**Chapter 27 Plans and Calculations**

27.1\* Working Plans

27.1.1\*

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

27.1.1.1

Working plan submittals shall include the following:

Working plans of the system(s), per 27.1.3

Hydraulic calculations where systems are required to be calculated

Data sheets for the system components where required by the authority having jurisdiction

\*Signed owner's certificate

27.1.1.2

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

27.1.1.3

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

27.1.2

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

27.1.3

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:

Name of owner and occupant.

Location, including street address.

Point of compass.

Full height cross section or schematic diagram, including structural member information if required for clarity and including ceiling construction and method of protection for nonmetallic piping.

Ceiling/roof heights and slopes not shown in the full height cross section.

Location of partitions.

Location of fire walls.

Occupancy class of each area or room.

Location and size of concealed spaces, closets, attics, and bathrooms.

Any small enclosures in which no sprinklers are to be installed.

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.

Other sources of water supply, with pressure or elevation.

Make, type, model, and nominal K-factor of sprinklers, including sprinkler identification number.

Temperature rating and location of high-temperature sprinklers.

Total area protected by each system on each floor.

Number of sprinklers on each riser per floor.

Total number of sprinklers on each dry pipe system, preaction system, combined dry pipe-preaction system, or deluge system.

Approximate capacity in gallons of each dry pipe system.

Pipe type and schedule of wall thickness.

Nominal pipe size and cutting lengths of pipe (or center-to-center dimensions). Where typical branch lines prevail, it shall be necessary to size only one typical line.

Location and size of riser nipples.

Type of fittings and joints and location of all welds and bends. The contractor shall specify on drawing any sections to be shop welded and the type of fittings or formations to be used.

Type and locations of hangers, sleeves, braces, and methods of securing sprinklers when applicable.

All control valves, check valves, drain pipes, and test connections.

Make, type, model, and size of backflow prevention assembly, and means to forward flow test at system demand.

Make, type, model, and size of alarm or dry pipe valve.

Make, type, model, and size of preaction or deluge valve.

Kind and location of alarm bells.

Size and location of standpipe risers, hose outlets, hand hose, monitor nozzles, and related equipment.

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.

Piping provisions for flushing.

Where the equipment is to be installed as an addition to an existing system, enough of the existing system indicated on the plans to make all conditions clear.

For hydraulically designed systems, the information on the hydraulic data nameplate.

A graphic representation of the scale used on all plans.

Name, address, and phone number(s) of contractor.

Hydraulic reference points shown on the plan that correspond with comparable reference points on the hydraulic calculation sheets.

The minimum rate of water application (density or flow or discharge pressure), the design area of water application, in-rack sprinkler demand, and the water required for hose streams both inside and outside.

The total quantity of water and the pressure required noted at a common reference point for each system.

Relative elevations of sprinklers, junction points, and supply or reference points.

If room design method is used, all unprotected wall openings throughout the floor protected.

Calculation of loads for sizing and details of sway bracing.

Zones of influence used in calculations for seismic bracing indicated on plans.

The setting for pressure-reducing valves.

Information about listed antifreeze solution used (type and amount).

Size and location of hydrants showing size and number of outlets and if outlets are to be equipped with independent gate valves. Whether hose houses and equipment are to be provided, and by whom, shall be indicated. Static and residual hydrants that were used in flow tests shall be shown.

Size, location, and piping arrangement of fire department connections.

Edition year of NFPA 13 to which the sprinkler system is designed.

27.1.4

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.

27.1.5\* Working Plans for Automatic Sprinkler Systems With Non-Fire Protection Connections

27.1.5.1

Special symbols shall be used and explained for auxiliary piping, pumps, heat exchangers, valves, strainers, and the like, clearly distinguishing these devices and piping runs from those of the sprinkler system.

27.1.5.2

Model number, type, and manufacturer's name shall be identified for each piece of auxiliary equipment.

27.2 Hydraulic Calculation Procedures

27.2.1\* General

27.2.1.1

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.

27.2.1.2

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 Sections 29.4 and 29.5.

27.2.1.3

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.

27.2.1.4\*

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.

27.2.1.5

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

27.2.1.6

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

27.2.2 Formulas

27.2.2.1 Friction Loss Formula

27.2.2.1.1

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

where:

p = frictional resistance (psi/ft of pipe)

Q = flow (gpm)

C = friction loss coefficient

d = actual internal diameter of pipe (in.)

27.2.2.1.2

For SI units, the following equation shall be used:

where:

pm = frictional resistance (bar/m of pipe)

Qm = flow (L/min)

C = friction loss coefficient

dm = actual internal diameter (mm)

27.2.2.1.3

For antifreeze systems greater than 40 gal (150 L) in size, the friction loss shall also be calculated using the Darcy-Weisbach formula:

where:

ΔP = friction loss (psi)

f = friction loss factor from Moody diagram

l = length of pipe or tube (ft)

ρ = density of fluid (lb/ft3)

Q = flow in pipe or tube (gpm)

d = inside diameter of tube (in.)

27.2.2.2 Velocity Pressure Formula

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

where:

Pv = 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)

27.2.2.3 Normal Pressure Formula

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

where:

Pn = normal pressure

Pt = total pressure [psi (bar)]

Pv = velocity pressure [psi (bar)]

27.2.2.4 Hydraulic Junction Points

27.2.2.4.1

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

27.2.2.4.2

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

27.2.2.4.3

Pressure balancing shall be permitted through the use of a K-factor developed for branch lines or portions of systems using the formula in 27.2.2.5.

27.2.2.5 K-Factor Formula

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

where:

Kn = equivalent K at a node

Q = flow at the node

P = pressure at the node

27.2.3 Equivalent Pipe Lengths of Valves and Fittings

27.2.3.1 Pipe and Fittings

27.2.3.1.1

Table 27.2.3.1.1 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 27.2.3.1.1 Equivalent Schedule 40 Steel Pipe Length Chart

Fittings and Valves Fittings and Valves Expressed in Equivalent Feet (Meters) of Pipe

1/2 in. 3/4 in. 1 in. 11/4 in. 11/2 in. 2 in. 21/2 in. 3 in. 31/2 in. 4 in. 5 in. 6 in. 8 in. 10 in. 12 in.

(15 mm) (20 mm) (25 mm) (32 mm) (40 mm) (50 mm) (65 mm) (80 mm) (90 mm) (100 mm) (125 mm) (150 mm) (200 mm) (250 mm) (300 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) 5 (1.5) 7 (2.1) 9 (2.7) 11 (3.3) 13 (4)

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) 12 (3.7) 14 (4.3) 18 (5.5) 22 (6.7) 27 (8.2)

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) 8 (2.4) 9 (2.7) 13 (4) 16 (4.9) 18 (5.5)

Tee or cross (flow turned 90°) 3 (0.9) 4 (1.2) 5 (1.5) 6 (1.8) 8 (2.4) 10 (3) 12 (3.7) 15 (4.6) 17 (5.2) 20 (6.1) 25 (7.6) 30 (9.1) 35 (10.7) 50 (15.2) 60 (18.3)

Butterfly valve — — — — — 6 (1.8) 7 (2.1) 10 (3) — 12 (3.7) 9 (2.7) 10 (3) 12 (3.7) 19 (5.8) 21 (6.4)

Gate valve — — — — — 1 (0.3) 1 (0.3) 1 (0.3) 1 (0.3) 2 (0.6) 2 (0.6) 3 (0.9) 4 (1.2) 5 (1.5) 6 (1.8)

Vane type flow switch 6 (1.8) 9 (2.7) 10 (3) 14 (4.3) 17 (5.2) 22 (6.7) — 30 (9.1) — 16 (4.9) 22 (6.7) 29 (8.8) 36 (11)

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) 27 (8.2) 32 (10) 45 (14) 55 (17) 65 (20)

Note: Information on 1/2 in. pipe is included in this table only because it is allowed under Sections 29.4 and 29.5.

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

27.2.3.1.2

For saddle-type fittings having friction loss greater than that shown in Table 27.2.3.1.1, the increased friction loss shall be included in hydraulic calculations.

27.2.3.1.3 Equivalent Length Modifier

27.2.3.1.3.1

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 27.2.3.1.1 shall be multiplied by a factor derived from the following formula:

27.2.3.1.3.2

The factor thus obtained shall be further modified as required by Table 27.2.3.1.1. This table shall apply to other types of pipe listed in Table 27.2.3.1.1 only where modified by factors from 27.2.3.1.1 and 27.2.3.2.

27.2.3.2 C Factors

Table 27.2.3.1.1 shall be used with a Hazen-Williams C factor of 120 only.

27.2.3.2.1

For other values of C, the values in Table 27.2.3.1.1 shall be multiplied by the factors indicated in Table 27.2.3.2.1.

Table 27.2.3.2.1 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.

27.2.3.3 Valves

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

27.2.3.4

Hydraulic design calculations shall include a design area selected to include ceiling sprinklers adjacent to the water curtain.

27.2.3.5 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 27.2.3.1.1.

27.2.4\* Calculation Procedure

27.2.4.1\*

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 26.

27.2.4.1.1 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.

27.2.4.2 Density/Area Method

27.2.4.2.1\*

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.

27.2.4.2.2

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

27.2.4.2.3

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

27.2.4.2.4\*

Where the available floor area for a specific area/density design criteria, including any extension of area as required by 19.2.2 and Section 20.10, is less than the required minimum design area, the design area shall be permitted to only include those sprinklers within the available design area.

27.2.4.2.5

Where the total design discharge from these 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 connection of the branch line to the cross main furthest from the source to increase the overall demand, not including hose stream allowance, to the minimum required discharge.

27.2.4.3 CMSA Sprinkler Method

27.2.4.3.1

For CMSA sprinklers, 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 protected by the number of sprinklers to be included in the design area. The design area protected by the number of sprinklers to be used by the 1.2 rule shall be based on the maximum allowable area per sprinkler.

27.2.4.3.2

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

27.2.4.3.3

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

27.2.4.4 ESFR Sprinkler Method

For ESFR sprinklers, the design area shall consist of the most hydraulically demanding area of 12 sprinklers, consisting of 4 sprinklers on each of three branch lines, unless other specific numbers of design sprinklers are required in other sections of this standard.

27.2.4.5\* Gridded Systems

27.2.4.5.1

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

27.2.4.5.2

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 27.2.4.5.3 are met.

27.2.4.5.3

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

27.2.4.6 Design Densities

27.2.4.6.1\*

System piping shall be hydraulically designed using design densities and areas of operation in accordance with 19.3.3.2 or Chapter 20 as required for the occupancies or hazards involved.

27.2.4.6.2\*

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.

27.2.4.6.3

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.

27.2.4.6.4

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.

27.2.4.6.5\*

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

27.2.4.7\* Design Area Sprinklers

27.2.4.7.1

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.

27.2.4.7.1.1

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.

27.2.4.7.2\*

Where the design area is equal to or greater than the area in Table 27.2.4.7.2 for the hazard being protected by the sprinkler system, the discharge for sprinklers protecting small compartments 55 ft2 (5.1 m2) 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 27.2.4.7.2 Minimum Design Area

Occupancy Hazard Classification Minimum Design Area to Omit Discharge from Sprinklers in Small Compartments in Design Area [ft2 (m2)]

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)

27.2.4.7.2.1

The sprinklers in these small compartments shall be capable of discharging the minimum density appropriate for the hazard they protect in accordance with Figure 19.3.3.1.1.

27.2.4.7.2.2

The requirements of 27.2.4.7.2 shall only apply where the area of application is equal to or greater than the area shown in Table 27.2.4.7.2 for the appropriate hazard classification (including a 30 percent increase for dry pipe systems).

27.2.4.7.3

The requirements of 27.2.4.7.1.1 to include every sprinkler in the design area shall not apply where sprinklers are provided above and below obstructions such as wide ducts or tables.

27.2.4.7.3.1

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

27.2.4.7.3.2

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.

27.2.4.7.4

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

27.2.4.7.5

Calculations shall begin at the hydraulically most remote sprinkler.

27.2.4.7.6

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

27.2.4.7.7

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

27.2.4.8 Friction Loss

27.2.4.8.1

Pipe friction loss shall be calculated in accordance with the Hazen-Williams formula with C values from Table 27.2.4.8.1, as follows:

Pipe, fittings, and devices such as valves, meters, flow switches in pipes 2 in. (50 mm) or less in size, and strainers shall be included, and elevation changes that affect the sprinkler discharge shall be calculated.

Tie-in drain piping shall not be included in the hydraulic calculations.

The loss 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.

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.

Fitting loss for straight-through flow in a tee or cross shall not be included.

The loss of reducing elbows based on the equivalent feet value of the smallest outlet shall be calculated.

The equivalent feet value for the standard elbow on any abrupt 90-degree turn, such as the screw-type pattern shall be used.

The equivalent feet 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 27.2.3.1.1.)

Friction loss shall be excluded for the fitting directly connected to a sprinkler.

Losses through a pressure-reducing valve shall be included based on the normal inlet pressure condition. Pressure loss data from the manufacturer's literature shall be used.

Table 27.2.4.8.1 Hazen-Williams C Values

Pipe or Tube C Value\*

Unlined cast or ductile iron 100

Black steel (dry systems including preaction) 100

Black steel (wet systems including deluge) 120

Galvanized steel (dry systems including preaction) 100

Galvanized steel (wet systems including deluge) 120

Plastic (listed) all 150

Cement-lined cast- or ductile iron 140

Copper tube, brass or stainless steel 150

Asbestos cement 140

Concrete 140

\*The authority having jurisdiction is permitted to allow other C values.

27.2.4.8.2\*

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 27.2.2.1.3 using a Moody diagram and ε-factors that are representative of aged pipe otherwise following the methodology presented in 27.2.4.8.1.

27.2.4.9\* Orifice Plates

27.2.4.9.1

Orifice plates shall not be used for balancing the system.

27.2.4.9.2

Unless the requirements of 27.2.4.9.3 or 27.2.4.9.4 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.

27.2.4.9.3

Sprinklers with different K-factors shall be acceptable for special use such as exposure protection, small rooms or enclosures, or directional discharge. (See 3.3.196 for definition of small rooms.)

27.2.4.9.4

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.

27.2.4.10\* Pressures

27.2.4.10.1

When calculating flow from an orifice, the total pressure (Pt) shall be used, unless the calculation method of 27.2.4.10.2 is utilized.

27.2.4.10.2

Use of the normal pressure (Pn) 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.

27.2.4.10.3

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.

27.2.4.11 Minimum Operating Pressure

27.2.4.11.1

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

27.2.4.11.2

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

27.2.4.12 Maximum Operating Pressure

For extra hazard occupancies, palletized, solid-piled, bin box, back-to-back shelf storage, shelf storage, or rack storage, the maximum operating pressure of any sprinkler shall be 175 psi (12 bar).

27.2.5 In-Rack Sprinklers

27.2.5.1

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

27.2.5.2

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.

27.3 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.

27.4 Hydraulic Calculation Forms

27.4.1 General

Hydraulic calculations shall be prepared on form sheets that include a summary sheet, detailed worksheets, and a graph sheet. [See Figure A.27.4.2(a), Figure A.27.4.3, and Figure A.27.4.4 for copies of typical forms.]

27.4.2\* Summary Sheet

The summary sheet shall contain the following information, where applicable:

Date

Location

Name of owner and occupant

Building number or other identification

Description of hazard (for storage applications, the commodity classification, storage height, and rack configuration shall be included)

Name and address of contractor or designer

Name of approving agency

System design requirements, as follows:

Design area of water application, ft2 (m2).

Minimum rate of water application (density), gpm/ft2 (mm/min). Where sprinklers are listed with minimum water application in gpm (L/min) or pressure in psi (bar), the minimum rate of water application shall be indicated in gpm (L/min) or pressure, psi (bar).

Area per sprinkler, ft2 (m2).

Total water requirements as calculated, including allowance for inside hose, outside hydrants, and water curtain and exposure sprinklers

Allowance for in-rack sprinklers, gpm (L/min)

Limitations (dimension, flow, and pressure) on extended coverage or other listed special sprinklers

27.4.3\* Detailed Worksheets

Detailed worksheets or computer printout sheets shall contain the following information:

Sheet number

Sprinkler description and discharge constant (K)

Hydraulic reference points

Flow in gpm (L/min)

Pipe size

Pipe lengths, center-to-center of fittings

Equivalent pipe lengths for fittings and devices

Friction loss in psi/ft (bar/m) of pipe

Total friction loss between reference points

In-rack sprinkler demand balanced to ceiling demand

Elevation head in psi (bar) between reference points

Required pressure in psi (bar) at each reference point

Velocity pressure and normal pressure if included in calculations

Notes to indicate starting points or reference to other sheets or to clarify data shown

\*Diagram to accompany gridded system calculations to indicate flow quantities and directions for lines with sprinklers operating in the remote area

Combined K-factor calculations for sprinklers on drops, armovers, or sprigs where calculations do not begin at the sprinkler

27.4.4\* Graph Sheet

A graphic representation of the complete hydraulic calculation shall be plotted on semiexponential graph paper (Q1.85) and shall include the following:

Water supply curve

Sprinkler system demand

Hose allowance (where applicable)

In-rack sprinkler demand (where applicable)

27.4.5 Hydraulic Reports

27.4.5.1\* General

27.4.5.1.1

Hydraulic calculations shall be prepared on form sheets that include a summary sheet, a graph sheet, a water supply analysis, a node analysis, and detailed worksheets.

27.4.5.1.2

The data shall be presented in the order shown in Figure 27.4.5.1.2(a) through Figure 27.4.5.1.2(d).

FIGURE 27.4.5.1.2(a) Summary Sheet.

FIGURE 27.4.5.1.2(b) Graph Sheet.

FIGURE 27.4.5.1.2(c) Supply and Node Analysis Sheet.

FIGURE 27.4.5.1.2(d) Detailed Worksheet.

27.4.5.2 Summary Sheet

The summary sheet as shown in Figure 27.4.5.1.2(a) shall contain the following information, where applicable:

Project name and date

Location (including street address)

Owner or expected occupant of space being designed

Name, address, and phone number of installing contractor

Name and phone number of designer

Authority having jurisdiction

Standard or document system is being designed to, including the edition of the document

Design area number and location

Drawing or sheet number where design area is located

Occupancy or commodity classification and information

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

System type, including the system volume with type of protection system indicated in the notes

Sprinkler type, including coverage and response type

Slope of roof or ceiling within the design area

System design requirements, as follows:

Design area of application, ft2 (m2)

Minimum rate of water application (density), gpm/ft2 (mm/min)

Area per sprinkler, ft2 (m2)

Number of sprinklers calculated

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)

Ceiling height if used for quick response sprinkler reduction

Elevation of highest calculated sprinkler

Water supply information, including the following:

Date and time of test

Location of the test and flow hydrant(s)

Source of the water for the flow test

Elevation of the test hydrant relative to the finished floor

Size of fire pump, gpm @ psi

Size of on-site water tank

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

27.4.5.3 Graph Sheet

A graphic representation of the complete hydraulic calculation shall be plotted on semiexponential graph paper (Q1.85) as shown in Figure 27.4.5.1.2(b) and shall include the following:

Water supply curve

Sprinkler system demand

Hose demand (where applicable)

In-rack sprinkler demand (where applicable)

Additional pressures supplied by a fire pump or other source (when applicable)

27.4.5.4 Supply Analysis

Information summarized from the graph sheet as shown in Figure 27.4.5.1.2(c) shall include the following:

Node tag at the source

Static pressure [psi (bar)] available at the source

Residual pressure [psi (bar)] available at the source

Total flow [gpm (L/min)] available at the source

Available pressure [psi (bar)] at the source when the total calculated demand is flowing

Total calculated demand [gpm (L/min)] at the source

Required pressure [psi (bar)] when flowing total calculated demand

27.4.5.5 Node Analysis

Organized information as shown in Figure 27.4.5.1.2(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:

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

Elevation in ft (m) of each node tag

K-factor of flowing nodes (such as sprinklers)

Hose allowance in gpm (L/min) requirements for the node tag

Pressure in psi (bar) at the node

Discharge in gpm (L/min) calculated at the node

Notes that indicate any special requirements for the node

27.4.5.6 Detailed Worksheets

Detailed worksheets as shown in Figure 27.4.5.1.2(d) or computer printout sheets shall contain the following information:

Sheet number

Hydraulic reference points used in each step

Elevation in ft (m) at each hydraulic reference point

Sprinkler description and discharge constant (K) for the flowing reference point

Flow in gpm (L/min) for the flowing reference point (when applicable)

Total flow in gpm (L/min) through each step

Nominal pipe size in in. (mm)

Actual internal diameter of pipe in in. (mm)

Quantity and length in ft (m) of each type of fitting and device

Pipe lengths in ft (m), center-to-center of fittings

Equivalent pipe lengths in ft (m) of fittings and devices for the step

Total equivalent length in ft (m) of pipes and fitting for the step

C-factor used in each step

Friction loss in psi/ft (bar/m) of pipe

Sum of the pressures from the previous step (starting pressure at beginning)

Elevation head in psi (bar) between reference points

Total friction loss in psi (bar) between reference points

Required pressure in psi (bar) at each reference point

Notes and other information shall include the following:

Velocity pressure and normal pressure if included in calculations

In-rack sprinkler demand balanced to ceiling demand

Notes to indicate starting points or reference to other sheets or to clarify data shown

Diagram to accompany gridded system calculations to indicate flow quantities and directions for lines with sprinklers operating in the remote area

Combined K-factor calculations for sprinklers on drops, armovers, or sprigs where calculations do not begin at the sprinkler

The pressure [psi/(bar)] loss assigned the backflow device when included on a system

Friction factor and Reynolds number when the Darcy-Weisbach equation is used

27.5 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 19.3.2.

27.5.1\* General

27.5.1.1

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

27.5.1.2

Sprinkler systems having sprinklers with K-factors other than 5.6 nominal, listed piping material other than that covered in Table 7.3.1.1, extra hazard Group 1 and Group 2 systems, and exposure protection systems shall be hydraulically calculated.

27.5.1.3

The number of automatic sprinklers on a given pipe size on one floor shall not exceed the number given in 27.5.2, 27.5.3, or 27.5.4 for a given occupancy.

27.5.1.4\* 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 27.5.2, 27.5.3, or 27.5.4.

27.5.1.5 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.

27.5.1.6 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.

27.5.2 Schedule for Light Hazard Occupancies

27.5.2.1 Branch Lines

27.5.2.1.1

Unless permitted by 27.5.2.1.2 or 27.5.2.1.3, branch lines shall not exceed eight sprinklers on either side of a cross main.

27.5.2.1.2

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 11/4 in. (32 mm), respectively, and the sizes thereafter standard.

27.5.2.1.3

Ten sprinklers shall be permitted to be placed on a branch line, making the two end lengths 1 in. (25 mm) and 11/4 in. (32 mm), respectively, and feeding the tenth sprinkler by a 21/2 in. (65 mm) pipe.

27.5.2.2 Pipe Sizes

27.5.2.2.1

Pipe sizes shall be in accordance with Table 27.5.2.2.1.

Table 27.5.2.2.1 Light Hazard Pipe Schedules

Steel Copper

in. mm

1 in. (25 mm) 2 sprinklers 1 in. 25 mm 2 sprinklers

11/4 in. (32 mm) 3 sprinklers 11/4 in. 32 mm 3 sprinklers

11/2 in. (40 mm) 5 sprinklers 11/2 in. 40 mm 5 sprinklers

2 in. (50 mm) 10 sprinklers 2 in. 50 mm 12 sprinklers

21/2 in. (65 mm) 30 sprinklers 21/2 in. 65 mm 40 sprinklers

3 in. (80 mm) 60 sprinklers 3 in. 80 mm 65 sprinklers

31/2 in. (90 mm) 100 sprinklers 31/2 in. 90 mm 115 sprinklers

4 in. (100 mm) See Section 4.5 4 in. 100 mm See Section 4.5

27.5.2.2.2

Each area requiring more sprinklers than the number specified for 31/2 in. (90 mm) pipe in Table 27.5.2.2.1 and without subdividing partitions (not necessarily fire walls) shall be supplied by mains or risers sized for ordinary hazard occupancies.

27.5.2.3

Where sprinklers are installed above and below ceilings in accordance with Figure 27.5.2.3(a) through Figure 27.5.2.3(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 27.5.2.3(a) Arrangement of Branch Lines Supplying Sprinklers Above and Below Ceiling.

FIGURE 27.5.2.3(b) Sprinkler on Riser Nipple from Branch Line in Lower Fire Area.

FIGURE 27.5.2.3(c) Arrangement of Branch Lines Supplying Sprinklers Above, Between, and Below Ceilings.

27.5.2.4

Unless the requirements of 27.5.2.5 are met, pipe sizing up to and including 2 1/2 in. (65 mm) shall be as shown in Table 27.5.2.4 utilizing the greatest number of sprinklers to be found on any two adjacent levels.

Table 27.5.2.4 Number of Sprinklers Above and Below Ceiling

Steel Copper

1 in. (25 mm) 2 sprinklers 1 in. (25 mm) 2 sprinklers

11/4 in. (32 mm) 4 sprinklers 11/4 in. (32 mm) 4 sprinklers

11/2 in. (40 mm) 7 sprinklers 11/2 in. (40 mm) 7 sprinklers

2 in. (50 mm) 15 sprinklers 2 in. (50 mm) 18 sprinklers

21/2 in. (65 mm) 50 sprinklers 21/2 in. (65 mm) 65 sprinklers

27.5.2.5

Branch lines and cross mains supplying sprinklers installed entirely above or entirely below ceilings shall be sized in accordance with Table 27.5.2.2.1.

27.5.2.6\*

Where the total number of sprinklers above and below a ceiling exceeds the number specified in Table 27.5.2.4 for 21/2 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 27.5.2.2.1 for the number of sprinklers above or below a ceiling, whichever is larger.

27.5.3 Schedule for Ordinary Hazard Occupancies

27.5.3.1

Unless permitted by 27.5.3.2 or 27.5.3.3, branch lines shall not exceed eight sprinklers on either side of a cross main.

27.5.3.2

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 11/4 in. (32 mm), respectively, and the sizes thereafter standard.

27.5.3.3

Ten sprinklers shall be permitted to be placed on a branch line, making the two end lengths 1 in. (25 mm) and 11/4 in. (32 mm), respectively, and feeding the tenth sprinkler by a 21/2 in. (65 mm) pipe.

27.5.3.4

Pipe sizes shall be in accordance with Table 27.5.3.4.

Table 27.5.3.4 Ordinary Hazard Pipe Schedule

Steel Copper

1 in. (25 mm) 2 sprinklers 1 in. (25 mm) 2 sprinklers

11/4 in. (32 mm) 3 sprinklers 11/4 in. (32 mm) 3 sprinklers

11/2 in. (40 mm) 5 sprinklers 11/2 in. (40 mm) 5 sprinklers

2 in. (50 mm) 10 sprinklers 2 in. (50 mm) 12 sprinklers

21/2 in. (65 mm) 20 sprinklers 21/2 in. (65 mm) 25 sprinklers

3 in. (80 mm) 40 sprinklers 3 in. (80 mm) 45 sprinklers

31/2 in. (90 mm) 65 sprinklers 31/2 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 4.5 8 in. (200 mm) See Section 4.5

27.5.3.5

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 27.5.3.5.

Table 27.5.3.5 Number of Sprinklers — Greater Than 12 ft (3.7 m) Separations

Steel Copper

21/2 in. (65 mm) 15 sprinklers 21/2 in. (65 mm) 20 sprinklers

3 in. (80 mm) 30 sprinklers 3 in. (80 mm) 35 sprinklers

31/2 in. (90 mm) 60 sprinklers 31/2 in. (90 mm) 65 sprinklers

Note: For other pipe and tube sizes, see Table 27.5.3.4.

27.5.3.6

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.

27.5.3.7

Pipe sizing up to and including 3 in. (76 mm) shall be as shown in Table 27.5.3.7 in accordance with Figure 27.5.2.3(a), Figure 27.5.2.3(b), and Figure 27.5.2.3(c) utilizing the greatest number of sprinklers to be found on any two adjacent levels.

Table 27.5.3.7 Number of Sprinklers Above and Below a Ceiling

Steel Copper

1 in. (25 mm) 2 sprinklers 1 in. (25 mm) 2 sprinklers

11/4 in. (32 mm) 4 sprinklers 11/4 in. (32 mm) 4 sprinklers

11/2 in. (40 mm) 7 sprinklers 11/2 in. (40 mm) 7 sprinklers

2 in. (50 mm) 15 sprinklers 2 in. (50 mm) 18 sprinklers

21/2 in. (65 mm) 30 sprinklers 21/2 in. (65 mm) 40 sprinklers

3 in. (80 mm) 60 sprinklers 3 in. (80 mm) 65 sprinklers

27.5.3.8

Branch lines and cross mains supplying sprinklers installed entirely above or entirely below ceilings shall be sized in accordance with Table 27.5.3.4 or Table 27.5.3.5.

27.5.3.9\*

Where the total number of sprinklers above and below a ceiling exceeds the number specified in Table 27.5.3.7 for 3 in. (80 mm) pipe, the pipe supplying such sprinklers shall be increased to 31/2 in. (90 mm) or larger and sized thereafter according to the schedule shown in Table 27.5.2.2.1 or Table 27.5.3.4 for the number of sprinklers above or below a ceiling, whichever is larger.

27.5.3.10

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 27.5.3.5, taking into consideration the sprinklers protecting the occupied area only, or Table 27.5.3.7, whichever requires the greater size of pipe.

27.5.4\* Extra Hazard Occupancies

Extra hazard occupancies shall be hydraulically calculated.