

NFPA 15  
Water Spray  
Fixed Systems  
for Fire  
Protection  
1990 Edition



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There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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**NFPA 15**  
**Standard for**  
**Water Spray Fixed Systems for Fire Protection**  
**1990 Edition**

This edition of NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, was prepared by the Technical Committee on Water Spray Fixed Systems, released by the Correlating Committee on Water Extinguishing Systems, and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 21-24, 1990 in San Antonio, TX. It was issued by the Standards Council on July 20, 1990, with an effective date of August 17, 1990, and supersedes all previous editions.

The 1990 edition of this document has been approved by the American National Standards Institute.

**Origin and Development of NFPA 15**

Standards for Water Spray Systems for Fire Protection, formerly "Water Spray Nozzles and Extinguishing Systems," first prepared by the Committee on Manufacturing Hazards, were tentatively adopted in 1939, with final adoption in 1940. Subsequently, these standards were placed under the jurisdiction of the Committee on Special Extinguishing Systems and a new edition was adopted in 1947. In 1959 the committee organization was further changed to place primary responsibility in the hands of the Committee on Water Spray, under the general supervision of the General Committee on Special Extinguishing Methods. In 1966 the General Committee on Special Extinguishing Methods was discontinued, and the Committee on Water Spray was constituted as an independent committee. Revised editions were presented in 1969, 1973, 1977, 1979, and 1982.

The 1985 edition incorporated several technical changes concerning special piping provisions. The format of the document was also changed to more closely follow the NFPA *Manual of Style*.

Given the limited changes in water spray technology over the past few years, it was apparent that the 1985 edition could be reconfirmed with referenced publications being updated.

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**NOTICE:** An asterisk (\*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 9.

### Foreword

The term "water spray" refers to the use of water in a form having a predetermined pattern, particle size, velocity, and density discharged from specially designed nozzles or devices. Water spray fixed systems are usually applied to special fire protection problems, since the protection can be specifically designed to provide for effective fire control, extinguishment, prevention, or exposure protection. Water spray systems may be independent of, or supplementary to, other forms of protection.

This standard deals with water spray protection from fixed nozzle systems only. It does not cover water spray protection from portable nozzles, sprinkler systems, monitor nozzles, or other means of application covered by other standards of the National Fire Protection Association.

The design of specific systems may vary considerably, depending on the nature of the hazard and the basic purposes of protection. Because of these variations and the wide choice in the characteristics of spray nozzles, these systems must be competently designed, installed, and maintained. It is essential that their limitations as well as their capabilities be thoroughly understood by the designer.

Water spray fixed systems are most commonly used to protect processing equipment and structures, flammable liquid and gas vessels, piping, and equipment such as transformers, oil switches, and motors. Such protection has also been shown to be effective on many combustible solids.

There are several methods of hydraulic calculation that will produce satisfactory results. There is a need, however, for a uniform method of hydraulic calculations for the sake of simplicity and consistency. For this reason a recommended method has been included in Appendix A of this standard.

## Chapter 1 General Provisions

**1-1 Scope.** This standard covers the design, installation, maintenance, and testing of water spray fixed systems for fire protection service.

**1-2 Purpose.** The purpose of this standard is to provide the minimum requirements for fixed water spray systems based upon sound engineering principles, test data, and field experience. Nothing in this standard is intended to restrict new technologies or alternate arrangements providing the level of safety prescribed by the standard is not lowered.

### 1-3 Definitions.

**Approved.** Acceptable to the "authority having jurisdiction."

**NOTE:** The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

**Authority Having Jurisdiction.** The "authority having jurisdiction" is the organization, office, or individual responsible for "approving" equipment, an installation, or a procedure.

**NOTE:** The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local, or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction;" at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

**Automatic Detection Equipment.** Equipment that will automatically detect heat, flame, smoke, flammable gases, or other conditions likely to produce fire or explosion and cause automatic actuation of alarm and protection equipment.

**Control of Burning.** Application of water spray to equipment or areas where a fire may occur to control the rate of burning and thereby limit the heat release from a fire until the fuel can be eliminated or extinguishment effected.

**Density.** The unit rate of water application to an area or surface expressed in gallons per minute per square foot [(L/min)/m<sup>2</sup>].

**Exposure Protection.** Application of water spray to structures or equipment to limit absorption of heat to a level that will minimize damage and prevent failure, whether source of heat is external or internal.

**Fire Detection Equipment.** Equipment which will automatically detect one or more components directly related to combustion such as heat, smoke, flame and other fire phenomenon.

**Flammable and Combustible Liquids.** See NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids*.

**Flammable Gas Detection Equipment.** Equipment that will automatically detect a percent volume concentration of a flammable gas or vapor relative to a predetermined level. References to flammable gas detectors in this document shall mean continuous analyzing catalytic diffusion-type flammable gas detectors.

**Flammable (Explosive) Limits.** See NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*.

**Impingement.** The striking of a protected surface by water droplets issuing directly from a water spray nozzle.

**Insulated Equipment, Structures, or Vessels.\*** Equipment, structures, or vessels provided with insulation that, for the expected duration of exposure, will protect steel from exceeding a temperature of 850°F (454°C) for structural members, or 650°F (343°C) for vessels, and where the insulation system is:

- (a) Noncombustible and fire retardant,
- (b) Mildew and weather resistant,
- (c) Resistant to the force of hose streams, and
- (d) Secured by fire and corrosion resistant fastenings.

**Labeled.** Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

**Listed.** Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specific manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

**Nonabsorbing Ground.** Earth or fill that is not readily permeable or absorbent to large quantities of flammable or combustible liquid or water or both. Most soils are not considered sufficiently permeable or absorbent to be considered absorbing ground. Pavings, such as concrete or asphalt, are considered nonabsorbing.

**Rundown.** The downward travel of water along a surface, caused by the momentum of the water or by gravity.

**Shall.** Indicates a mandatory requirement.

**Should.** Indicates a recommendation or that which is advised but not required.

**Slippage.** The horizontal component of the travel of water along a surface beyond the point of impact, caused by the momentum of the water.

**Water Spray Nozzle.** A normally open water discharge device that, when supplied with water under pressure, will distribute the water in a special, directional pattern peculiar to the particular device. (See Section 4-8.)

**Water Spray System.** A special fixed pipe system connected to a reliable source of fire protection water supply and equipped with water spray nozzles for specific water discharge and distribution over the surface or area to be protected. The piping system is connected to the water supply through an automatically or manually actuated valve that initiates the flow of water. An automatic valve is actuated by operations of automatic detection equipment installed in the same areas as the water spray nozzles. (In special cases the automatic detection equipment may also be located in another area.)

**Water Wastage.** That discharge from water spray nozzles that is ineffective on the surface being protected. Some causes of wastage are wind velocity and sometimes the overcarry of discharge pattern beyond the targeted surface.

**Wet Water.** Any water to which a compatible wetting agent has been added in quantities specified by the manufacturer.

#### 1-4 Applicability.

**1-4.1** Water spray is applicable for protection of specific hazards and equipment and may be installed independently of or supplementary to other forms of fire protection systems or equipment.

**1-4.2 Hazards.** Water spray protection is acceptable for the protection of hazards involving:

- (a) Gaseous and liquid flammable materials,
- (b) Electrical hazards such as transformers, oil switches, motors, cable trays, and cable runs,
- (c) Ordinary combustibles such as paper, wood, and textiles,
- (d) Certain hazardous solids.

**1-5\* Uses.** In general, water spray may be used effectively for any one or a combination of the following purposes:

- (a) Extinguishment of fire,
- (b) Control of burning,
- (c) Exposure protection,
- (d) Prevention of fire.

**1-6 Limitations.** There are limitations to the use of water spray that shall be recognized. Such limitations involve the nature of the equipment to be protected, the physical and chemical properties of the materials involved, and the environment of the hazard.

Other standards also consider limitations to the application of water (sloper, frothing, electrical clearances, etc.). (See NFPA 49, *Hazardous Chemicals Data*, and NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*.)

### 1-7 Materials Involved.

**1-7.1** A careful study shall be made of the physical and chemical properties of the materials for which water spray protection is being considered, in order to determine the advisability of its use. The flash point, specific gravity, viscosity, miscibility, and solubility of the material, temperature of the water spray, and the normal temperature of the hazard to be protected are among the factors that must be given consideration.

**1-7.2** The sloper or frothing hazard shall be considered where water spray may encounter confined materials at a high temperature or having a wide distillation range.

**1-7.3** Water soluble materials, such as alcohol, require special consideration. Fires involving spills of such materials may usually be controlled, until extinguished by dilution, and in some cases the surface fire may be extinguished by an adequate application rate and coverage. Each water soluble material shall be tested under the conditions of use to determine the applicability of a water spray system, unless sufficient supportive data is already available.

**1-7.4\*** Water spray shall not be used for direct application to materials that react with water, such as metallic sodium or calcium carbide, which produce violent reactions or increase hazardous products as a result of heated vapor emission; or for liquefied gases at cryogenic temperatures (such as liquefied natural gas), which boil violently when heated by water.

**1-8 Equipment Involved.** Consideration shall be given to the possibility of damage, distortion, or failure of equipment operating at high surface temperatures.

**1-9 Electrical Clearances.** All system components shall be so located as to maintain minimum clearances from live parts as shown in Table 1-9.

As used in this standard, "clearance" is the air distance between water spray equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential. The minimum clearances listed in Table 1-9 are for the purpose of electrical clearance under normal conditions; they are not intended for use as "safe" distances during fixed water spray system operation.

The clearances given are for altitudes of 3,300 ft (1000 m) or less. At altitudes in excess of 3,300 ft (1000 m) the clearance shall be increased at the rate of 1 percent for each 330 ft (100 m) increase in altitude above 3,300 ft (1000 m).

The clearances are based upon minimum general practices related to design Basic Insulation Level (BIL) values. To coordinate the required clearance with the electrical design, the design BIL of the equipment being protected shall be used as a basis, although this is not material at nominal line voltages of 161 kV or less.

Up to electrical system voltages of 161 kV, the design BIL kV and corresponding minimum clearances, phase to ground, have been established through long usage.

At voltages higher than 161 kV, uniformity in the relationship between design BIL kV and the various electrical system voltages has not been established in practice. For these higher system voltages it has become common practice to use BIL levels dependent on the degree of protection that is to be obtained. For example, in 230 kV systems, BILs of 1050, 900, 825, 750, and 650 kV have been utilized.

Required clearance to ground may also be affected by switching surge duty, a power system design factor that along with BIL must correlate with selected minimum clearances. Electrical design engineers may be able to furnish clearances dictated by switching surge duty. Table 1-9 deals only with clearances required by design BIL. The selected clearance to ground shall satisfy the greater of switching surge or BIL duty, rather than to be based upon nominal voltage.

**Table 1-9**  
Clearance from Water Spray Equipment  
to Live Uninsulated Electrical Components

Nominal System Voltage (kV)	Maximum System Voltage (kV)	Design BIL (kV)	Minimum* (in.)	Clearance (mm)
To 13.8	14.5	110	7	178
23	24.3	150	10	254
34.5	36.5	200	13	330
46	48.3	250	17	432
69	72.5	350	25	635
115	121	550	42	1067
138	145	650	50	1270
161	169	750	58	1473
230	242	900	76	1930
		1050	84	2134
345	362	1050	84	2134
		1300	104	2642
500	550	1500	124	3150
		1800	144	3658
765	800	2050	167	4242

\*For voltages up to 161 kV the clearances are taken from NFPA 70, *National Electrical Code*®. For voltages 230 kV and above the clearances are taken from Table 124 of ANSI C-2, *National Electrical Safety Code*.

NOTE: BIL values are expressed as kilovolts (kV), the number being the crest value of the full wave impulse test that the electrical equipment is designed to withstand. For BIL values that are not listed in the table, clearances may be found by interpolation.

Possible design variations in the clearance required at higher voltages are evident in the table, where a range of BIL values is indicated opposite the various voltages in the high voltage portion of the table. However, the clearance between uninsulated energized parts of the electrical system equipment and any portion of the water spray system shall not be less than the minimum clearance provided elsewhere for electrical system insulations on any individual component.

**1-9.1** When the design BIL is not available, and when nominal voltage is used for the design criteria, the highest minimum clearance listed for this group shall be used.

**1-10 System Design.** Water spray system design shall be entrusted only to responsible persons fully experienced in this field. (See Section 4-1.)

**1-11 Certification of Water Spray Systems.** The contractor shall prepare and submit a description and diagram of the system and its purpose, maintenance and instruction bulletins, and the applicable parts of the Sprinkler Contractors Certificate covering material and tests (see NFPA 13, *Standard for the Installation of Sprinkler Systems*) certifying that the work has been completed and tested in accordance with plans and specifications, before requesting final approval of the water spray system.

**1-12 Units.** Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection. These units are listed in Table 1-12 with conversion factors.

Table 1-12

Name of Unit	Unit Symbol	Conversion Factor
liter	L	1 gal = 3.785 L
liter per minute per square meter	(L/min)/m <sup>2</sup>	1 gpm/ft <sup>2</sup> = 40,746 (L/min)/m <sup>2</sup>
cubic decimeter	dm <sup>3</sup>	1 gal = 3.785 dm <sup>3</sup>
Pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 10 <sup>5</sup> Pa

For additional conversions and information see ASTM E380, *Standard for Metric Practice*.

**1-12.1** If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value may be approximate.

**1-12.2** The conversion procedure for the SI units has been to multiply the quantity by the conversion factor and then round the result to the appropriate number of significant digits.

## Chapter 2 System Components

### 2-1 Component Parts.

**2-1.1** All component parts shall be coordinated to provide complete systems. Systems shall be operable by automatic means with supplementary manual tripping means.

Manual operation, only, is acceptable where:

(a) Automatic operation of the system presents a hazard to personnel, or

(b) A system is isolated and is attended by trained personnel at all times.

**2-1.2** Only listed new materials and devices shall be employed in the installation of systems except that, where age and condition permit, listed devices such as special system water control valves and their accessories, circuit closers, water motor alarm devices, nonautomatic pattern spray nozzles, etc., may be reused, but if reused they shall be reconditioned by the original manufacturer. The original manufacturer shall furnish a certificate stating that such specified devices have been reconditioned and tested and are considered satisfactory for reuse.

**2-1.3** For protection of piping components (such as pipe, fittings, valves, pipe supports, etc.) against damage where subject to earthquake, see the applicable sections of NFPA 13, *Standard for the Installation of Sprinkler Systems*.

**2-2 Corrosion Protection.** System components installed out of doors, or in the presence of a corrosive atmosphere, shall be constructed of materials that will resist corrosion or be covered with protective coatings. The threaded ends of galvanized pipe, after installation, shall be protected against corrosion.

**2-3 Spray Nozzles.** Care shall be taken in the application of nozzle types. Distance of "throw" or location of nozzle from surface shall be limited by the nozzle's discharge characteristics. (See Section 4-8.)

Care shall also be taken in the selection of nozzles to obtain waterways that are not easily obstructed by debris, sediment, sand, etc., in the water. Requirements for strainers and their placement are described in Sections 2-10 and 4-11.

### 2-4 Piping.

**2-4.1** Pipe and tube used in water spray systems shall be of the materials listed in Table 2-4.1. The chemical properties, physical properties, and dimensions of the materials listed in Table 2-4.1 shall conform at least to the standards cited in the table. Pipe and tube used in water spray systems shall be designed to withstand a working pressure of not less than 175 psi (12.1 bars). Whenever the word "pipe" is used, it shall be understood to also mean "tube."

Table 2-4.1  
Piping Specifications

Ferrous Piping (Welded & Seamless)	
Specification for Welded and Seamless Steel Pipe	ASTM A53
Specification for Electric-Resistance-Welded Steel Pipe	ASTM A135
Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use	ASTM A795
Wrought Steel Pipe — Dimensional Standardization	ANSI B36.10

**2-4.2** When steel pipe listed in Table 2-4.1 is used and joined by threaded fittings referenced in 2-5.1 or by couplings used with pipe having cut grooves, the minimum wall thickness shall be in accordance with Schedule 30 (in sizes 8 in. and larger) or Schedule 40 (in sizes less than 8 in.) in Table A-2 of ASTM A53 for pressures up to 300 psi (20.7 bars).

*Exception:* When welded and seamless steel pipe listed in Table 2-4.1 is used and joined by welding or by rolled groove coupling systems, a minimum pipe wall thickness equivalent to Schedule 10 pipe, as specified in ASTM A135, is permitted for pressures up to 300 psi (20.7 bars) for pipe sizes up to 5-in., 0.134 in. (3.40 mm) for 6-in., and 0.188 in. (4.78 mm) for 8-in. and 10-in. pipe.

**2-4.3** Galvanized pipe shall be used.

*Exception No. 1:* Black steel pipe may be used in atmospheres that are noncorrosive or detrimental to galvanized pipe and where orifices of the spray nozzles are larger than  $\frac{3}{8}$  in. (9.5 mm).

*Exception No. 2:* Where the atmosphere or the system water will cause excessive corrosion in black or galvanized steel pipe, other types of metallic piping or coated pipe shall be used.

**2-4.4** The galvanizing of galvanized pipe shall be in accordance with specifications of the above standards.

**2-4.5** Other pipe or tubing that has been investigated and listed for this service by a testing and inspection agency may be used. The use of such tubing shall involve careful consideration of the following factors:

- (a) Pressure rating,
- (b) Beam strength (hangers and spacing),
- (c) Corrosion (chemical and electrolytic),
- (d) Methods of joining (strength, permanence, fire endurance),
- (e) Availability of fittings (less for water spray nozzle outlets and proper routing),
- (f) Resistance to limited exposure time without water and resistance to rapid temperature change and steam pressure generated upon the admittance of water.

## 2-5 Fittings.

**2-5.1** All fittings shall be of a type specifically approved for fire protection systems and of a design suitable for the working pressures involved, but not less than 175 psi (12.1 bars) cold water pressures. Ferrous fittings shall be of steel, malleable iron, or ductile iron in dry sections of the piping exposed to possible fire or in self-supporting systems. Galvanized fittings shall be used where galvanized pipe is required.

Examples of materials used for fittings are:

Ductile Iron Fittings	ASTM A536
Malleable Iron Fittings	ANSI B16.3
Wrought Steel Buttwelding	ANSI B16.9

**2-5.2** Rubber-gasketed fittings may be used to connect pipe in fire exposed areas when the water spray system is automatically controlled. Fire exposed areas in which these fittings are located shall be protected by automatic water spray systems or other approved means.

**2-6 Hangers.** Hangers shall be of a type approved for use with the piping involved. (See Section 4-10.)

Hangers used outdoors or in locations where corrosive conditions exist shall be galvanized or suitably coated for protection against the corrosive conditions of the location.

**2-7 Valves.** All valves shall be of a type approved for the purpose. Manual shutoff or control valves shall be of the indicating type.

## 2-8 Control Equipment.

**2-8.1** Automatic valves shall be special system water control valves approved for the use intended.

**2-8.2** Control of automatic valves shall be by means of approved accessories for special systems.

**2-8.3** Manual devices may actuate the automatic control valves by mechanical, hydraulic, pneumatic, electrical, or other approved means. The manual device shall be amply strong to prevent breakage. Manual controls shall not require a pull of more than 40 lb (force) (178 N) nor a movement of more than 14 in. (356 mm) to secure operation.

**2-8.4** Automatic detection equipment shall be of a type listed by a testing laboratory for the intended usage, such as with special system water control valves. When used, electrical-type detection equipment shall meet the area electrical classification in which the equipment will be used.

**2-8.4.1** Automatic flammable gas detection equipment shall be calibrated for the specific flammable gas involved.

**2-9 Pressure Gages.** Required pressure gages shall be of approved type and shall have a maximum limit not less than twice the normal working pressure when installed. They shall be so installed as to permit easy removal and shall be located where they will not be subject to freezing.

## 2-10 Strainers.

**2-10.1** Pipeline strainers shall be specifically approved for use in water supply connections. Strainers shall be capable of removing from the water all solids of sufficient size to obstruct the spray nozzles [normally  $\frac{1}{8}$ -in. (3.2-mm) perforations are suitable]. In addition, the strainer shall be capable of continued operation without serious increase in head loss, for a period estimated to be ample when considering the type of protection provided, the condition of the water, and similar local circumstances. (See 4-11.3.)

**2-10.2** Pipeline strainer designs shall incorporate a flushout connection.

**2-10.3** Individual strainers for spray nozzles, where required, shall be of approved type capable of removing from the water all solids of sufficient size to obstruct the spray nozzle they serve.

## 2-11\* Alarms.

**2-11.1** The location, purpose, and type of system shall determine the alarm service to be provided.

**2-11.2** An alarm, actuated independently of water flow, to indicate operation of the detection system shall be provided on each automatically controlled system.

**2-11.3** Electrical fittings and devices designed for use in hazardous locations shall be used where required by NFPA 70, *National Electrical Code*.

**2-12 Fire Department Connections.** Fire department connections, where used, shall be of a type approved for the purpose. (See 3-3.2.)

**2-13 Flushing Connections.** A suitable flushing connection shall be incorporated in the design of the system to facilitate routine flushing as required by 6-2.9.

### Chapter 3 Water Supplies

**3-1 General.** It is of vital importance that water supplies be selected that provide water as free as possible from foreign materials.

#### 3-2 Volume and Pressure.

**3-2.1\*** The water supply flow rate and pressure shall be capable of maintaining water discharge at the design rate and duration for all systems designed to operate simultaneously.

**3-2.2** For water supply distribution systems, an allowance for the flow rate of hose streams or other fire protection water requirements shall be made in determining the maximum demand.

Sectional control shutoff valves shall be located with particular care so that they will be accessible during an emergency.

**3-2.3** When only a limited water source is available, sufficient water for a second operation shall be provided so that the protection can be reestablished without waiting for the supply to be replenished.

#### 3-3 Sources.

**3-3.1\*** The water supply for water spray systems shall be from reliable fire protection water supplies, such as:

- (a) Connections to waterworks systems,
- (b) Gravity tanks (in special cases pressure tanks), or
- (c) Fire pumps with adequate water supply.

**3-3.2\* Fire Department Connections.** One or more fire department connections shall be provided in all cases where water supply is marginal and/or where auxiliary or primary water supplies may be augmented by the response of suitable pumper apparatus responding to the emergency. Fire department connections are valuable only when fire department pumping capacities can equal maximum demand flow rate. Careful consideration shall be given to such factors as the purpose of the system, reliability, and capacity and pressure of the water system. The possibility of serious exposure fires and similar local conditions shall be considered. A pipeline strainer in the fire department connection shall be provided if indicated by Section 4-11. Where a fire department connection is required, suitable suction provisions for the responding pumper apparatus shall be provided.

NOTE: See also the applicable sections of NFPA 13, *Standard for the Installation of Sprinkler Systems*; NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*; and NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

### Chapter 4 System Design and Installation

**4-1 Workmanship.** Water spray system design, layout, and installation shall be entrusted to none but fully experienced and responsible parties. Water spray system installation is a specialized field of sprinkler system installation that is a trade in itself.

**4-2 Plans, Specifications, and Hydraulic Calculations.** Before a water spray system is installed or existing equipment remodeled, complete working plans, specifications, and hydraulic calculations shall be prepared and made available to interested parties. For details concerning plans, specifications, and hydraulic calculations, see Chapter 7.

**4-3\* Design Guides.** Water spray system designs shall conform to the applicable requirements of the following standards of the National Fire Protection Association, except where otherwise specified herein:

NFPA 13	<i>Installation of Sprinkler Systems</i>
NFPA 14	<i>Installation of Standpipe and Hose Systems</i>
NFPA 18	<i>Wetting Agents</i>
NFPA 20	<i>Installation of Centrifugal Fire Pumps</i>
NFPA 22	<i>Water Tanks for Private Fire Protection</i>
NFPA 24	<i>Installation of Private Fire Service Mains and Their Appurtenances</i>
NFPA 70	<i>National Electrical Code</i>
NFPA 71	<i>Central Station Signaling Systems</i>
NFPA 72	<i>Protective Signaling Systems</i>
NFPA 72E	<i>Automatic Fire Detectors</i>

**4-3.1** Components of the electrical portions of these protective systems, where installed in locations subject to hazardous vapors or dusts, shall be of types approved for use therein.

#### 4-4 Density and Application.

##### 4-4.1\* Extinguishment.

**4-4.1.1** Extinguishment of fires by water spray may be accomplished by surface cooling, by smothering from produced steam, by emulsification, by dilution, or by various combinations thereof. Systems shall be designed so that, within a reasonable period of time, extinguishment shall be accomplished and all surfaces shall be cooled sufficiently to prevent flashback occurring after the system is shut off.

**4-4.1.2** The design density for extinguishment shall be based on test data or knowledge concerning conditions similar to those that will apply in the actual installation. A general range of water spray application rates that will apply to most ordinary combustible solids or flammable liquids is from 0.2 gpm per sq ft to 0.5 gpm per sq ft [8.1 (L/min)/m<sup>2</sup> to 20.4 (L/min)/m<sup>2</sup>] of protected surface.

NOTE: There is some data available on water application rates needed for extinguishment of certain combustibles or flammables; however, much additional test work is needed before minimum rates can be established.

**4-4.1.3\*** Each of the following methods or a combination of them shall be considered when designing a water spray system for extinguishment purposes:

- (a) Surface cooling,
- (b) Smothering by produced steam,
- (c) Emulsification,
- (d) Dilution,
- (e) Other factors.

**4-4.1.4\* Cable Trays and Cable Runs.** When insulated wire and cable or nonmetallic tubing is to be protected by an automatic water spray (open nozzle) system maintained for extinguishment of fire that originates within the cable or tube (i.e., the insulation or tubing is subject to ignition and propagation of fire), the system shall be hydraulically designed to impinge water directly on each tray or group of cables or tubes at the rate of 0.15 gpm per sq ft [6.1 (L/min)/m<sup>2</sup>] on the horizontal or vertical plane containing the cable or tubing tray or run.

*Exception: Other water spray densities and methods of application may be used if verified by test and acceptable to the authority having jurisdiction.*

Automatic detection devices shall be sufficiently sensitive to rapidly detect smoldering or slow-to-develop flames. When it is contemplated that spills of flammable liquids or molten materials will expose cables, nonmetallic tubing, and tray supports, design of protection systems shall be in accordance with that recommended for exposure protection. [See 4-4.3.3(d).]

#### 4-4.2 Control of Burning.

**4-4.2.1** A system for the control of burning shall function at full effectiveness until there has been time for the flammable materials to be consumed, for steps to be taken to shut off the flow of leaking material, for the assembly of repair forces, etc. System operation for hours may be required.

**4-4.2.2** Nozzles shall be installed to impinge on the areas of the source of fire and where spills may travel or accumulate. The water application rate on the probable surface of the spill shall be at the rate of not less than 0.50 gpm per sq ft [20.4 (L/min)/m<sup>2</sup>].

**4-4.2.3** Pumps or other devices that handle flammable liquids or gases shall have the shafts, packing glands, connections, and other critical parts enveloped in directed water spray at a density of not less than 0.50 gpm per sq ft [20.4 (L/min)/m<sup>2</sup>] of projected surface area.

#### 4-4.3 Exposure Protections.

##### 4-4.3.1\* General.

(a) The system shall be able to function effectively for the duration of the exposure fire that is estimated from a knowledge of the nature and quantities of the combustibles and

the probable effect of fire fighting equipment and materials. System operation for hours may be required.

(b) Automatic water spray systems for exposure protection shall be designed to operate before the formation of carbon deposits on the surfaces to be protected and before the possible failure of any containers of flammable liquids or gases because of the temperature rise. The system and water supplies shall, therefore, be designed to discharge effective water spray from all nozzles within 30 seconds following operation of the detection system.

(c) The densities specified for exposure protection contemplate minimal wastage of 0.05 gpm per sq ft [2.0 (L/min)/m<sup>2</sup>]. (See Section 4-8.)

##### 4-4.3.2\* Vessels.

(a) These rules for exposure protection contemplate emergency relieving capacity for vessels, based upon a maximum allowable heat input of 6,000 Btu per hour per sq ft (18 930 W/m<sup>2</sup>) of exposed surface area. The density shall be increased to limit the heat absorption to a safe level in the event required emergency relieving capacity is not provided.

(b) Water shall be applied to vertical or inclined vessel surfaces at a net rate of not less than 0.25 gpm per sq ft [10.2 (L/min)/m<sup>2</sup>] of exposed uninsulated surface.

(c) Where rundown is contemplated for vertical or inclined surfaces the vertical distance between nozzles shall not exceed 12 ft (3.7 m).

(d) The horizontal extremities of spray patterns shall at least meet.

(e) Spherical or horizontal cylindrical surfaces below the vessel equator cannot be considered wettable from rundown.

(f) Where projections (manhole flanges, pipe flanges, support brackets, etc.) will obstruct water spray coverage, including rundown or slippage on vertical surfaces, additional nozzles shall be installed around the projections to maintain the wetting pattern that otherwise would be seriously interrupted.

(g) Bottom and top surfaces of vertical vessels shall be completely covered by directed water spray at an average rate of not less than 0.25 gpm per sq ft [10.2 (L/min)/m<sup>2</sup>] of exposed uninsulated surface. Consideration may be given to slippage but on the bottom surfaces the horizontal extremities of spray patterns shall at least meet.

(h) Special attention shall be given to distribution of water spray around relief valves and around supply piping and valve connection projections.

(i) Uninsulated vessel skirts shall have water spray applied on one exposed (uninsulated) side, either inside or outside, at a net rate of not less than 0.10 gpm per sq ft [4.1 (L/min)/m<sup>2</sup>].

##### 4-4.3.3 Structures and Miscellaneous Equipment.

(a) Horizontal, stressed (primary) structural steel members shall be protected by nozzles spaced not greater than 10 ft (3 m) on centers (preferably on alternate sides) and of such size and arrangement as to discharge not less than 0.10 gpm per sq ft [4.1 (L/min)/m<sup>2</sup>] over the wetted area. (See Figure 4-4.3.3.)

(b) Vertical structural steel members shall be protected by nozzles spaced not greater than 10 ft (3 m) on centers (preferably on alternate sides) and of such size and arrangement

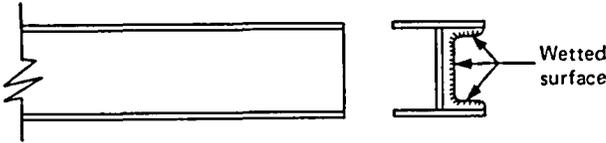


Figure 4-4.3.3 The wetted surface of structural member — beam or column — is defined as one side of the web and the inside surface of one side of the flanges as shown above.

as to discharge not less than 0.25 gpm per sq ft [10.2 (L/min)/m<sup>2</sup>] over the wetted area. (See Figure 4-4.3.3.)

(c) Metal pipe, tubing, and conduit runs shall be protected by water spray directed towards the horizontal plane surface projected by the bottom of the pipes or tubes.

Nozzles shall be selected to provide essentially total impingement on the entire horizontal surface area within which pipes or tubes are or could be located.

For single-level pipe racks, water spray nozzles shall discharge onto the underside of the pipe at a plan view density of 0.25 gpm per sq ft [10.2 (L/min)/m<sup>2</sup>].

For two-level pipe racks, water spray nozzles shall discharge onto the underside of the lower level at a plan view density of 0.20 gpm per sq ft [8.2 (L/min)/m<sup>2</sup>] and additional spray nozzles shall discharge onto the underside of the upper level at a plan view density of 0.15 gpm per sq ft [6.1 (L/min)/m<sup>2</sup>].

For three-, four-, and five-level pipe racks, water spray nozzles shall discharge onto the underside of the lowest level at a plan view density of 0.20 gpm per square foot [8.2 (L/min)/m<sup>2</sup>] and additional spray nozzles shall discharge onto the underside of alternate levels at a plan view density of 0.15 gpm per sq ft [6.1 (L/min)/m<sup>2</sup>]. Water spray shall be applied to the underside of the top level even if immediately above a protected level.

For pipe racks of six or more levels, water spray nozzles shall discharge onto the underside of the lowest level at a plan view density of 0.20 gpm per sq ft [8.2 (L/min)/m<sup>2</sup>] and additional spray nozzles shall discharge onto the underside of alternate levels at a plan view density of 0.10 gpm per sq ft [4.1 (L/min)/m<sup>2</sup>]. Water spray shall be applied to the underside of the top level even if immediately above a protected level.

Water spray nozzles are to be selected and located such that extremities of water spray patterns shall at least meet and the discharge shall essentially be confined to the plan area of the pipe rack.

Spacing between nozzles shall not exceed 10 ft (3 m) and nozzles shall be no more than 2 ft 6 in. (0.8 m) below the bottom of the pipe level being protected.

Consideration shall be given to obstruction to the spray patterns presented by pipe supporting steel. Where such interferences exist, nozzles shall be spaced within the bays.

Structural supports shall be protected in accordance with 4-4.3.3(a) and 4-4.3.3(b).

*Exception No. 1: Water spray protection with the same density as specified previously may be applied to the top of pipes on racks where water spray piping cannot be installed below the rack due to possibility of physical damage or space is inadequate for proper installation.*

*Exception No. 2: Vertically stacked piping may be protected by water spray directed at one side of the piping at a density of 0.15 gpm per sq ft [6.1 (L/min)/m<sup>2</sup>].*

(d) *Cable Trays and Cable Runs.* When electrical cables or tubing in open trays or runs are to be protected by water spray from fire or spill exposure, a basic rate of 0.3 gpm per sq ft [12.2 (L/min)/m<sup>2</sup>] of projected horizontal or vertical plane area containing the cables or tubes shall be provided. Water spray nozzles shall be arranged to supply water at this rate over and under or to the front and rear of cable or tubing runs and to the racks and supports.

Where flame shields equivalent to 1/8-in. (1.6-mm) thick steel plate are mounted below cable or tubing runs, the water density requirements may be reduced to 0.15 gpm per sq ft [6.1 (L/min)/m<sup>2</sup>] over the upper surface of the cable or rack. The steel plate or equivalent flame shield shall be wide enough to extend at least 6 in. (152 mm) beyond the siderails of the tray or rack in order to deflect flames or heat emanating from spills below cable or conduit runs.

Where other water spray nozzles are arranged to extinguish, control, or cool exposing liquid surfaces, the water spray density may be reduced to 0.15 gpm per sq ft [6.1 (L/min)/m<sup>2</sup>] over the upper surface, front, or back of the cable or tubing tray or run.

Fixed water spray systems designed for protecting cable or tubing and their supports from heat of exposure from flammable or molten liquid spills shall be automatically actuated.

#### 4-4.3.4 Transformers.

(a) Transformer protection shall contemplate essentially complete impingement on all exterior surfaces, except underneath surfaces that in lieu thereof may be protected by horizontal projection. The water shall be applied at a rate not less than 0.25 gpm per sq ft [10.2 (L/min)/m<sup>2</sup>] of projected area of rectangular prism envelope for the transformer and its appurtenances and not less than 0.15 gpm per sq ft [6.1 (L/min)/m<sup>2</sup>] on the expected nonabsorbing ground surface area of exposure. Additional application is needed for special configurations, conservator tanks, pumps, etc. Spaces greater than 12 in. (305 mm) in width between radiators, etc., shall be individually protected.

(b) Water spray piping shall not be carried across the top of the transformer tank, unless impingement cannot be accomplished with any other configuration and provided the required distance from the live electrical components is maintained. (See Section 1-9.)

(c) In order to prevent damage to energized bushings or lightning arrestors, water spray shall not envelop this equipment by direct impingement, unless so authorized by the manufacturer or manufacturer's literature and the owner.

#### 4-4.3.5 Belt Conveyors.

(a) *Drive Unit.* Water spray system shall be installed to protect the drive rolls, the take-up rolls, the power units and the hydraulic-oil unit. The rate of water application shall be 0.25 gpm per sq ft [10.2 (L/min)/m<sup>2</sup>] of roll and belt.

Nozzles shall be located to direct water spray onto the surfaces to extinguish fire in hydraulic oil, belt, or contents on the belt. Water spray impingement on structural elements shall be such as to provide protection against radiant heat or impinging flame.

(b) *Conveyor Belt.* Water spray system shall be installed to automatically wet the top belt, its contents, and the bottom return belt. Discharge patterns of water spray nozzles shall envelop, at a rate of 0.25 gpm per sq ft [10.2 (L/min)/m<sup>2</sup>] of top and bottom belt area, the structural parts and the idler-rolls supporting the belt. Water spray system protection shall be extended onto transfer belts, transfer equipment, and transfer buildings beyond each transfer point. Or, systems for the protection of adjacent belts or equipment shall be interlocked in such a manner that the feeding belt water spray system will automatically actuate the water spray system protecting the first segment of the downstream equipment.

Special consideration shall be given to the interior protection of the building, gallery, or tunnel housing the belt conveyor equipment.

Also, the exterior structural supports for galleries shall be protected from exposure such as fires in flammables located adjacent to the galleries.

The effectiveness of belt conveyor protection is dependent upon rapid detection and appropriate interlocks between the detection system and the machinery. (See *Chapter 8.*)

#### 4-4.4\* Fire and Explosion Prevention.

4-4.4.1 The system shall be able to function effectively for a sufficient time to dissolve, dilute, disperse, or cool flammable or hazardous materials. The possible duration of release of the materials shall be considered in the selection of duration times.

4-4.4.2 The rate of application shall be based upon experience with the product or upon test.

4-5\* **Size of System.** Separate fire areas shall be protected by separate systems. Single systems shall be kept as small as practicable, giving consideration to the water supplies and other factors affecting reliability of the protection. The hydraulically designed discharge rate for a single system or multiple systems designed to operate simultaneously shall not exceed the available water supply. (See *Chapter 3.*)

#### 4-6 Separation of Fire Areas.

4-6.1 Separation of fire areas shall be by space, fire barriers, diking, special drainage, or by combination of these. In the separation of fire areas consideration shall be given to the possible flow of burning liquids before or during operation of the water spray systems.

#### 4-6.2\* Area Drainage.

(a) Adequate provisions shall be made to promptly and effectively dispose of all liquids from the fire area during operation of all systems in the fire area. Such provisions shall be adequate for:

1. Water discharged from fixed fire protection systems at maximum flow conditions.
2. Water likely to be discharged by hose streams.
3. Surface water.
4. Cooling water normally discharged to the system.

(b) There are four methods of disposal or containment:

1. Grading.
2. Diking.
3. Trenching.
4. Underground or enclosed drains.

(c) The method used shall be determined by:

1. The extent of the hazard.
2. The clear space available.
3. The protection required.

Where the hazard is low, the clear space is adequate, and the degree of protection required is not great, grading is acceptable. Where these conditions are not present, consideration shall be given to dikes, trenching, or underground or enclosed drains.

(d) For the methods of drainage or diking, see NFPA 30, *Flammable and Combustible Liquids Code.*

#### 4-7 Valves.

4-7.1 **Shutoff Valves.** Each system shall be provided with a shutoff valve so located as to be readily accessible during a fire in the area the system protects or adjacent areas, or, for systems installed for fire prevention, during the existence of the contingency for which the system is installed.

4-7.1.1 Valves controlling water spray systems, except underground gate valves with roadway boxes, shall be supervised open by one of the following methods:

- (a) Central station, proprietary or remote station alarm service.
- (b) Local alarm service that will cause the sounding of an audible signal at a constantly attended point.
- (c) Locking valves open.
- (d) Sealing of valves and approved weekly recorded inspection when valves are located within fenced enclosures under the control of the owner. (See *NFPA 26, Recommended Practices for the Supervision of Valves Controlling Water Supplies for Fire Protection.*)

#### 4-7.2 Automatically Controlled Valves.

(a) Automatically controlled valves shall be as close to the hazard protected as accessibility during the emergency will permit, so that a minimum of piping is required between the automatic valve and the spray nozzles.

(b) Remote manual tripping devices, where required, shall be conspicuously located where readily accessible during the emergency and adequately identified as to the system controlled.

4-7.3 **Drain Valves.** Readily accessible drains shall be provided for low points in underground and aboveground piping.

#### 4-8 Spray Nozzles.

4-8.1 **Selection.** The selection of the type and size of spray nozzles shall be made with proper consideration given to such factors as physical character of the hazard involved, draft or

wind conditions, material likely to be burning, and the general purpose of the system. (See Section 2-3.)

**4-8.2 Position.** Spray nozzles may be placed in any position necessary to obtain proper coverage of the protected area. Positioning of nozzles with respect to surfaces to be protected, or to fires to be controlled or extinguished, shall be guided by the particular nozzle design and the character of water spray produced. The effect of wind and fire draft on very small drop sizes or on larger drop sizes with little initial nozzle velocity shall be considered, since these factors will limit the distance between nozzle and surface and will limit the effectiveness of exposure protection, fire control, or extinguishment. Care shall be taken in positioning nozzles that water spray does not miss the targeted surface and reduce the efficiency or calculated discharge rate (gpm/ft<sup>2</sup>) [(L/min)/m<sup>2</sup>]. Care shall also be exercised in placement of spray nozzles protecting pipelines handling flammable liquids under pressure, where such protection is intended to extinguish or control fires resulting from leaks or ruptures.

#### 4-9 Piping.

**4-9.1 Size.** As effective protection is dependent on having adequate pressure and quantity of water available at all spray nozzles, each system requires individual consideration as to the size of the piping. This requires that the size of the piping be based upon hydraulic computations. (See Chapter 7.) However, piping shall not be less than 1 in. (25.4 mm) nominal diameter.

#### 4-9.2\* Installation.

##### 4-9.2.1 Threaded Pipe and Fittings.

**4-9.2.1.1** Steel pipe with wall thicknesses less than Schedule 30 [in sizes 8 in. (203 mm) and larger] or Schedule 40 [in sizes less than 8 in. (203 mm)] shall not be joined by threaded fittings.

**4-9.2.1.2** All threaded fittings and pipe shall have threads cut to ANSI B2.1, *Pipe Threads (Except Dryseal)*. Care shall be taken that the pipe does not extend into the fitting sufficiently to reduce the waterway.

**4-9.2.1.3** Pipe shall be reamed after cutting to remove all burrs and fins.

**4-9.2.1.4** Joint compound or tape shall be applied to the threads of the pipe and not in the fitting.

##### 4-9.2.2 Welded Pipe and Fittings.

**4-9.2.2.1** Field welding is permissible. Safe welding and cutting practices shall be followed.

**4-9.2.2.2** Welding methods that comply with all of the requirements of American Welding Society AWS D10.9, *Standard for Qualifications of Welding Procedures and Welders for Piping and Tubing*, Level AR-3, are acceptable means of joining water spray fixed piping.

**4-9.2.2.3** Welding procedures, welders, and welding machine operators shall be qualified as required by 4-9.2.2.9.

**4-9.2.2.4** Welded fittings and welded formations manufactured, fabricated, or joined in conformance with a qualified welding procedure as set forth herein are an acceptable product under this standard, provided that materials and wall thickness are comparable with other sections of this standard.

**4-9.2.2.5** No welding shall be performed if there is impingement of rain, snow, sleet, or high wind on the weld area of the pipe product.

**4-9.2.2.6** When welded outlets are formed:

(a) Holes in piping shall be cut to full inside diameter of fitting or shaped, contoured nipple,

(b) Discs shall be retrieved,

(c) Openings in piping shall be smooth,

(d) All slag and other welding residue shall be removed,

(e) Fittings or shaped, contoured nipples of any length shall not penetrate beyond the internal diameter of the piping.

**4-9.2.2.7** When reducing a pipe size in the run of a main, cross main, or branch, a suitable reducing fitting designed for that purpose shall be used.

**4-9.2.2.8** Welded parts shall be galvanized or suitably coated after welding.

##### 4-9.2.2.9 Qualifications.

(a) A welding procedure shall be prepared and qualified before any welding is done. Qualifications of the welding procedure to be used and the performance of welders and welding operators are required and shall comply with the requirements of AWS D10.9, *Standard for Qualifications of Welding Procedures and Welders for Piping and Tubing*, Level AR-3.

(b) Each contractor shall be responsible for all welding installed by the contractor.

(c) Each contractor shall be responsible for qualifying any welding procedure intended to be used by personnel of the contractor's organization.

(d) Each contractor shall be responsible for qualifying all of the welders and welding machine operators the contractor employs in compliance with the requirements of AWS D10.9, *Standard for Qualifications of Welding Procedures and Welders for Piping and Tubing*, Level AR-3.

(e) The contractor shall maintain certified records, which are available to the authority having jurisdiction, of the procedures used and the welders or welding machine operators employed by the contractor. Records shall show the date and the results of procedure and performance qualifications.

**4-9.2.3 Groove Joining Methods.** Pipe joined with mechanical grooved couplings shall be joined by an approved combination of couplings, gaskets, and grooves. When grooves are cut or rolled on the pipe they shall be dimensionally compatible with the coupling.

*Exception: Steel pipe with wall thicknesses less than Schedule 30 [in sizes 8 in. (203 mm) and larger] or Schedule 40 [in sizes less than 8 in. (203 mm)] shall not be joined by couplings used with pipe having cut grooves.*

**4-9.2.4** All underground supply piping after the automatic control valve shall be pitched  $\frac{1}{2}$  in. in 10 ft (4 mm/m) to drain in the same manner as the standards listed in Section 4-3 specify for aboveground piping. Provision shall be made to drain underground and overhead piping.

**4-9.2.5** Provision shall be made for test gages at or near the highest or most remote nozzle on each major separate section of the system. At least one gage connection shall be provided at or near the nozzle calculated as having the least pressure under normal flow conditions.

#### 4-10 Hangers.

**4-10.1** System piping shall be adequately supported so as to be expected to maintain its integrity under fire conditions. All supports in the fire area shall be protected by the system.

**4-10.2** Tapping or drilling of load-bearing structural members is not permitted unless the design of the structural members contemplates this feature or their design is such that the additional load can be safely tolerated, and no other arrangement is feasible. Attachments may be made to existing steel or concrete structures and in some cases to equipment and its supports. Where welding of supports directly to vessels or equipment is necessary, it shall be done in a safe manner in conformance with the provisions of all safety, structural, and fire codes and standards.

**4-10.3** Where the usual methods of supporting piping for fire protection purposes cannot be used, the piping shall be supported in such a manner as to produce the strength equivalent to that afforded by such usual means of support. In such cases, piping arrangements that are essentially self-supporting may be employed together with such hangers as are necessary.

#### 4-11 Strainers.

**4-11.1** Main pipeline strainers shall be provided for all systems utilizing nozzles with waterways less than  $\frac{3}{8}$  in. (9.5 mm) and for any system where the water is likely to contain obstructive material.

**4-11.2** Mainline pipeline strainers shall be installed so as to be accessible for flushing or cleaning during the emergency.

**4-11.3** Individual strainers shall be provided at each nozzle where water passageways are smaller than  $\frac{1}{8}$  in. (3.2 mm).

**4-11.4** Care shall be taken in the selection of strainers, particularly where nozzle waterways are less than  $\frac{1}{4}$  in. (6.5 mm) in least dimension. Consideration shall be given to size of screen perforation, to volume available for accumulation without excessive friction loss and the facility for inspection and cleaning.

#### 4-12 Gages. Gages shall be installed as follows:

(a) Below the seat of the automatic valve and arranged so as to indicate the residual pressure in the riser with the test pipe valve wide open.

(b) At each independent pipe from an air supply to an automatic valve.

(c) On the water supply connection to hydraulically controlled automatic valves.

(d) At the air pump supplying an air receiver.

(e) At an air receiver.

## Chapter 5 Acceptance Tests

### 5-1 Flushing of Piping.

**5-1.1 Supply Piping.** Underground mains and lead-in connections to system risers shall be flushed thoroughly before connection is made to system piping, in order to remove foreign materials that may have entered the underground during the course of the installation or that may have been present in existing piping. The minimum rate of flow shall not be less than the water demand rate of the system that is determined by the system design or not less than that necessary to provide a velocity of 10 ft per second (3 m/s), whichever is greater. For all systems the flushing operations shall be continued for a sufficient time to ensure thorough cleaning. When planning the flushing operations, consideration shall be given to disposal of the water issuing from the test outlets.

*Exception: When the flow rate, as listed in Table 5-1.1, cannot be verified or met, supply piping shall be flushed at the maximum flow rate available to the system under fire conditions.*

Table 5-1.1

Flow Required to Produce a Velocity of 10 Ft per Second (3 m/s) in Pipes

Pipe Size (in.)	Flow (gpm)	(L/min)
4	390	1476
6	880	3331
8	1560	5905
10	2440	9235
12	3520	13 323

**5-1.2 System Piping.** All system piping shall be flushed where practicable; otherwise, cleanliness shall be determined by visual examination.

**5-2 Hydrostatic Pressure Tests.** All new system piping shall be hydrostatically tested in accordance with the provisions of NFPA 13, *Standard for the Installation of Sprinkler Systems*.

### 5-3 Water Discharge Test.

**5-3.1** When practicable, full flow tests with water shall be made of system piping as a means of checking the nozzle layout, discharge pattern, any obstructions, and determination of relation between design criteria and actual performance and to ensure against clogging of the smaller piping and the discharge devices by foreign matter carried by the water.

**5-3.2** When practicable, the maximum number of systems that may be expected to operate in case of fire shall be in full operation simultaneously in order to check the adequacy and condition of the water supply.

**5-3.3** The discharge pressure at the highest, most remote nozzle shall be at least that for which the system was designed.

#### 5-4 Operating Tests.

**5-4.1** All operating parts of the system shall be fully tested to assure they are in operating condition.

**5-4.2** The operating tests shall include a test of automatic detection equipment.

**5-5\*** Acceptance Test Suggestions. (See Appendix A-5.5.)

## Chapter 6 Periodic Testing and Maintenance

### 6-1 General.

**6-1.1** Water spray systems require competent and effective care and maintenance to assure that they will perform their purpose effectively at the time of fire. Systems shall be serviced and tested periodically by personnel trained in this work. An inspection contract with a qualified agency for service, test, and operation at regular intervals is recommended.

**6-1.2** Operating and maintenance instructions and layouts shall be available or can be posted at control equipment and at the plant fire headquarters. Selected plant personnel shall be trained and assigned to the task of operating and maintaining the equipment.

**6-1.3** At weekly or other frequent, regularly scheduled plant inspections, equipment shall be checked visually for obvious defects, such as broken or missing parts, nozzle loading, or other evidence of impaired protection.

### 6-2 Maintenance.

**6-2.1 Water Supplies.** Proper precautions shall be taken to ensure that water supplies are kept turned on and are in full operating condition at all times when hazard or exposure exists.

**6-2.2 Strainers.** Strainers, except individual nozzle strainers (see 6-2.8), shall be thoroughly inspected after each operation or flow test and cleaned if necessary. Routine inspection and cleaning shall be performed annually, and more frequently if necessary, based on experience.

**6-2.3 Piping.** All piping shall be examined at regular intervals to determine condition and proper drainage. Frequency of inspections will be dependent upon local conditions and shall be at intervals of not more than one year.

**6-2.4** Flow tests of open head spray systems shall be made yearly or more frequently as determined from experience.

**6-2.5 Control Valves and Devices.** Control valves and automatic detection equipment shall be tested at least annually by qualified personnel. Flammable gas detection equipment shall be tested and calibrated at least quarterly by qualified personnel.

**6-2.6** Manual tripping devices and valves, including O. S. and Y. gate and post indicator valves, shall be operated at least annually.

**6-2.7** Where normally opened valves are closed following system operation or test, suitable procedures shall be instituted to ensure that they are reopened and that the system is promptly and properly restored to full normal operating condition. Main drain flow tests shall be made after valves are reopened. (See NFPA 13A, *Recommended Practice for the Inspection, Testing and Maintenance of Sprinkler Systems.*)

**6-2.8 Spray Nozzles.** All spray nozzles shall be inspected for proper positioning, external loading, and corrosion and cleaned if necessary at intervals of not more than 12 months or more frequently if necessary, based on experience. Local conditions may require such inspection and cleaning more frequently and may require internal inspection. After each operation, open spray nozzles equipped with individual screens shall be removed and the spray nozzle and screen cleaned, unless observation under flow conditions indicates this is not necessary.

**6-2.9 Flushing.** Underground lead-in connections to system risers shall be flushed at least annually, in accordance with 5-1.1. This may be accomplished by:

- (a) A flow test of the system or
- (b) Flowing water from a suitable flushing connection of adequate size.

## Chapter 7 Plans, Specifications, and Hydraulic Calculations

**7-1 Plans and Specifications.** Working plans, including elevations, shall be drawn to an indicated scale, show all essential details, and include the following data:

- (a) Date.
- (b) Name of owner and occupant.
- (c) Location, including street address.
- (d) Point of compass.
- (e) Structural features.
- (f) Relative elevations of nozzles, junction points, and supply or reference points.
- (g) Full information concerning water supplies, including pumps, underground mains, earthquake protection, etc., and flow test results.
- (h) Make, type, size, location, position, and direction of spray nozzles.
- (i) Make, type, model, and size of special system valve.
- (j) Types of alarms to be provided.
- (k) Number of each size and type of spray nozzles on each system.
- (l) Lengths of pipe and whether center to center or cutting lengths are shown.
- (m) Size of all pipe and fittings.

(n) Heat-responsive equipment, including type, arrangement, and location.

(o) Hydraulic reference points.

(p) Calculated system demand at a reference point, preferably the source of supply.

(q) Total designed water demand with number of systems designed to operate simultaneously at a reference point.

(r) Density requirements.

(s) Design purpose of system.

(t) Make and type of hangers and inserts.

(u) All control and check valves, strainers, drain pipes, and test pipes.

(v) Small hand hose and hose equipment.

(w) The weight or class, lining, and size of underground pipe and the depth that the top of the pipe is to be laid below grade.

(x) Provisions for flushing underground pipe.

(y) Accurate and complete layout of the hazard being protected.

(z) When the equipment to be installed is an addition or change, enough of the old system shall be indicated on the plans to make all conditions clear.

(aa) Name and address of contractor.

**7-2\* Hydraulic Calculations.** Hydraulic calculations shall be prepared on forms that include a summary sheet, detailed work sheets, and a graph sheet. (*See Appendix A-7-2 for sample calculations.*)

## Chapter 8 Automatic Detection Equipment

**8-1 General.** The arrangement of automatic detection equipment for water spray systems requires careful engineering and a different arrangement from that required for other types of systems. The provisions of this chapter are based upon the type of equipment presently available for use with special systems. Other types shall give at least equivalent performance. (*See NFPA 72E, Standard on Automatic Fire Detectors.*)

**8-2\* Selection.** Care shall be exercised in the selection and adjustment of detection equipment to assure proper operation and to guard against premature operation of the system from normally fluctuating conditions. For example, particular care shall be taken to compensate for normal temperature fluctuations in installations such as transformer protection involving heat exchangers having automatic fans and installations involving industrial ovens and furnaces. Additionally, protection of machinery involving movement of a hazardous material such as a belt conveyor would require a detection system having a faster response time than normal and appropriate interlocks to stop drive units, etc.

### 8-3 Protection.

**8-3.1 Corrosion Protection.** Detection equipment installed out of doors or in the presence of possible corrosive vapors or atmospheres shall be protected from corrosion by suitable

materials of construction or by suitable protective coatings applied by the equipment manufacturer.

**8-3.2 Protective Canopy.** Detection equipment requiring protection from the weather shall be provided with a canopy, hood, or other suitable protection.

**8-3.3 Mechanical Damage.** Detection equipment shall be located so as to be protected from mechanical damage.

**8-3.4 Mounting.** Detectors shall, in all cases, be supported independently of their attachment to wires or tubing.

**8-3.5 Earthquake Protection.** Consideration shall be given to the design of the detection system in areas subject to earthquake damage.

### 8-4\* Location and Spacing of Detectors.

**8-4.1** Automatic detection equipment shall be so located and adjusted as to operate reliably. The location of detectors shall be based upon data obtained from field experience, tests, engineering surveys, the manufacturer's recommendations, and recognized laboratory listing, insofar as these are applicable. In addition, location shall take into consideration such factors as the nature of the hazard being protected, air velocity, temperature variations, number and height of structural levels, shielding, indoors or outdoors, open or closed structures, and other variable conditions where the exercise of judgment based upon experience with such detection equipment in actual tests and service is needed. For example, the spacing and location of detectors for belt conveyors must include consideration of the nature of the material being conveyed, the combustibility of the belt, the speed at which the material is conveyed, the rapidity of detection necessary, the necessity of detection devices between upper and lower belts as well as above the conveyor belt, etc.

NOTE: For indoor installations, see NFPA 72E, *Standard on Automatic Fire Detectors*.

**8-4.2 Two or More Systems.** Where there are two or more systems in one area controlled by separate detection systems, those on each system shall be spaced as independently as if the dividing line between systems were a wall or partition or draft stop.

**8-4.3\* Flammable Gas Detectors.** Location of flammable gas detectors shall take into consideration the density of the flammable gas and its temperature and proximity to equipment where leakage is more likely to occur. Access for testing, calibration, and maintenance shall also be considered.

### 8-5\* Arrangement and Supervision of Systems.

**8-5.1 Electric Systems.** Water spray systems that depend for operation on electric thermostats, relay circuits, flammable gas detectors, or other similar equipment shall be so arranged that such equipment is normally energized or completely supervised in a manner that will result in positive notifications of an abnormal condition unless failure of the detection system results in the operation of the water spray system. Supervision shall include but not be limited to the tripping device, solenoid or valve, and any connecting wiring.

**8-5.2 Pneumatic and Hydraulic Systems.** Pneumatically and hydraulically operated systems shall be supervised in a manner so that failure will result in positive notification of the abnormal condition, unless the failure shall result in operation of the water spray system.

**8-6\* Response Time.** The detection system shall be designed to cause actuation of the special water control valve within 20 seconds under expected exposure conditions. Under test conditions the heat detector systems, when exposed to a standard heat test source, shall operate within 40 seconds. Under test conditions the flammable gas detector system, when exposed to a standard test gas concentration, shall operate within 20 seconds. These are to be considered the maximum response times subject to the considerations described in Section 8-2, 8-4.1, and 8-4.3.

## Chapter 9 Referenced Publications

**9-1** The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is current as of the date of the NFPA issuance of this document.

**9-1.1 NFPA Publications.** National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13-1989, *Standard for the Installation of Sprinkler Systems*

NFPA 14-1990, *Standard for the Installation of Standpipe and Hose Systems*

NFPA 18-1990, *Standard on Wetting Agents*

NFPA 20-1990, *Standard for the Installation of Centrifugal Fire Pumps*

NFPA 22-1987, *Standard for Water Tanks for Private Fire Protection*

NFPA 24-1987, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*

NFPA 30-1990, *Flammable and Combustible Liquids Code*

NFPA 49-1975, *Hazardous Chemicals Data*

NFPA 70-1990, *National Electrical Code*

NFPA 71-1989, *Standard for the Installation, Maintenance, and Use of Central Station Signaling Systems*

NFPA 72-1990, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*

NFPA 72E-1990, *Standard on Automatic Fire Detectors*

NFPA 321-1987, *Standard on Basic Classification of Flammable and Combustible Liquids*

NFPA 325M-1984, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*

**9-1.2 ANSI Publications.** American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI B2.1-1968, *Pipe Threads (Except Dryseal)*

ANSI B16.3-1985, *Malleable-Iron Screwed Fittings, 150 and 300 Lb.*

ANSI B16.9-1989, *Factory-Made Steel Butt Welding Fittings*

ANSI B36.10-1985, *Welded and Seamless Wrought Steel Pipe*

ANSI C2-1990, *National Electrical Safety Code*

**9-1.3 ASME Publication.** American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME Boiler and Pressure Vessel Code, Section IX, *Qualification Standard for Welding and Brazing Procedures, Welders, Brazers and Welding and Brazing Operators*, 1980 Edition

**9-1.4 ASTM Publications.** American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A135-1979, *Specifications for Electric-Resistance-Welded Steel Pipe*

ASTM A53-1987, *Specifications for Welded and Seamless Steel Pipe*

ASTM A536-1980, *Specifications for Ductile Iron Castings*

ASTM A795-1985, *Standard Specifications for Black and Hot-Dipped Zinc Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use*

ASTM E380-1986, *Standard for Metric Practice*

**9-1.5 AWS Publication.** American Welding Society, 2501 N W 7th Street, Miami, FL 33125.

AWS D10.9-1980, *Standard for Qualifications of Welding Procedures and Welders for Piping and Tubing*

## Appendix A

*This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.*

### A-1-3 Insulated Equipment, Structures, or Vessels.

(a) Noncombustible materials affording two-hour ratings under NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*, will usually satisfy the requirements of Section 1-3 when properly fastened and weather protected.

(b) For equipment, structures, and vessels of nonferrous metals, somewhat lower temperature limits than indicated in Section 1-3 may be required, based upon reliable metallurgical data.

### A-1-5 Uses.

(a) Extinguishment of fire by water spray is accomplished by cooling, smothering from produced steam, emulsification of some liquids, dilution in some cases, or a combination of these factors.

(b) Control of fires is accomplished by an application of water spray to the burning materials producing controlled burning. The principle of control may be applied where combustible materials are not susceptible to complete extinguishment by water spray or where complete extinguishment is not considered desirable.

(c) Effective exposure protection is accomplished by application of water spray directly to the exposed structures or equipment to remove or reduce the heat transferred to them from the exposing fire. Water spray curtains are less effective than direct application but may, under favorable conditions, provide some protection against fire exposure through subdivision of fire areas. Unfavorable conditions may include such factors as windage, thermal updrafts, and inadequate drainage.

(d) Start of fire is prevented by the use of water sprays to dissolve, dilute, disperse, or cool flammable materials or to reduce flammable vapor concentrations below the Lower Flammable Limit (LFL).

**A-1-7.4 Water Reactive Materials.** In special cases, where adequate safeguards have been provided, water spray systems for the protection of structures, equipment, or personnel in the presence of such materials as described in 1-7.4 may be acceptable.

#### A-2-11 Alarms.

(a) Outdoor water-motor or electric-alarm gongs, responsive to system water flow, may be required.

(b) Central station or proprietary station water-flow alarm service is desirable, but where not available it may be advisable to connect electrical alarm units to the public fire department alarm headquarters, or other constantly attended location where aid may be readily secured.

**A-3-2.1 Volume and Pressure.** For large areas protected by many adjacent systems, it may not be necessary to base the design flow rate on all systems operating simultaneously. With drainage designed to reduce the flow of flammables to adjacent areas, the maximum design flow rate could be determined by adding the flow rate for any system to the flow rates for all immediately adjacent systems. (See example in Table A-3-2.1.) The largest sum determined from considering all logical combinations should be used. This maximum anticipated flow rate basis is valid when the systems selected are judged to represent the worst case situation. Most fires would be adequately controlled with fewer systems operating.

The duration of water flow is a matter of engineering judgment.

#### A-3-3.1 Water Supply.

(a) *Cycle Systems.* Where the quantity of water supply is extremely limited, a cycle water system may be acceptable in some instances. For such an arrangement water could be collected by means of a fire drainage trench and interceptor system. Suction would then be taken from the last pass in the interceptor (or separator). However, caution should be observed when designing such a system and full consideration should be given to such items as type of flammables involved, foreign materials that may be present in the drainage system, and valving arrangements.

**Table A-3-2.1**  
Determining Design Flow Rate Multiple Water Spray  
Fixed Systems

System 1	System 2	System 3	System 4	System 5	System 6
1800 gpm (6813 L/min)	2100 gpm (7947 L/min)	1950 gpm (7381 L/min)	2300 gpm (8706 L/min)	2400 gpm (9084 L/min)	1700 gpm (6435 L/min)
System Flow					
1	2	3	4	5	6
1800	2100	1950	2300	2400	1700
2	3	4	5	6	1
2100	1950	2300	2400	1700	1800
3	4	5	6	1	2
1950	2300	2400	1700	1800	2100
5850		6350		6650	

The combination of Systems 3, 4, and 5 creates the largest flow; therefore, the design flow rate for this installation is selected as 6650 gpm (25 170 L/min). Total water demand would be 6650 gpm (25 170 L/min) plus an allowance for hose stream application.

(b) *Pressure Tanks.* Pressure tanks generally are of inadequate volume to serve as a water supply for water spray systems. In special cases, however, such as remotely located transformers, where pressure tanks can furnish an adequate volume and pressure, they may be acceptable.

(c) *Auxiliary Supplies.* Readily available sources of water supply should be made accessible as auxiliary supplies for water spray systems. Cross-connections from service water systems in industrial plants should, where permissible, be made to fire main systems. Where connections are made from public waterworks systems it is necessary to guard against possible contamination of the public supply. The requirements of the public health authority should be determined and followed. The effect of reducing water pressures when large quantities of water are drawn for fire fighting must be carefully studied to prevent potentially dangerous operating situations. Manual operation of auxiliary sources may be acceptable.

**A-3-3.2 Fire Department Connections.** Suitable suction provisions may entail the following:

(a) Suitable suction hydrants accessible to apparatus on primary or auxiliary supplies or both.

(b) Suitable all-weather landings or locations where pumper apparatus may take suction at surface water supplies.

**A-4-3** Design guides for water spray system design should conform to the applicable recommendations of the following recommended practices of the National Fire Protection Association, except where otherwise recommended herein:

NFPA 26, *Recommended Practice for the Supervision of Valves Controlling Water Supplies for Fire Protection*;

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*.

#### A-4-4.1 Extinguishment — General.

(a) Where systems are designed for extinguishment of fires involving solids, consideration should be given to such factors as penetrating ability of the water and the configuration and state of the material.

(b) Where extinguishment of flammable or combustible liquids is contemplated, the rate of water application necessary will depend on such characteristics of the fuel as vapor pressure, flash point, viscosity, water solubility, and specific gravity. Care should be observed with very viscous heated materials, such as asphalt, because of the potential slop-over or froth-over hazard. When water spray extinguishment systems are designed for material of this type, the use of non-foaming agents, special containment capacity, drains, or extensions of the spray system beyond the immediate area of the initial containment should be contemplated. Care should also be observed with materials having a hazardous chemical reaction with water.

(c) In all cases, the positioning of nozzles with respect to burning surfaces to be extinguished is to be guided by the particular nozzle design, the water pressure available, and the character of water spray produced. The effect of wind and fire draft on very small drop sizes or on larger drop sizes with little initial nozzle velocity will limit the distance between nozzle and surface.

#### A-4-4.1.3 Extinguishment — Methods.

(a) *Surface Cooling.* Where extinguishment by surface cooling is contemplated, the design provides for complete water spray coverage over the entire surface. Surface cooling is not effective on gaseous products or flammable liquids having a flash point below the temperature of the applied water and is not generally satisfactory for flammable liquids having flash points below 140°F (60°C).

(b) *Smothering by Steam Produced.* Where this effect is contemplated the intensity of the expected fire should be sufficient to generate adequate steam from the applied water spray and conditions should be otherwise favorable for the smothering effect. The water spray is to be applied to essentially all the areas of expected fire. This effect should not be contemplated where the material protected may generate oxygen when heated.

(c) *Emulsification.* This effect should be contemplated only for liquids not miscible with water. The water spray should be applied over the entire area of flammable liquids. For those having low viscosities the coverage should be uniform and the minimum rate required should be applied and the nozzle pressure should not be less than the minimum on which approval is based. For more viscous materials the coverage should be complete but need not be so uniform and the unit rate of application may be lower. Wet water may be considered where the effect of emulsification is contemplated.

(d) *Dilution.* Where extinguishment by dilution is contemplated, the material should be miscible with water. The application rate should be adequate to effect extinguishment within the required period of time based upon the expected volume of material and the percentage of dilution necessary to make it nonflammable, but not less than that required for control and cooling.

(e) *Other Factors.* The system design may contemplate other extinguishing factors, in some cases, such as a continuous film of water over the surface where the material is not miscible with water and has a density much greater than 1.0 (such as asphalt, tar, carbon disulfide, and some nitrocellulose solutions). Water spray may also be used on some materials to produce extinguishment as a result of rapid cooling below the temperature at which the material will decompose chemically at a self-sustaining rate.

NOTE: For the effect of droplet size, see NBFU Research Report No. 10, *The Mechanism of Extinguishment of Fire by Finely Divided Water.*

**A-4-4.1.4** Manually operated fixed water spray systems are not considered to be effective because of rapid deterioration of the cable insulation when exposed to fire.

Interlocks should be provided between the fire detection system and the electrical systems to deenergize all power circuits that are not connected to critical processes.

#### A-4-4.3.1 Exposure Protection — General.

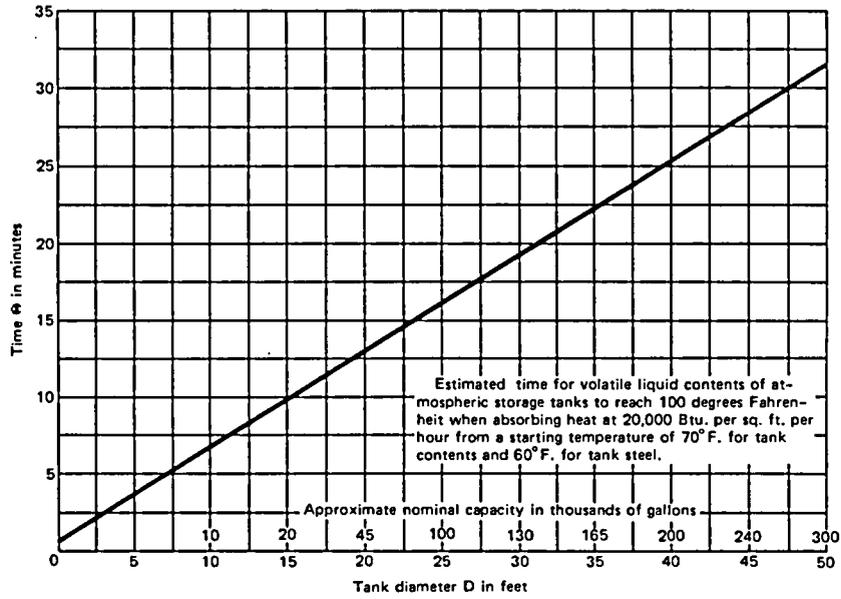
(a) Generally, the upper portions of equipment and the upper levels of supporting structures are less severely exposed by fire than are the lower portions or levels due to the accumulation at grade level of fuel from spillage or equipment rupture. Consideration may thus be given to reducing the degree of (or eliminating) water spray protection for the upper portions of high equipment or levels of structures, provided a serious accumulation of fuel, or torch action from broken process piping or equipment, cannot occur at these elevations and serious exposure does not exist. Examples are some distillation columns, above the 30- or 40-ft (9.2- or 12.2-m) level and above the third or fourth level of multi-level open structures.

(b) Where equipment, structures, or vessels are provided with insulation systems that are considered of some value, but that do not fully meet the requirements for the definition of Insulated (see Section 1-3), consideration may be given to the reduction of water application rates specified for exposure protection.

#### A-4-4.3.2 Exposure Protection — Vessels.

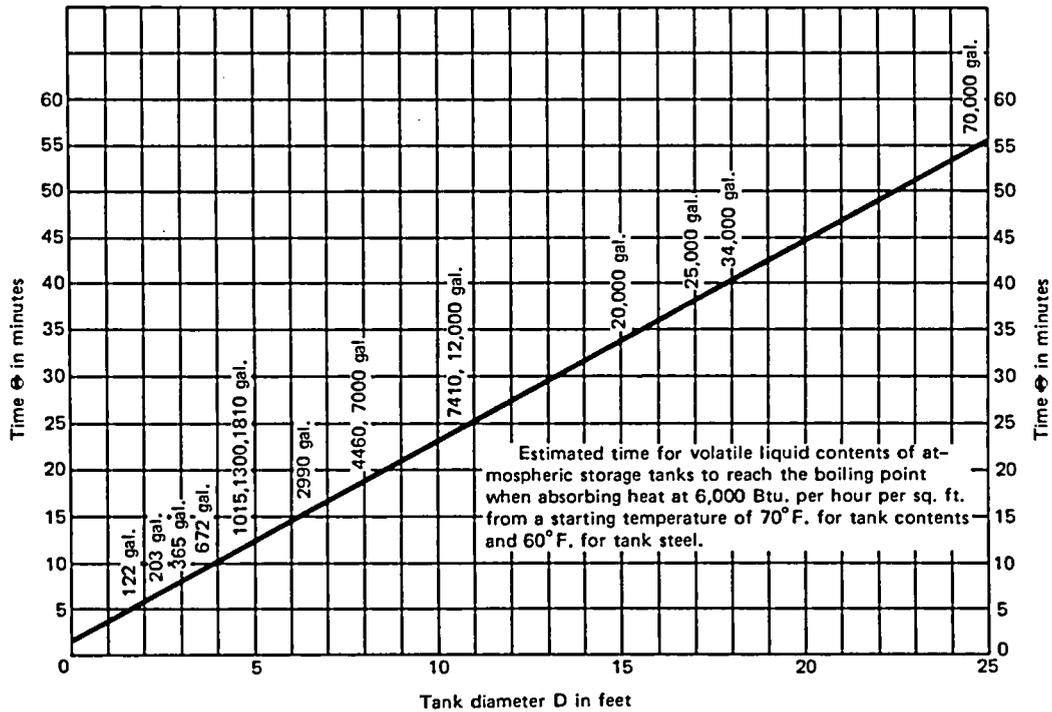
(a) It has been established that uninsulated vessels, under average plant conditions, when enveloped with flame, may be expected to absorb heat at a rate of at least 20,000 Btu per sq ft per hour (63 100 W/m<sup>2</sup>) of exposed surface wetted by the contents. Unwetted, uninsulated steel equipment absorbs heat rapidly, and failure occurs from overpressure or overheating, or both, when such equipment is exposed to fire. Figure A-4-4.3.2(a) is a time-temperature curve showing the lengths of time required for vessels of different sizes containing volatile materials to have their contents heated to 100°F (38°C) from a starting temperature of 70°F (21°C) for tank contents and 60°F (16°C) for the tank steel. (See *Requirements for Relief of Overpressure in Vessels Exposed to Fire*, J. J. Duggan, C. H. Gilmour, P. F. Fisher; Transactions of the ASME, January, 1944, 1-53; *Venting of Tanks Exposed to Fire*, NFPA Quarterly, October, 1943; and Rubber Reserve Company Memorandum 89, *Heat Input to Vessels.*)

The application of water spray to a vessel enveloped by fire will reduce the heat input rate to a value on the order of 6,000 Btu per sq ft per hour (18 930 W/m<sup>2</sup>) of exposed surface wetted by the contents when the unit rate of water application is 0.2 gal per minute per sq ft [8.2 (L/min)/m<sup>2</sup>] of exposed surface. The 6,000 Btu per hour per sq ft (18 930 W/m<sup>2</sup>) rate was also established in Rubber Reserve Company Memorandum 123, *Protection of Vessels Exposed to Fire.* Figure A-4-4.3.2(b) shows the estimated time for volatile liquid contents of atmospheric storage tanks to reach the boiling point when absorbing heat at 6,000 Btu per hour per sq ft (18 930 W/m<sup>2</sup>). This may be compared with Figure A-4-4.3.2(a) to show the benefits derived from water spray systems.



For SI Units: 1 Btu per sq ft per hour = 3.155 W/m<sup>2</sup>; °C = 5/9 (°F - 32);  
 1 gal = 0.003 79 m<sup>3</sup>; 1 ft = 0.305 m.

Figure A-4-4.3.2(a).



For SI Units: 1 Btu per sq ft per hour = 3.155 W/m<sup>2</sup>; 1 gal = 0.003 79 m<sup>3</sup> = 3.785 L; °C = 5/9 (°F - 32);  
 1 ft = 0.305 m.

Figure A-4-4.3.2(b).

(b) Where the temperature of a vessel or its contents should be limited, higher densities than called for under 4-4.3.2(b) or (g) may be required.

(c) Internally insulated or lined vessels require special consideration to determine necessary water spray requirements.

**A-4-4.4** Water spray systems designed for extinguishment, exposure protection, or control of burning can disperse flammable gases for fire and explosion prevention. When designing water spray systems primarily for dispersion of flammable gases (for fire and explosion prevention), the following should be considered:

(a) Some experimental test data indicates the rate of application for prevention of flammable gas cloud formation from significant leaks should be at least 0.60 gpm per sq ft [24.4 (L/min)/m<sup>2</sup>] into the projected area.

(b) Spray nozzles should be of the size and type to discharge a dense spray into the area of possible flammable vapor leakage at sufficient velocity to rapidly dilute the flammable vapors to a level below the lower flammable limit.

(c) Spray nozzles should be positioned to provide coverage of potential leak sources such as flanges, flexible connections, pumps, valves, vessels, containers, etc.

(d) In order to provide suitable coverage of the areas involved, the spray nozzles may be located in a grid similar to that used for an automatic sprinkler system.

NOTE: See NFPA 69, *Standard on Explosion Prevention Systems*.

**A-4-5** Experience has shown that in most installations a design discharge rate of 3,000 gpm (11 355 L/min) should not be exceeded for a single system.

**A-4-6.2 Drainage.** As stated, there are four methods of drainage: (1) grading, (2) diking, (3) trenching, and (4) underground or enclosed drains, the application of which must be determined by the extent of the hazard and the degree of protection desired.

**Grading** — Where grading is employed a slope of not less than 1 percent should be provided. Concrete surfacing is most desirable. However, other hard surfacing or crushed rock is acceptable.

**Diking** — Where diking is employed dikes should be in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*. Figure A-4-6.2(a) is based on NFPA requirements and will serve to illustrate the necessary features of adequate diking.

**Trenching** — General specifications for drainage trench and recovery systems installation, which is a desirable drainage arrangement for storage and equipment areas, are as follows:

(a) Purpose of Drainage Trench.

1. To remove from the area and promptly and effectively dispose of all accidentally spilled liquids and water discharged from fixed spray systems or hose streams, or both.

2. To provide, by means of partial closure of trench top, a basin within which ignited flammable liquids may be safely consumed by controlled burning without seriously exposing adjacent equipment.

3. To act as a container for retention of accidentally spilled, unignited high value liquids for salvage purposes.

(b) Construction of Drainage Trench.

1. Drainage trench should be constructed of reinforced concrete, except that expanded blast furnace slag aggregate should be used in precast trench cover.

2. The minimum size of any drainage trench should be 3 ft wide and 1 ft 6 in. deep (0.92 m wide and 0.46 m deep). In no case should the depth exceed the width.

3. Whether the closed portion of the trench top is precast or constructed of grating and steel plate, the open section should be equal to one-third the width of the trench, located centrally. Distance from either edge of the open area of the top to either inside wall should not be less than 12 in. (305 mm). Open section should be covered with 1¼-in. (32-mm) steel walkway grating.

4. Sumps should be poured monolithically with trench. Watertight bonds should be provided for joining concrete tank pad to trench.

5. Where piling is required in the construction of concrete pad it should also be used for support of trench and sump.

6. Slope of trench floor to sump should be a minimum of one percent.

(c) Drainage Trench Capacity Requirements.

1. Flowing: (Surface area served by the trench)

a. 750 gpm per 2,400 sq ft (2839 L/min per 223 m<sup>2</sup>) — drainage from fire hose discharge, plus

b. 1,500 gpm per 2,400 sq ft (5678 L/min per 223 m<sup>2</sup>) (maximum) — drainage where fixed water spray systems are installed, plus

c. Normal surface drainage.

2. Holding: (Total trench volume)

a. Should be equal to the total capacity of largest vessel in the area, served by the trench.

b. Holding capacity may be disregarded for water insoluble liquids where individual drains are provided to an interceptor where such insolubles may be separated and retained.

c. Where individual drains, separators, or interceptors are not used, shutoff valves should be provided for each trench system to prevent accidentally spilled materials from polluting public waterways.

(d) Tank Pads and Curbs.

1. Tank pads, if used, should be constructed of concrete and sloped toward trench with at least a two percent grade.

2. Concrete curbs should be provided around the perimeter of the tank pad or process area and between groups served by a common trench, to confine accidental liquid spillages to their respective areas.

3. Curbs should be formed in a concave manner to throw back sudden wash of flammable liquid from a large spill.

(e) *Separators and Interceptors.* Separators and interceptors should be designed to remove from drainage systems water insoluble liquids that may be either reclaimed or destroyed. In any event, these materials, which are usually flammable or toxic or both, are thus prevented from entering public waterways. Separators should be installed in locations sufficiently remote from processing and storage areas to be beyond the range of fire exposure.

(f) *Underground or Enclosed Drains.* The capacity of the system should be equivalent to required flowing capacities of the drainage trenches connected to it, plus any additional drains on the system, plus drainage for any anticipated future developments that may be required. All points of connection should be sealed [see detail of sump, Figure A-4-6.2(b)] to prevent propagation of flame through the drainage system. A skimming device is useful for removing objectionable materials from the water surface in the sump.

(g) *General.* [See Figures A-4-6.2(b) and A-4-6.2(c).]

1. Drainage trenches should be installed to serve to divide two rows of tanks or equipment, one row on each side, so that runoff from any vessel will enter directly into trench without exposing adjacent vessels.
2. Where holding capacity is not a factor, small quantities of water may be directed into trench continuously to keep it clean and to assure a positive seal in the sump at all times.

3. The installation of piping in drainage trenches should be avoided. Where it is necessary for pipe to enter or leave a drainage trench, passage should be through the grating; if through walls, the openings should be vaportight.

4. The drainage system and grating shall be kept clean and free of debris.

**A-4-9.2 Installation.** Main headers should be installed underground or at least as near as possible to ground level as protection against the effects of possible fire, explosion, or mechanical injury. Where overhead piping is necessary, it should not pass over another hazard. Piping may be looped if desired.

**A-5-5 Acceptance Test Suggestions.**

(a) All tests should be made by the contractor in the presence of an authorized inspector. When an inspector is not available, tests may be witnessed by, and the test certificate signed by, the owner or owner's representative.

(b) Before asking for final approval of the protective equipment, installing companies should furnish a written statement to the effect that the work covered by its contract has been completed and all specified flushing of underground, lead-in, and system piping has been successfully completed, together with specified hydrostatic pressure tests.

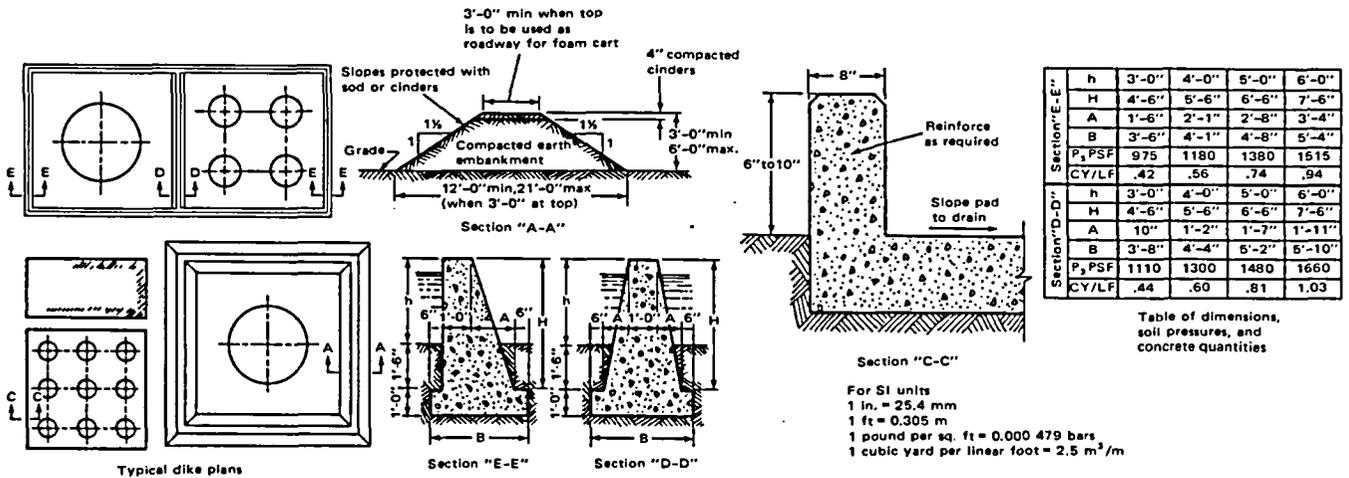


Figure A-4-6.2(a) Standard for field storage tanks.

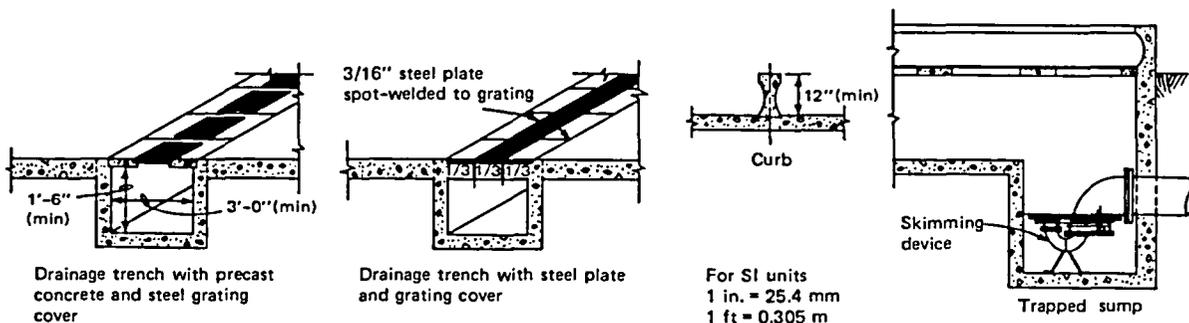


Figure A-4-6.2(b) Drainage system details for tank areas containing flammable liquids.

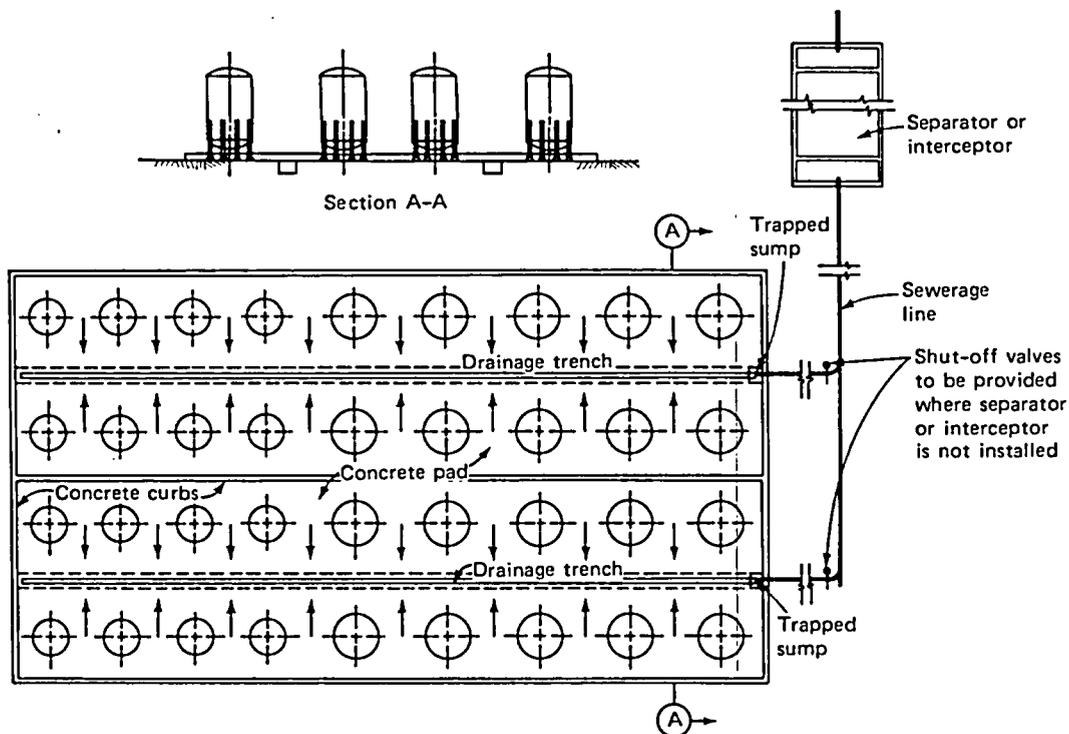


Figure A-4-6.2(c) Suggested design for drainage system for tank areas containing flammable liquids.

(c) The applicable parts of the Sprinkler Contractor's Certificate Covering Materials and Tests (see *NFPA 13, Standard for the Installation of Sprinkler Systems*) should be completed and submitted, certifying that the work has been completed and tested in accordance with approved plans and specifications.

#### A-7-2 Hydraulic Calculation — General.

(a) *Summary Sheet.* The summary sheet [for sample summary sheet see Figure A-7-2(a)] should contain the following information:

1. Date.
2. Location.
3. Name of owner and occupant.
4. Building or plant unit number.
5. Description of hazard.
6. Name and address of contractor.
7. Authority having jurisdiction.
8. Design purpose.
9. Minimum rate of water application (density) in gpm per sq ft [(L/min)/m<sup>2</sup>].
10. Total water requirements as calculated including allowance for inside hose and outside hydrants.
11. Water supply information.

(b) *Detailed Work Sheets.* Detailed work sheets or computer printout sheets [for sample work sheet, see Figure A-7-2(b)] should contain the following information:

1. Sheet number, date, job number, and identification of calculations covered.
2. Description and discharge constant (K) (or provide the discharge curve or tabulation) for each nozzle type.
3. Hydraulic reference points.
4. Flow in gpm (L/min).
5. Pipe size in inches.
6. Pipe lengths, center to center of fittings in ft (m).
7. Equivalent pipe lengths for fittings and devices in ft (m).
8. Friction loss in psi per ft of pipe (bars/m).
9. Total friction loss in psi (bars) between reference points.
10. Elevation head in psi (bars) between reference points.
11. Required pressure in psi (bars) at each reference point.
12. Velocity pressure and normal pressure if included in calculations.
13. Notes to indicate starting points, reference to other sheets or to clarify data shown.
14. When extending existing equipment, hydraulic calculations are to be furnished indicating the previous design, volume, and pressure at points of connection, and adequate additional calculations to indicate effect on existing systems.

**Summary Sheet — Hydraulic Calculation**

Name and Address of Contractor.....  
 Contract No..... Calculator..... Date.....  
 Name of Owner and Occupant.....  
 Address.....  
 Building or Plant Unit Number.....  
 Description of Hazard.....  
 Authority Having Jurisdiction.....

**System Requirements**

Design Purpose: Extinguishment.....  
 Exposure Protection.....  
     Control..... Fire Protection.....  
 Type System: Automatic..... Manual.....  
 Density gpm per sq ft [(L/min)/m<sup>2</sup>].....  
 Total Nozzle Flow Required.....gpm (L/min)  
 Allowance for Inside Hose Stations.....gpm (L/min)  
 Allowance for Outside Hydrants.....gpm (L/min)  
 Total Water Required.....gpm (L/min) at.....psi (bars)  
 Remarks: .....

**Water Supply Information**

Type of Water Supply:      Public.....      Private.....  
 Static Pressure.....psi (bars)  
  
 Residual Pressure  
     gpm (L/min) Flowing.....at.....psi (bars)  
     Elevation.....ft (m)..... Location .....

Elevation.....ft (m)..... Location .....

Pump Data:  
     Rated Capacity .....gpm (L/min) at.....psi (bars)  
     Elevation .....ft (m)..... Location .....

Elevation .....ft (m)..... Location .....

Tank Data:  
     Capacity .....gals (m<sup>3</sup>) — Elevation .....ft (m)  
     Location .....

Remarks: .....

Figure A-7-2(a) Sample summary sheet.

HYDRAULIC CALCULATIONS

FOR System Shown on Fig. A-7090-a

All Nozzles Type N90

(Nozzle Discharge Constant 9.0)

SHEET NO. 1 OF 2

BY J. E. C

DATE 12-3-68

JOB NO. 1571

Nozzle Ident. & Location	Flow in G. P. M.	Pipe Size	Pipe Fittings & Device	Equiv. Pipe Length	Friction Loss p.s.f./foot	Pressure Summary	Normal Pressure	Nozzle Elev.	NOTES
1-N90 ①	40.2	1	E=2.0	LGTH. 0.5 FTG. 2.0 TOT. 2.5	.47	PT 20.0 PE — PF 1.2	PT — PV — PN —	21.0'	$Q_1 = 9.0 \sqrt{20} = 40.2$
2-N90 ②	40.2	1	E=4.0	LGTH. 4.0 FTG. 4.0 TOT. 10.0	.47	PT 21.2 PE — PF 4.7	PT — PV — PN —		
3-N90 ③	40.6	1 1/2	E=3.0	LGTH. 5.0 FTG. 3.0 TOT. 9.0	.46	PT 25.9 PE — PF 4.1	PT 25.9 PV 2.0 PN 23.9		$Q_3 = 8.3 \sqrt{25.9} = 40.6$ For $K_3$ Calc., See ①
4-N90 ④	43.5	1 1/2	T=8.0	LGTH. 2.0 FTG. 8.0 TOT. 10.0	.48	PT 30.0 PE — PF 4.8	PT 30.0 PV 2.6 PN 27.4		$Q_4 = 8.3 \sqrt{27.4} = 43.5$
5-N90 ⑤	124.3	2	E=5.0	LGTH. 5.0 FTG. 5.0 TOT. 10.0	.50	PT 34.8 PE 0.4 PF 5.0	PT — PV — PN —		
6-N90 ⑥	180.0	2 1/2		LGTH. 4.0 FTG. — TOT. 4.0	.58	PT 40.2 PE — PF 2.3	PT 40.2 PV 5.5 PN 34.7	29.0'	$Q_6 = 30.6 \sqrt{34.7} = 180$ For $K_6$ Calc., See ①
7-N90 ⑦	180.0	3	E=7.0	LGTH. 5.0 FTG. 7.0 TOT. 12.0	.40	PT 47.5 PE — PF 4.8	PT 42.5 PV 4.8 PN 37.7		$Q_7 = 30.6 \sqrt{37.7} = 180$
8-N90 ⑧	616.6	3		LGTH. 10.0 FTG. — TOT. 10.0	.40	PT 47.5 PE 4.3 PF 4.0	PT — PV — PN —		
14-N90 ⑭	640.0	6	E=20.0 Rel V=10.0 C.V.=9.0	LGTH. 17.0 FTG. 41.0 TOT. 60.0	.054	PT 55.6 PE 4.1 PF 2.2	PT 55.6 PV 1.3 PN 54.3	19.0'	$Q_8 = 30.6 \sqrt{54.3} = 640.$ For $K_8$ Calc., See ①
15-N90 ⑮	1256.6	6		LGTH. — FTG. — TOT. —		PT 62.2 PE — PF —	PT — PV — PN —	9.5'	
				LGTH. — FTG. — TOT. —		PT — PE — PF —	PT — PV — PN —		Note: From last yr Year Hydrants Static Pressure: 87 p.s.i.
				LGTH. — FTG. — TOT. —		PT — PE — PF —	PT — PV — PN —		Residual Pressure: 80 p.s.i. Flow: 1300 g.p.m. ~2300 g.p.m. available at 62.7 p.s.i.
				LGTH. — FTG. — TOT. —		PT — PE — PF —	PT — PV — PN —		
				LGTH. — FTG. — TOT. —		PT — PE — PF —	PT — PV — PN —		
				LGTH. — FTG. — TOT. —		PT — PE — PF —	PT — PV — PN —		
				LGTH. — FTG. — TOT. —		PT — PE — PF —	PT — PV — PN —		
				LGTH. — FTG. — TOT. —		PT — PE — PF —	PT — PV — PN —		

Figure A-7-2(b) Calculation of system shown in Figure A-7-2(i)(1) with velocity pressure included.

HYDRAULIC CALCULATIONS

FOR System Shown on Fig. A-7020-a  
All Nozzles Type N90  
(Nozzle Discharge Constant 9.0)

SHEET NO. 2 OF 2  
 BY J. E. C.  
 DATE 12-3-68  
 JOB NO. 1571

Nozzle Ident. & Location	Flow in G. P. M.	Pipe Size	Pipe Fittings & Device	Equiv. Pipe Length	Friction Loss P.S.I./Foot	Pressure Summary	Normal Pressure	Nozzle Elev.	NOTES
1-N90 ①	40.2	1	T=3.0	LGTH. 2.5	.47	PT 20.0	PT	21.0'	$K_0 = \frac{40.2}{\sqrt{23.3}} = 8.3$
	40.2		T=3.0	FIG. 7.0		PF	PV		
	40.2		TOT. 7.5	PF 3.3		PN			
②				LGTH.		PT 22.5	PT		
				FIG.		PF	PV		
				TOT.		PF	PN		
1-N90 ③	40.2	1		LGTH. 3.0	.47	PT 20.0	PT	21.0'	
	40.2			FIG. -		PF	PV		
	40.2			TOT. 3.0		PF 1.4	PN		
1-N90 ④	39.6	1 1/4	T=4.0	LGTH. 1.5	.24	PT 21.4	PT 21.4		
	79.0			FIG. 5.0		PF -	PV 2.0		
	79.0			TOT. 7.5		PF 3.3	PN 17.4		
2-N90 ⑤	77.8	2	T=10.0	LGTH. 1.8	.23	PT 24.7	PT	20.0'	$K_0 = \frac{157.6}{\sqrt{21.6}} = 30.6$
	157.6			FIG. 10.8		PF 8.4	PV		
	157.6			TOT. 11.8		PF 2.5	PN		
Lower Pipe LEVEL ⑥				LGTH.		PT	PT		
				FIG.		PF	PV		
				TOT.		PF	PN		
14-N90 ⑦	616.6	3	T=15.0	LGTH. 2	.40	PT 42.5	PT		$K_0 = \frac{616.6}{\sqrt{50.3}} = 86.8$
	616.6			FIG. 15		PF 8.0	PV		
	616.6			TOT. 20		PF 30.5	PN		
⑧				LGTH.		PT	PT		
				FIG.		PF	PV		
				TOT.		PF	PN		
⑨				LGTH.		PT	PT		
				FIG.		PF	PV		
				TOT.		PF	PN		
⑩				LGTH.		PT	PT		
				FIG.		PF	PV		
				TOT.		PF	PN		
⑪				LGTH.		PT	PT		
				FIG.		PF	PV		
				TOT.		PF	PN		
⑫				LGTH.		PT	PT		
				FIG.		PF	PV		
				TOT.		PF	PN		
⑬				LGTH.		PT	PT		
				FIG.		PF	PV		
				TOT.		PF	PN		
⑭				LGTH.		PT	PT		
				FIG.		PF	PV		
				TOT.		PF	PN		

Figure A-7-2(b) Continued.

Notes for Figure A-7-2(b).

The velocity pressure  $P_v$  is determined by trial. It is necessary to estimate the flow  $Q$  in the pipe on the upstream side of the nozzle to determine a trial  $P_v$ , which is used to determine a trial  $P_v$ , a trial  $q$ , and a trial  $Q$ . After determining the trial  $Q$  use this value to determine a new  $P_v$ . If the new  $P_v$  is approximately equal to the trial  $P_v$  consider the trial  $Q$  to be the actual  $Q$  and proceed with the calculations. If the  $P_v$  does not check with the trial  $P_v$  estimate  $Q$  again and proceed with successive corrections until an actual  $P_v$  is obtained that checks with a trial  $P_v$ .

NOZZLE IDENT. AND LOCATION	FLOW IN l/MIN.	PIPE SIZE	PIPE FITTINGS AND DEVICES M	EQUIV. PIPE LENGTH M	FRICTION LOSS BARS/M	PRESSURE SUMMARY BARS	NORMAL PRESSURE BARS	NOTES
1-N90 ①	q 152	1	E=0.6	L 0.2	0.11	Pt 1.38	Pt	$q_1 = 129.6 \sqrt{1.38}$ = 152
	Q 152		F 0.6	T 0.8		Pe	Pv	
②	q	1	2E=1.2	L 1.8	0.11	Pt 1.46	Pt	
	Q 152		F 1.2	T 3.0		Pe	Pv	
1-N90 ③	q 154	1 1/4	E=0.9	L 1.8	0.10	Pt 1.79	Pt 1.79	$q_3 = 119.5 \sqrt{1.65}$ = 154 for $K_s$ Calc see $\diamond$
	Q 306		F 0.9	T 2.7		Pe	Pv 0.14	
1-N90 ④	q 165	1 1/2	T=2.4	L 0.6	0.11	Pt 2.07	Pt 2.07	$q_4 = 119.5 \sqrt{1.89}$ = 165
	Q 471		F 2.4	T 3.0		Pe	Pv 0.18	
3-N90 ⑤	q 471	2	E=1.5	L 1.5	0.11	Pt 2.40	Pt	
	Q 941		F 1.5	T 3.0		Pe 0.03	Pv	
4-N90 ⑥	q 681	2 1/2		L 1.2	0.13	Pt 2.77	Pt 2.77	$q_6 = 437 \sqrt{2.39}$ = 681
	Q 1622		F -	T 1.2		Pe	Pv 0.38	
4-N90 ⑦	q 712	3	E=2.1	L 1.5	0.09	Pt 2.93	Pt 2.93	$q_7 = 437 \sqrt{2.61}$ = 712
	Q 2334		F 2.1	T 3.6		Pe	Pv 0.32	
⑧	q -	3		L 3.0	0.09	Pt 3.26	Pt	
	Q 2334		F -	T 3.0		Pe 0.30	Pv	
14-N90 ⑨	q 2442	6	2E=8.6	L 5.8	0.01	Pt 3.83	Pt 3.83	$q_9 = 1250 \sqrt{3.75}$ = 2422
	Q 4756		Del.V=3.0	F 12.5		Pe 0.28	Pv 0.08	
⑩	q -			L		Pt 4.34	Pt	
	Q 4756		F	T		Pe	Pv	
	q			L		Pt	Pt	
	Q			F		Pe	Pv	
				T		Pf	Pn	
						Pt		

Figure A-7-2(b) Metric calculation shown in Figure A-7-2(i)(1) with velocity pressure included. Nozzle constant =  $K_m = 129.6$ .

NOZZLE IDENT. AND LOCATION	FLOW IN l/MIN.	PIPE SIZE	PIPE FITTINGS AND DEVICES M	EQUIV. PIPE LENGTH M	FRICTION LOSS BARS/M	PRESSURE SUMMARY BARS	NORMAL PRESSURE BARS	NOTES
1-N90 ①	q 152	1	E=0.6	L 0.2	0.11	Pt 1.38	Pt	$K_3 = \frac{152}{\sqrt{1.62}}$ = 119.5
			T=1.5	F 2.1		Pe	Pv	
	Q 152			T 2.3		Pf 0.24	Pn	
	q			L		Pt 1.62	Pt	
				F		Pe	Pv	
	Q			T		Pf	Pn	
②	q			L		Pt	Pt	
				F		Pe	Pv	
	Q			T		Pf	Pn	
1-N90 ④	q 152	1		L 0.9	0.11	Pt 1.38	Pt	
				F -		Pe	Pv	
	Q 152			T 0.9		Pf 0.10	Pn	
1-N90 ⑤	q 150	1 1/4	T=1.8	L 0.5	0.10	Pt 1.48	Pt 1.48	
				F 1.8		Pe	Pv 0.14	
	Q 302			T 2.3		Pf 0.23	Pn 1.34	
2-N90 ⑥	q 302	2	T=3.0	L 0.3	0.05	Pt 1.71	Pt	$K_6 = \frac{604}{\sqrt{1.91}}$ = 437
				F 3.0		Pe 0.03	Pv	
	Q 604			T 3.3		Pf 0.17	Pn	
	q			L		Pt 1.91	Pt	
				F		Pe	Pv	
	Q			T		Pf	Pn	
Lower ③	Pipe Level			L		Pt	Pt	
	q			F		Pe	Pv	
	Q			T		Pf	Pn	
14-N90 ⑨	q	3	T=4.6	L 1.5	0.09	Pt 2.93	Pt	$K_9 = \frac{2334}{\sqrt{3.48}}$ = 1250
				F 4.6		Pe 0.55	Pv	
	Q 2334			T 6.1		Pf 3.48	Pn	
	q			L		Pt	Pt	
				F		Pe	Pv	
	Q			T		Pf	Pn	
	q			L		Pt	Pt	
				F		Pe	Pv	
	Q			T		Pf	Pn	
						Pt		

Figure A-7-2(b) Metric Continued. Nozzle constant =  $K_m = 129.6$ .

(c) *Graph Sheets.* The graph sheet should be made to  $n^{1.85}$ . Water supply curves and system requirements plus hose demand should be plotted so as to present a graphic summary of the complete hydraulic calculation. [For sample graph sheet, see Figure A-7-2(c).]

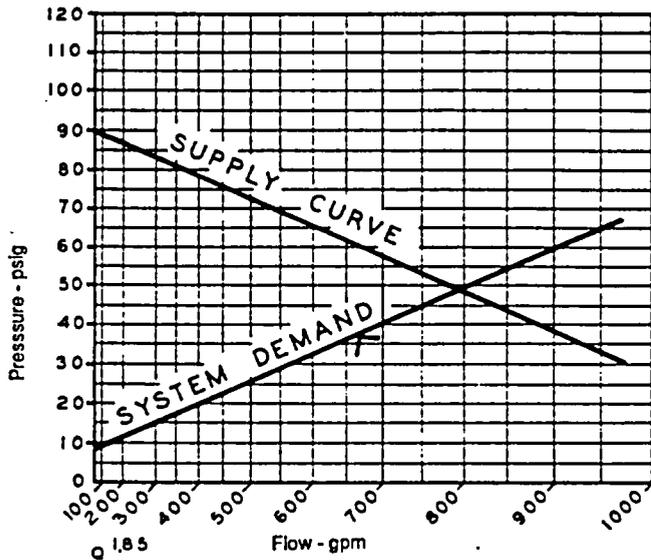


Figure A-7-2(c) Sample graph sheet.

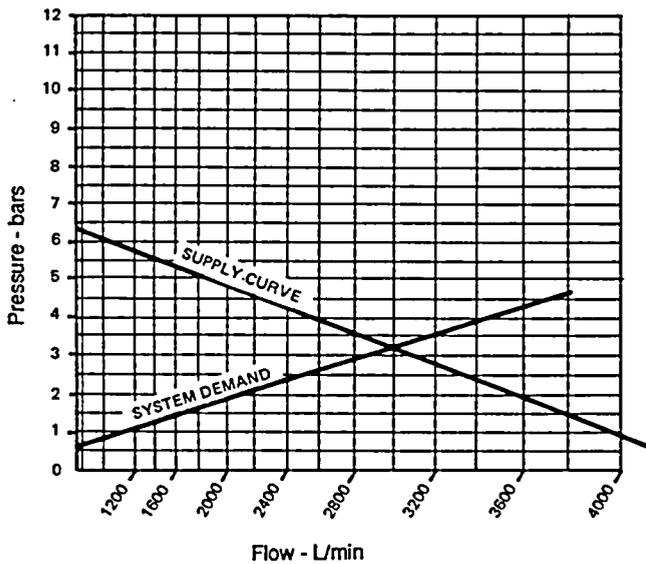


Figure A-7-2(c) Metric.

**Notes for Figures A-7-2(c) and A-7-2(c) Metric.**

Graphic summary of hydraulic calculations shown in Figure A-7-2(c), and assuming 250 gpm (946 L/min) outside hydrant flow requirements and 4.0 psi (0.28 bars) underground friction loss.

System requirements =  
 404.6 gpm (1531 L/min) at 33.21 psi (2.29 bars).  
 Hose stream requirements =  
 250 gpm (946 L/min); additional 4.0 psi (0.28 bars) required.  
**TOTAL WATER REQUIREMENTS =**  
 654.6 gpm (2777 L/min) at 37.21 psi (2.57 bars).  
 $P_e = 8.8$  psi (0.61 bars).

(d) *Abbreviations and Symbols.* The following standard abbreviations and symbols should be used.

Symbol or Abbreviation	Item
$P$	Pressure in psig.
$P_m$	Pressure in bars.
$gpm$	Flow rate in US gallons per minute.
$q$	Flow increment in gpm to be added at a specific location.
$q_m$	Flow increment in liters per minute (L/min) to be added at a specific location.
$Q$	Summation of flow in gpm at a specific location.
$Q_m$	Summation of flow in L/min at a specific location.
$P_t$	Total pressure at a point in a pipe.
$P_f$	Pressure loss due to friction between points indicated in location column.
$P_e$	Pressure due to elevation difference between indicated points. This can be a plus value or a minus value. Where minus, the symbol (-) shall be used; where plus, no sign need be indicated.
$P_v$	Velocity pressure at a point in a pipe.
$P_n$	Normal pressure at a point in a pipe.
$E$	90° Elbow.
$EE$	45° Elbow.
$Lt E$	Long turn Elbow.
$Cr$	Cross.
$T$	Tee, flow turned 90°
$GV$	Gate Valve.
$Del V$	Deluge Valve.
$DPV$	Dry-Pipe Valve.
$ALV$	Alarm Valve.
$CV$	Swing Check Valve.
$St$	Strainer.
$psig$	Pounds per square inch gage.
$v$	Velocity of water in pipe in feet per second.
$v_m$	Velocity of water in pipe in meters per second.
$g$	Acceleration due to gravity in feet per second (generally 32.0 or 32.16 is used).
$g_m$	Acceleration due to gravity 9.807 meters per second.
$K$	A constant.
$K_m$	A constant (SI).
$C$	Hazen and Williams friction loss coefficient.
$p$	Frictional resistance per foot of pipe in psi per foot.
$p_m$	Frictional resistance per meter of pipe in bars per meter.
$d$	Actual internal diameter of pipe used, in inches.
$d_m$	Actual internal diameter of pipe in millimeters.

(e) Formulae.

1. Pipe friction losses should be determined on the basis of Hazen and Williams formula. [See Figure A-7-2(e).]

$$P = \frac{4.52 Q^{1.85}}{C^{1.85} d^{4.87}}$$

For SI Units

$$P_m = 6.05 \times \frac{Q_m^{1.85}}{C^{1.85} d_m^{4.87}} \times 10^5$$

2. The velocity pressure should be determined on the basis of

$$P_v = 0.433 \frac{v^2}{g}$$

Where  $v$  is the upstream velocity.

$$P_{vm} = \frac{v_m^2}{200}$$

3. Normal pressure should be determined on the basis of

$$P_n = P_t - P_v$$

4. Hydraulic junction point calculations except for loops should be balanced to the higher pressure by the formula

$$Q = K \sqrt{P} \text{ or } K = \frac{Q}{\sqrt{P}} \text{ or}$$

$$\frac{Q'}{Q^2} = \sqrt{\frac{P'}{\rho^2}} \text{ (corrected for elevations)}$$

5. The discharge of a nozzle may be calculated by the formula

$$Q = K \sqrt{P}$$

$$Q_m = K_m \sqrt{P_m}$$

$$K_m = 14.4 K$$

NOTE 1:  $P$  may be the total or normal pressure according to whether or not the velocity pressure is being included.

NOTE 2: Piping may be looped to divide the the total water flowing to the design area.

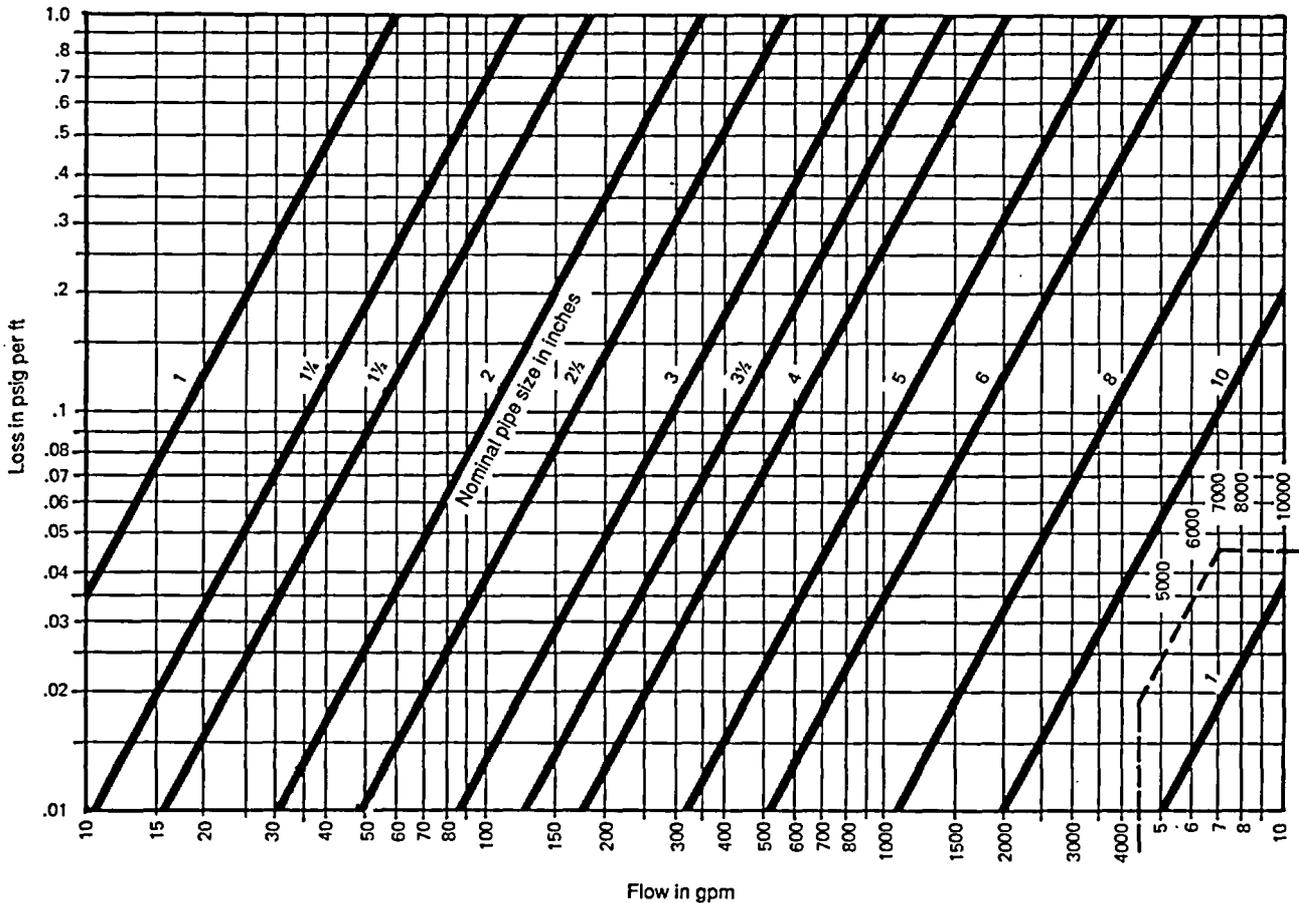


Figure A-7-2(e) Friction loss in Schedule 40 steel pipe, Hazen & Williams C-120.

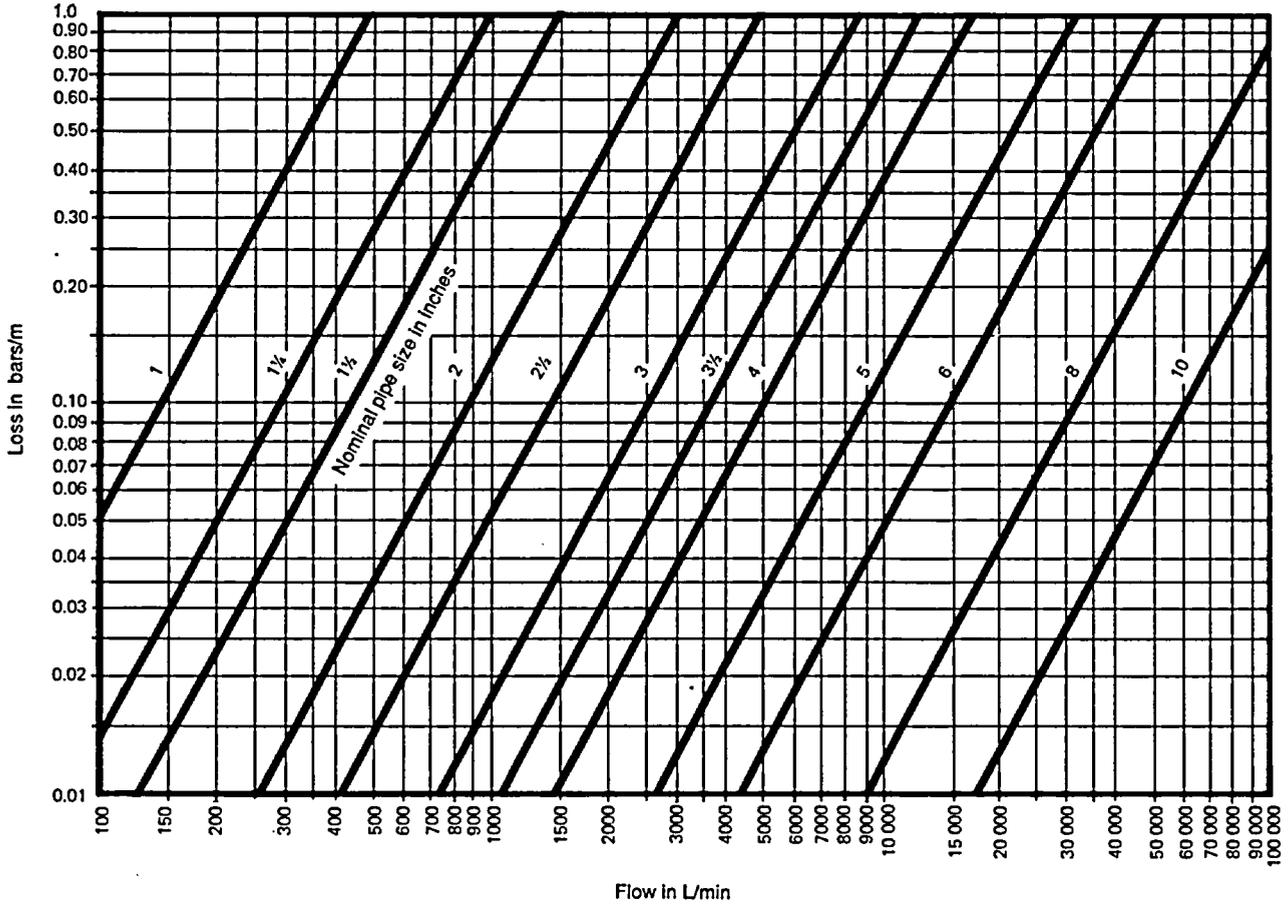


Figure A-7-2(e) Metric. Friction loss in Schedule 40 steel pipe, Hazen & Williams C-120.

(f) *Velocity Pressure.*

1. The velocity pressure  $P_v$  may or may not be included in the calculations at the discretion of the designer.

NOTE: The omission of the velocity pressure from the calculations introduces an error that is generally on the safe side. However, under some conditions with high velocity, the velocity pressures should be considered.

2. The velocity pressure  $P_v$  is a measure of the energy required to keep the water in a pipe in motion. At the end of the nozzle or end section of system (when considering junction of sections of systems) the total pressure available in the pipe at that point should be considered as causing flow. However, at other nozzles or junction points the pressure causing flow will be the normal pressure, which is the total pressure minus the velocity pressure. Figure A-7-2(f) may be used for determining velocity pressures, or velocity pressure may be determined by dividing the flow in gpm squared by the proper constant from Table A-7-2(f).

3. The following assumptions are to be used in applying velocity pressure to the calculations.

a. At any nozzle along a pipe, except the end nozzle, only the normal pressure can act on the nozzle. At the end nozzle, the total pressure can act.

b. At any nozzle along a pipe, except the end nozzle, the pressure acting to cause flow from the nozzle is equal to the total pressure minus the velocity pressure on the upstream side.

c. To find the normal pressure at any nozzle except the end nozzle, assume a flow from the nozzle in question, and determine the velocity pressure for the total flow on the upstream side. Because normal pressure = total pressure - velocity pressure, the value of the normal pressure so found should result in a nozzle flow approximately equal to the assumed flow. If not, a new value should be assumed and the calculation repeated.

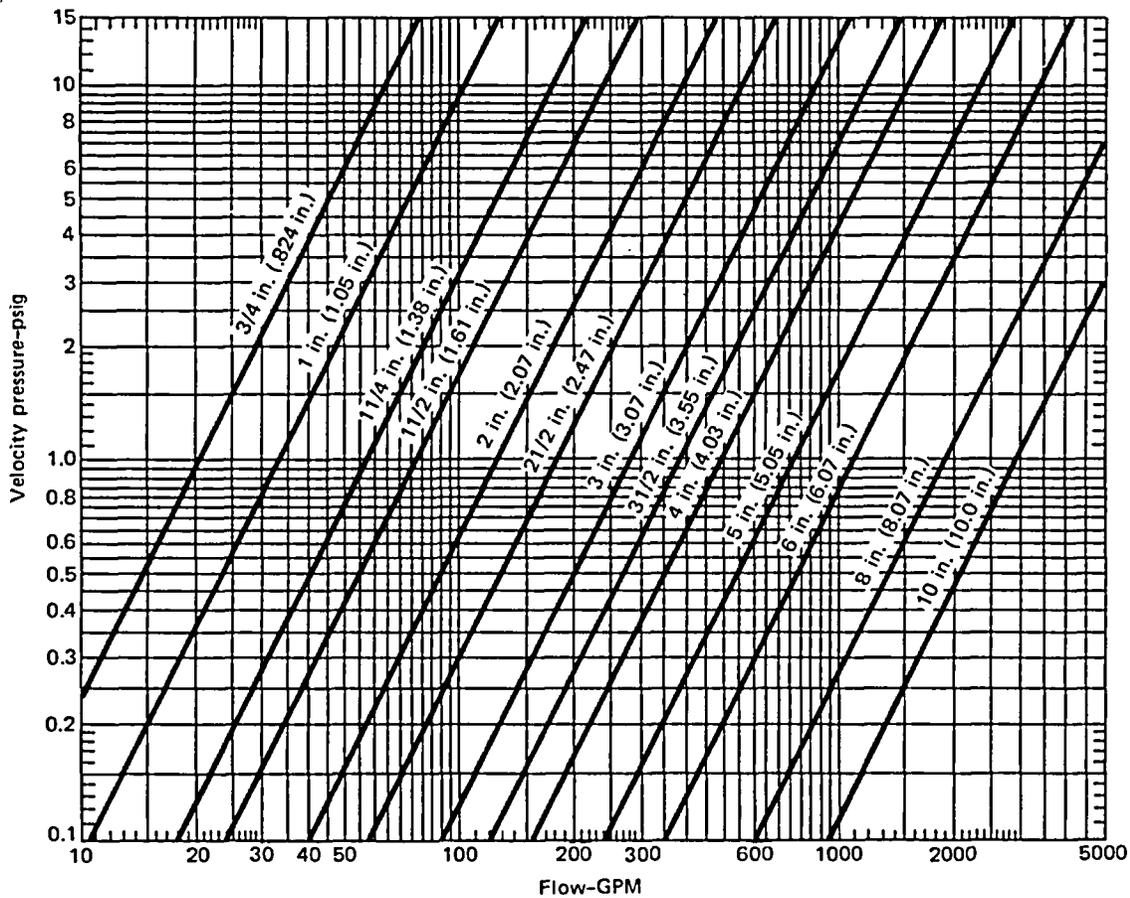


Figure A-7-2(f) Graph for the determination of velocity pressure.

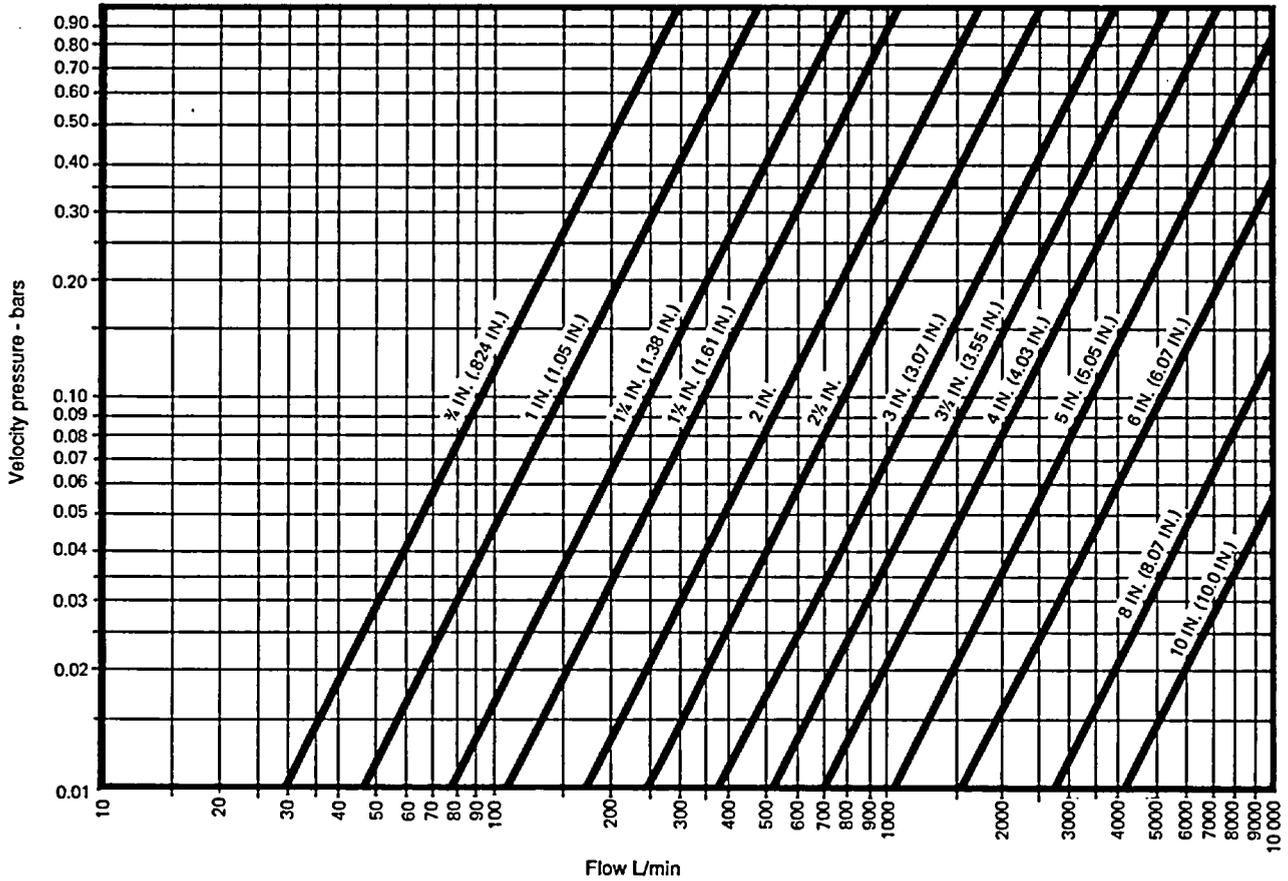


Figure A-7-2(f) Metric. Graph for the determination of velocity pressure.

Table A-7-2(f)

Pipe Schedule	Pipe Size	Constant Based on Actual I.D.
40	1	1,080
40	1 1/4	3,230
40	1 1/2	5,980
40	2	16,200
40	2 1/2	33,100
40	3	78,800
40	3 1/2	141,000
40	4	234,000
40	5	577,000
40	6	1,204,000
30	8	3,780,000
40	8	3,620,000

(g) Equivalent Pipe Lengths of Valves and Fittings.

1. Table A-7-2(g) should be used to determine equivalent lengths of pipe for fittings.
2. Specific friction loss values or equivalent pipe lengths for deluge valves, strainers, and other devices are to be made available.

Table A-7-2(g) Equivalent Pipe Length Chart

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet (m) of Pipe						
	3/4 in.	1 in.	1 1/4 in.	1 1/2 in.	2 in.	2 1/2 in.	3 in.
45° Elbow	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	3 (0.9)
90° Standard Elbow	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	7 (2.1)
90° Long Turn Elbow	1 (0.3)	2 (0.6)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)
Tee or Cross (Flow Turned 90°)	4 (1.2)	5 (1.5)	6 (1.8)	8 (2.4)	10 (3.1)	12 (3.7)	15 (4.6)
Gate Valve	—	—	—	—	1 (0.3)	1 (0.3)	1 (0.3)
Butterfly Valve	—	—	—	—	6 (1.8)	7 (2.1)	10 (3.1)
Swing Check*	4 (1.2)	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	14 (4.3)	16 (4.9)

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet (m) of Pipe						
	3 1/2 in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
45° Elbow	3 (0.9)	4 (1.2)	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	13 (4.0)
90° Standard Elbow	8 (2.4)	10 (3.1)	12 (3.7)	14 (4.3)	18 (5.5)	22 (6.7)	27 (8.2)
90° Long Turn Elbow	5 (1.5)	6 (1.8)	8 (2.4)	9 (2.7)	13 (4.0)	16 (4.9)	18 (5.5)
Tee or Cross (Flow Turned 90°)	17 (5.2)	20 (6.1)	25 (7.6)	30 (9.2)	35 (10.7)	50 (15.3)	60 (18.3)
Gate Valve	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)
Butterfly Valve	—	12 (3.7)	9 (2.7)	10 (3.1)	12 (3.7)	19 (5.8)	21 (6.4)
Swing Check*	19 (5.8)	22 (6.7)	27 (8.2)	32 (9.8)	45 (13.7)	55 (16.8)	65 (19.8)

Use with Hazen and Williams C = 120 only. For other values of C, the figures in Table A-7-2(g) should be multiplied by the factors indicated below:

Value of C	100	120	130	140
Multiplying Factor	0.713	1.00	1.16	1.32

(This is based upon the friction loss through the fitting being independent of the C factor applicable to the piping.)

Specific friction loss values or equivalent pipe lengths for alarm valves, dry-pipe valves, deluge valves, strainers, and other devices or fittings should be made available to the authority having jurisdiction.

\*Due to the variations in design of swing check valves, the pipe equivalents indicated in the above chart are to be considered average.

NOTE: Use the equivalent feet (m) value for the "standard elbow" on any abrupt ninety-degree turn such as the screw-type pattern. Use the equivalent feet (m) value for the "long turn elbow" on any sweeping ninety-degree turn such as flanged, welded, or mechanical joint elbow type.

(h) *Calculating Procedure.* In order to maintain consistency in hydraulic calculations, whether done by hand or by computer, the following rules should be followed. Experience has shown that good results are obtained if the calculations are made in accordance with these rules. It is recognized that satisfactory results may be obtained by using other methods. However, in order to simplify the checking of calculations and to obtain more consistent correlation between calculated system characteristics and actual system characteristics it is desirable to use a standard method.

1. The first work sheet should start at a remote nozzle and proceed directly to a point of known or proposed water supply. Branch calculations should be made on subsequent sheets.

2. Include the friction loss on all pipe and devices such as valves, meters, and strainers.

3. Include all fittings where a change in direction of the flow occurs as follows:

a. Calculate the loss for a tee or a cross where flow direction change occurs, based on the equivalent pipe length for the smaller size of the tee or cross in the path of the turn. Do not include any loss for that portion of the flow that passes straight through the run of a tee or a cross.

b. Calculate the loss of reducing elbows based on the equivalent feet value of the smallest outlet. Use the equivalent feet value for the "standard elbow" on any abrupt 90-degree turn, such as the screw-type pattern. Use the equivalent feet value for the "long turn elbow" on any sweeping 90-degree turn, such as a flanged, welded, or mechanical joint-type elbow.

c. Friction loss should be excluded for tapered reducers and for the fitting directly supplying the spray nozzle.

4. Include all elevation changes affecting the discharge or the total required pressure, where it occurs.

5. Piping may be looped to divide the total water flowing to the design area.

6. The water allowance for outside hydrants when served from the same underground mains may be added to the system requirement at the system connection to the underground main. The total water requirement should then be calculated through the underground main to the point of supply.

7. Orifice plates should not be used for balancing the system.

8. Calculate pipe friction loss in accordance with the Hazen and Williams formula using "C" values as shown in Table A-7-2(h). These calculations contemplate the use of the actual pipe internal diameter in the formula.

Table A-7-2(h)

Pipe or Tube	Hazen and Williams "C" Value*
Unlined Cast or Ductile Iron	100
Black Steel	100
Galvanized (all)	120
Plastic (listed) - Underground	150
Cement Lined Cast or Ductile Iron	140
Copper Tube or Stainless Steel	150

\*The authority having jurisdiction may recommend other "C" values.

SI Units: 1 in. = 25.4 mm; 1 ft = 0.305 m.

(i) *Sample Calculations.* Figure A-7-2(i)(1) shows a hypothetical water spray system layout. Figure A-7-2(b) shows a sample calculation for this system using pipe sizing and nozzles with constants such that the velocity pressures generally exceed 5 percent of the total pressures, and the designer elected to include velocity pressures. Figure A-7-2(i)(2) shows a sample calculation for this system, using pipe sizing and nozzles with constants such that velocity pressures are less than 5 percent of the total pressures, and the velocity pressures were not included in the calculation.

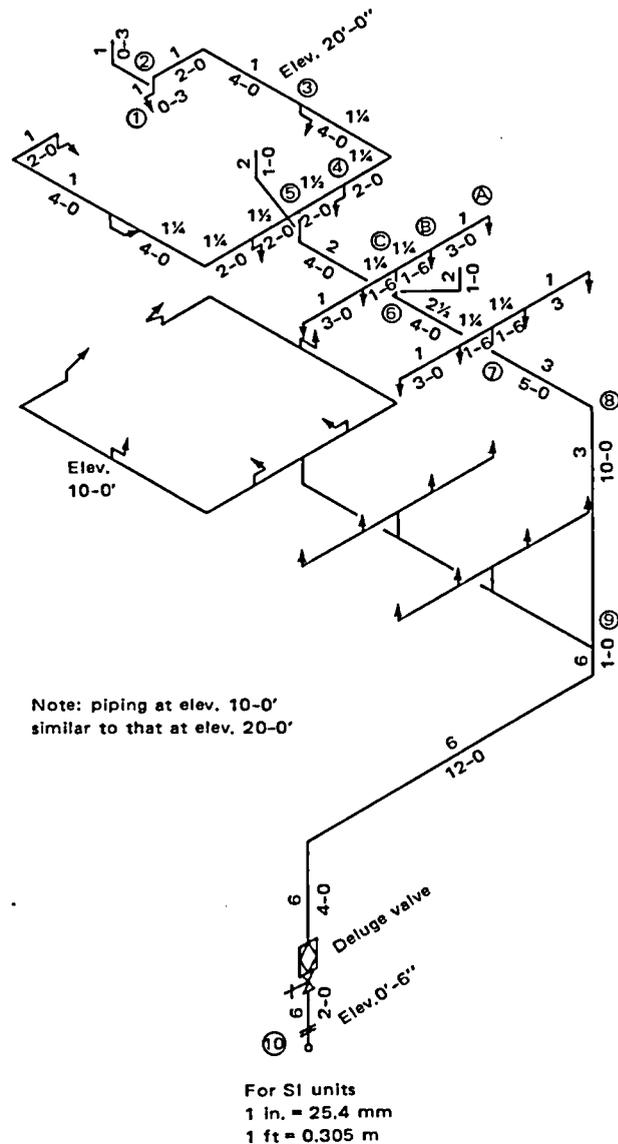


Figure A-7-2(i)(1) Drawing of water spray system used for sample calculation shown in Figures A-7-2(b) and A-7-2(i)(2).

The flow from nozzles may be obtained from discharge curves rather than individual calculations at the preference of the calculator. Similarly, flow characteristics of lines or sections of systems may be obtained by plotting results on charts made up to  $n^{1.85}$  or  $n^2$  rather than by calculating constants (K - values).

Figure A-7-2(i)(2) shows a sample calculation for the system shown in Figure A-7-2(i)(1) using pipe sizing and nozzles with constants such that velocity pressures are less than 5 percent of the total pressures, and the velocity pressures were not included in the calculation.

HYDRAULIC CALCULATIONS

FOR System Shown on Fig. A-7090-a  
All Nozzles Type N-30  
(Nozzle Discharge Constant 30)

SHEET NO. 1 OF 2  
 BY J. E. C.  
 DATE 12-3-68  
 JOB NO. 1572

Nozzle Ident & Location	Flow in G. P. M.	Pipe Size	Pipe Fittings & Device	Equiv. Pipe Length	Friction Loss p.s.i./foot	Pressure Summary	Normal Pressure	Nozzle Elev.	NOTES
1-N30 ①	13.4	1	IE=2.0	LGTH. 5	.06	PT 20.1	PT	21.0'	$q_1 = 3.0 \sqrt{20.1} = 13.4$
	13.4			FTG. 2.0		PE	PV		
				TOT. 2.5		Pf 0.2	Pm		
②	13.4	1	ZE=4.0	LGTH. 6.0	.06	PT 20.3	PT		
	13.4			FTG. 4.0		PE	PV		
				TOT. 10.0		Pf 0.6	Pm		
1-N30 ③	13.5	1 1/4	IF=3.0	LGTH. 6.0	.06	PT 20.9	PT		$q_3 = 2.95 \sqrt{20.9} = 13.5$
	26.9			FTG. 3.0		PE	PV		
				TOT. 9.0		Pf 0.5	Pm		See ④ for K <sub>3</sub> Cales.
1-N30 ④	13.6	1 1/2	IT=8.0	LGTH. 2.0	.06	PT 21.4	PT		$q_4 = 2.95 \sqrt{21.4} = 13.6$
	40.5			FTG. 8.0		PE	PV		
				TOT. 10.0		Pf 0.6	Pm		
3-N30 ⑤	40.5	2	IE=5.0	LGTH. 5.0	.06	PT 22.0	PT		
	81.0			FTG. 5.0		PE	PV		
				TOT. 10.0		Pf 0.6	Pm		
4-N30 ⑥	56.1	2 1/2		LGTH. 4.0	.07	PT 23.0	PT	20.0'	$q_6 = 11.7 \sqrt{23.0} = 56.1$
	137.1			FTG. —		PE	PV		
				TOT. 4.0		Pf 0.3	Pm		See ④ for K <sub>6</sub> Cales.
4-N30 ⑦	56.5	3	IE=7.0	LGTH. 5.0	.05	PT 23.3	PT		$q_7 = 11.7 \sqrt{23.3} = 56.5$
	193.6			FTG. 7.0		PE	PV		
				TOT. 12.0		Pf 0.6	Pm		
⑧	193.6	3		LGTH. 10.0	.05	PT 23.9	PT		
	193.6			FTG. —		PE	PV		
				TOT. 10.0		Pf 0.5	Pm		
14-N30 ⑨	211.0	6	ZE=28.0 Del V=10.0 G.Y.=3.0	LGTH. 19.0	.007	PT 28.7	PT	10.0'	$q_9 = 39.3 \sqrt{28.7} = 211$
	404.6			FTG. 41.0		PE	PV		
				TOT. 60.0		Pf 0.4	Pm		See ④ for K <sub>9</sub> Cales
⑩	404.6	✓		LGTH. —		PT 33.4	PT	0.5'	
	404.6			FTG. —		PE	PV		
				TOT. —		Pf —	Pm		Note: See Fig. A-7090-d for Water Supply Information.
				LGTH. —		PT —	PT		
				FTG. —		PE —	PV		
				TOT. —		Pf —	Pm		
				LGTH. —		PT —	PT		
				FTG. —		PE —	PV		
				TOT. —		Pf —	Pm		
				LGTH. —		PT —	PT		
				FTG. —		PE —	PV		
				TOT. —		Pf —	Pm		
				LGTH. —		PT —	PT		
				FTG. —		PE —	PV		
				TOT. —		Pf —	Pm		

Figure A-7-2(i)(2) Calculation of system shown in Figure A-7-2(i)(1) with velocity pressure not included.