



Sprinkler System Design & Hydraulic Calculation Quick Guide • Part 1: Fundamentals

NFPA 13 (2022 ed.): hazard classes, density/area, coverage, spacing, K-factor & minimum pressure

PART

1

of 4

1 Fundamentals

2 Layout & Pipe Sizing

3 Remote Area & Pump

4 Worked Example

1 Hazard Classification & Design Basis

Ch. 4 • Table 19.2.3.1.1 • Annex A

Class	Typical occupancies (Annex A examples)	Density D gpm/ft ²	Design area A ft ²	Sprinklers Q = D × A	Max As • spacing*
LH	Offices, schools, hospitals, churches, hotel rooms	0.10 (4.1 mm/min)	1,500 (140 m ²)	150 gpm (568 L/min)	225 ft ² • 15 ft
OH1	Laundries, restaurant service areas, electronics plants	0.15 (6.1 mm/min)	1,500 (140 m ²)	225 gpm (852 L/min)	130 ft ² • 15 ft
OH2	Dry cleaners, mercantile, machine shops, library stacks	0.20 (8.1 mm/min)	1,500 (140 m ²)	300 gpm (1,136 L/min)	130 ft ² • 15 ft
EH1	Aircraft hangars, saw mills, upholstering with plastic foam	0.30 (12.2 mm/min)	2,500 (230 m ²)	750 gpm (2,839 L/min)	100 ft ² • 12 ft
EH2	Flammable liquid spraying, open oil quenching, plastics processing	0.40 (16.3 mm/min)	2,500 (230 m ²)	1,000 gpm (3,785 L/min)	100 ft ² • 12 ft

*Standard pendent/upright spray, hydraulically calculated (Tables 10.2.4.2.1(a)–(c)). LH 225 ft² applies to noncombustible / unobstructed construction; EH 100 ft² / 12 ft where density ≥ 0.25 gpm/ft². NFPA 13 (2022) uses these single design points for new systems (larger 3,000 ft² option only where 19.2.3.1.5 applies).

2 Coverage & Spacing Rules

Ch. 10

LIGHT

225 ft²

20.9 m² • max 15 ft (4.6 m)

ORDINARY

130 ft²

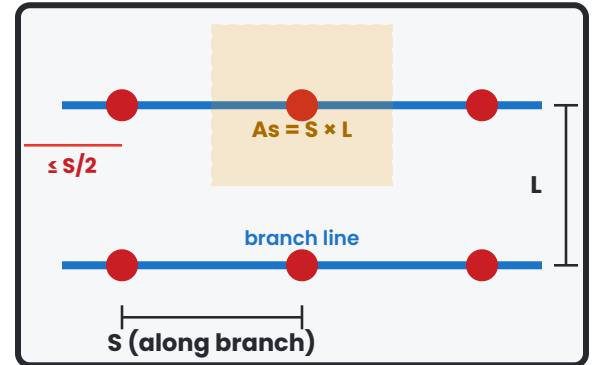
12.1 m² • max 15 ft (4.6 m)

EXTRA (D ≥ 0.25)

100 ft²

9.3 m² • max 12 ft (3.7 m)

- Min. 6 ft (1.8 m) between sprinklers, to avoid cold-soldering of neighbours
- Distance to wall ≤ ½ of the allowable spacing (e.g. 7.5 ft at 15 ft) and ≥ 4 in (100 mm)
- Check **both** limits: $A_s = S \times L \leq \text{max area}$ **and** $S, L \leq \text{max spacing}$
- No standard spray sprinkler may protect more than 225 ft² (20.9 m²)



3 Four Formulas You Use Every Day

SPRINKLER DISCHARGE

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

Q gpm • K gpm/psi^½ • P psi at the head. Reverse: $P = (Q/K)^2$

DENSITY / AREA

$$Q = D \times A$$

System: D × design area. Per head: $q = D \times A_s$ (the minimum each head must give)

COVERAGE PER HEAD

$$A_s = S \times L$$

S = along branch line, L = between branch lines (ft or m)

HEADS OPERATING

$$N = A / A_s$$

Always round up to a whole sprinkler

4 Common K-Factors

Table 7.2.2.1

Nominal K gpm/psi ^½	Metric K L/min/bar ^½	Flow vs K-5.6	Flow at 7 psi	Typical use
K-5.6	80	100%	14.8 gpm	LH / OH
K-8.0	115	140%	21.2 gpm	OH / EH
K-11.2	160	200%	29.6 gpm	EH / storage
K-14.0	200	250%	37.0 gpm	Storage
K-16.8	240	300%	44.4 gpm	Storage
K-25.2	360	450%	66.7 gpm	Storage

5 Minimum Pressure

28.2.4.11

⚠ 7 PSI (0.5 BAR) MINIMUM

Every sprinkler in the calculation must have at least 7 psi, or more if its listing requires. Usually the density, not 7 psi, governs.

QUICK CHECK (OUR NUMBERS)

OH1, heads at 12 ft × 10 ft → $A_s = 120 \text{ ft}^2$

$q = 0.15 \times 120 = 18.0 \text{ gpm}$

K-5.6: $P = (18.0 / 5.6)^2 = 10.33 \text{ psi} \geq 7 \checkmark$

Heads in 1,500 ft²: $1500 / 120 = 12.5 \rightarrow 13$

1 gpm = 3.785 L/min

1 psi = 0.0689 bar

1 ft = 0.3048 m

1 ft² = 0.0929 m²

1 gpm/ft² = 40.7 mm/min



Sprinkler System Design & Hydraulic Calculation

Quick Guide • Part 2: Layout & Pipe Sizing

Head selection, spacing layout, Hazen–Williams, C-factors, fittings and velocity

PART

2

of 4

1 Fundamentals

2 Layout & Pipe Sizing

3 Remote Area & Pump

4 Worked Example

1 Sprinkler Head Selection Ch. 7 / 9 / 10

ORIENTATION

Pendent under finished ceilings,
upright on exposed pipe,
sidewall in LH (OH only if listed).
Deflector **1–12 in** below ceiling.

RESPONSE

Quick-response heads are
required throughout **Light**
Hazard (limited exceptions).
Never paint or coat a sprinkler
on site.

TEMPERATURE

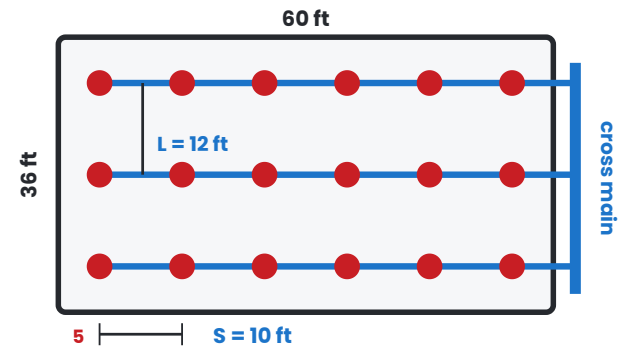
Ordinary 135–170 °F (57–77 °C)
for normal rooms; higher near
heaters and hot ceilings.

K-FACTOR

K–5.6 suits most LH/OH. Higher
density or bigger A_s → **K–8.0+**
keeps pressure, and pump size,
down.

2 Layout in 4 Steps (our room: 60 × 36 ft, OH)

- **Branch lines** on the long side: 60 ft / 6 heads → **S = 10 ft** (≤ 15), 5 ft to walls
- **Space the lines**: 36 ft / 3 lines → **L = 12 ft**, 6 ft to walls (≤ 7.5 ft ✓)
- **Check area**: $A_s = 10 \times 12 = 120 \text{ ft}^2 \leq 130$ ✓ (≥ 6 ft apart ✓)
- **Compare options**: 5×4 heads (S 12, L 9) = **20**; our 6×3 = **18**. 5×3 (S 12, L 12) fails: A_s 144 > 130



3 Hazen–Williams Friction Loss 28.2.2.1

US UNITS • PSI PER FOOT OF PIPE

$$p = 4.52 \times Q^{1.85} / (C^{1.85} \times d^{4.87})$$

Q = flow (gpm) • C = friction factor • d = actual internal diameter (in). Section loss $h_f = p \times (L + L_e)$, L_e = fitting equivalent length.

SI: p (bar/m) = $6.05 \times 10^{-5} Q^{1.85} / (C^{1.85} d^{4.87})$, Q in L/min, d in mm. Double the flow → $\approx 3.6\times$ the loss.

4 Velocity

NOT AN NFPA 13 LIMIT

NFPA 13 sets no maximum velocity; friction limits it. Many project specs cap it near **20 ft/s (6 m/s)**: **common practice**, so follow the spec / AHJ.

$$v = 0.4085 Q / d^2 \text{ (ft/s, gpm, in)}$$

5 Pipe Data Sheet: Sch 40 Steel, C = 120 Table 28.2.3.1.1 + our H–W results

Size	ID in	Equivalent length L_e (ft)				Friction loss, psi per 100 ft, at flow				
		90° elbow	Tee 90° turn	Gate	Swing check	25 gpm	50 gpm	100 gpm	250 gpm	500 gpm
1 in	1.049	2	5	–	5	19.7	70.9	–	–	–
1¼ in	1.380	3	6	–	7	5.17	18.6	–	–	–
1½ in	1.610	4	8	–	9	2.44	8.80	31.7	–	–
2 in	2.067	5	10	1	11	0.72	2.61	9.40	–	–
2½ in	2.469	6	12	1	14	0.30	1.10	3.95	21.5	–
3 in	3.068	7	15	1	16	0.11	0.38	1.37	7.48	–
4 in	4.026	10	20	2	22	0.03	0.10	0.37	1.99	7.18
6 in	6.065	14	30	3	32	<0.01	0.01	0.05	0.27	0.98

Straight-through tee: no loss. Other C : $L_e \times 0.713$ (C 100), $\times 1.33$ (140), $\times 1.51$ (150). Alarm / dry valves, strainers, backflow: manufacturer data. Shading: amber = velocity 12–20 ft/s; – = above 20 ft/s.

6 C-Factors Table 28.2.4.8.1

Pipe / tube	C	Pipe / tube	C
Black / galvanised steel, wet	120	Listed plastic (e.g. CPVC)	150
Black / galvanised steel, dry, pre-action	100	Copper, brass, stainless steel	150
Unlined cast / ductile iron	100	Cement-lined cast / ductile iron	140

The AHJ may allow other values. Some new dry systems (e.g. nitrogen-filled) may use $C = 120$.

SIZING TIP

2 in Sch 40 ID is **2.067 in**, Sch 10 is **2.157 in**. Always use the **real ID**: $d^{4.87}$ makes small changes count.



Sprinkler System Design & Hydraulic Calculation

Quick Guide • Part 3: Remote Area & Pump

Remote area, operating sprinklers, hose allowance, elevation, pump curve and tank sizing

PART

3

of 4

1 Fundamentals

2 Layout & Pipe Sizing

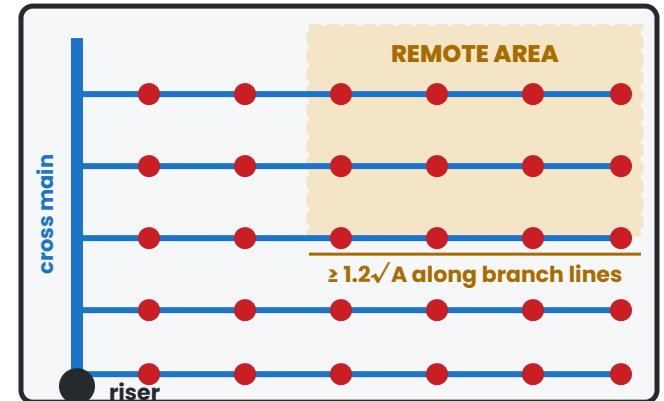
3 Remote Area & Pump

4 Worked Example

1 Remote (Design) Area 28.2.4.2

- The **hydraulically most demanding** area, normally the farthest from the riser (most friction, highest elevation)
- A **rectangle**: side parallel to the branch lines $\geq 1.2\sqrt{A}$. 1,500 ft² → **46.5 ft**; 2,500 ft² → **60 ft**
- Heads per branch line = $1.2\sqrt{A} / S$, **rounded up**; the rest go on the next line
- Operating heads $N = A / A_s$, **rounded up**

Coverage A_s	N at 1,500 ft ²	N at 2,500 ft ²
100 ft ²	15	25
120 ft ²	13	21
130 ft ²	12	20
225 ft ²	7	12



2 Hose Stream Allowance & Duration Table 19.2.3.1.2

Hazard	Inside hose gpm	Total inside + outside	Duration
LH	0, 50 or 100	100 gpm (380 L/min)	30 min
OH	0, 50 or 100	250 gpm (950 L/min)	60 – 90 min
EH	0, 50 or 100	500 gpm (1,900 L/min)	90 – 120 min

HOW TO APPLY

- Inside hose is **part of** the total, not extra
- Add hose flow at the **supply connection**, never through the remote heads
- Lower duration only if alarms are **supervised & monitored** at a constantly attended location

3 Total Demand & Indicative Tank (minimums, before pipe imbalance)

Hazard	Sprinklers D×A gpm	Hose gpm	Total gpm	Longest duration, min	Tank = total × time	≈ volume
LH	150	100	250	30	7,500 gal	28 m ³
OH1	225	250	475	90	42,750 gal	162 m ³
OH2	300	250	550	90	49,500 gal	187 m ³
EH1	750	500	1,250	120	150,000 gal	568 m ³
EH2	1,000	500	1,500	120	180,000 gal	681 m ³

Calculated flow is higher than D×A because heads nearer the riser see more pressure (Part 4 example: 258.3 vs 234 gpm, +10%). Always use the calculated figure.

4 Pressure Build-up to the Pump

REQUIRED PRESSURE AT PUMP DISCHARGE

$$P = P_{\text{remote}} + \Sigma h_f + 0.433 \cdot \Delta z + P_{\text{devices}}$$

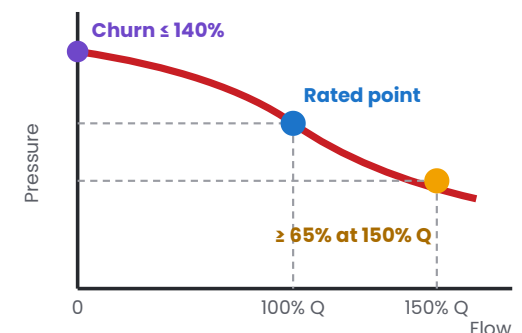
$P_{\text{remote}} = (q/K)^2$ at the end head (≥ 7 psi) · Σh_f = pipe + fittings · elevation **0.433 psi/ft** (0.098 bar/m) · devices = alarm valve, backflow (manufacturer data). Subtract any positive suction pressure.

TANK CAPACITY

$$V = (Q_{\text{sprinkler}} + Q_{\text{hose}}) \times \text{duration}$$

gal × 3.785 = litres. Add volume the AHJ or local code requires for other systems and unusable dead water.

5 Fire Pump (NFPA 20)



- Rated flow $\geq$ demand (ratings ...400, 450, **500**, 750, 1,000 gpm...)
- Rated pressure $\geq$ required; never operate past **150%**



Sprinkler System Design & Hydraulic Calculation

Quick Guide • Part 4: Worked Example

One fully worked remote-area calculation: flow and pressure build-up to pump duty and tank volume

1

Fundamentals

2

Layout & Pipe Sizing

3

Remote Area & Pump

4

Worked Example

1

Design Data: OH1 Electronics Assembly Area (our example)

HAZARD

OH1

0.15 gpm/ft² / 1,500 ft²

SPRINKLER

K-5.6

pendent, wet, C = 120

SPACING

13 × 10 ft

As = 130 ft² ≤ 130 ✓

HEADS

12

1500/130 = 11.5 → 12

SHAPE

4 × 3

46.5 / 13 → 4 per line

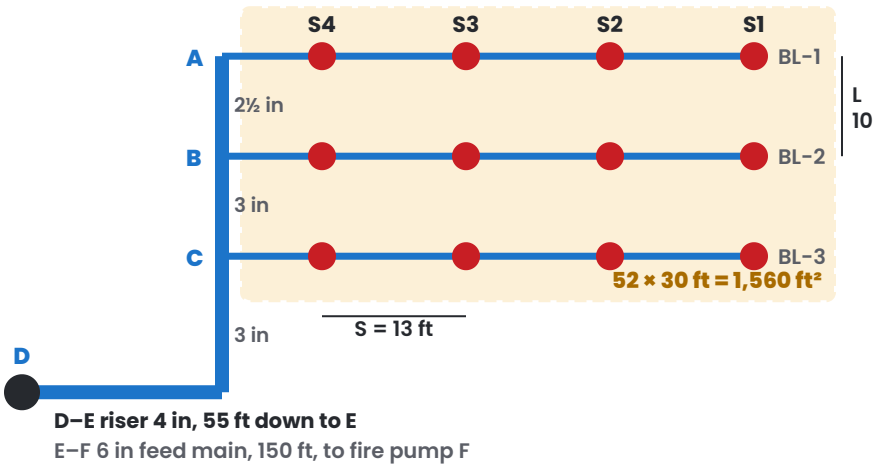
HEIGHT / HOSE

55 ft

+ 250 gpm, 90 min

2

Layout & Node Points



3

Start at the End Head, Work Back

S1, MOST REMOTE HEAD

$$q = 0.15 \times 130 = 19.50 \text{ gpm} \rightarrow P = (19.50/5.6)^2 = 12.13 \text{ psi} \geq 7 \checkmark$$

Each next head: $q = 5.6\sqrt{P}$ at its own (higher) pressure:
BL-1 = 19.50 + 20.76 + 21.95 + 23.14 = 85.35 gpm at A, 18.23 psi

BRANCH-LINE K (IDENTICAL LINES)

$$K_{BL} = 85.35 / \sqrt{18.23} = 19.99$$
$$BL-2 = 19.99\sqrt{18.53} = 86.05 \text{ gpm}$$
$$BL-3 = 19.99\sqrt{18.90} = 86.90 \text{ gpm}$$

Sprinkler demand = 258.30 gpm (978 L/min)

4

Section-by-Section Hydraulic Table (Sch 40 black steel, C = 120)

Hazen-Williams

Section	Pipe (ID in)	Q gpm	L + Le = Lt ft	psi/ft	h _f psi	P end psi	v ft/s
S1 end head (start)	K-5.6	19.50	–	–	–	12.13	–
S1-S2 branch line	1 in (1.049)	19.50	13 + 0 = 13	0.1242	1.61	13.74	7.2
S2-S3 branch line	1¼ in (1.380)	40.26	13 + 0 = 13	0.1249	1.62	15.36	8.6
S3-S4 branch line	1½ in (1.610)	62.21	13 + 0 = 13	0.1318	1.71	17.07	9.8
S4-A branch line	2 in (2.067)	85.35	6.5 + 10 = 16.5	0.0701	1.16	18.23	8.2
A-B cross main	2½ in (2.469)	85.35	10 + 0 = 10	0.0295	0.30	18.53	5.7
B-C cross main	3 in (3.068)	171.40	10 + 0 = 10	0.0372	0.37	18.90	7.4
C-D main to riser	3 in (3.068)	258.30	25 + 7 = 32	0.0795	2.54	21.44	11.2
D-E riser	4 in (4.026)	258.30	55 + 12 = 67	0.0212	1.42	22.86	6.5
E-F feed main to pump	6 in (6.065)	258.30	150 + 63 = 213	0.0029	0.62	23.48	2.9
Total pipe + fitting friction (23.48 - 12.13)					11.35		

Le: 2 in tee 10 · 3 in elbow 7 · 4 in elbow 10 + gate 2 · 6 in 2 elbows 28 + gate 3 + check 32 (Table 28.2.3.1.1). Max velocity 11.2 ft/s.

5

Pressure Build-up

12.13

end head

11.35

friction

23.82

55 ft × 0.433

3.0

valves*

$$12.13 + 11.35 + 23.82 + 3.00 = 50.30 \text{ psi (3.47 bar)} \cdot +10\% \text{ margin} = 55.33 \text{ psi}$$

*Alarm valve + flow switch allowance assumed at 3 psi; use the manufacturer's figure. Suction pressure taken as 0 (conservative). 10% margin is common practice, not NFPA 13.

6

Result: Pump & Tank

TOTAL DEMAND

508.3 gpm

258.30 + 250 hose
@ 50.30 psi

FIRE PUMP

750 gpm

@ 60 psi rated
150%: 1,125 gpm @ ≥39 psi

TANK = 508.3 GPM × 90 MIN

45,747 gal ≈ 173 m³

173,152 L · churn ≤ 84 psi · 750 gpm = next standard rating above 508 gpm