28.1 * Working Plans.

28.1.1 *

Working plans shall be submitted for approval to the authority having jurisdiction before any equipment is installed or remodeled.

28.1.1.1

Working plan submittals shall include the following:

(1) Working plans of the system(s), per 28.1.3
(2) Hydraulic calculations where systems are required to be calculated
(3) Data sheets for the system components where required by the authority having jurisdiction
(4)* Signed owner's certificate

28.1.1.2

Submittals shall be permitted to be in electronic format when approved by the authority having jurisdiction.

28.1.1.3

A copy of the approved plans shall be given to the owner or owner's representative.

28.1.2

Deviation from approved plans shall require permission of the authority having jurisdiction.

28.1.3

Working plans shall be drawn to an indicated scale, on sheets of uniform size, with a plan of each floor, and shall show those items from the following list that pertain to the design of the system:

(1) Name and address of building being protected
(2) Name, telephone number, and address of installing contractor
(3) Point of compass and graphic scale indications on drawings and details as applicable
(4)* Full height cross section or schematic diagram, including structural member information as required for clarity
(5) Location of all partitions that extend to or are within a minimum of 18 in. (450 mm) to the finished ceiling or exposed deck above
(6) Location of all fire-rated partitions, fire barriers, draft stops, and draft curtains
(7) Identification of all rooms and spaces, regardless of occupancy or use
(8) Identification and labeling of all spaces, above and below ceilings, where sprinklers will be omitted, including appropriate citation of the section(s) of this standard for such omission(s)
(9) Location of all fixtures, diffusers, lights, and devices installed in or mounted to the ceiling structure, regardless of the ceiling type (i.e., finished or exposed to structure)
(10) Label finished or exposed ceiling heights for each space, including those that are sloped greater than 2 in 12 (16.7 percent)
(11)* Location and identification of major mechanical, plumbing, and electrical equipment installed above or below the ceiling spaces if sprinkler protection is being provided for those areas
(12)* Location and identification of all major structural members, and identification and labeling of construction types (i.e., obstructed or unobstructed) for each space or portion thereof in the building, as applicable
(13)* Location and identification of concealed spaces, regardless of combustibility, and of architectural and/or structural features not shown or easily identifiable in the floor plan or reflected ceiling plan views
(14) Water source(s) supply information, including the following:
    (a) Location
    (b) Type
    (c) Size
    (d) Dimensions
    (e) Capacity
    (f) Configuration
    (g) Elevation

(h) Static pressure
(i) Flow rate
(j) Residual pressure
(k) Flow test locations, dates, and sources (i.e., city or private)
(l) Any adjustments from the raw data required by the engineer of record (i.e., owner's certificate) or the water authority, if applicable
(m) Size of city main in street and whether dead end or circulating; if dead end, direction and distance to nearest circulating main; and city main test results and system elevation relative to test hydrant
(n) Private fire service main sizes, lengths, locations, weights, materials, point of connection to city main; the sizes, types, and locations of valves, valve indicators, regulators, meters, and valve pits; and the depth that the top of the pipe is laid below grade

(15) Information from the owner's certificate required by Section 4.2, including the edition of this standard being used
(16) Identification and labeling of design criteria for each room and/or space as shown on building plan, including the following:
(a) Hazard classification associated with each room or space
(b) Identification and location of all rooms and spaces intended for storage, including the following:
i. Commodity classification
ii.* Storage type and configuration
iii. Height of storage for each dedicated room or space
iv. Type of packaging to be used
(17) Identification and labeling of all sprinkler systems, including type and overall area protected by each system
(18) Location and labeling for the size, dimension, elevation, and type of all major sprinkler system components, including the following *(see 28.1.3.1)*:
(a) Pipe, fittings, valves, and test and drain locations
(b) Sprinkler legend, per system, including the following:
i. Orientation
ii. Finish
iii. Manufacturer
iv. Model
v. SIN number
vi. K-factor
vii. Temperature rating
viii. Response type
ix. Quantity of each
x. If extended coverage or residential type, spacing utilized for this application
xi. Sprinkler wrench model number(s)
(c) Manufacturer, model, length, maximum number of bends, and minimum bend radius and corresponding K-factor applied to flexible sprinkler hose
(19) Location and labeling of all system flushing, forward flow, water flow alarm, and test and drain locations
(20) Location and labeling of sprinkler system riser(s) and,if applicable, standpipe location(s)
(21) Location and labeling of fire department connections
(22) Location and labeling of hydraulic calculation information, including the following:
(a) Graphic indication of each area of operation, including a description of any allowed density or area modifications applied
(b) Labeling of all node locations that correspond to each hydraulic calculation
(23) Location and labeling of seismic system components, including the following:
(a) Zones of influence
(b) Bracing and restraint assemblies
(c) Flexible couplings and penetration clearances
(d) Maximum spacing of components
(e) Design angle category(ies)
(24) Sprinkler system details and information for other system components necessary for the complete installation, including the following:
(a) Hanger and/or hanger assemblies intended to be used throughout
(b) Total system volume for dry and double interlock preaction systems
(c) Hydraulic calculation summary information, including the following:
i. Method of calculation
ii. Total water and pressure required

iii. Hose demand

(d) Special information, settings, or values required for ongoing inspection, testing, and maintenance and system use, including the following:

i. Pressure regulating device features and means for conducting a flow test
ii. Dry pipe, preaction, and/or deluge systems
iii. Location of all low point drains
iv. Information regarding antifreeze solution used

28.1.3.1

Where a proposed new system will connect to or be installed adjacent to an existing system(s), plans shall show adequate portions of the existing system(s) pertinent to the design and installation of the new system in addition to the items listed in 28.1.3(23).

28.1.4

A signed copy of the owner's certificate and the working plan submittal shall include the manufacturer's installation instructions for any specially listed equipment, including descriptions, applications, and limitations for any sprinklers, devices, piping, or fittings.

28.2 Hydraulic Calculation Procedures.

28.2.1 * General.

28.2.1.1

A calculated system for a building, or a calculated addition to a system in an existing sprinklered building, shall supersede the rules in this standard governing pipe schedules, except that all systems shall continue to be limited by area.

28.2.1.2

Pipe sizes shall be no less than 1 in. (25 mm) nominal for black or galvanized steel piping and $^{3}/_{4}$ in. (20 mm) nominal for copper tubing or brass, stainless steel, or nonmetallic piping listed for fire sprinkler service unless permitted by Section 30.5 and 30.5.2.

28.2.1.3

The size of pipe, number of sprinklers per branch line, and number of branch lines per cross main shall otherwise be limited only by the available water supply.

28.2.1.4 *

Unless required by other NFPA standards, the velocity of water flow shall not be limited when hydraulic calculations are performed using the Hazen–Williams or Darcy Weisbach formulas.

28.2.1.5

However, sprinkler spacing and all other rules covered in this and other applicable standards shall be observed.

28.2.1.6

Hydraulic calculations shall extend to the effective point of the water supply where the characteristics of the water supply are known.

28.2.2 Formulas.

28.2.2.1 Friction Loss Formula.

28.2.2.1.1

Pipe friction losses shall be determined on the basis of the Hazen–Williams formula, as follows:

$$p = \frac{4.52Q^{1.85}}{C^{1.85}d^{4.87}} \qquad [28.2.2.1.1]$$

where:

p = frictional resistance (psi/ft of pipe)

Q = flow (gpm)

C = friction loss coefficient

d = actual internal diameter of pipe (in.)

28.2.2.1.2

For SI units, the following equation shall be used:

$$p_m = 6.05\left(\frac{Q_m^{1.85}}{C^{1.85}d_m^{4.87}}\right)10^5 \quad [28.2.2.1.2]$$

where:

p_m = frictional resistance (bar/m of pipe)

Q_m = flow (L/min)

C = friction loss coefficient

d_m = actual internal diameter (mm)

28.2.2.1.3

For antifreeze systems greater than 40 gal (150 L) in size, the friction loss shall also be calculated using the Darcy–Weisbach formula [use Equation 28.2.2.1.3a (US) or Equation 28.2.2.1.3b (SI)]:

$$\Delta P = 0.000216 f \frac{l\rho Q^2}{d^5} \quad [28.2.2.1.3a]$$

where:

ΔP = friction loss (psi)

f = friction loss factor from Moody diagram

l = length of pipe or tube (ft)

ρ= density of fluid (lb/ft^3)

Q = flow in pipe or tube (gpm)

d = inside diameter of tube (in.)

$$\Delta P_m = 2.252 f \frac{l\rho Q^2}{d^5} \quad [28.2.2.1.3b]$$

where:

ΔP_m = friction loss (bar)

f = friction loss factor from Moody diagram

l = length of pipe or tube (m)

ρ= density of fluid (kg/m^3)

Q = flow in pipe or tube (L/min)

d = inside diameter of tube (mm)

28.2.2.2 Velocity Pressure Formula.

Velocity pressure shall be determined on the basis of the following formula:

$$P_v = \frac{0.001123Q^2}{D^4} \quad [28.2.2.2]$$

where:

P_v = velocity pressure (psi) (SI, 1 psi = 0.0689 bar)

Q = flow (gpm) (SI, 1 gal = 3.785 L)

D = inside diameter (in.) (SI, 1 in. = 25.4 mm)

28.2.2.3 Normal Pressure Formula.

Normal pressure (P_n) shall be determined on the basis of the following formula:

$$P_n = P_t - P_v \quad [28.2.2.3]$$

where:

P_n = normal pressure

P_t = total pressure [psi (bar)]

P_v = velocity pressure [psi (bar)]

28.2.2.4 Hydraulic Junction Points.

28.2.2.4.1

Pressures at hydraulic junction points shall balance within 0.5 psi (0.03 bar).

28.2.2.4.2

The highest pressure at the junction point, and the total flows as adjusted, shall be carried into the calculations.

28.2.2.4.3

Pressure balancing shall be permitted through the use of a K-factor developed for branch lines or portions of systems using the formula in 28.2.2.5.

28.2.2.5 K-Factor Formula.

K-factors, flow from an orifice, or pressure from an orifice shall be determined on the basis of the following formula:

$$K_n = \frac{Q}{\sqrt{P}} \quad [28.2.2.5]$$

where:

K_n = equivalent K at a node

Q = flow at the node

P = pressure at the node

28.2.3 Equivalent Pipe Lengths of Valves and Fittings.

28.2.3.1 Pipe and Fittings.

28.2.3.1.1

Table 28.2.3.1.1 shall be used to determine the equivalent length of pipe for fittings and devices unless manufacturer’s test data indicate that other factors are appropriate.

Table 28.2.3.1.1 Equivalent Schedule 40 Steel Pipe Length Chart

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet (Met									
	½ in. (15 mm)	¾ in. (20 mm)	1 in. (25 mm)	1¼ in. (32 mm)	1½ in. (40 mm)	2 in. (50 mm)	2½ in. (65 mm)	3 in. (80 mm)	3½ in. (90 mm)	4 in. (100 mm)
45° elbow	—	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	3 (0.9)	3 (0.9)	4 (1.2)
90° standard elbow	1 (0.3)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	7 (2.1)	8 (2.4)	10 (3.0)

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet (Met									
	½ in. (15 mm)	¾ in. (20 mm)	1 in. (25 mm)	1¼ in. (32 mm)	1½ in. (40 mm)	2 in. (50 mm)	2½ in. (65 mm)	3 in. (80 mm)	3½ in. (90 mm)	4 in. (100 mm)
90° long-turn elbow	0.5 (0.2)	1 (0.3)	2 (0.6)	2 (0.6)	2 (0.6)	3 (0.9)	4 (1.2)	5 (1.5)	5 (1.5)	6 (1.8)
Tee or cross (flow turned 90°)	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)	8 (2.4)	10 (3.0)	12 (3.7)	15 (4.6)	17 (5.2)	20 (6.1)
Butterfly valve	—	—	—	—	—	6 (1.8)	7 (2.1)	10 (3.0)	—	12 (3.7)
Gate valve	—	—	—	—	—	1 (0.3)	1 (0.3)	1 (0.3)	1 (0.3)	2 (0.6)
Vane type flow switch			6 (1.8)	9 (2.7)	10 (3.0)	14 (4.3)	17 (5.2)	22 (6.7)	—	30 (9.1)
Swing check*	—	—	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.3)	14 (4.3)	16 (4.9)	19 (5.8)	22 (6.7)

Note: Information on ½ in. (15 mm) pipe is included in this table only because it is allowed under 30.5.2.4 and 30.5.6.

*Due to the variation in design of swing check valves, the pipe equivalents indicated in this table are considered average.

28.2.3.1.2

For saddle-type fittings having friction loss greater than that shown in Table 28.2.3.1.1, the increased friction loss shall be included in hydraulic calculations.

28.2.3.1.3 Equivalent Length Modifier.

28.2.3.1.3.1

For internal pipe diameters different from Schedule 40 steel pipe [Schedule 30 for pipe diameters 8 in. (200 mm) and larger], the equivalent length shown in Table 28.2.3.1.1 shall be multiplied by a factor derived from the following formula:

$$\left(\frac{\text{Actual inside diameter}}{\text{Schedule 40 steel pipe inside diameter}}\right)^{4.87} = \text{Factor} \quad [28.2.3.1.3.1]$$

28.2.3.1.3.2

The factor thus obtained shall be further modified as required by Table 28.2.3.1.1. This table shall apply to other types of pipe listed in Table 28.2.3.1.1 only where modified by factors from 28.2.3.1.1 and 28.2.3.2.

28.2.3.2 *C* Factors.

Table 28.2.3.1.1 shall be used with a Hazen–Williams *C* factor of 120 only.

28.2.3.2.1

For other values of *C*, the values in Table 28.2.3.1.1 shall be multiplied by the factors indicated in Table 28.2.3.2.1.

Table 28.2.3.2.1 *C* Value Multiplier

Value of *C*	100	130	140	150
Multiplying factor	0.713	1.16	1.33	1.51

Note: These factors are based upon the friction loss through the fitting being independent of the *C* factor available to the piping.

28.2.3.3 Valves and Components.

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

28.2.3.4 Differing Values.

Specific friction loss values or equivalent pipe lengths for listed fittings not in Table 7.4.1 shall be used in hydraulic calculations where these losses or equivalent pipe lengths are different from those shown in Table 28.2.3.1.1.

28.2.4 * Calculation Procedure.

28.2.4.1 *

For all systems the design area shall be the hydraulically most demanding based on the criteria of Chapter 19, Chapter 20, or the special design approaches in accordance with the requirements of Chapter 27.

28.2.4.1.1 Room Design Method.

Where the design is based on the room design method, the calculation shall be based on the room and communicating space, if any, that is hydraulically the most demanding.

28.2.4.2 Density/Area Method.

28.2.4.2.1 *

Where the design is based on the density/area method, the design area shall be a rectangular area having a dimension parallel to the branch lines at least 1.2 times the square root of the area of sprinkler operation *(A)* used, which shall permit the inclusion of sprinklers on both sides of the cross main.

28.2.4.2.2

Any fractional sprinkler shall be carried to the next higher whole sprinkler.

28.2.4.2.3

In systems having branch lines with an insufficient number of sprinklers to fulfill the 1.2 or 1.4 requirement, the design area shall be extended to include sprinklers on adjacent branch lines supplied by the same cross main.

28.2.4.2.3.1 *

Where additional sprinklers are carried over to the next branch line, the flow from the sprinklers that create the hydraulically most demanding remote area within the dimension required by 28.2.4.2.1 shall be selected.

28.2.4.2.4

Where the available floor area for a specific area/density design criteria, including any extension of area as required by 19.1.2 and Section 20.13, is less than the required minimum design area, the design area shall be permitted to only include those sprinklers within the available design area.

28.2.4.2.5 *

Where the total design discharge from the operating sprinklers is less than the minimum required discharge determined by multiplying the required design density times the required minimum design area, an additional flow shall be added at the point of common connection closest to the source to increase the overall demand, not including hose stream allowance, to the minimum required discharge.

28.2.4.2.6 *

Where a sprinkler’s assigned area of discharge is defined by the presence of a full-height wall assembly, the area on the opposite side of the wall of the flowing sprinkler shall not be counted towards the total design area.

28.2.4.3 CMSA Sprinkler Method.

28.2.4.3.1

For CMSA sprinklers, the design area shall be a rectangular area having a dimension parallel to the branch lines determined in accordance with 28.2.4.2 with the design area *(A)* being calculated by multiplying the required number of sprinklers by the actual floor area covered by those sprinklers.

28.2.4.3.2

Any fractional sprinkler shall be carried to the next higher whole sprinkler.

28.2.4.3.3

In systems having branch lines with an insufficient number of sprinklers to fulfill the dimension along the branch line requirement, the design area shall be extended to include sprinklers on adjacent branch lines supplied by the same cross main.

28.2.4.4 ESFR Sprinkler Method.

For ESFR sprinklers, the design area shall be in accordance with the applicable sections in Chapters 23 and 25.

28.2.4.4.1

Where the design area was increased to 18 sprinklers due to the slope of the ceiling or roof, the design area shall be five sprinklers on the most demanding three branch lines and the three most demanding sprinklers on the next most demanding branch line.

28.2.4.5 * Gridded Systems.

28.2.4.5.1

For gridded systems, the designer shall verify that the hydraulically most demanding area is being used.

28.2.4.5.2

A minimum of two additional sets of calculations shall be submitted to demonstrate peaking of demand area friction loss when compared to areas immediately adjacent on either side along the same branch lines, unless the requirements of 28.2.4.5.3 are met.

28.2.4.5.3

Computer programs that show the peaking of the demand area friction loss shall be acceptable based on a single set of calculations.

28.2.4.6 Design Densities.

28.2.4.6.1 *

System piping shall be hydraulically designed using design densities and areas of operation in accordance with 19.2.3.2 or Chapter 20 as required for the occupancies or hazards involved.

28.2.4.6.2 *

The density shall be calculated on the basis of floor area of sprinkler operation. Where sprinklers are installed under a sloped ceiling, the area used for this calculation shall be the horizontal plane below the sprinklers.

28.2.4.6.3

The area covered by any sprinkler used in hydraulic design and calculations shall be the horizontal distances measured between the sprinklers on the branch line and between the branch lines in accordance with 9.5.2.

28.2.4.6.4

Where sprinklers are installed above and below a ceiling or in a case where more than two areas are supplied from a common set of branch lines, the branch lines and supplies shall be calculated to supply the largest water demand.

28.2.4.6.5 *

For sloped ceiling applications, the area of sprinkler application for density calculations shall be based upon the projected horizontal area.

28.2.4.7 * Design Area Sprinklers.

28.2.4.7.1

Each sprinkler in the design area and the remainder of the hydraulically designed system shall discharge at a flow rate at least equal to the stipulated minimum water application rate (density) multiplied by the area of sprinkler operation.

28.2.4.7.1.1

Where sprinklers are required to discharge a specific flow or pressure rather than a density, each sprinkler in the design area shall discharge at a flow or pressure at least equal to the minimum required.

28.2.4.7.2 *

Where the design area is equal to or greater than the area in Table 28.2.4.7.2 for the hazard being protected by the sprinkler system, the discharge for sprinklers protecting small compartments 55 ft^2 (5.1 m^2) or less, such as closets, washrooms, and similar compartments that are in the design area, shall be permitted to be omitted from the hydraulic calculations.

Table 28.2.4.7.2 Minimum Design Area

Occupancy Hazard Classification	Minimum Design Area to Omit Discharge from Sprinklers in Small Compartments in Design Area [ft^2 (m^2)]
Light hazard–wet pipe system	1500 (140)
Light hazard–dry pipe system	1950 (180)
Ordinary hazard–wet pipe system	1500 (140)
Ordinary hazard–dry pipe system	1950 (180)
Extra hazard–wet pipe system	2500 (130)
Extra hazard–dry pipe system	3250 (300)

28.2.4.7.2.1

The sprinklers in these small compartments shall be capable of discharging the minimum density appropriate for the hazard they protect in accordance with Table 19.2.3.1.1.

28.2.4.7.2.2

The requirements of 28.2.4.7.2 shall only apply where the area of application is equal to or greater than the area shown in Table 28.2.4.7.2 for the appropriate hazard classification (including a 30 percent increase for dry pipe systems).

28.2.4.7.3 *

The requirements of 28.2.4.7.1 and 28.2.4.7.1.1 to include every sprinkler in the design area shall not apply where sprinklers are provided above and below obstructions.

28.2.4.7.4 Supplemental Sprinklers.

28.2.4.7.4.1

Supplemental sprinklers under the obstruction shall not be required to be included in the hydraulic calculation of the ceiling sprinklers.

28.2.4.7.4.2

Where the piping to sprinklers under obstructions follows the same sizing pattern as the branch lines, no additional hydraulic calculations shall be required for sprinklers under obstructions.

28.2.4.7.4.3

Where the requirements of 28.2.4.7.4.2 are not met, a level of supplemental sprinklers shall be calculated to verify pipe sizes.

(A) *

The number of supplemental sprinklers shall include up to a maximum of four adjacent sprinklers attached to a branch line.

(B)

For density/area applications, the area of coverage of each sprinkler shall only include the footprint of the obstruction it is protecting.

(C)

For density/area applications, the design criteria shall be in accordance with Section 19.5.

(D)

For CMSA and ESFR sprinklers, the discharge pressure shall be in accordance with 20.16.4.

(E)

The level of supplemental sprinklers shall not be required to be balanced with the overhead system.

28.2.4.7.5

Water demand of sprinklers installed in concealed spaces shall not be required to be added to the ceiling demand.

28.2.4.7.6

Calculations shall begin at the hydraulically most remote sprinkler.

28.2.4.7.7

The calculated pressure at each sprinkler shall be used to determine the discharge flow rate for that particular sprinkler.

28.2.4.7.8

Where sprinklers are installed under a sloped ceiling, the area shall be calculated on a horizontal plane below the sprinklers.

28.2.4.8 Friction Loss.

28.2.4.8.1

Pipe friction loss shall be calculated in accordance with the Hazen–Williams formula with *C* values from Table 28.2.4.8.1, as follows:

(1) Pipe, fittings, flexible sprinkler hose fittings, and devices such as valves, meters, flow switches, and strainers shall be included, and elevation changes that affect the sprinkler discharge shall be calculated.
(2) Tie-in drain piping shall not be included in the hydraulic calculations.
(3) Losses for a tee or a cross shall be calculated where flow direction change occurs based on the equivalent pipe length of the piping segment in which the fitting is included.
(4) The tee at the top of a riser nipple shall be included in the branch line, the tee at the base of a riser nipple shall be included in the riser nipple, and the tee or cross at a cross main–feed main junction shall be included in the cross main.
(5) Losses for straight-through flow in a tee or cross shall not be included.
(6) The loss of reducing elbows based on the equivalent length value of the smallest outlet shall be calculated.
(7) The equivalent length value for the standard elbow on any abrupt 90-degree turn, such as the screw-type pattern, shall be used.
(8) The equivalent length value for a fitting with a bushing shall be the same as for a similarly sized and configured reducing fitting.
(9) The equivalent length value for the long-turn elbow on any sweeping 90-degree turn, such as a flanged, welded, or mechanical joint-elbow type, shall be used. *(See Table 28.2.3.1.1.)*
(10) Losses shall be permitted to be excluded for tapered reducers.
(11) Losses shall be permitted to be excluded for a fitting with or without a bushing, directly connected to a sprinkler, except as required in 28.2.3.1.2 and 28.2.3.4.
(12) Losses for flexible sprinkler hose fittings shall be based upon the number of bends referenced in the listing for the hose length.
(13) Losses through a pressure-reducing valve shall be included based on the normal inlet pressure condition, and pressure loss data from the manufacturer's literature shall be used.
(14) In new systems, an increased *C* value of 120 shall be permitted where nitrogen is provided in accordance with 8.2.10.
(15) In new systems, an increased *C* value of 120 shall be permitted where vacuum pressure is provided in accordance with Section 8.11.
(16) In new systems, an increased *C* value of 120 shall be permitted where a vapor corrosion inhibitor is provided in accordance with 8.2.11.

Table 28.2.4.8.1 Hazen–Williams *C* Values

Pipe or Tube	*C* Value[a]
Unlined cast or ductile iron	100
Black steel (dry systems including preaction)	100
Black steel (wet systems including deluge)	120
Black steel (dry system including preaction) using nitrogen[b]	120
Black steel (dry system including preaction) using vacuum pressure[c]	120
Black steel (dry system including preaction) using a vapor corrosion inhibitor[d]	120
Galvanized steel (dry systems including preaction)	100
Galvanized steel (wet systems including deluge)	120
Galvanized steel (dry systems including preaction) using nitrogen[b]	120
Galvanized steel (dry systems including preaction) using vacuum pressure[c]	120
Galvanized steel (dry systems including preaction) using a vapor corrosion inhibitor[d]	120
Plastic all (listed)	150

Pipe or Tube	*C* Value[a]
Cement-lined cast- or ductile iron	140
Copper tube, brass or stainless steel	150
Asbestos cement	140
Concrete	140

[a]The authority having jurisdiction is permitted to allow other *C* values.

[b]Nitrogen supply shall be installed in accordance with 8.2.10.

[c]Vacuum pressure shall be installed in accordance with Section 8.11.

[d]Vapor corrosion inhibitor shall be installed in accordance with 8.2.11.

28.2.4.8.2 *

For antifreeze systems greater than 40 gal (150 L) in size, the pipe friction loss shall be calculated using the Darcy-Weisbach equation shown in 28.2.2.1.3 using a Moody diagram and ε-factors that are representative of aged pipe otherwise following the methodology presented in 28.2.4.8.1.

28.2.4.9 Orifice Plates.

28.2.4.9.1

Orifice plates shall not be used for balancing the system.

28.2.4.9.2

Unless the requirements of 28.2.4.9.3 or 28.2.4.9.4 are met, mixing of sprinklers of different K-factors by reducing the K-factor of adjacent sprinklers on the same branch line leading back to the main for the purpose of minimizing sprinkler over discharge shall not be permitted.

28.2.4.9.3 *

Sprinklers with different K-factors shall be acceptable for specific uses, such as exposure protection, small enclosures, smaller portions of a room, or directional discharge, where an adjacent sprinkler does not need to discharge as much water.

28.2.4.9.4

Extended-coverage and residential sprinklers with a different K-factor shall be acceptable for part of the protection area where installed in accordance with their listing.

28.2.4.10 * Pressures.

28.2.4.10.1

When calculating flow from an orifice, the total pressure (P_t) shall be used, unless the calculation method of 28.2.4.10.2 is utilized.

28.2.4.10.2

Use of the normal pressure (P_n) calculated by subtracting the velocity pressure from the total pressure shall be permitted. Where the normal pressure is used, it shall be used on all branch lines and cross mains where applicable.

28.2.4.10.3

Flow from a sprinkler shall be calculated using the nominal K-factor except that the manufacturer's adjusted K-factors shall be utilized for dry-type sprinklers.

28.2.4.11 Minimum Operating Pressure.

28.2.4.11.1

Minimum operating pressure of any sprinkler shall be 7 psi (0.5 bar).

28.2.4.11.2

Where a higher minimum operating pressure for the desired application is specified in the listing of the sprinkler, this higher pressure shall be required.

28.2.4.12 Maximum Operating Pressure.

For sprinklers in extra hazard occupancies or designed in accordance with Chapters 20 through 26, the maximum operating pressure of any sprinkler shall be 175 psi (12 bar).

28.2.5 In-Rack Sprinklers.

28.2.5.1

Pipes to in-rack sprinklers shall be sized by hydraulic calculations.

28.2.5.2

Water demand of sprinklers installed in racks or water curtains shall be added to the ceiling sprinkler water demand at the point of connection. Demands shall be balanced to the higher pressure.

28.3 Hose Allowance.

Water allowance for outside hose shall be added to the sprinkler and inside hose requirement at the connection to the city water main or a yard hydrant, whichever is closer to the system riser.

28.4 Hydraulic Calculation Forms and Reports.

28.4.1 Handwritten Hydraulic Calculation Forms.

28.4.1.1 General.

Handwritten hydraulic calculations shall be prepared on form sheets that include a summary sheet, detailed worksheets, and a graph sheet. *[See Figure A.28.4.1.2(a), Figure A.28.4.1.3, and Figure A.28.4.1.4 for copies of typical forms.]*

28.4.1.2 * Summary Sheet.

The summary sheet shall contain the information included in 28.4.2.2, where applicable.

28.4.1.3 * Detailed Worksheets.

Detailed worksheets shall contain the information included in 28.4.2.6.

28.4.1.4 * Graph Sheet.

A graphic representation of the complete hydraulic calculation shall be plotted on semiexponential graph paper ($Q^{1.85}$) and shall include the information in 28.4.2.3.

28.4.2 Computer-Generated Hydraulic Calculation Reports.

28.4.2.1 * General.

28.4.2.1.1

Computer-generated hydraulic calculation reports shall include a summary sheet, a graph sheet, a water supply analysis, a node analysis, and detailed worksheets.

28.4.2.1.2

The data shall be presented in the order shown in Figure 28.4.2.1.2(a) through Figure 28.4.2.1.2(d).

Figure 28.4.2.1.2(a) Summary Sheet.

HYDRAULIC CALCULATIONS
for

Project name: _____

Location: _____

Drawing no.: _____ Date: _____

Design

Remote area number: _____

Remote area location: _____

Occupancy classification: _____

Density: _____ gpm/ft^2 (mm/min)

Area of application: _____ ft^2 (m^2)

Coverage per sprinkler: _____ ft^2 (m^2)

Type of sprinklers calculated: _____

No. of sprinklers calculated: _____

In-rack demand: _____

Hose streams: _____

Total water required (including hose streams): _____ gpm (mm/min) @ _____ psi (bar)

Type of system: _____

Volume of dry or preaction system: _____ gal (l)

Water supply information

Date: _____

Location: _____

Source: _____

Name of contractor: _____

Address: _____

Phone number: _____

Name of designer: _____

Authority having jurisdiction: _____

Notes: (Include peaking information or gridded systems here.) _____

NFPA 13

Figure 28.4.2.1.2(b) Graph Sheet.

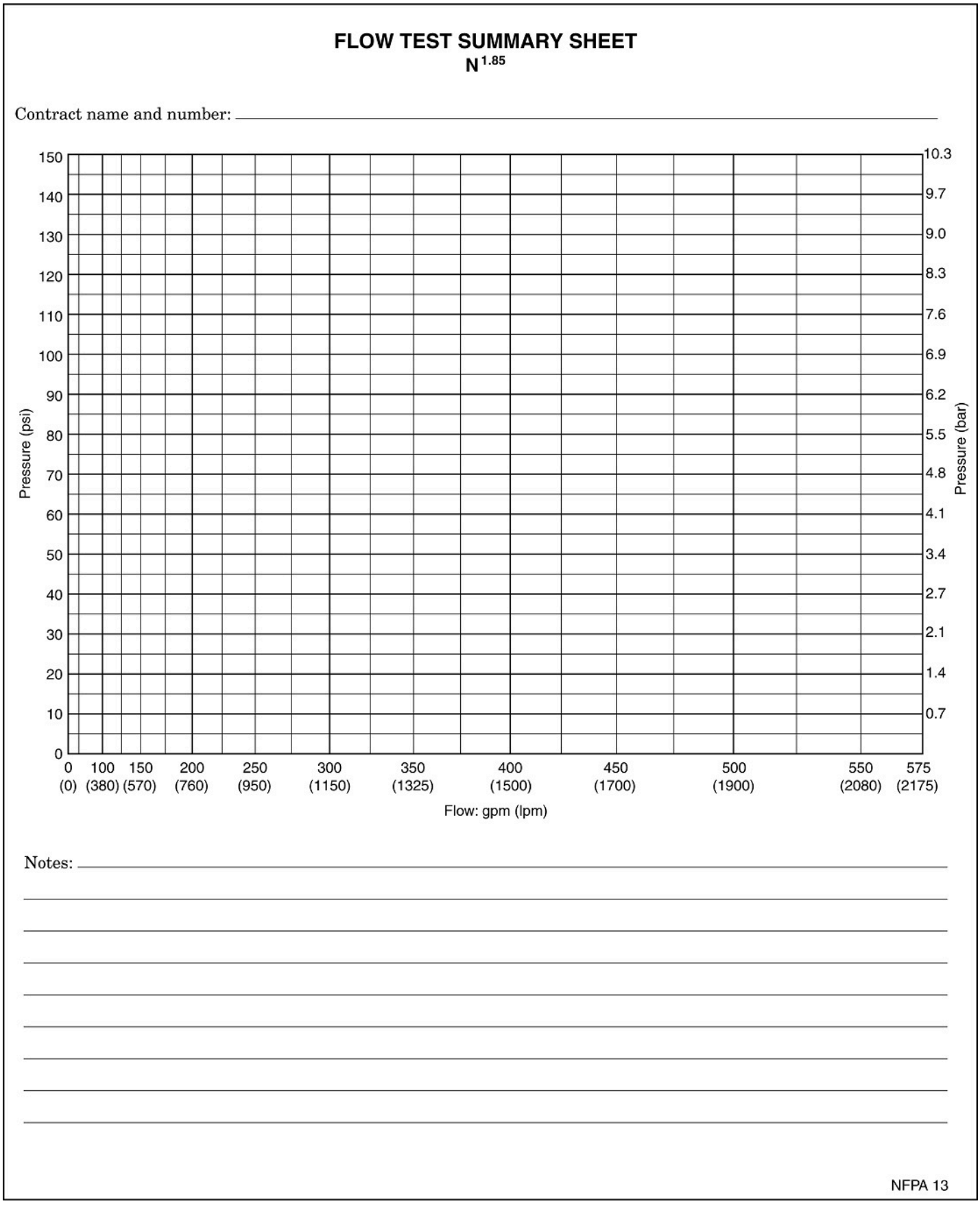


Figure 28.4.2.1.2(c) Supply and Node Analysis Sheet.

SUPPLY ANALYSIS

Node at Source	Static Pressure	Residual Pressure	Flow	Available Pressure	Total Demand	Required Pressure
Data	Data	Data	Data	Data	Data	Data

NODE ANALYSIS

Node Tag	Elevation	Node Type	Pressure at Node	Discharge at Node	Notes
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data
Data	Data	Data	Data	Data	Data

NFPA 13

Figure 28.4.2.1.2(d) Detailed Worksheet.

Job name: ______________________________ Sheet number: __________

PIPE INFORMATION

Node 1	Elev 1 (ft) (m)	K-Factor	Flow added — this step (q)	Nominal ID	Fittings— quantity and length	L ft (m)	C Factor	total (P_t)	Notes
						F ft (m)	P_f per foot (m) (psi) (bar)	elev (P_e)	
Node 2			Total flow (Q)	Actual ID		T ft (m)		frict (P_f)	
data 1	data 1	data 1	data 1	data	data	data	data	data 1	
data 2	data 2		data	data	data	data	data	data	data
					data	data		data	
data 1	data 1	data 1	data 1	data	data	data	data	data 1	
data 2	data 2		data	data	data	data	data	data	data
					data	data		data	
data 1	data 1	data 1	data 1	data	data	data	data	data 1	
data 2	data 2		data	data	data	data	data	data	data
					data	data		data	
data 1	data 1	data 1	data 1	data	data	data	data	data 1	
data 2	data 2		data	data	data	data	data	data	data
					data	data		data	
data 1	data 1	data 1	data 1	data	data	data	data	data 1	
data 2	data 2		data	data	data	data	data	data	data
					data	data		data	
data 1	data 1	data 1	data 1	data	data	data	data	data 1	
data 2	data 2		data	data	data	data	data	data	data
					data	data		data	
data 1	data 1	data 1	data 1	data	data	data	data	data 1	
data 2	data 2		data	data	data	data	data	data	data
					data	data		data	

NFPA 13

28.4.2.2 Summary Sheet.

The summary sheet as shown in Figure 28.4.2.1.2(a) shall contain the following information, where applicable:

(1) Project name and date
(2) Location (including street address)
(3) Owner or expected occupant of space being designed

(4) Name, address, and phone number of installing contractor
(5) Name and phone number of designer
(6) Authority having jurisdiction
(7) Standard or document system is being designed to, including the edition of the document
(8) Design area number and location
(9) Drawing or sheet number where design area is located
(10) Occupancy or commodity classification and information
(11) For storage applications (including miscellaneous), additional information including storage height, ceiling height, storage configuration, aisle width, orientation of upright or pendent, sprinkler K-factor and sprinkler temperature, and the table and or curve utilized in the design
(12) System type, including the system volume with type of protection system indicated in the notes
(13) Sprinkler type, including coverage and response type
(14) Slope of roof or ceiling within the design area
(15) System design requirements, as follows:
    (a) Design area of application, ft^2 (m^2)
    (b) Minimum rate of water application (density), gpm/ft^2 (mm/min)
    (c) Area per sprinkler, ft^2 (m^2)
    (d) Number of sprinklers calculated
(16) Total water requirements as calculated, including allowance for inside hose, outside hydrants, water curtain, and exposure sprinklers, and allowance for in-rack sprinklers, gpm (L/min)
(17) Ceiling height if used for quick response sprinkler reduction
(18) Elevation of highest calculated sprinkler
(19) Water supply information, including the following:
    (a) Date and time of test
    (b) Location of the test and flow hydrant(s)
    (c) Source of the water for the flow test
    (d) Elevation of the test hydrant relative to the finished floor
    (e) Size of fire pump, gpm @ psi (L/min @ bar)
    (f) Size of on-site water tank
(20) Notes that include peaking information for calculations performed by a computer program, type of preaction system, limitations (dimension, flow, and pressure) on extended-coverage or other listed special sprinklers, system type, including the system volume

28.4.2.3 Graph Sheet.

A graphic representation of the complete hydraulic calculation shall be plotted on semiexponential graph paper ($Q^{1.85}$) as shown in Figure 28.4.2.1.2(b) and shall include the following:

(1) Water supply curve
(2) Sprinkler system demand
(3) Hose demand (where applicable)
(4) In-rack sprinkler demand (where applicable)
(5) Additional pressures supplied by a fire pump or other source (when applicable)

28.4.2.4 Supply Analysis.

Information summarized from the graph sheet as shown in Figure 28.4.2.1.2(c) shall include the following:

(1) Node tag at the source
(2) Static pressure [psi (bar)] available at the source
(3) Residual pressure [psi (bar)] available at the source
(4) Total flow [gpm (L/min)] available at the source
(5) Available pressure [psi (bar)] at the source when the total calculated demand is flowing
(6) Total calculated demand [gpm (L/min)] at the source
(7) Required pressure [psi (bar)] when flowing total calculated demand

28.4.2.5 Node Analysis.

Organized information as shown in Figure 28.4.2.1.2(c) regarding the node tags given to each hydraulic reference point on the system as indicated on the shop drawings shall include the following information:

(1) Node tag for each specific point on the system used in the hydraulic calculations

(2) Elevation in ft (m) of each node tag
(3) K-factor of flowing nodes (such as sprinklers)
(4) Hose allowance in gpm (L/min) requirements for the node tag
(5) Pressure in psi (bar) at the node
(6) Discharge in gpm (L/min) calculated at the node
(7) Notes that indicate any special requirements for the node

28.4.2.6 Detailed Worksheets.

Detailed worksheets as shown in Figure 28.4.2.1.2(d) or computer printout sheets shall contain the following information:

(1) Sheet number
(2) Hydraulic reference points used in each step
(3) Elevation in ft (m) at each hydraulic reference point
(4) Sprinkler description and discharge constant (*K*) for the flowing reference point
(5) Flow in gpm (L/min) for the flowing reference point (when applicable)
(6) Total flow in gpm (L/min) through each step
(7) Nominal pipe size in in. (mm)
(8) Actual internal diameter of pipe in in. (mm)
(9) Quantity and length in ft (m) of each type of fitting and device
(10) Pipe lengths in ft (m), center-to-center of fittings
(11) Equivalent pipe lengths in ft (m) of fittings and devices for the step
(12) Total equivalent length in ft (m) of pipes and fitting for the step
(13) C-factor used in each step
(14) Friction loss in psi/ft (bar/m) of pipe
(15) Sum of the pressures from the previous step (starting pressure at beginning)
(16) Elevation head in psi (bar) between reference points
(17) Total friction loss in psi (bar) between reference points
(18) Required pressure in psi (bar) at each reference point
(19) Notes and other information shall include the following:
    (a) Velocity pressure and normal pressure if included in calculations
    (b) In-rack sprinkler demand balanced to ceiling demand
    (c) Notes to indicate starting points or reference to other sheets or to clarify data shown
    (d) Diagram to accompany gridded system calculations to indicate flow quantities and directions for lines with sprinklers operating in the remote area
    (e) Combined K-factor calculations for sprinklers on drops, armovers, or sprigs where calculations do not begin at the sprinkler
    (f) The pressure [psi/(bar)] loss assigned the backflow device when included on a system
    (g) Friction factor and Reynolds number when the Darcy–Weisbach equation is used

28.5 Pipe Schedules.

Pipe schedules shall not be used, except in existing systems and in new systems or extensions to existing systems described in Chapter 19. Water supplies shall conform to 19.2.2.

28.5.1 * General.

28.5.1.1

The pipe schedule sizing provisions shall not apply to hydraulically calculated systems.

28.5.1.2

The following sprinkler systems shall not be permitted to be pipe schedule:

(1) Those having sprinklers with K-factors other than nominal 5.6
(2) Those having listed piping materials other than those covered in Table 7.3.1.1
(3) Those having listed fittings other than what is covered in Table 7.4.1
(4) Extra hazard Group 1 and Group 2 systems
(5) Exposure protection systems

28.5.1.3

The number of automatic sprinklers on a given pipe size on one floor shall not exceed the number given in 28.5.2, 28.5.3, or 28.5.4 for a given occupancy.

28.5.1.4 * Size of Risers.

Each system riser shall be sized to supply all sprinklers on the riser on any one floor as determined by the standard schedules of pipe sizes in 28.5.2, 28.5.3, or 28.5.4.

28.5.1.5 Slatted Floors, Large Floor Openings, Mezzanines, and Large Platforms.

Buildings having slatted floors or large unprotected floor openings without approved stops shall be treated as one area with reference to pipe sizes, and the feed mains or risers shall be of the size required for the total number of sprinklers.

28.5.1.6 Stair Towers.

Stair towers, or other construction with incomplete floors, if piped on independent risers, shall be treated as one area with reference to pipe sizes.

28.5.2 Schedule for Light Hazard Occupancies.

28.5.2.1 Branch Lines.

28.5.2.1.1

Unless permitted by 28.5.2.1.2 or 28.5.2.1.3, branch lines shall not exceed eight sprinklers on either side of a cross main.

28.5.2.1.2

Where more than eight sprinklers on a branch line are necessary, lines shall be permitted to be increased to nine sprinklers by making the two end lengths 1 in. (25 mm) and 1¼ in. (32 mm), respectively, and the sizes thereafter standard.

28.5.2.1.3

Ten sprinklers shall be permitted to be placed on a branch line, making the two end lengths 1 in. (25 mm) and 1¼ in. (32 mm), respectively, and feeding the tenth sprinkler by a 2½ in. (65 mm) pipe.

28.5.2.2 Pipe Sizes.

28.5.2.2.1

Pipe sizes shall be in accordance with Table 28.5.2.2.1.

Table 28.5.2.2.1 Light Hazard Pipe Schedules

Steel		Copper	
1 in. (25 mm)	2 sprinklers	1 in. (25 mm)	2 sprinklers
1¼ in. (32 mm)	3 sprinklers	1¼ in. (32 mm)	3 sprinklers
1½ in. (40 mm)	5 sprinklers	1½ in. (40 mm)	5 sprinklers
2 in. (50 mm)	10 sprinklers	2 in. (50 mm)	12 sprinklers
2½ in. (65 mm)	30 sprinklers	2½ in. (65 mm)	40 sprinklers
3 in. (80 mm)	60 sprinklers	3 in. (80 mm)	65 sprinklers
3½ in. (90 mm)	100 sprinklers	3½ in. (90 mm)	115 sprinklers
4 in. (100 mm)	See Section 4.4.	4 in. (100 mm)	See Section 4.4.

28.5.2.2.2

Each area requiring more sprinklers than the number specified for 3½ in. (90 mm) pipe in Table 28.5.2.2.1 and without subdividing partitions (not necessarily fire walls) shall be supplied by mains or risers sized for ordinary hazard occupancies.

28.5.2.3

Where sprinklers are installed above and below ceilings in accordance with Figure 28.5.2.3(a) through Figure 28.5.2.3(c), and such sprinklers are supplied from a common set of branch lines or separate branch lines from a common cross main, such branch lines shall not exceed eight sprinklers above and eight sprinklers below any ceiling on either side of the cross main.

Figure 28.5.2.3(a) Arrangement of Branch Lines Supplying Sprinklers Above and Below Ceiling.

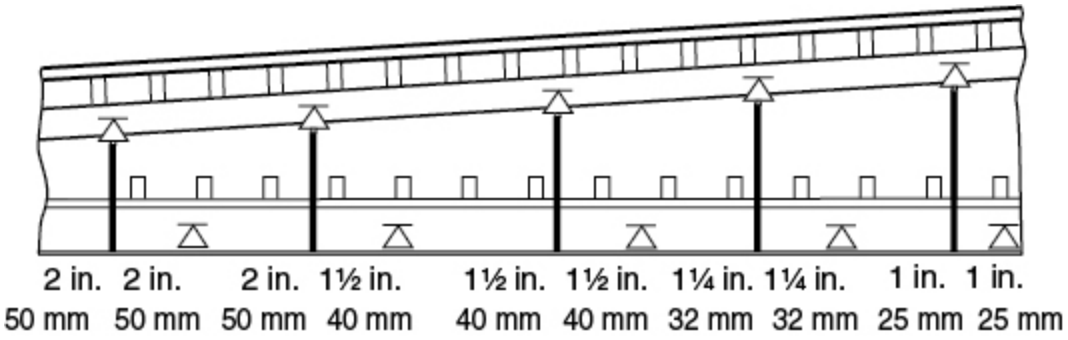


Figure 28.5.2.3(b) Sprinkler on Riser Nipple from Branch Line in Lower Fire Area.

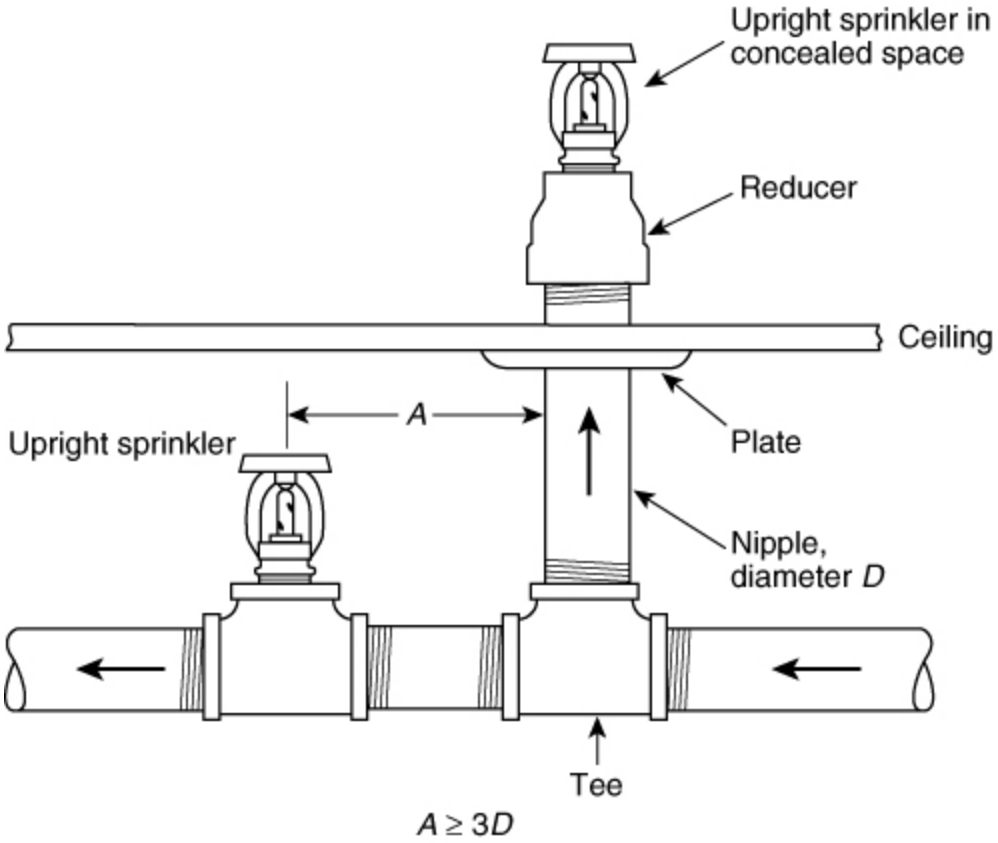
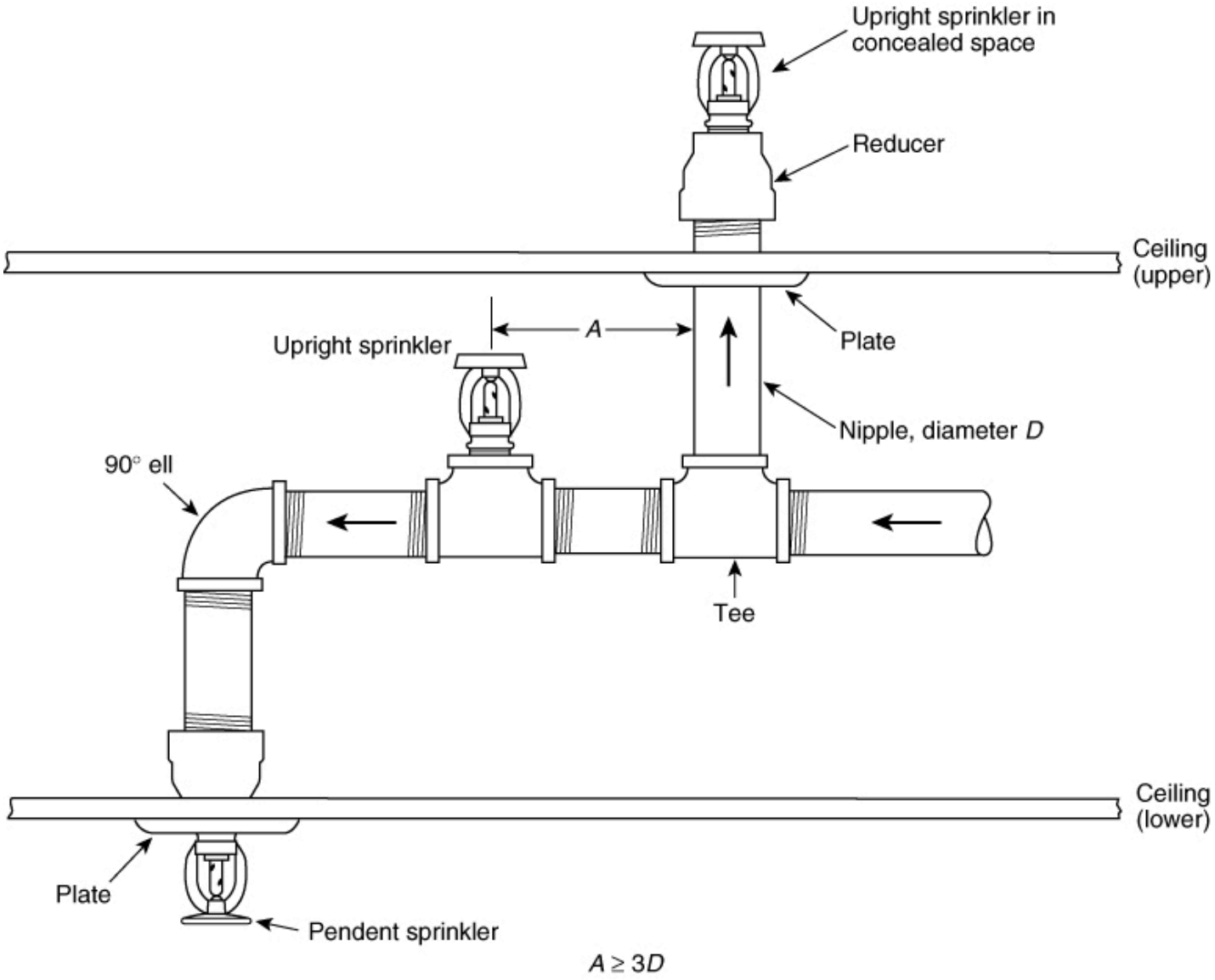


Figure 28.5.2.3(c) Arrangement of Branch Lines Supplying Sprinklers Above, Between, and Below Ceilings.



28.5.2.4

Unless the requirements of 28.5.2.5 are met, pipe sizing up to and including 2 ½ in. (65 mm) shall be as shown in Table 28.5.2.4 utilizing the greatest number of sprinklers to be found on any two adjacent levels.

Table 28.5.2.4 Number of Sprinklers Above and Below Ceiling

Steel		Copper	
1 in. (25 mm)	2 sprinklers	1 in. (25 mm)	2 sprinklers
1¼ in. (32 mm)	4 sprinklers	1¼ in. (32 mm)	4 sprinklers
1½ in. (40 mm)	7 sprinklers	1½ in. (40 mm)	7 sprinklers
2 in. (50 mm)	15 sprinklers	2 in. (50 mm)	18 sprinklers
2½ in. (65 mm)	50 sprinklers	2½ in. (65 mm)	65 sprinklers

28.5.2.5

Branch lines and cross mains supplying sprinklers installed entirely above or entirely below ceilings shall be sized in accordance with Table 28.5.2.2.1.

28.5.2.6 *

Where the total number of sprinklers above and below a ceiling exceeds the number specified in Table 28.5.2.4 for 2 1/2 in. (65 mm) pipe, the pipe supplying such sprinklers shall be increased to 3 in. (75 mm) and sized thereafter according to the schedule shown in Table 28.5.2.2.1 for the number of sprinklers above or below a ceiling, whichever is larger.

28.5.3 Schedule for Ordinary Hazard Occupancies.

28.5.3.1

Unless permitted by 28.5.3.2 or 28.5.3.3, branch lines shall not exceed eight sprinklers on either side of a cross main.

28.5.3.2

Where more than eight sprinklers on a branch line are necessary, lines shall be permitted to be increased to nine sprinklers by making the two end lengths 1 in. (25 mm) and 1 1/4 in. (32 mm), respectively, and the sizes thereafter standard.

28.5.3.3

Ten sprinklers shall be permitted to be placed on a branch line, making the two end lengths 1 in. (25 mm) and 1 1/4 in. (32 mm), respectively, and feeding the tenth sprinkler by a 2 1/2 in. (65 mm) pipe.

28.5.3.4

Pipe sizes shall be in accordance with Table 28.5.3.4.

Table 28.5.3.4 Ordinary Hazard Pipe Schedule

Steel		Copper	
1 in. (25 mm)	2 sprinklers	1 in. (25 mm)	2 sprinklers
1 1/4 in. (32 mm)	3 sprinklers	1 1/4 in. (32 mm)	3 sprinklers
1 1/2 in. (40 mm)	5 sprinklers	1 1/2 in. (40 mm)	5 sprinklers
2 in. (50 mm)	10 sprinklers	2 in. (50 mm)	12 sprinklers
2 1/2 in. (65 mm)	20 sprinklers	2 1/2 in. (65 mm)	25 sprinklers
3 in. (80 mm)	40 sprinklers	3 in. (80 mm)	45 sprinklers
3 1/2 in. (90 mm)	65 sprinklers	3 1/2 in. (90 mm)	75 sprinklers
4 in. (100 mm)	100 sprinklers	4 in. (100 mm)	115 sprinklers
5 in. (125 mm)	160 sprinklers	5 in. (125 mm)	180 sprinklers
6 in. (150 mm)	275 sprinklers	6 in. (150 mm)	300 sprinklers
8 in. (200 mm)	See Section 4.4.	8 in. (200 mm)	See Section 4.4.

28.5.3.5

Where the distance between sprinklers on the branch line exceeds 12 ft (3.7 m) or the distance between the branch lines exceeds 12 ft (3.7 m), the number of sprinklers for a given pipe size shall be in accordance with Table 28.5.3.5.

Table 28.5.3.5 Number of Sprinklers — Greater Than 12 ft (3.7 m) Separations

Steel		Copper	
2 1/2 in. (65 mm)	15 sprinklers	2 1/2 in. (65 mm)	20 sprinklers
3 in. (80 mm)	30 sprinklers	3 in. (80 mm)	35 sprinklers
3 1/2 in. (90 mm)	60 sprinklers	3 1/2 in. (90 mm)	65 sprinklers

Note: For other pipe and tube sizes, see Table 28.5.3.4.

28.5.3.6

Where sprinklers are installed above and below ceilings and such sprinklers are supplied from a common set of branch lines or separate branch lines supplied by a common cross main, such branch lines shall not exceed eight sprinklers above and eight sprinklers below any ceiling on either side of the cross main.

28.5.3.7

Pipe sizing up to and including 3 in. (76 mm) shall be as shown in Table 28.5.3.7 in accordance with Figure 28.5.2.3(a), Figure 28.5.2.3(b), and Figure 28.5.2.3(c) utilizing the greatest number of sprinklers to be found on any two adjacent levels.

Table 28.5.3.7 Number of Sprinklers Above and Below a Ceiling

Steel		Copper	
1 in. (25 mm)	2 sprinklers	1 in. (25 mm)	2 sprinklers
1¼ in. (32 mm)	4 sprinklers	1¼ in. (32 mm)	4 sprinklers
1½ in. (40 mm)	7 sprinklers	1½ in. (40 mm)	7 sprinklers
2 in. (50 mm)	15 sprinklers	2 in. (50 mm)	18 sprinklers
2½ in. (65 mm)	30 sprinklers	2½ in. (65 mm)	40 sprinklers
3 in. (80 mm)	60 sprinklers	3 in. (80 mm)	65 sprinklers

28.5.3.8

Branch lines and cross mains supplying sprinklers installed entirely above or entirely below ceilings shall be sized in accordance with Table 28.5.3.4 or Table 28.5.3.5.

28.5.3.9 *

Where the total number of sprinklers above and below a ceiling exceeds the number specified in Table 28.5.3.7 for 3 in. (80 mm) pipe, the pipe supplying such sprinklers shall be increased to 3½ in. (90 mm) or larger and sized thereafter according to the schedule shown in Table 28.5.2.2.1 or Table 28.5.3.4 for the number of sprinklers above or below a ceiling, whichever is larger.

28.5.3.10

Where the distance between the sprinklers protecting the occupied area exceeds 12 ft (3.7 m) or the distance between the branch lines exceeds 12 ft (3.7 m), the branch lines shall be sized in accordance with either Table 28.5.3.5, taking into consideration the sprinklers protecting the occupied area only, or Table 28.5.3.7, whichever requires the greater size of pipe.

28.5.4 * Extra Hazard Occupancies.

Extra hazard occupancies shall be hydraulically calculated.