potential for high temperature combustion gases to accumulate under the roof. The system should have 180 degree spray nozzles or open sprinklers located just below the roof or canopy, and designed to provide 0.30 gpm/ft^2 (12.2 lpm/m^2) of floor area. Where the building has a sub-floor area, basement or pipe trenches containing the lubrication system equipment, additional coverage may be required below floor level at the same 0.30 gpm/ft^2 (12.2 lpm/m^2) application rate.

7.3.8 Turbines

Where water spray is provided on expansion turbines in hydrocarbon service the system should be treated the same as an equivalently sized compressor.

7.3.9 Motors

Electric motors, particularly totally enclosed type, do not present a significant fire potential. However, these motors can be seriously damaged if exposed to a severe fire. Water spray protection may be appropriate for very large, expensive, or hard to replace motors that are potentially exposed to fire. Where water spray is provided it should cover all exposed external surfaces of the motor. The system should be designed to provide an application rate of 0.25 gpm/ft^2 (10.2 lpm/m^2) of protected surface.

7.3.10 Fired Heater Supports

Water spray systems are not often used for fired heaters. Where water spray systems are provided to protect exposed (non-fireproofed) critical supports for fired heaters they should be designed to deliver an application rate of 0.25 gpm/ft^2 (10.2 lpm/m^2) of surface area.

7.3.11 Cooling Towers

When water spray systems are provided to protect critical combustible cooling towers they should be designed in accordance with NFPA 214, which calls for water spray application for various portions of the tower ranging from 0.15 to 0.50 gpm/ft^2 (6.1 to 20.4 lpm/m^2) of protected surface.

When water spray systems are not installed, it is common practice to rely on emergency response to protect active cooling water towers and to rely on maintenance procedures to keep the internals wet when the cooling water tower is shutdown.

7.3.12 Hydrocarbon Loading Racks

Truck and rail loading racks that handle flammable liquids generally are not suited for protection by fixed water spray systems. The water spray will not secure or extinguish spilled flammable hydrocarbon and it is difficult to position nozzles to effectively cover the truck or rail car. Foam water spray nozzles or foam equipped monitor nozzles provide a preferred method of protection. Refer to NFPA 16 and/or NFPA 11 for further details.

LPG rail car loading racks have had fixed water spray systems installed for protection when adequate coverage could not be provided by monitor nozzles. In these instances water spray nozzles should be positioned to cover the exposed portions of the loading rack, such as the loading arms and the rail car. This requires water spray nozzles on both sides of the rail spot to provide complete coverage of the rail car. The system should be designed to provide an application rate of 0.25 gpm/ft^2 (10.2 lpm/m^2) of protected surface.

7.3.13 Well Heads

Well heads (Christmas trees) for onshore oil or gas production wells seldom require fixed protection systems. These well heads are typically located in areas which are remote from the public and other equipment and the emergency shut-in systems can be depended upon to block in the flow should a fire occur. However, well heads on offshore production platforms provide a different concern. The number of well heads adjacent to each other and their close proximity to other production equipment will often warrant consideration of fixed water spray systems. In some cases, regulatory authorities may require the provision of a water spray system in the well bay area.

In enclosed or partially enclosed well bays there is generally deck structure above the well heads. Should a well head fire occur, it is important to protect the structure above as well as protect the adjacent well heads. An effective arrangement is to position wide angle nozzles just below the overhead structure and directed downward to envelope

the well heads. The system should be designed to provide an application rate of not less than 0.50 gpm/ft^2 (20.4 lpm/m^2) of protected area at deck level.

On some platforms the well heads are located on an open deck with no structure above. An alternative design for protecting this type of arrangement involves placing high flow rate nozzles at the base of the well head, directed upward. Four nozzles should be arranged in a square pattern surrounding the well head. The discharge angle and positioning should be such that the extremities of the well head are enveloped in the spray. Each nozzle should deliver between 50 and 60 gpm (190 and 230 lpm) to provide 200 to 240 gpm (760 to 920 lpm) per well head.

7.3.14 Atmospheric Storage Tanks

Atmospheric storage tanks generally do not warrant fixed water spray protection and (with the exception of horizontal tanks) do not readily lend themselves to this type of protection. When reviewing an atmospheric storage tank's protection from an external fire, the design personnel should recognize that cooling water is of potential benefit only for the exposed portions of the roof and for those portions of the shell that are not in contact with the liquid contents. Those portions of the tank most likely not to be in contact with liquid include the roof of cone roofed and covered floating roof tanks and the upper portion of the shell on all tanks. If spray is used, typically only the upper 12 to 24 ft (3.7 to 7.4 m) of shell is sprayed; up to 12 ft (3.7 m) of rundown is allowed on inclined and vertical surfaces. If there are wind girders at the top of the tank, spray nozzles should be placed below each girder ring.

Where water spray protection is used the system should be designed to provide an application rate of 0.10 gpm/ft^2 (4.1 lpm/m^2) of protected surface. Generally between one-quarter to one-half of the total tank surface could be exposed when a fire is in an adjacent tank. Since the exact location of the exposing fire or the amount of liquid in the exposed tank may not be known before the fire occurs, total protection would require that the entire tank be sprayed. However, water sprayed on surfaces that are not being exposed to fire is wasted and takes resources from other fire suppression efforts; sectionalization of fixed spray systems can help ensure efficient use of firewater. Application of water by hose streams and monitor nozzles has the potential for more efficient use of available water, however their effectiveness may be limited by the ability to gain access to a position from which to apply the cooling stream. Preparation, management and suppression of fires in atmospheric storage tanks is addressed in API Recommended Practice 2021.

7.3.15 Process Buildings And Structures

Flammable liquid or gas process equipment situated within congested buildings or partially open structures typically presents the highest potential for major fire. In addition, equipment within the process buildings and structures is typically the least accessible for protection with hose streams and monitor nozzles and thus represent appropriate applications for fixed water spray systems. In congested areas it is often impractical to cover each equipment item or structural member as described in the preceding sections. As an alternative, an overhead water spray system can be installed to cover large areas of the process structure or building. Nozzle manufacturers should be consulted for limitations on nozzle coverage.

In this design, wide angle (180 degree) nozzles or open sprinklers are positioned at the ceiling level so as to envelope all of the equipment within the protected area. The positioning and spacing of the nozzles generally follow the rules of NFPA 13 for sprinkler systems. The system should be designed to provide an application rate of not less than 0.30 gpm/ft^2 (12.2 lpm/m^2) of floor area.

Areas beneath large pieces of equipment, access platforms, mezzanines, and similar items that can shield the floor area and other equipment below, usually require supplemental nozzles for coverage at the same application rate. All portions of the floor where a spill fire could accumulate and all equipment and structural members to be protected should be wetted by the discharge from the system. Where mezzanine and intermediate floors use open grating, the supplemental application rate below the grate may be reduced to 0.15 gpm/ft^2 (6.1 lpm/m^2) of floor area.

7.3.16 Nonmetallic Electrical Cable and Tubing Runs

The preferred protection is to route critical control and power wiring away from fire risk areas such as above hot-oil pumps or near furnaces. Where routing outside a fire risk area is not feasible cables should be fire rated or protected by passive fire protection. In existing situations where these solutions are not feasible open cable trays/conduit banks may be protected by fixed sprays at an application rate of 0.30 gpm/ft^2 (12.2 lpm/m^2).

8 System Design

8.1 General

Because of the complexities of water spray systems, only trained, knowledgeable individuals should be involved in the design and application of water spray systems. Only equipment designed and intended for the application should be used. Performance data shall be available to substantiate test results.

8.2 Water Supply

The flow rate and pressure of the water supply should be adequate to maintain water discharge at the design rate and duration for all systems, hose streams, and monitor nozzles that are designed to operate simultaneously. Maintaining an effective discharge pressure for hose streams and monitor nozzles may be the determining factor in establishing the total design. Evaluation and determination of the supply source should be based on the reliability and suitability of all available water sources.

8.3 Water Demand

Many factors determine the appropriate size of a water spray system. These include:

a) the nature of hazards involved;

b) the amount, type, and spacing of equipment to be protected;

c) the adequacy of other protection; and

d) the size of the area that could be involved in a single fire.

The extent of the water spray system needed can be minimized by:

a) subdividing the area by means of fire walls or adequate separation distances;

b) limiting the spread of flammable liquids (usually by appropriately designed normal plant drainage systems or if necessary by means of special drainage provisions);

c) by using a combination of these approaches.

It is preferable for each fire area to be protected by its own system; however, the total demand for a large process area is usually much greater than can be met by the largest possible single water spray system.

The size of a single water spray system should be limited so that the design discharge rate, calculated at the minimum pressures at which the nozzles are effective, generally will not exceed 3000 gpm (11,350 lpm). The hydraulically designed discharge rate for a single system or for multiple systems designed to operate simultaneously should not exceed the available water supply while taking into consideration other concurrent fire suppression demands. The initial design capacity of a system should not normally exceed 2200 gpm (8316 lpm). A minimum

additional future capacity of at least 200 gpm (756 lpm) should be provided for each additional system up to a maximum total capacity of 3000 gpm (11,350 lpm).

Revisions and expansions of existing systems nearly always occur, causing an increase in firewater demand. Allowance for more pumping capacity, larger fire water mains, and more drainage facilities should therefore be considered by the designer. API Recommended Practice 2001 and NFPA 20 and 24 provide more guidance on fire protection water systems.

8.4 Water Spray Nozzles

Nozzle orifice sizes smaller than $^{3}/_{8}$ in. clear passage should be avoided when potential for solids in water supply capable of obstructing spray nozzles exists. For the same reason nozzles with individual strainers are not recommended; see Section 5.5 for discussion of strainers. Where possible nozzles should be connected to the top of water lines.

8.5 Hydraulic Calculations and Drawings

Hydraulic calculations should be performed in accordance with NFPA 15. The system shall be designed so that the pressure at each nozzle is in accordance with its listing. The discharge pressure of nozzles in outdoor locations should not be less than 30 psi (210 kilopascals) at the most hydraulically remote nozzle. Original hydraulic design calculations shall be maintained and updated for each revision. As-built drawings with revisions shall be maintained.

8.6 Piping

Piping downstream of a system control valve should normally be dry. Provisions should be made to drain the piping after it has flowed. Care shall be taken in the design and installation of spray systems to minimize the number of low points and “trapped” sections of pipe that will require drains. Take-offs should be from the top of lines to minimize the potential for plugging. Water headers should have flush-out connections. The design and installation of water spray piping should not interfere with maintenance or the operation of process equipment. In areas where freezing of the water supply is possible, winterizing freeze protection should be provided for normally stagnant above ground water supply piping up to and including the control valve. Piping unions may be beneficial to facilitate removal during maintenance; however, screwed unions should not be used on pipe larger than 2 in. (51 mm). Choice and application of fittings should be in accordance with NFPA 15.

9 Testing and Maintenance

9.1 Flushing

In all water spray systems, the piping should be thoroughly flushed to remove any debris before the nozzles are installed for flow testing. Flushing connections should be provided on the end of cross mains and feed mains $2^{1}/_{2}$ in. (63.5 mm) and larger in diameter. Flushing connections should be provided for strainers (as discussed in Section 5.5). Systems that use salt water should be flushed with fresh water.

9.2 Hydrostatic Testing

The piping system should be hydrostatically tested for two hours at a pressure of 200 psig (1380 kilopascals) or, when the maximum operating pressure exceeds 150 psig (1035 kilopascals), at a pressure of 50 psig (345 kilopascals) more than the maximum pressure. Plugs should be installed at all nozzle points to provide a closed system for testing. All leaks should be repaired. A static pneumatic leak test of all piping for a pilot-head type detection system and system piping, including instrumentation and actuating devices is recommended. For a successful leak test, the design pressure plus 4 pounds per square inch (28 kilopascals) should be maintained for 24 hours.

9.3 System Flow Testing

Each fixed water spray system should be subjected to a full flow test upon installation, after any modification, and subsequently at a frequency [typically not less frequent than annually] to be determined by the owner to verify system reliability. It may be convenient to schedule the test to be performed during a unit shutdown. During the test, residual pressure, activation time, water spray nozzle positions, and spray patterns should be observed. Containers which can be opened (then closed after timed periods) during a flow test can be placed at various locations in the system to determine if the desired density is being achieved. Plugging and aiming problems should be corrected to provide the intended coverage. The water spray systems should be reset, and all systems should be checked to verify that they are in their normal operating position. Videotaping flow tests may provide a beneficial resource for subsequent analysis and for emergency response training.

9.4 Maintenance

Although water spray systems are intended to enhance safety and plant protection, their effectiveness is only as good as the effectiveness of their maintenance. A program of periodic inspection, testing, and maintenance should be established and administered by persons who are well trained and qualified. NFPA 25 provides relevant guidance.

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