Seminar on
Water Supply Analysis and Hydraulic Calculations

OBJECTIVES

At the conclusion of this seminar, participants will be able to:

- Calculate a sprinkler system
- Select density / remote area
- Select appropriate K-factor
- Choose appropriate C-value
- Determine friction loss
- Plot water supply and system demand point
- Determine hose demand

AGENDA

Module	Content
1	Water Supplies and Graphical Determination
2	Design Assumptions
3	Calculating Friction Loss
4	Determination of Water Supply
5	Standpipe System Calculation
6	Water Curtain and Rack Sprinklers
7	Hydraulic Calculation Exercises

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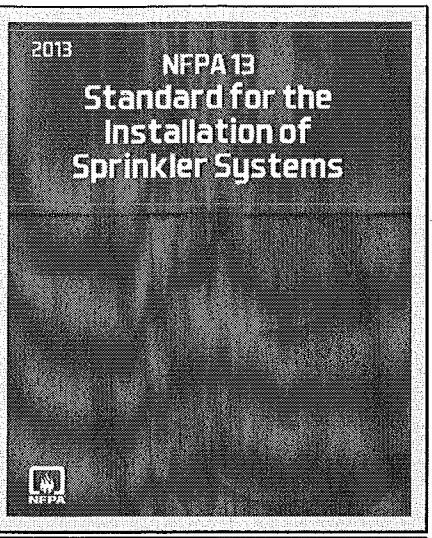
Welcome

Hydraulic Calculations





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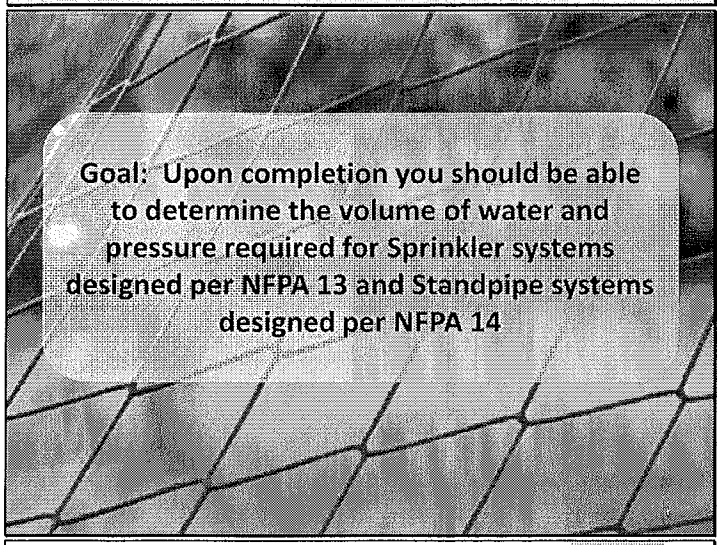
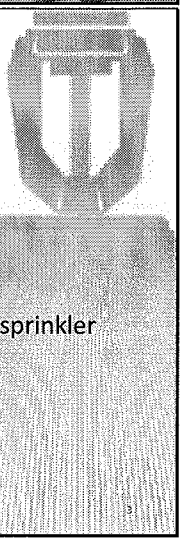


Goal: Upon completion you should be able to determine the volume of water and pressure required for Sprinkler systems designed per NFPA 13 and Standpipe systems designed per NFPA 14

Course Overview



Topics Include:

- Sprinkler Hydraulic Calculations Theory
- Water Supplies
- Design Density/Area
- Demand (flow) at the most demanding sprinkler
- Determining pressure and flow
- Choosing the right sprinkler
- Friction & Elevation losses in piping

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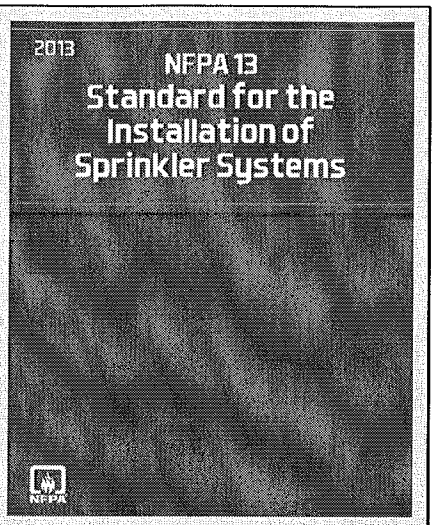
Module 1

Water Supplies and Graphical Determination



Basic Principles Applied

1. A sufficient volume of water must be discharged at the required pressure for each operating sprinkler, to control or suppress the fire.
2. Sufficient water must be provided for all sprinklers (or hose valves) within the design area.
3. System components, including pipes need to be cost effective to meet the needs of a competitive market.
4. The available water supply must deliver more water and pressure than needed by the system

Water Supplies & Graphical Determination

Acceptable Water Supplies:

- –Reliable water works system
- –Fire pump
- –Storage tank
- –Rivers, lakes, etc.

pg 243 NFPA 13

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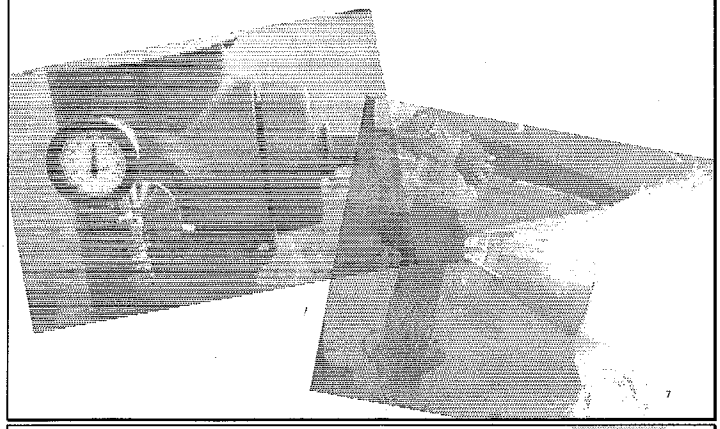
Critical Analysis



NFPA requires system evaluation if the fire pump degrades more than 5% of the design values.

Public wall pressure asme to be about 1.5 bar.

Flow Test Equipment Needed

- 200 psi (14 bar) bourdon pressure gauge with 1 psi (0.0689 bar) graduations
- Pitot tubes (one for each flowing hydrant)
- Hydrant wrenches (one for each hydrant)
- 50 or 60 psi (3.5 or 4.0 bar) bourdon pressure gauges with 1 psi (0.0689 bar) graduations, and scales with 1/16 in. (1.6 mm) graduations
- Nozzles, Hose Monsters, hose, means of restraining hose or diffusers (for each hydrant outlet being flowed)

Equipment

- A special hydrant cap tapped with a hole into which a short length of 1/4 in. (6.35 mm) brass pipe is fitted; this pipe is provided with a T connection for the 200 psi (14 bar) gauge and a cock at the end for relieving air pressure
- **All pressure gauges must be calibrated at least every 12 months**

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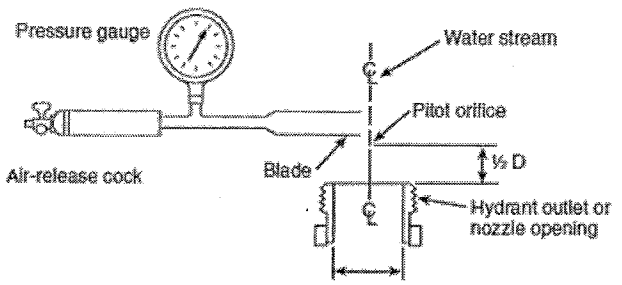
Pitot Readings



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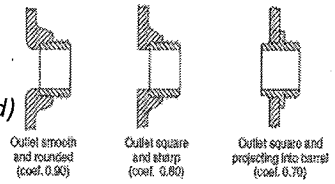
Hydrant Coefficient

Where stream straighteners are used, a coefficient of 0.95 is suggested unless the coefficient of the tube is known.

$$Q = 29.84 \times c \times d^2 \times \sqrt{p}$$

where:
c = coefficient of discharge
d = diameter of outlet in inches
p = pitot pressure (velocity head) in psi



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or air present in flow
If ½D not achieved, pressure will be lower; conservative error!

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Table 4.10.1(b) Theoretical Discharge Through Circular Orifices (Liters of Water per Minute)

Pitot Pressure* (kPa)	Meters†	Velocity Discharge (m/sec)	Orifice Size (mm)											
			51	57	60	64	67	70	76	83	89	95	101	114
6.89	0.70	3.72	455	568	629	716	785	857	1010	1204	1385	1578	1783	2272
13.8	1.41	5.26	644	804	891	1013	1111	1212	1429	1704	1960	2233	2524	3215
20.7	2.11	6.44	788	984	1091	1241	1360	1485	1750	2087	2400	2735	3091	3938
27.6	2.81	7.43	910	1137	1260	1433	1571	1714	2021	2410	2771	3158	3569	4547
34.5	3.52	8.31	1017	1271	1408	1602	1756	1917	2259	2695	3099	3530	3990	5084
103	10.55	14.39	1758	2196	2433	2769	3034	3312	3904	4656	5354	6100	6895	8784
110	11.25	14.87	1817	2269	2515	2861	3136	3423	4035	4812	5533	6304	7125	9078
117	11.95	15.33	1874	2341	2593	2951	3234	3530	4161	4963	5706	6502	7349	9362
124	12.66	15.77	1929	2410	2670	3038	3329	3634	4284	5109	5874	6693	7565	9638
131	13.36	16.20	1983	2477	2744	3122	3422	3735	4403	5251	6038	6880	7776	9906
138	14.06	16.62	2035	2542	2817	3205	3512	3834	4519	5390	6197	7061	7981	10168
152	15.47	17.43	2136	2668	2956	3363	3686	4023	4743	5657	6504	7410	8376	10671
165	16.88	18.21	2225	2779	3080	3504	3840	4192	4941	5893	6776	7721	8727	11118
179	18.28	18.95	2318	2895	3208	3650	4000	4366	5147	6138	7058	8042	9090	11580
193	19.69	19.67	2407	3006	3331	3790	4153	4534	5344	6374	7329	8350	9438	12024
207	21.10	20.36	2492	3113	3450	3925	4301	4695	5535	6601	7590	8648	9775	12453
221	22.50	21.03	2575	3217	3564	4055	4444	4851	5719	6821	7842	8935	10100	12867
234	23.91	21.67	2650	3310	3668	4173	4573	4992	5884	7018	8070	9195	10393	13240
248	25.31	22.30	2728	3408	3776	4296	4708	5139	6058	7225	8308	9466	10699	13630
262	26.72	22.91	2804	3502	3881	4416	4839	5282	6227	7426	8539	9729	10997	14010
276	28.13	23.50	2878	3595	3983	4532	4967	5422	6391	7622	8764	9986	11287	14379
290	29.53	24.09	2950	3685	4083	4646	5091	5557	6551	7813	8984	10236	11570	14740

Table from NFPA 291. Please keep in mind when using this table that it has not factored in the "coefficient of discharge". i.e. C is equals to 1.0

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Metric Table Notes:

in metric unit

(1)This table is computed from the formula $Q_n = 0.0666cd^2\sqrt{P_n}$, with c = 1.00. The theoretical discharge of seawater, as from fireboat nozzles, can be found by subtracting 1 percent from the figures in Table 4.10.2.1, or from the formula $Q_n = 0.065cd^2 m\sqrt{P_n}$.

(2)Appropriate coefficient should be applied where it is read from the hydrant outlet. Where more accurate results are required, a coefficient appropriate on the particular nozzle must be selected and applied to the figures of the table. The discharge from circular openings of sizes other than those in the table can readily be computed by applying the principle that quantity discharged under a given head varies as the square of the diameter of the opening.

*This pressure corresponds to velocity head.

†1 kPa = 0.102 m of water. For pressure in bars, multiply by 0.01.

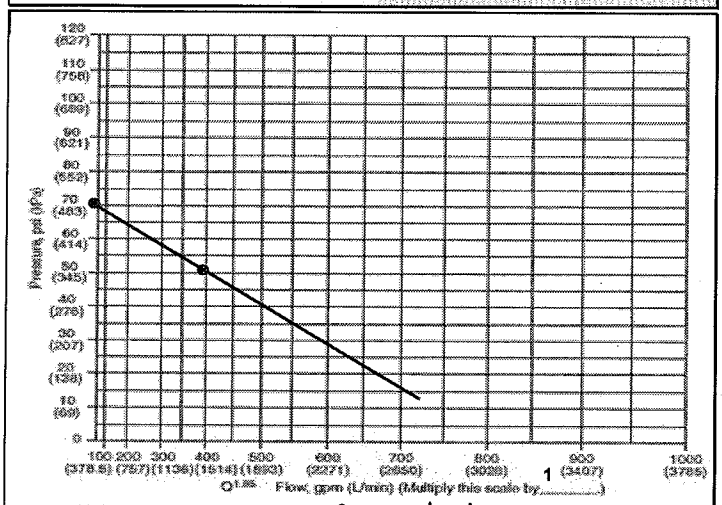
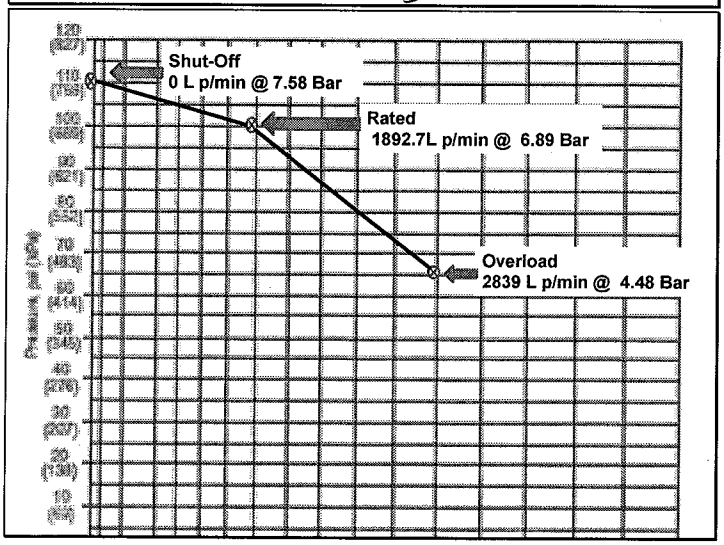


FIGURE 4.11.4 Sample Graph Sheet. for hydrant test



Fire Pump Curve

NFPA 20

Overload = 150% of rated flow at not less than 65% rated pressure

Pump water/dep pressure/flow need not be the rated pressure/flow so long the design pressure/flow is within the rated pump curve

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City Pressure + Fire Pump Output = Net Discharge Head

$$P_d = P_s - [(P_s-P_r) (Q_d/Q_r)^{1.85}]$$

Where:

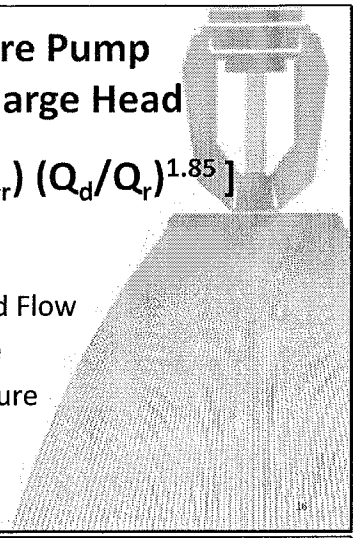
P_d = Pressure @ Desired Flow

P_s = Static Test Pressure

P_r = Residual Test Pressure

Q_d = Desired Flow

Q_r = Residual Test Flow



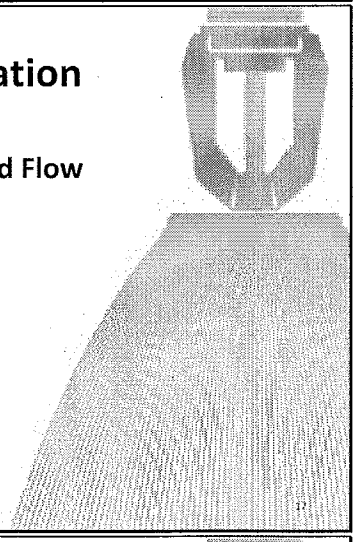
Pressure Calculation

P_d = Pressure @ Desired Flow

P_d =

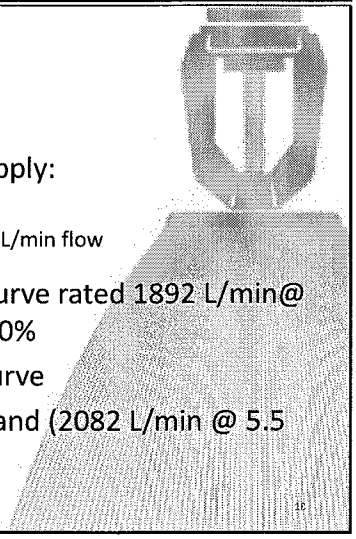
P_d =

P_d =



Activity 1.1

1. Plot the city water supply:
   - 207 kPa static (0 flow)
   - 138 kPa residual @ 94.64 L/min flow
2. Plot the Fire Pump Curve rated 1892 L/min@ 4.82 bar, shutoff is 110%
3. Plot the combined curve
4. Plot the system demand (2082 L/min @ 5.5 bar)



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Water Supplies and Graphical Determination

Activity 1.1 – Participant Directions

Group Size: Table Teams

Activity Objective: Participants will use $N^{1.85}$ graph paper to determine appropriate hydraulic criteria.

1. Using the graph paper supplied, plot the following water supply test results:
   Static: 207 kPA
   Residual: 138 kPA
   Flow: ~~2464~~ 3028 L/min

2. Using the graph paper supplied, plot the fire pump curve for the following fire pump: 1892 L/min @ 4.82 bar, churn is 110%.

3. Plot the combined curve.

4. Plot the following system demand on both curves: 2082 L/min @ 5.5 bar. Are both water supplies adequate for this system?

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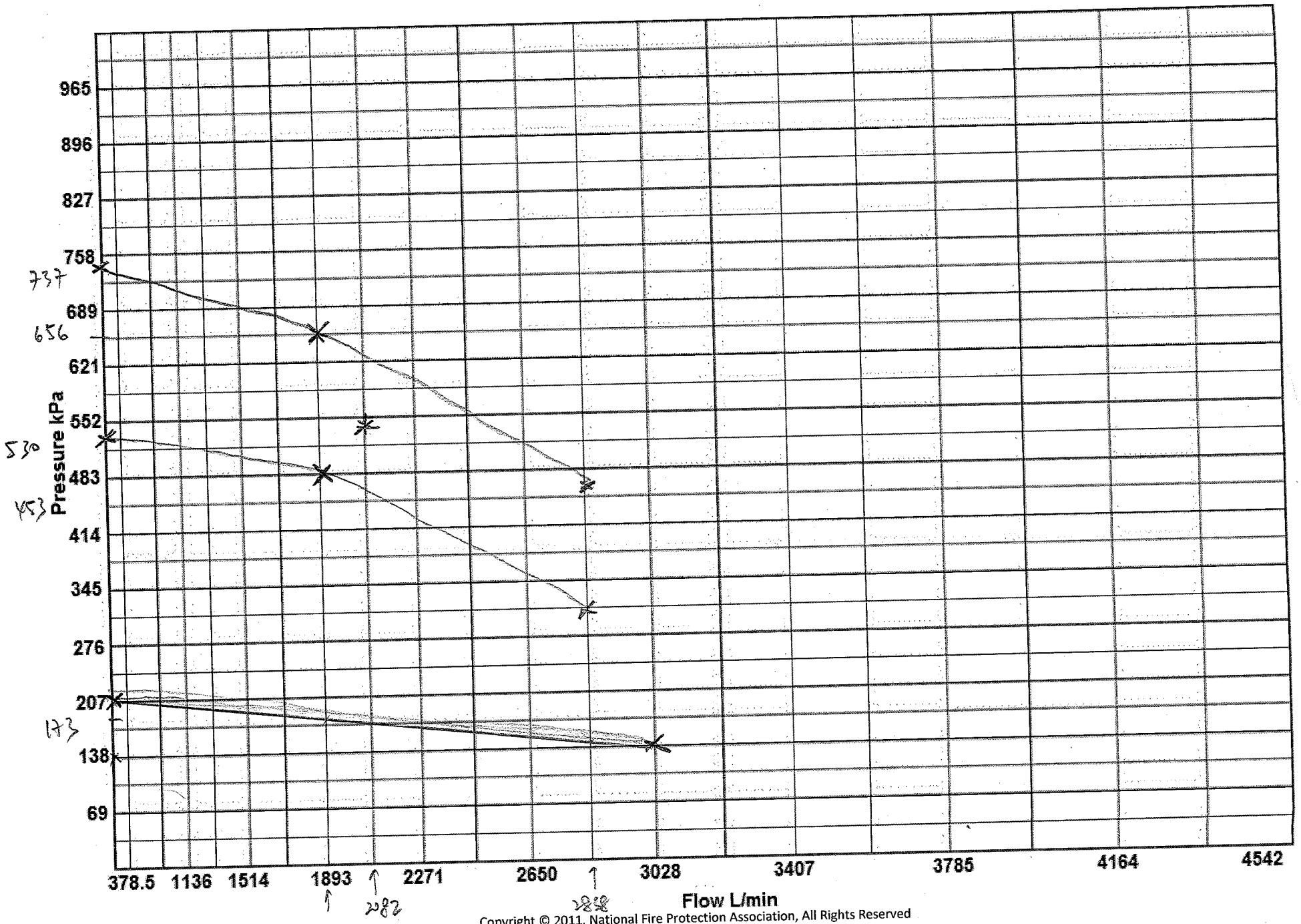

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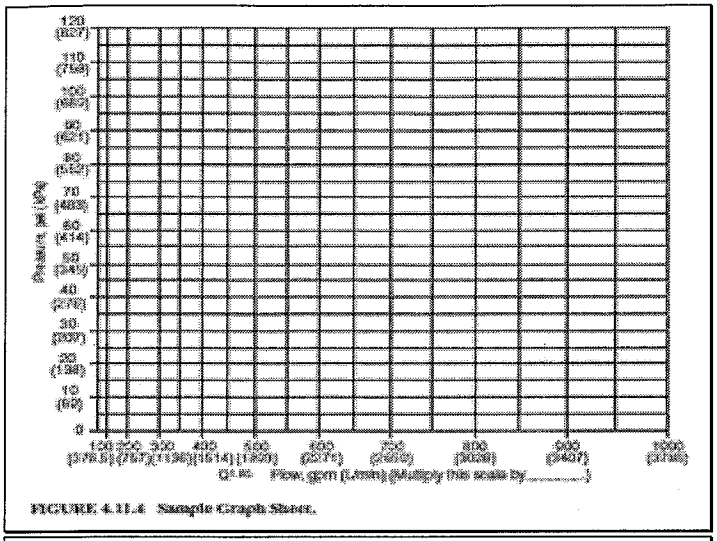

FIGURE 4.11.4 Sample Graph Sheet.

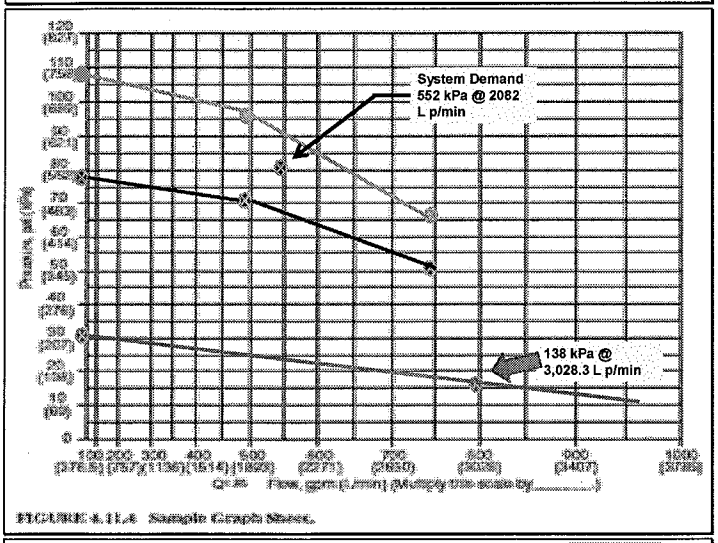

FIGURE 4.11.4 Sample Graph Sheet.

Module 1 Review

1. Overview of system demand for water & pressure – beginning at last sprinkler and flowing back to the supply
2. Evaluate water supply capacity in terms of pressure and volume
3. Plot water supply graph with and without fire pump
4. Plot system demand point

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Module 2

Design Criteria



Module Objectives

- Determine classification of occupancies
- Select density and area of operation from corresponding curve
- Discuss the impact of modifiers
- Determine size, shape and location of remote area
- Sprinkler spacing
- Establish reference points
- Discuss & evaluate pressure loss due to elevation

Classification of Occupancy (NFPA 13 Chapter 5)

- Light Hazard
- Ordinary Hazard
- Extra Hazard

NFPA 13 pg 266 for list of classifications (Annex A)

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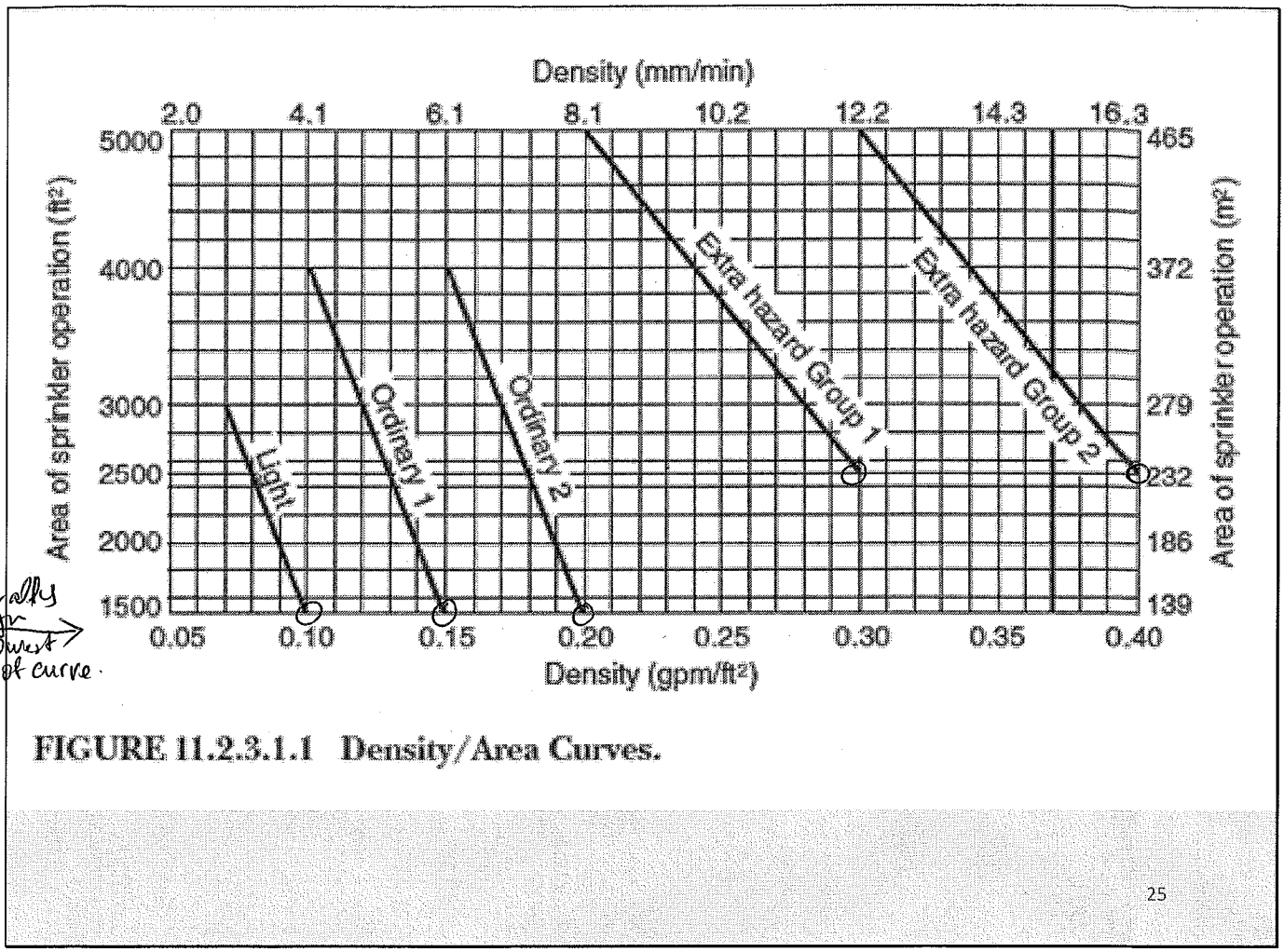

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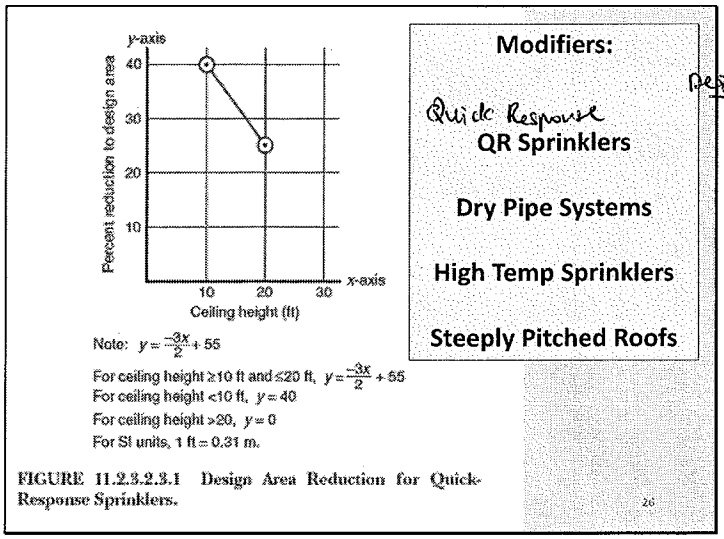

p.13-124

Design Area
↓ - 25 to 40%
↑ +30%
↓ - 25% for CMH
↑ +30%
density to remain.

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Area Adjustments

- Dry Systems – add 30%
- Sloped Ceilings – add 30%
- High Temperature Sprinklers – deduct 25%

- Multiple adjustments are possible but compounded

eg: 139 x 1.3 x 1.3 x 0.75

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Section 11.2.3, p.13-124

Sprinkler temperature rating: Pg 28 NFPA 13

Remote Area Shape & Size

- Assume a remote area of 139 m² with sprinkler coverage of 11.14 m²/sprkl
- Total Sprinklers to calculate = 139 ÷ 11.14 = **12.47**
  - **We calculate 13 sprinklers**
- Number of sprinklers per branch line to calculate
- 1.2 x √ remote area 1.2 x √ 139 = 11.789 meters
  - 11.789 meters ÷ 3.6576 meters = 3.22
  - **We calculate 4 sprinklers**

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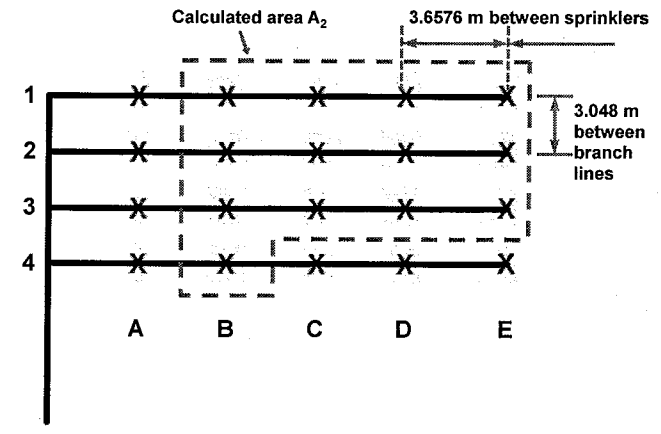
Most remote area may not be the most "hydraulically demanding"

Annex Pg 395



Pg 4B is hydraulically more demanding than 4E

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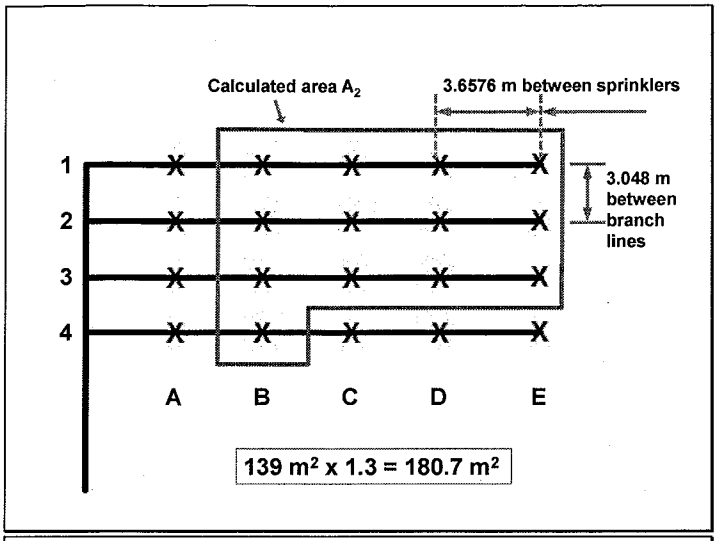

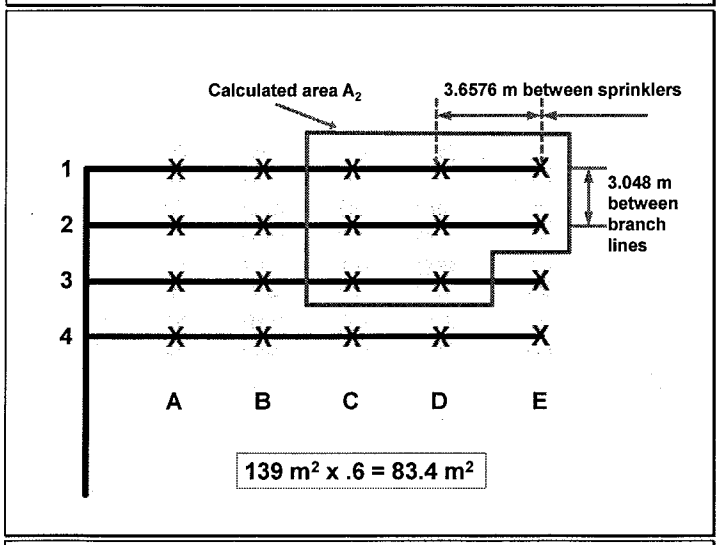

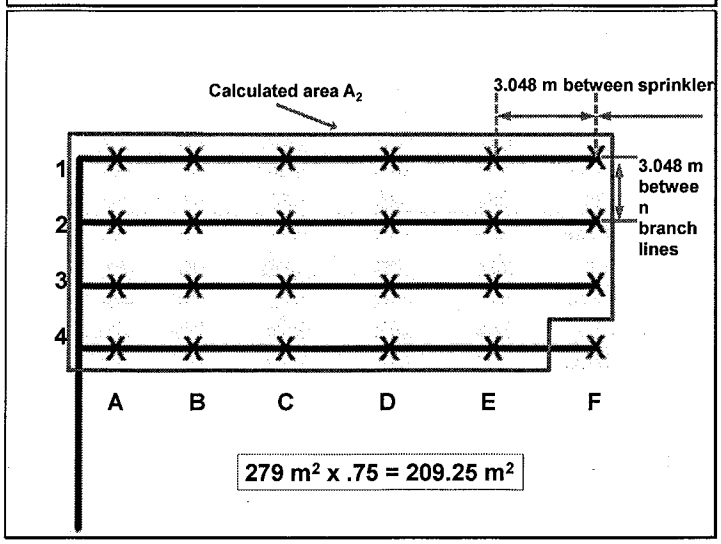

Section 11.2.3.6, p.13-124

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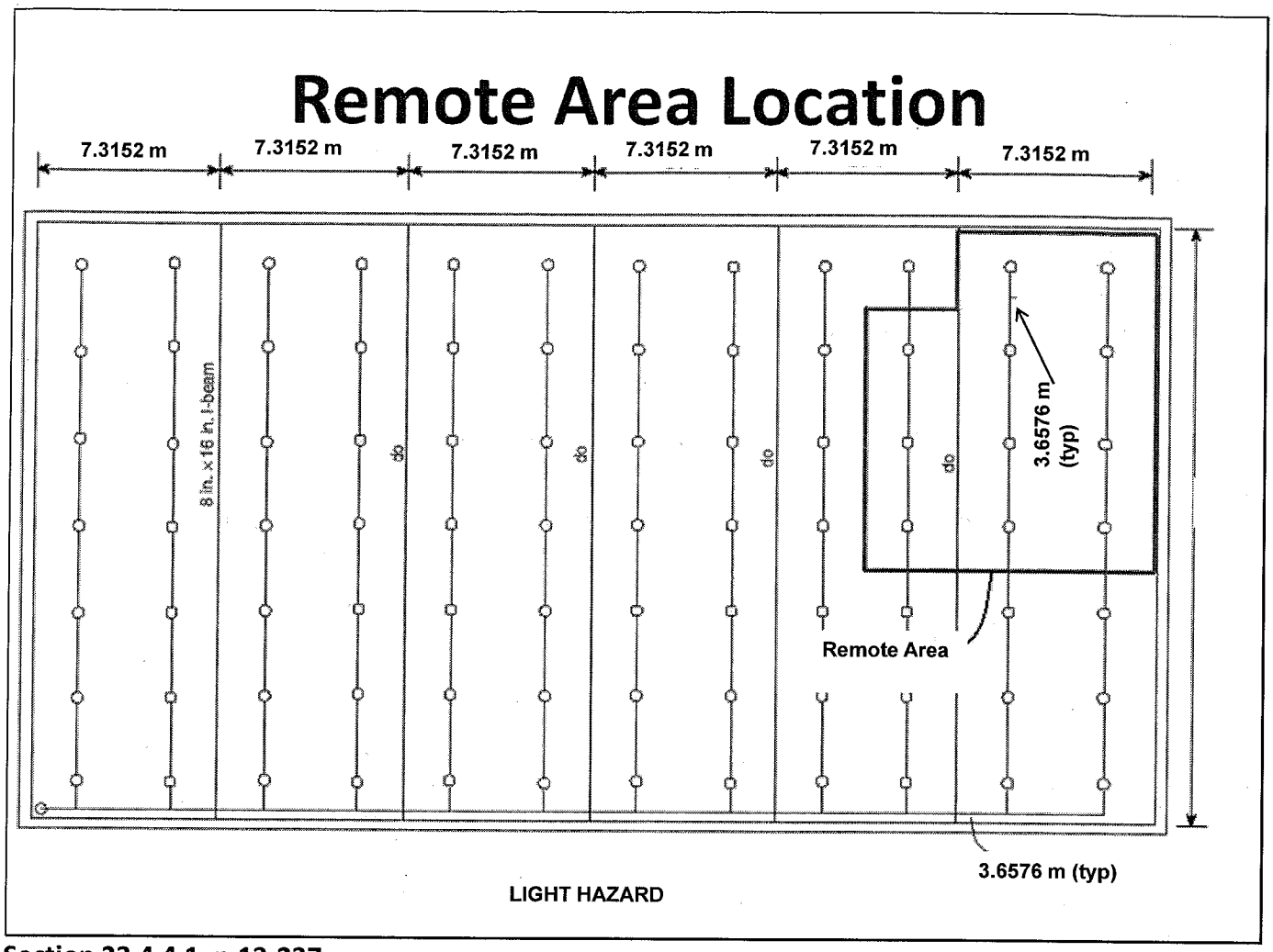
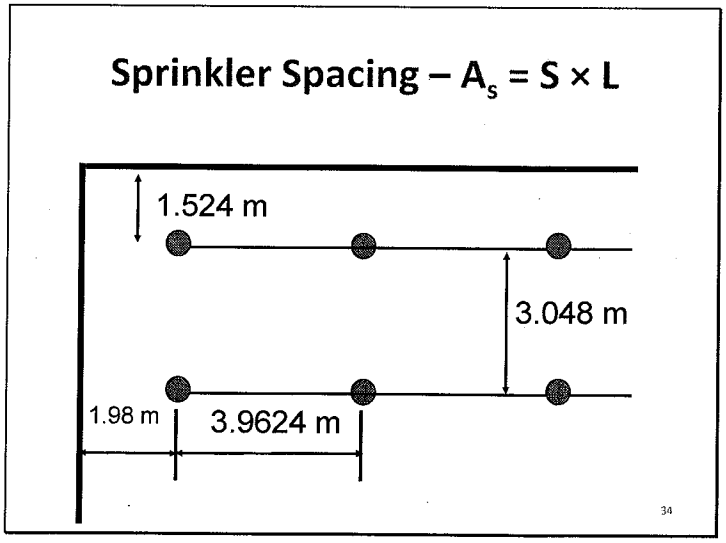


Section 23.4.4.1, p.13-237

NFPA Chapt 8-5



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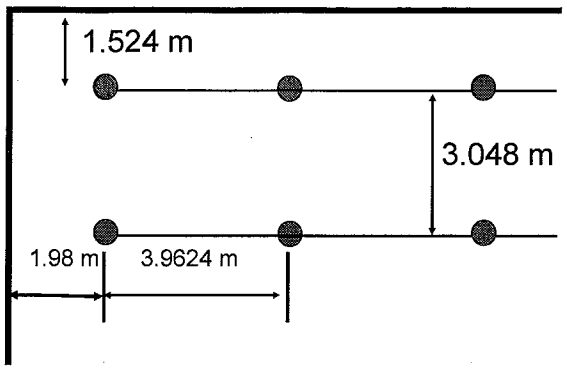
S=3.9624 m

L=3.048 m

A=S x L= 12.077 m²



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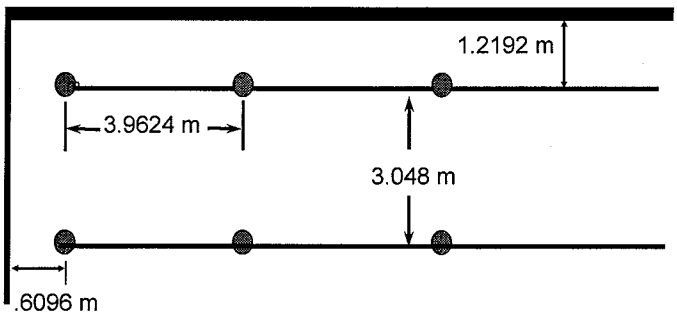
Sprinkler Spacing



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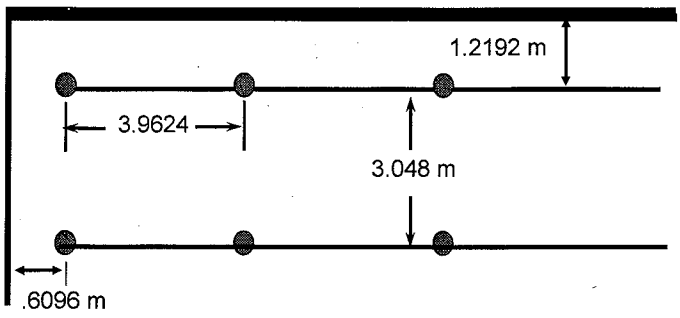
A=S x L= 12.077 m²



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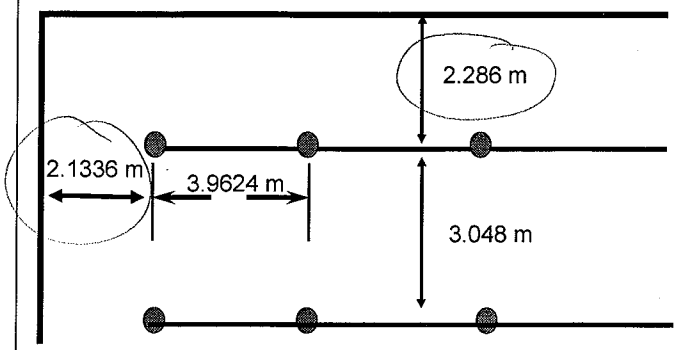
Sprinkler Spacing Impacts Flow



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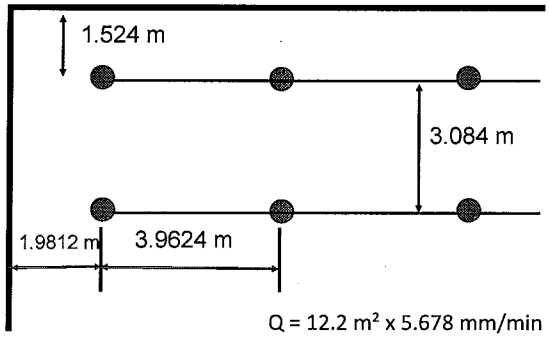
S = 4.2672 m
L = 4.572 m
A = S x L = 19.5 m²
Only for Light Hazard.

Sprinkler Flow @ 1st Sprinkler
Q = A x D



Q = 12.2 m² x 5.678 mm/min
Q = 69.27 mm/min (6.927 L p/min)

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Hydraulic Formulas

$$Q = K\left(\sqrt{P}\right)$$

$$P = (Q \div K)^2$$

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

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Selecting a K-Factor

- Flow from a sprinkler must be calculated from the nominal K-Factor
- Minimum operating pressure of any sprinkler must be at least 0.48263 bar (48.263 kPa) (0.5 bar)

Section 23.4.4.9.3, p.13-239

Selecting a K-Factor

Q = 12.077 m^2 x 6.1 liters per minute/m^2 Q = 73.815 L/min

$$P = (Q + K)^2$$

p = (73.67 L/min / 80) ^{2}

p = 0.847 bar

Selecting a K-Factor

Q = 12.077 m^2 x 6.1 liters per min/m^2 Q = 73.67 L/min

$$P = (Q + K)^2$$

p = (73.67 L/min / 115) ^{2}

p = 0.41 bar

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Re-Calculating Flow at Minimum Pressure

$$Q = K\left(\sqrt{P}\right)$$

With a minimum pressure of :

Q = 115 (√p)

Q = 115 x 0.694

Q = 79.81 L/min

Page 13-123

Outside Hose = WR, Hydrants

Hosereel = Inside hose

Wet Riser = Steel pipe Class 1

Table 11.2.3.1.2 Hose Stream Allowance and Water Supply Duration Requirements for Hydraulically Calculated Systems

Occupancy	Inside Hose		Total Combined Inside and Outside Hose		Duration (minutes)
	gpm	L/min	gpm	L/min	
Light hazard	0, 50, or 100	0, 189, or 379	100	379	30
Ordinary hazard	0, 50, or 100	0, 189, or 379	250	946	60–90
Extra hazard	0, 50, or 100	0, 189, or 379	500	1893	90–120

Activity 2.1

- Select hydraulic criteria
- Determine the size and shape of the area of operation
- Determine the required flow and K-factor for sprinklers
- Determine the flow for hose

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Design Assumptions

Activity 2.1 – Participant Directions

Group Size: Table Teams

Activity Objective: Participants will use NFPA 13 to determine appropriate hydraulic criteria.

1. Using **Handout 2.1.2**, Sample Occupancy Classifications, and NFPA 13 determine the classification of occupancy and density and area of operation for the building illustrated on the plan, **Handout 2.1.1**.

– Light Hazard
– 4.1 mm/min @ 139 m²

A = S × L = 3.9 × 3.9 = max area per sprinkler
⇒ 20.9 m²
⇒ 139/20.9 = 6.6 pt ≈ 7 pt
⇒ 139/12.1 = 11.5 pt ≈ 12 pt

2. Based on the area of operation selected in item #1 above, determine and plot the shape and size of the remote area.

A = S × L = 3.7 × 3.7 = 13.69
⇒ 139/13.69 = 10.15 ≈ 11 pt

Sprinkler/branch line = 1.2 × √139 / 3.7
= 14.2 m / 3.7
= 3.8 spt ≈ 4 spt

3. Based on the discharge density selected in item #1, determine the required flow per sprinkler and the k-factor.

Q = 4.1 mm/min × 13.69 m² = 56.129 L/min
K = Q/√P = 56.129/√10.48 = 81.3

Q = 4.1 mm/min × 12 m² = 49.61 L/min
K = Q/√P = 49.61/√0.5 = 70.2

4. What is the needed flow for hose streams in this occupancy?

Inside hose ⇒ 50 gpm
Outside hose ⇒ 50 gpm
Total ⇒ 100 gpm

379 L/min for inside hose.

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Activity
Work Space

$A = 3.7 \times 3.7 = 13.69 \simeq 13.7$

$k = 80$

$Q = A\,d = 13.7 \times 4.1 = 56.1$ L/min

$Q = k\sqrt{P} \Rightarrow P = \left(\frac{Q}{k}\right)^2 = 0.49$ bar

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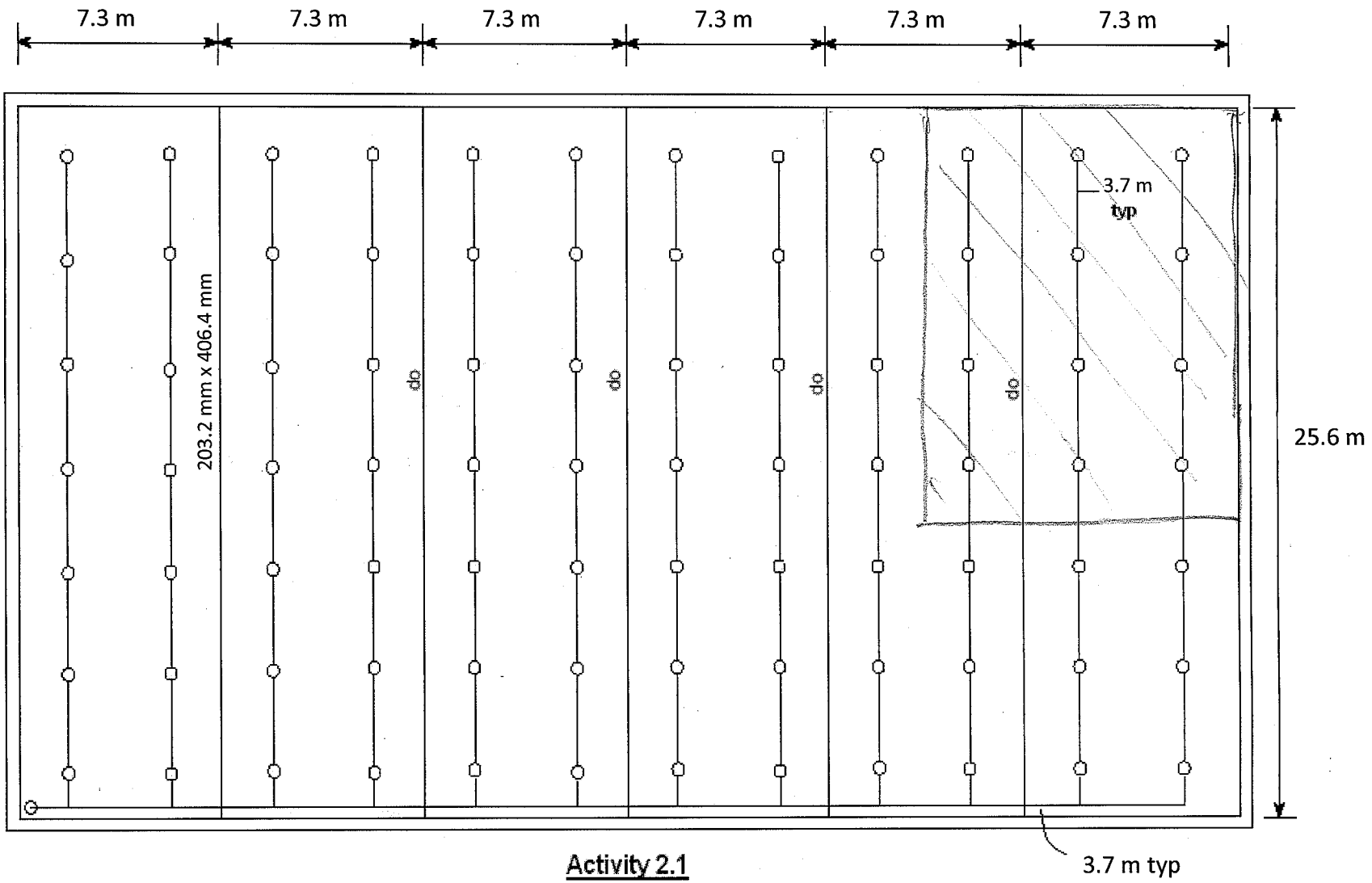

Activity 2.1

Plan View – Office Building

h/o 2.1.1

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Design Assumptions
Handout 2.1.2

Sample Occupancy Classifications

A.5.2 Light hazard occupancies include occupancies having uses and conditions similar to the following:
Churches
Clubs
Eaves and overhangs, if of combustible construction with no combustibles beneath
Educational
Hospitals
Institutional
Libraries, except large stack rooms
Museums
Nursing or convalescent homes
Offices, including data processing
Residential
Restaurant seating areas
Theaters and auditoriums, excluding stages and prosceniums
Unused attics
A.5.3.1 Ordinary hazard occupancies (Group 1) include occupancies having uses and conditions similar to the following:
Automobile parking and showrooms
Bakeries
Beverage manufacturing
Canneries
Dairy products manufacturing and processing
Electronic plants
Glass and glass products manufacturing
Laundries
Restaurant service areas
A.5.3.2 Ordinary hazard occupancies (Group 2) include occupancies having uses and conditions similar to the following:
Cereal mills
Chemical plants — ordinary
Confectionery products
Distilleries
Dry cleaners
Feed mills
Horse stables
Leather goods manufacturing

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Libraries — large stack room areas
Machine shops
Metal working
Mercantile
Paper and pulp mills
Paper process plants
Piers and wharves
Post offices
Printing and publishing
Repair garages
Resin application area
Stages
Textile manufacturing
Tire manufacturing
Tobacco products manufacturing
Wood machining
Wood product assembly

A.5.4.1 Extra hazard occupancies (Group 1) include occupancies having uses and conditions similar to the following:
Aircraft hangars (except as governed by NFPA 409, Standard on Aircraft Hangars)
Combustible hydraulic fluid use areas
Die casting
Metal extruding
Plywood and particle board manufacturing
Printing [using inks having flash points below 100°F (38°C)]
Rubber reclaiming, compounding, drying, milling, vulcanizing
Saw mills
Textile picking, opening, blending, garnetting, or carding, combining of cotton, synthetics, wool shoddy, or burlap
Upholstering with plastic foams

A.5.4.2 Extra hazard occupancies (Group 2) include occupancies having uses and conditions similar to the following:
Asphalt saturating
Flammable liquids spraying
Flow coating
Manufactured home or modular building assemblies (where finished enclosure is present and has combustible interiors)
Open oil quenching
Plastics processing
Solvent cleaning
Varnish and paint dipping

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Module 2 - Review



- Determine classification of occupancy
- Select density and area of operation corresponding to occupancy selected
- Determine the size, shape and location of remote area
- Calculate starting flow and pressure
- Determine hose allowances and water supply duration

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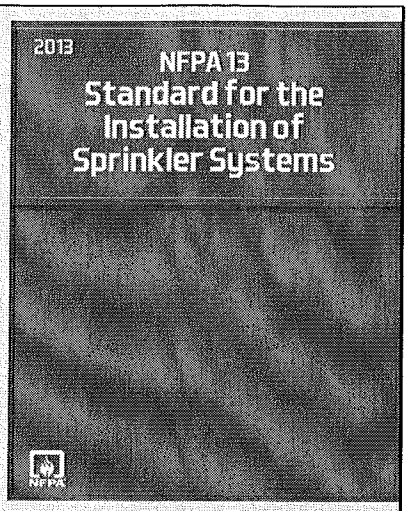
Module 3

Calculating Friction Loss

$$p_m = 0.05\left(\frac{Q^{1.85}}{C^{1.85} d^{4.87}}\right)10^5$$





Objectives

- Apply C-values to system piping
- Calculate Head Loss using Hazen-Williams and Friction Loss Tables
- Calculate Friction Loss Through Pipe

Hydraulic Calculation Forms

- Hydraulic Design Information Sheet
- Hydraulic Calculation Sheet
- Friction Loss Tables – Pipe
- Friction Loss Table - Fittings

pg 232 to 235 of NFPA 13

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Table 23.4.4.7.1 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 or stainless steel	150
Asbestos cement	140
Concrete	140

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

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Note C-value is different from domestic plumbing systems.

Hazen Williams Formula:

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

where:
P_m = frictional resistance (bar/m of pipe)
Q_m = flow (L/min)
C = friction loss coefficient
d_m = actual internal diameter (mm)

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Friction Loss

23.4.4.7.1 Pipe friction loss shall be calculated in accordance with the Hazen–Williams formula with *C* values from Table 23.4.4.7.1, as follows:

(1) Include pipe, fittings, and devices such as valves, meters, flow switches in pipes 2 in. or less in size, and strainers, and calculate elevation changes that affect the sprinkler discharge.
(2) Tie-in drain piping shall not be included in the hydraulic calculations.
(3) Calculate the loss for a tee or a cross 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.

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Friction Loss

(5) Do not include fitting loss for straight-through flow in a tee or cross.
(6) Calculate the loss of reducing elbows based on the equivalent feet value of the smallest outlet.
(7) Use the equivalent feet value for the standard elbow on any abrupt 90-degree turn, such as the screw-type pattern.
(8) Use 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. *(See Table 23.4.3.1.1.)*
(9) Friction loss shall be excluded for the fitting directly connected to a sprinkler.
(10) 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.

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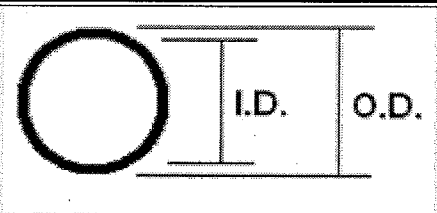

1" sch 40: 1.315" O.D. / 1.049" I.D.

1" sch 10: 1.315" O.D. / 1.097" I.D.

Using the Friction Loss Table in your handout, what is the loss per ft for each pipe (above) flowing 20 gpm? (C=120)

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Applying Hazen Williams Formula

23.4.2.1.2 For SI units, the following equation shall be used:

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

where:
p_m = frictional resistance (bar/m of pipe)
Q_m = flow (L/min)
C = friction loss coefficient
d_m = actual internal diameter (mm)

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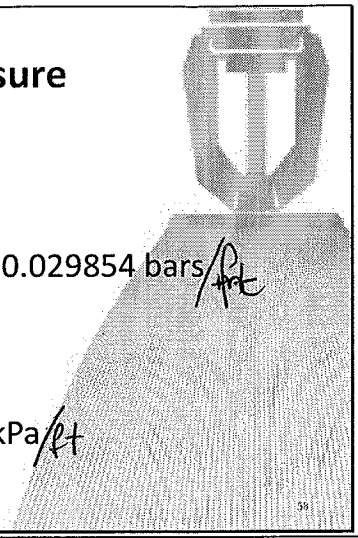
Elevation Pressure

.433 lbs/in² (psi)/ft = 0.029854 bars/ft

or

2.9854 kPa/ft



Fittings

Table 23.4.3.1.1 Equivalent Schedule 40 Steel Pipe Length Chart

	Fittings and Valves Expressed in Equivalent Feet (Meters) of Pipe														
	¼ in.	⅜ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
Fittings and Valves	(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 (3.4)	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)	3 (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)
Swing check*	—	—	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	14 (4.3)	16 (4.9)	19 (5.8)	22 (6.7)	27 (8.2)	32 (9.8)	45 (13.7)	55 (16.8)	65 (20)

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: Information on ½ in. pipe is included in this table only because it is allowed under 8.15.19.4 and 8.15.19.5.
*Due to the variation in design of swing check valves, the pipe equivalents indicated in this table are considered average.

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Equivalent Length Modifier

23.4.5.1.5.1 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 23.4.5.1.1 shall be multiplied by a factor derived from the following formula:

$$\left(\frac{\text{Actual inside diameter}}{\text{Schedule 40 steel pipe inside diameter}}\right)^{\text{exp}} = \text{Factor}$$

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Hydraulic Calculation Worksheet

Hyd. Ref. Point	Qa / Qt (gpm)	Dia. "C" Pf/M	Fitting or Eqv.	Ln.	Pipe Ftng's Total	Pt Pe Pf (psi)	Pt Pv Pn	*******	Notes
1	19.50	26.645		0.0	3.962	12.125		K Factor = 80.72	
to		120.0		0.0	0.0	0.0			
2	19.5	0.4076		0.0	3.962	1.615		Vel = 0.58	
2	20.76	35.052		0.0	3.962	13.740		K Factor = 80.72	
to		120.0		0.0	0.0	0.0			
3	40.26	0.4096		0.0	3.962	1.623		Vel = 0.70	
3	21.95	40.894		0.0	3.962	15.363		K Factor = 80.72	
to		120.0		0.0	0.0	0.0			
4	62.21	0.4324		0.0	3.962	1.713		Vel = 0.79	
4	23.14	40.894	2T	4.88	6.248	17.076		K Factor = 80.72	
to		120.0		0.0	4.880	0.433			
RN1	85.35	0.7763		0.0	11.128	8.639		Vel = 1.08	

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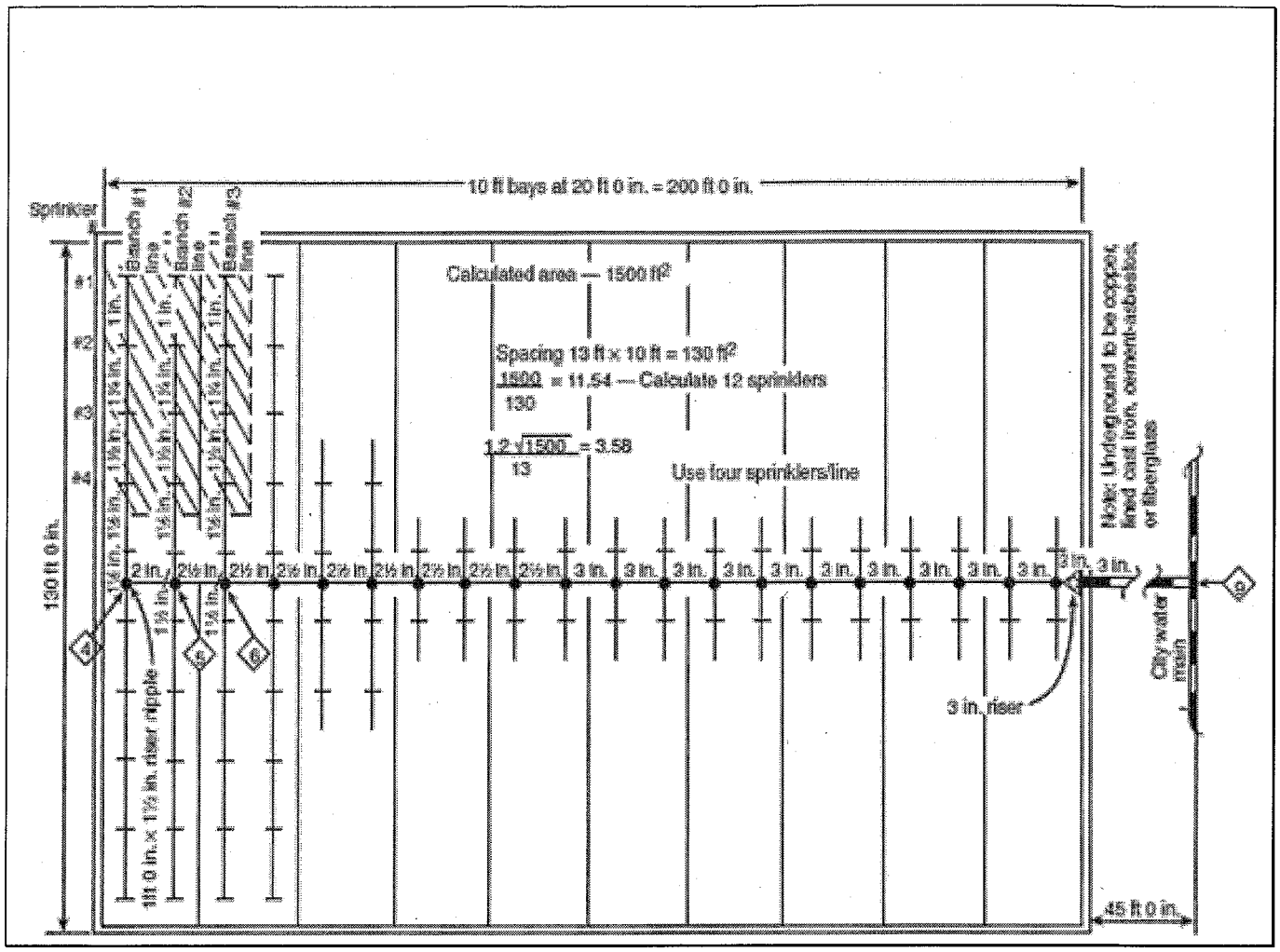

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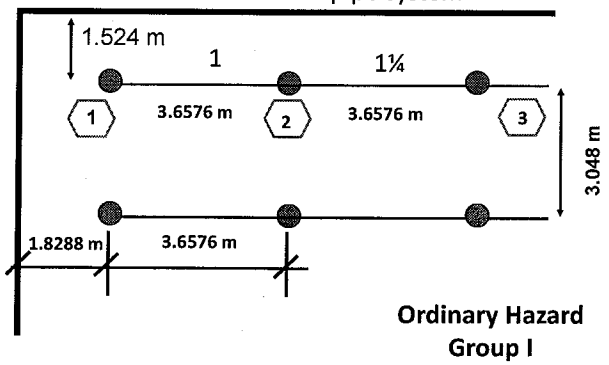
Hyd. Ref. Point	Qa Qt	Dia. "C" Pf/M	Fitting or Eqv.	Ln.	Pipe Ftng's Total	Pt Pe Pf	Pt Pv Pn	*******	Notes	******
RN1	0.0	40.894			0.0	0.305	26.148			
to		120.0			0.0	0.0	0.0			
CM1	85.35	0.7738			0.0	0.305	0.236		Vel =	1.08
CM1	0.0	52.502			0.0	3.048	26.384			
to		120.0			0.0	0.0	0.0			
CM2	85.35	0.2300			0.0	3.048	0.701		Vel =	0.66
CM2	86.30	62.713			0.0	3.048	27.085		Qa =	326.65
to		120.0			0.0	0.0	6.496			
CM3	171.65	0.3527			0.0	3.048	1.075		Vel =	0.93
CM3	86.10	62.713			0.0	21.336	34.656		Qa =	325.89
to		120.0			0.0	0.0	0.0			
CM4	257.75	0.7478			0.0	21.336	15.955		Vel =	1.39
CM4	0.0	77.927	5E		10.65	36.271	50.611			
to		120.0	1G		0.3	10.950	0.0			
FIS	257.75	0.2598			0.0	47.221	12.266		Vel =	0.90
FIS	0.0	74.955	5E		13.317	15.240	62.877			
to		150.0	1T		5.714	19.407	0.0			
TEST	257.75	0.2080	1G		0.375	34.647	7.205		Vel =	0.97
	0.0									
	257.75						70.082		K Factor =	30.79

Sprinkler Spacing

11.148 m² x 6.1 liter per min/m² = 6.8 L/min

Sch #40 – Wet pipe system



Ordinary Hazard Group I

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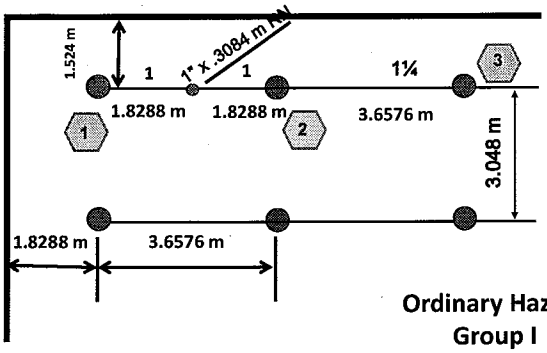
Branch Line Calculation

Hyd. Ref. Point	Qa Qt	Dia. "C" Pf/M	Fitting or Eqv.	Ln.	Pipe Ftng's Total	Pt Pe Pf	Pt Pv Pn	*******	Notes
1	68.12	26.64	0.0		3.658	0.712		K Factor = 80.72	
to		120.0	0.0		0.0	0.0			
2	68.12	0.0243	0.0		3.658	0.089		Vel = 2.04	
2	72.24	35.052	0.0		3.658	0.801		K Factor = 80.72	
to		120.0	0.0		0.0	0.0			
3	140.36	0.0243	0.0		3.658	0.089		Vel = 2.42	
3	76.14	35.052	0.0		3.658	0.890		K Factor = 80.72	
to		120.0	0.0		0.0	0.0			
A	216.5	0.0541	0.0		3.658	0.198		Vel = 3.74	
	0.0								
	216.50					1.088		K Factor = 207.56	

Calculate Pipe with Offset

11.148 m² x 6.1 liter per min/m² = 68 L/m

Sch #40 – Wet pipe system



Ordinary Hazard Group I

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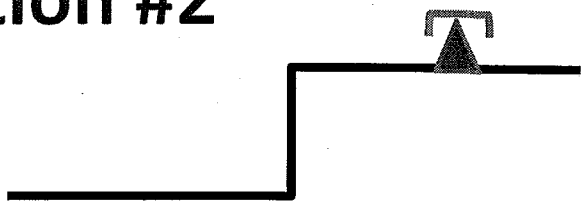
Branch line Calculation #2 with off-set



Hyd. Ref. Point	Qa Qt	Dia. "C" Pf/M	Fitting or Eqv.	Ln.	Pipe Ftng's Total	Pt Pe Pf	Pt Pv Pn	******* Notes ***
1	68.12	26.64	2E	1.22	3.962	0.712		K Factor = 80.72
to		120.0		0.0	1.220	0.030		
2	68.12	0.0243		0.0	5.182	0.126		Vel = 2.04
2	75.20	35.052		0.0	3.658	0.868		K Factor = 80.72
to		120.0		0.0	0.0	0.0		
3	143.32	0.0252		0.0	3.658	0.092		Vel = 2.48
3	79.09	35.052		0.0	3.658	0.960		K Factor = 80.72
to		120.0		0.0	0.0	0.0		
A	222.41	0.0569		0.0	3.658	0.208		Vel = 3.84
	0.0							
	222.41					1.168		K Factor = 205.79

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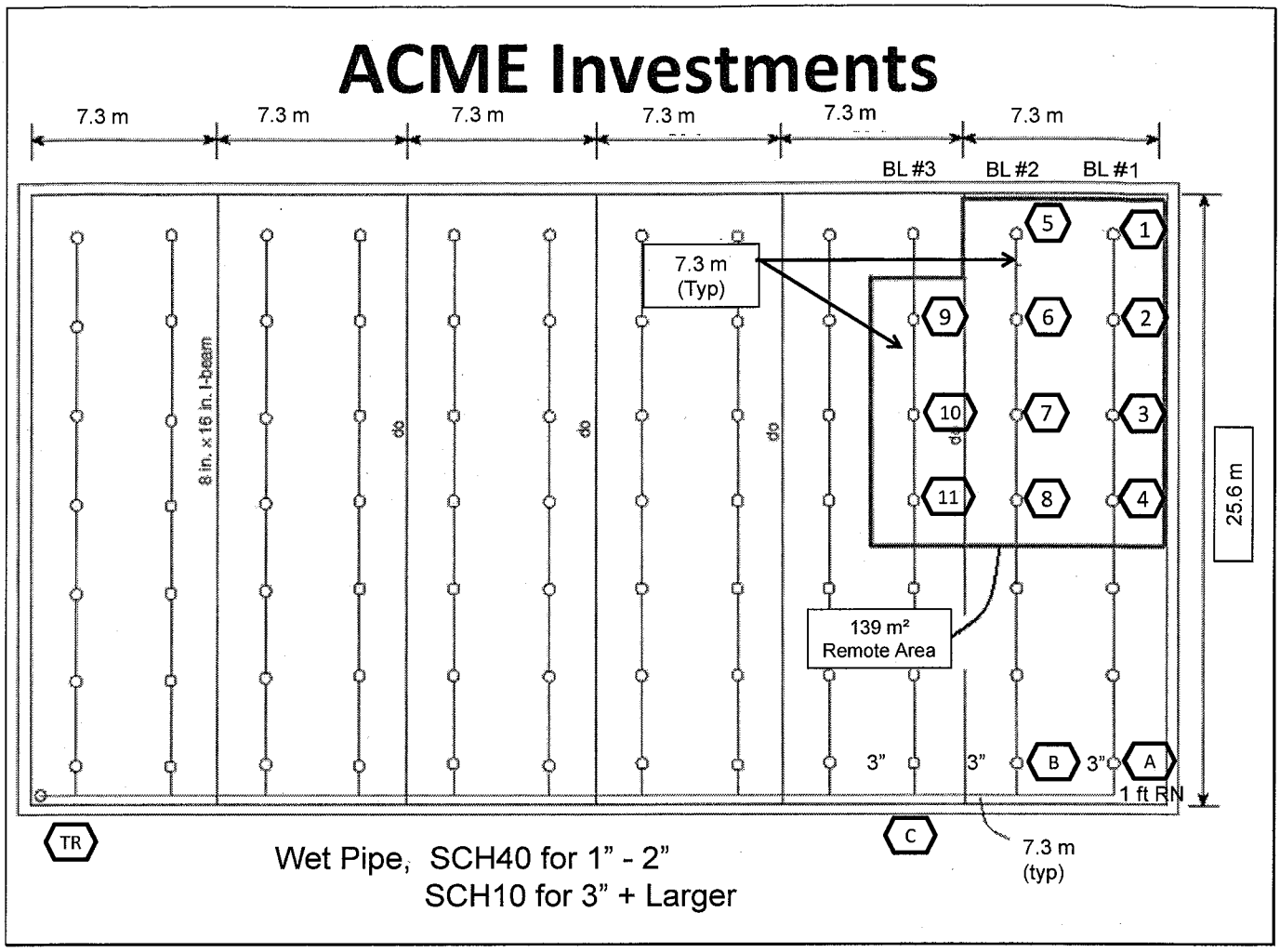

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Hyd. Ref. Point	Qa Qt	Dia. "C" Pf/M	Fitting or Eqv.	Ln.	Pipe Fitg's Total	Pt Pe Pf	Pt Pv Pn	*******	Notes
1	56.10	26.64		0.0	3.658	0.483		K Factor = 80.72	
to		120.0		0.0	0.0	0.0			
2	56.1	0.0169		0.0	3.658	0.062		Vel = 1.68	
2	59.58	35.052		0.0	3.658	0.545		K Factor = 80.72	
to		120.0		0.0	0.0	0.0			
3	115.68	0.0169		0.0	3.658	0.062		Vel = 2.00	
3	62.89	40.894		0.0	3.658	0.607		K Factor = 80.72	
to		120.0		0.0	0.0	0.0			
4	178.57	0.0178		0.0	3.658	0.065		Vel = 2.27	
4	66.19	52.5	1E	1.52	9.144	0.672		K Factor = 80.72	
to		120.0	1T	3.05	4.570	0.030			
A	244.76	0.0095		0.0	13.714	0.130		Vel = 1.88	
	0.0								
	244.76					0.832		K Factor = 268.34	

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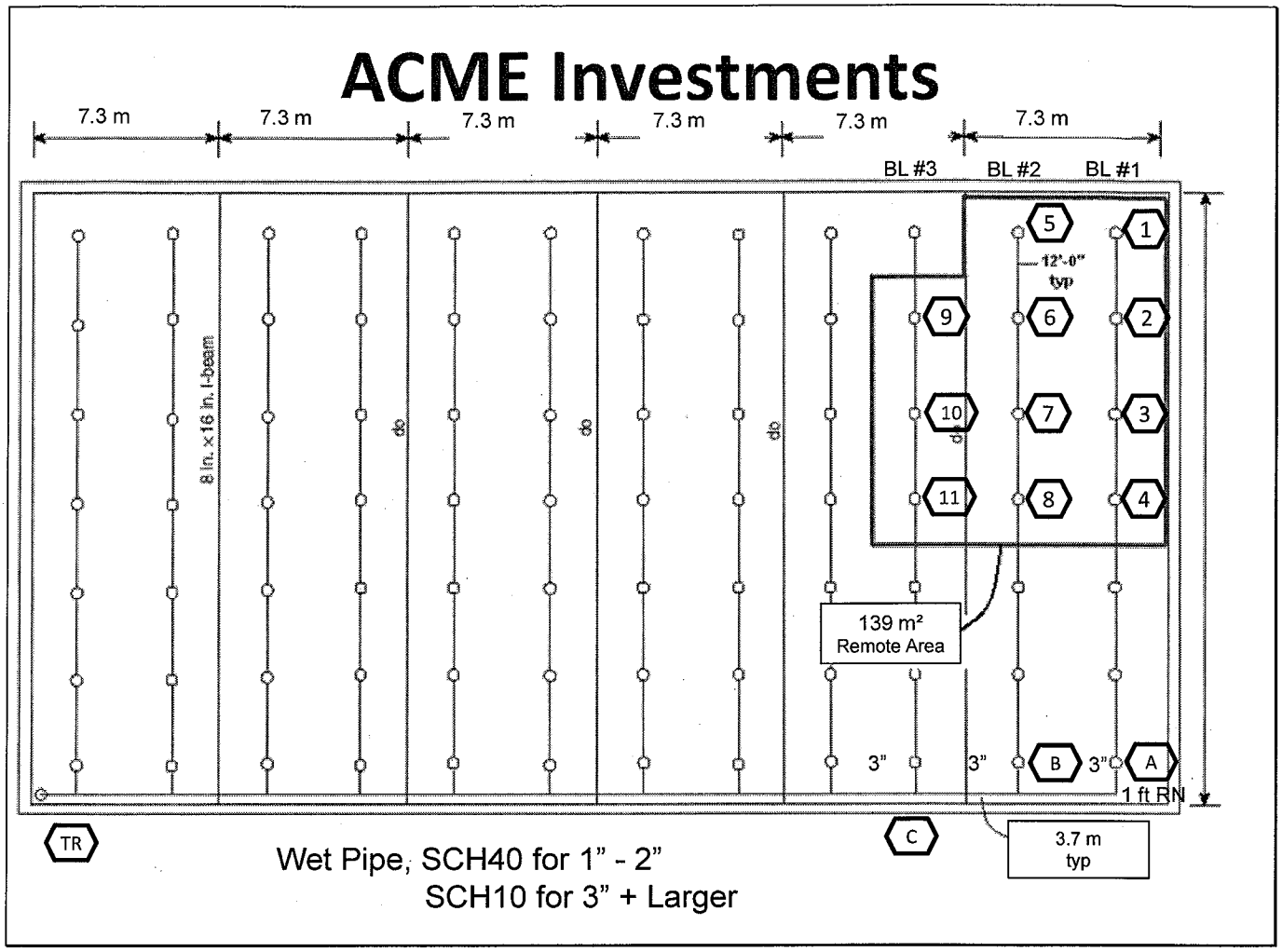

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Hyd. Ref. Point	Qa Qt	Dia. "C" Pf/M	Fitting or Eqv.	Ln.	Pipe Ftng's Total	Pt Pe Pf	Pt Pv Pn	*******	Notes
A	244.50	82.804		0.0	3.658	0.837		K Factor = 267.24	
to		120.0		0.0	0.0	0.0			
B	244.5	0.0011		0.0	3.658	0.004		Vel = 0.76	
B	245.04	82.804		0.0	3.658	0.841		K Factor = 267.24	
to		120.0		0.0	0.0	0.0			
C	489.54	0.0036		0.0	3.658	0.013		Vel = 1.52	
C	197.99	82.804	1E	2.861	34.747	0.854		K Factor = 214.20	
to		120.0		0.0	2.861	0.0			
TR	687.53	0.0070		0.0	37.608	0.263		Vel = 2.13	
TR	0.0	82.804		0.0	4.572	1.117			
to		120.0		0.0	0.0	0.448			
RSR	687.53	0.0068		0.0	4.572	0.031		Vel = 2.13	
RSR	0.0	106.2	1G	0.803	0.914	1.596			
to		120.0	1S	8.834	9.637	0.090			
UG	687.53	0.0019		0.0	10.551	0.020		Vel = 1.25	
UG	0.0	104.14	1T	8.866	32.918	1.706			
to		140.0	1E	4.433	13.298	0.239			
WS	687.53	0.0017		0.0	46.216	0.079		Vel = 1.35	
	378.50							Qa = 378.50	
	1066.03					2.024		K Factor = 749.31	

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Calculation of Identical Branch Line and Partial Branch Line Piping

Hyd. Ref. Point	Qa Qt	Dia. "C" Pf/M	Fitting or Eqv.	Ln.	Pipe Ftng's Total	Pt Pe Pf	Pt Pv Pn	Notes
9	56.10	35.052		0.0	3.658	0.483		K Factor = 80.72
to		120.0		0.0	0.0	0.0		
10	56.1	0.0044		0.0	3.658	0.016		Vel = 0.97
10	57.03	40.894		0.0	3.658	0.499		K Factor = 80.72
to		120.0		0.0	0.0	0.0		
11	113.13	0.0077		0.0	3.658	0.028		Vel = 1.44
11	58.62	52.5	1E	1.52	12.802	0.527		K Factor = 80.72
to		120.0	1T	3.05	4.570	0.030		
C	171.75	0.0050		0.0	17.372	0.086		Vel = 1.32
	0.0							
	171.75					0.643		K Factor = 214.19

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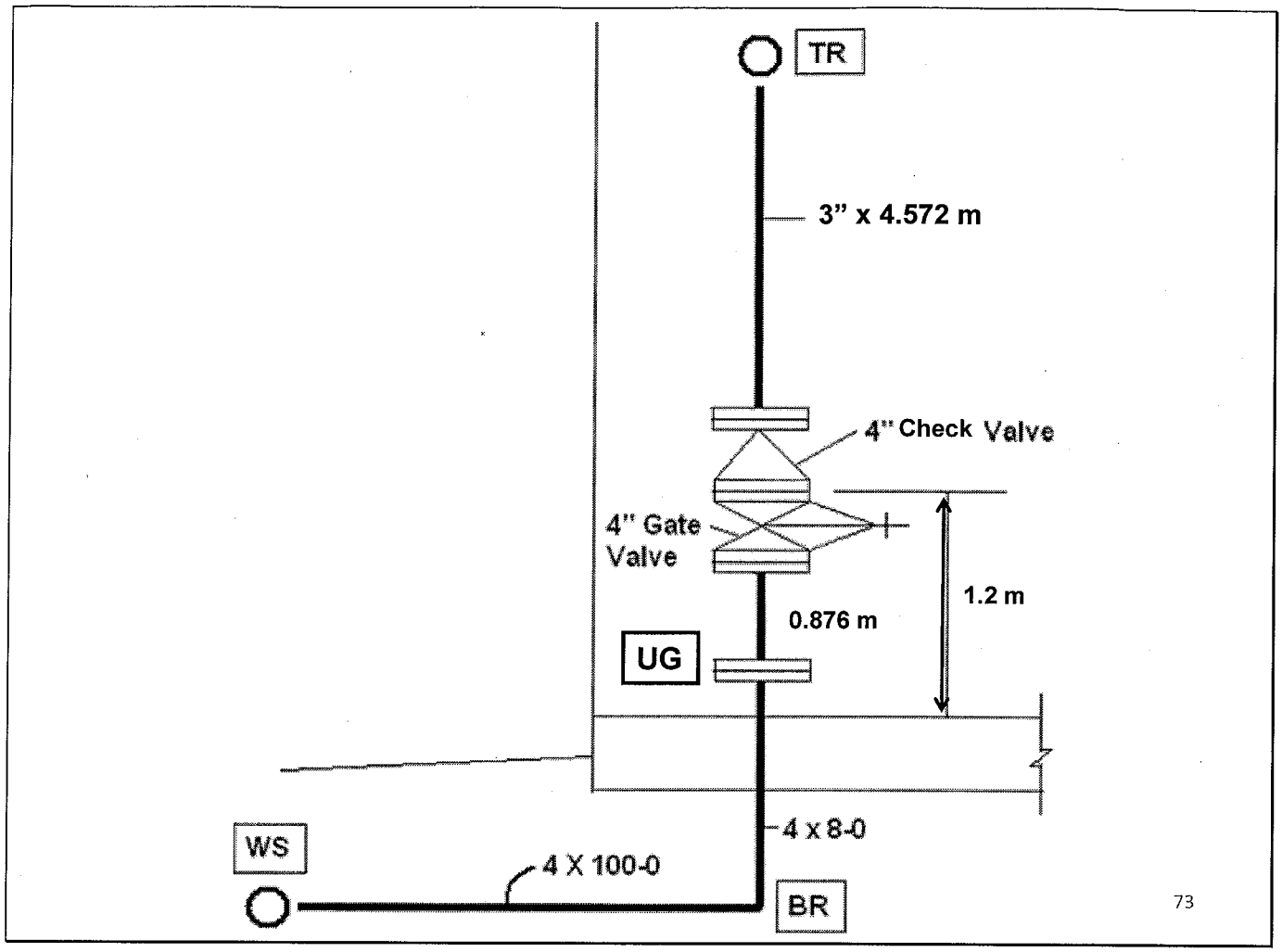

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Hyd. Ref. Point	Qa / Qt	Dia. "C" Pf/M	Fitting or Eqv.	Ln.	Pipe Ftng's Total	Pt Pe Pf	Pt Pv Pn	*******	Notes
A	244.50	82.804		0.0	3.658	0.837		K Factor = 267.24	
to		120.0		0.0	0.0	0.0			
B	244.5	0.0011		0.0	3.658	0.004		Vel = 0.76	
B	245.04	82.804		0.0	3.658	0.841		K Factor = 267.24	
to		120.0		0.0	0.0	0.0			
C	489.54	0.0036		0.0	3.658	0.013		Vel = 1.52	
C	197.99	82.804	1E	2.861	34.747	0.854		K Factor = 214.20	
to		120.0		0.0	2.861	0.0			
TR	687.53	0.0070		0.0	37.608	0.263		Vel = 2.13	
TR	0.0	82.804		0.0	4.572	1.117			
to		120.0		0.0	0.0	0.448			
RSR	687.53	0.0068		0.0	4.572	0.031		Vel = 2.13	
RSR	0.0	108.2	1G	0.803	0.914	1.596			
to		120.0	1S	8.834	9.637	0.090			
UG	687.53	0.0019		0.0	10.551	0.020		Vel = 1.25	
UG	0.0	104.14	1T	8.866	32.918	1.706			
to		140.0	1E	4.433	13.298	0.239			
WS	687.53	0.0017		0.0	46.216	0.079		Vel = 1.35	
	378.50							Qa = 378.50	
	1066.03					2.024		K Factor = 749.31	

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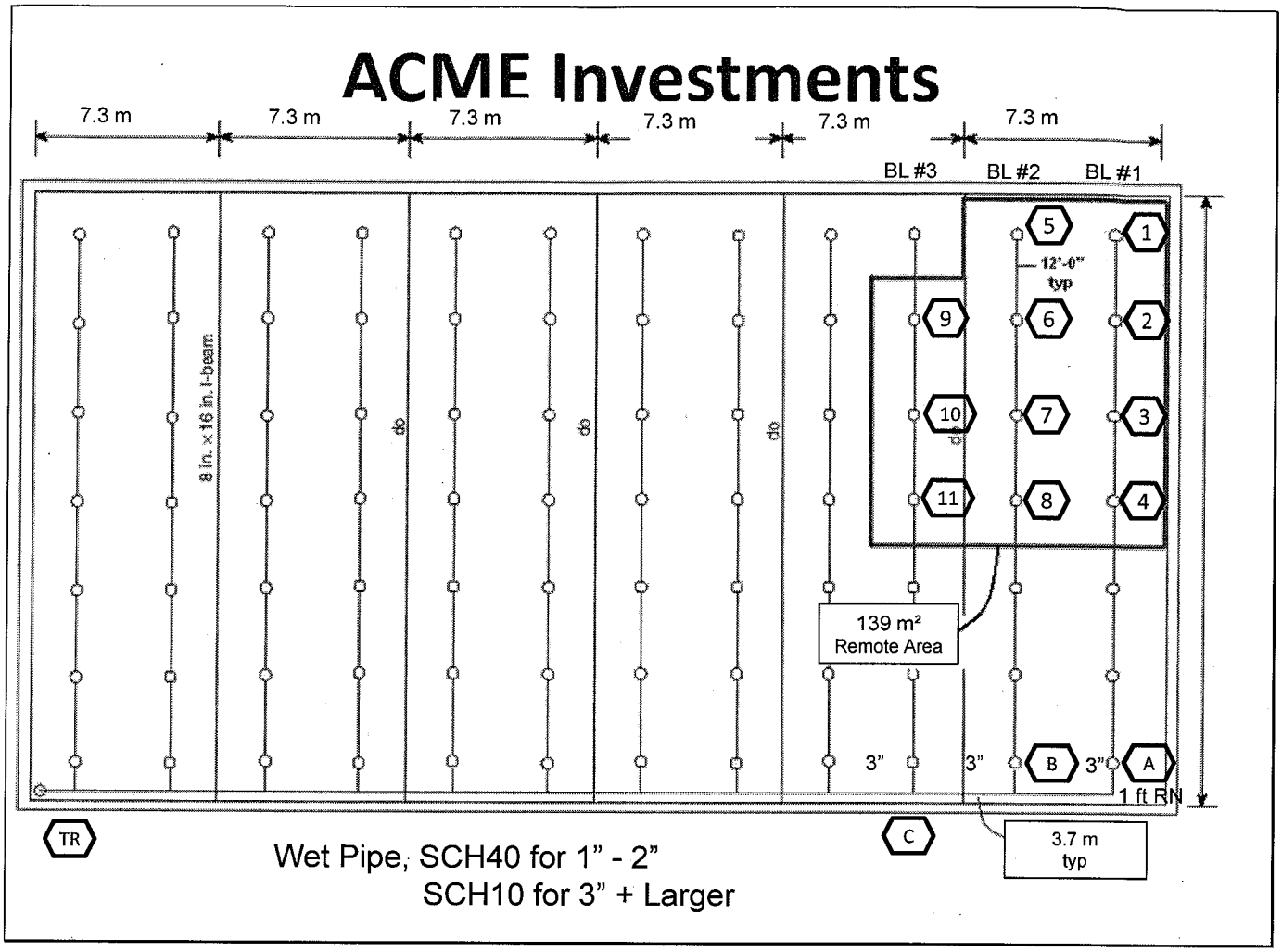

Module 3 Review

Sprinkler System Hydraulics

- Taking an organized approach
- Size and shape of remote area
- Hydraulic reference points
- C-values
- Friction & elevation pressure losses
- Hazen Williams formula & friction loss tables

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Module 4

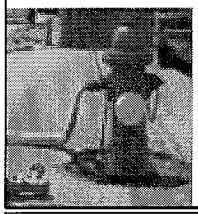
Determination of Water Supply

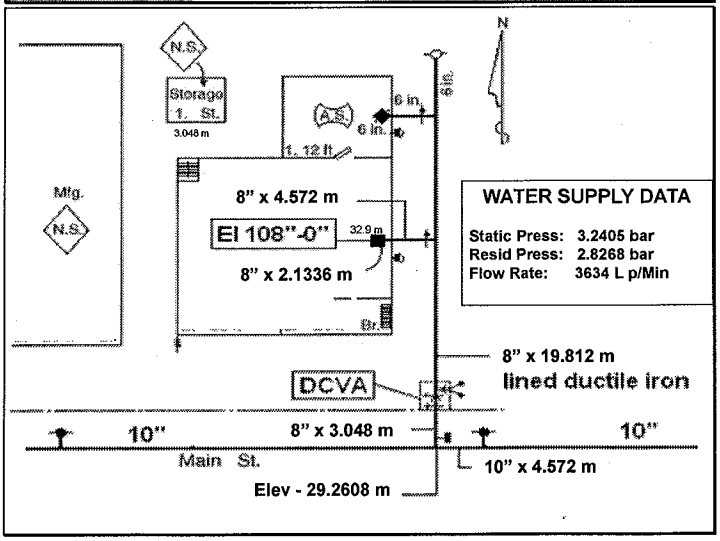


Water Supplies

Determine total output of

- City water and fire pump in series
- Fire pumps in series
- Fire pumps in parallel





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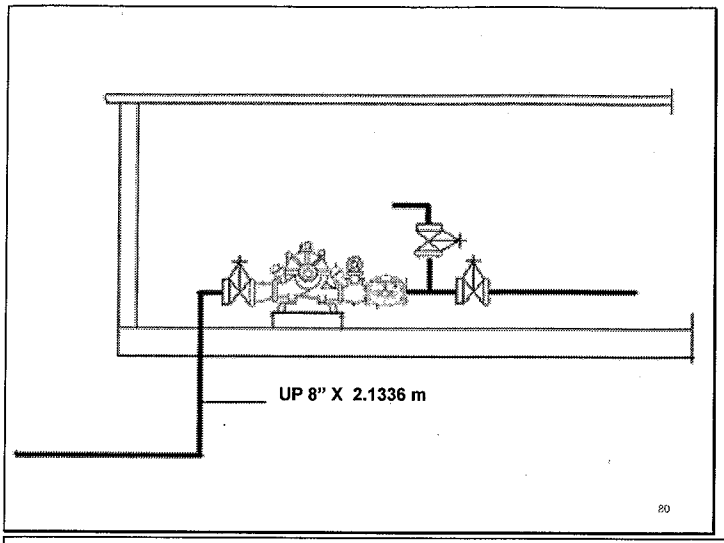

HYDRAULIC CALCULATIONS

Contract Number _____ Sheet No. _____ of _____

Name & Location Water Supply Calculation

Reference	Nozzle Ident. & Location	Flow in L/min (gpm)	Pipe Size mm (in.)	Pipe Fittings & Devices m (ft)	Equiv. Pipe Length m (ft)	Friction Loss bar/m (psi/ft)	Req. bar (psi)	Normal Pressure bar (psi)	Notes
WS		q Q 3,634	8	1 E 2 T 2 GV	Lgth. 29.56 Ftg. 27.74 Tot. 57.3	.35 mb	Pt 2.83 Pf 0.065 Pe 0.36	Pt Pv Pn	C=140
BFP		q Q 3,634	8		Lgth. Ftg. Tot.		Pt 3.255 Pf .207 Pe	Pt Pv Pn	
FP		q Q 3,634	8	1 GV	Lgth. .0305 Ftg. 1.219 Tot. 1.25	.50 mb	Pt 3.462 Pf .0069 Pe	Pt Pv Pn	@ Fire Pump
		q			Lgth.		Pt 3.471	Pt	

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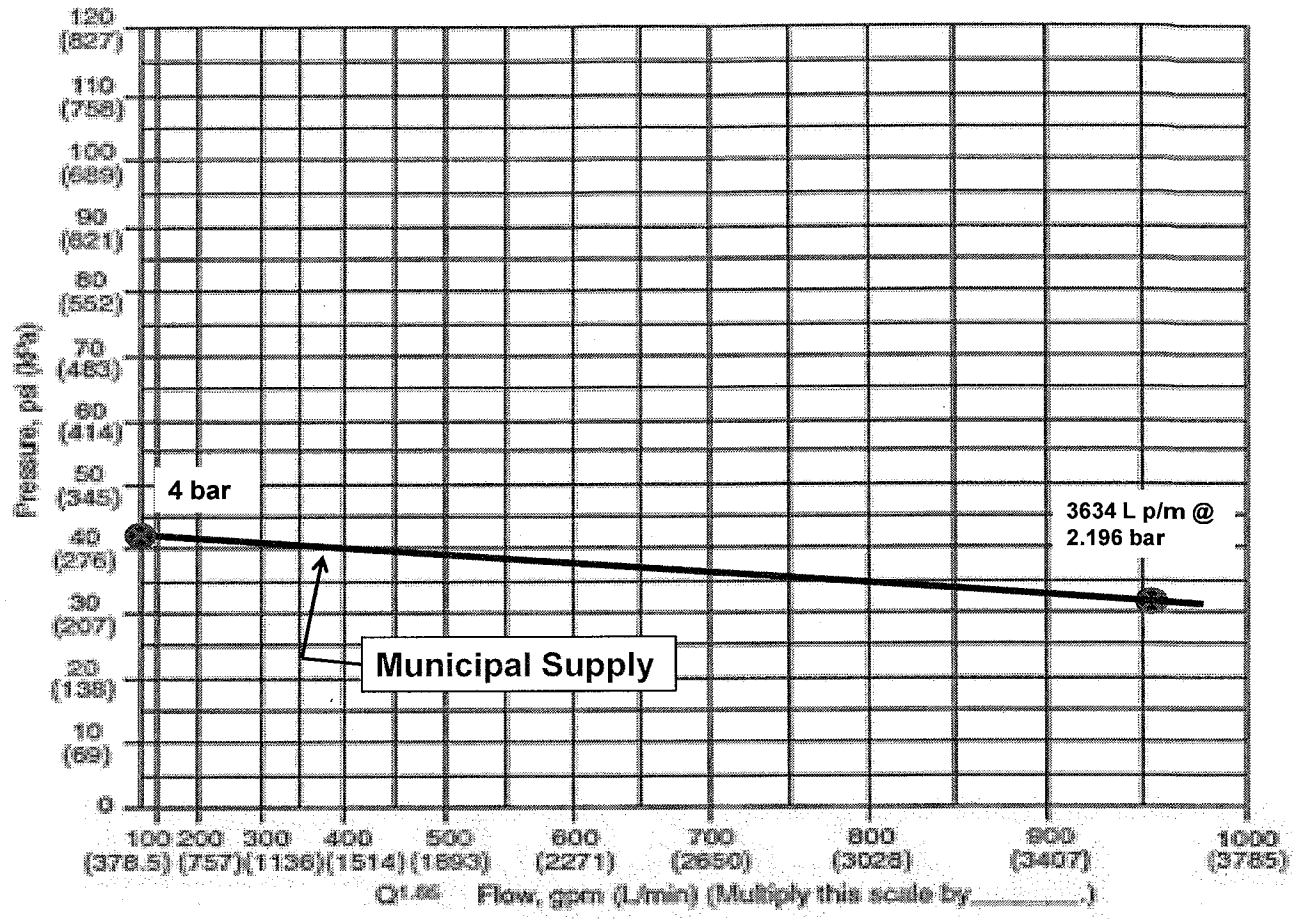

FIGURE 4.11.4 Sample Graph Sheet.

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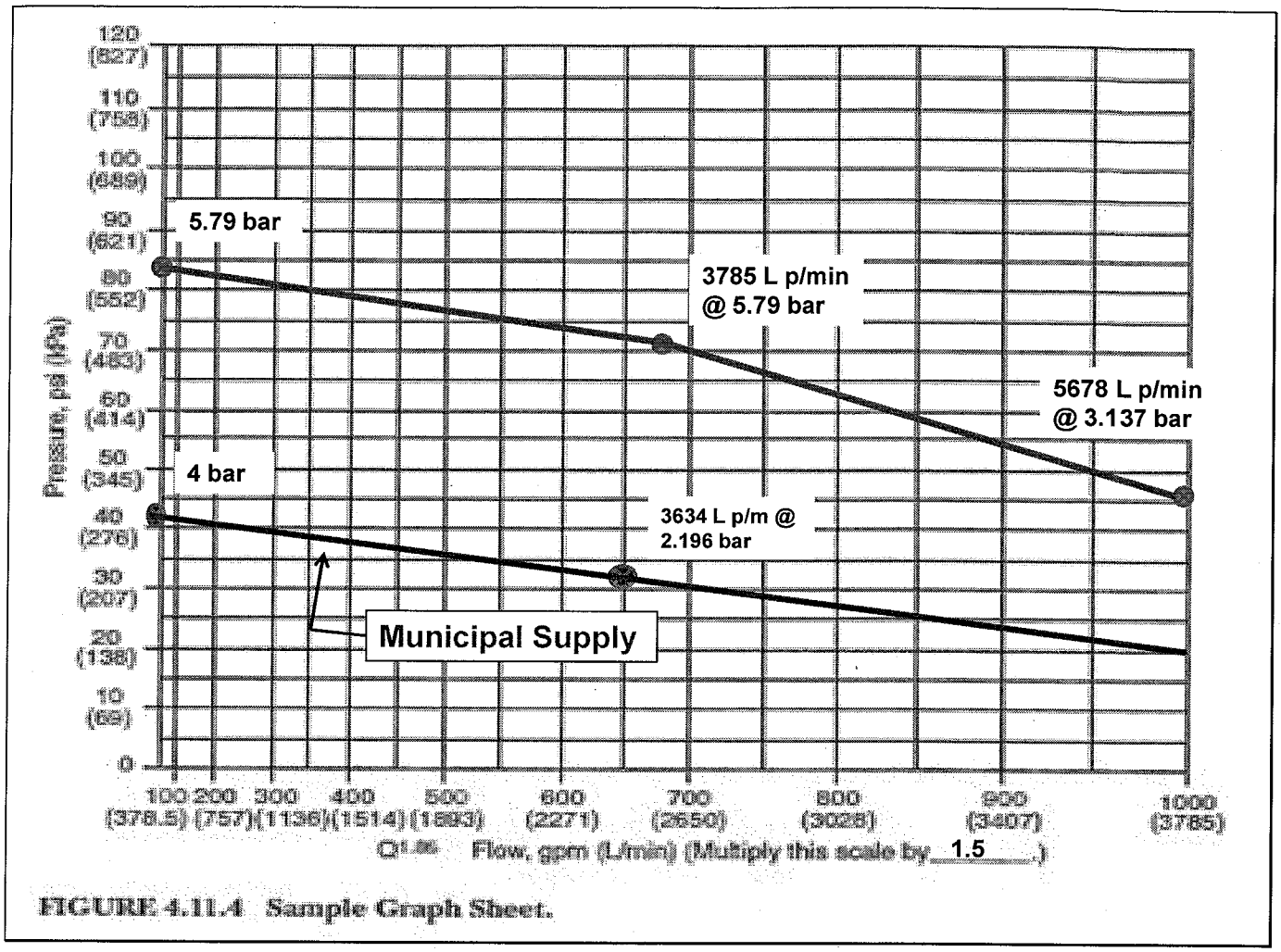

FIGURE 4.11.4 Sample Graph Sheet.

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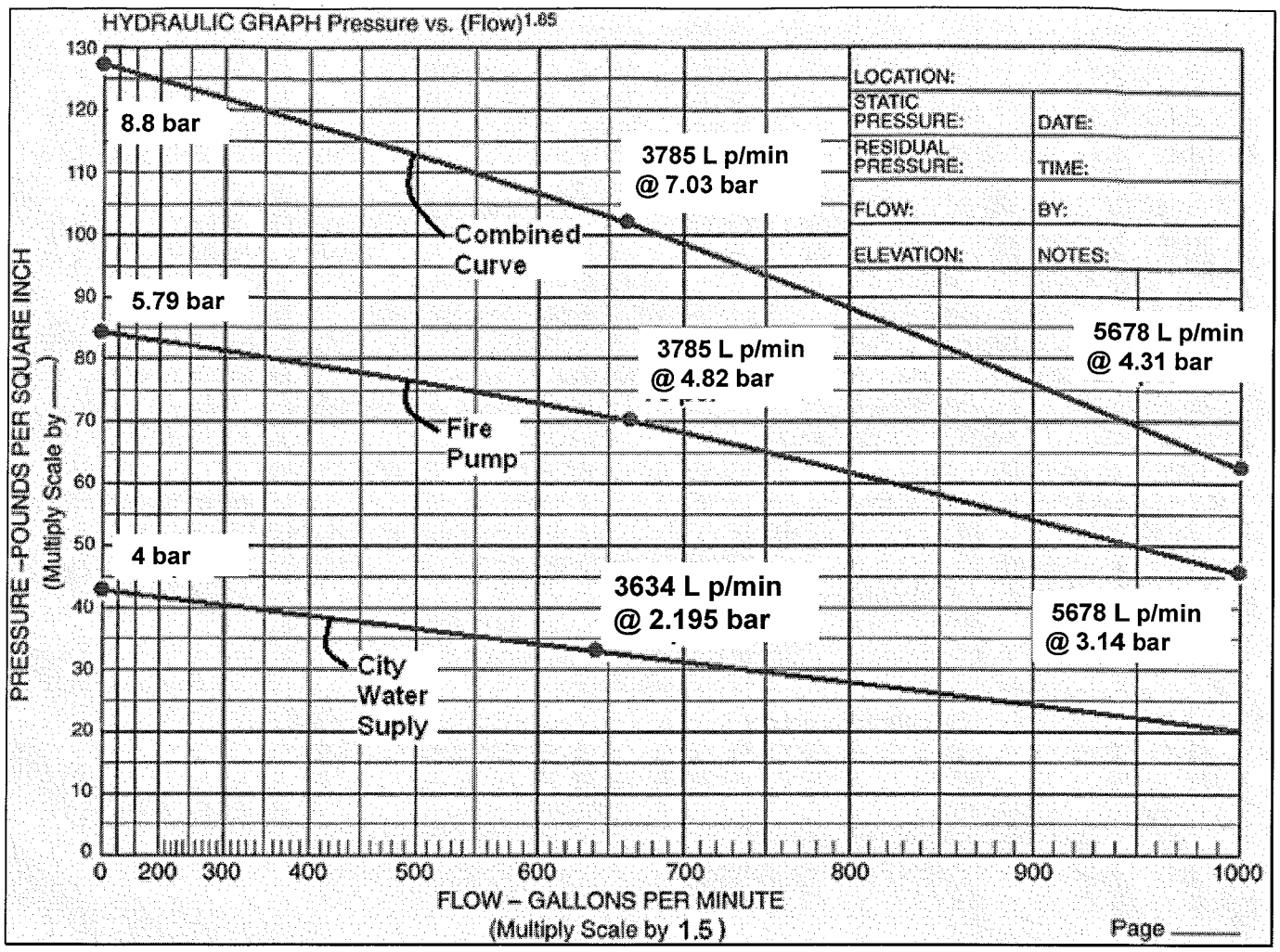

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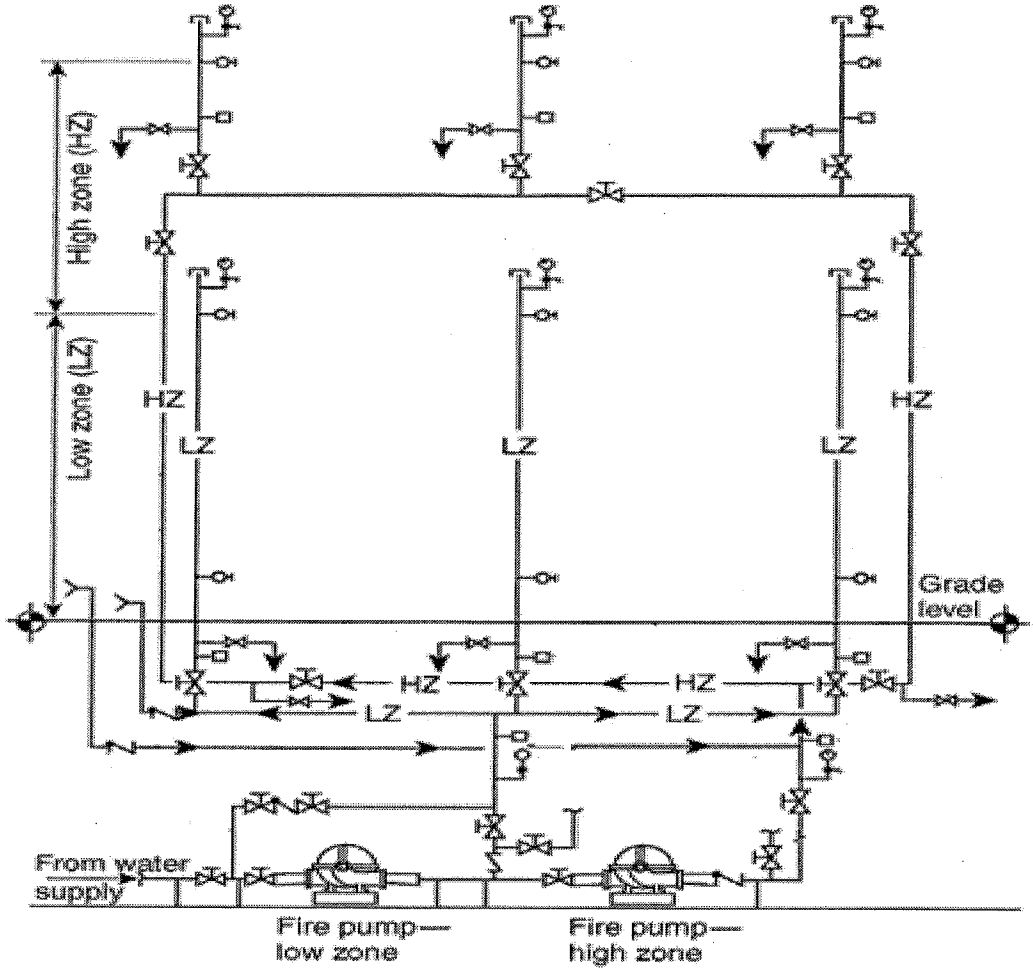

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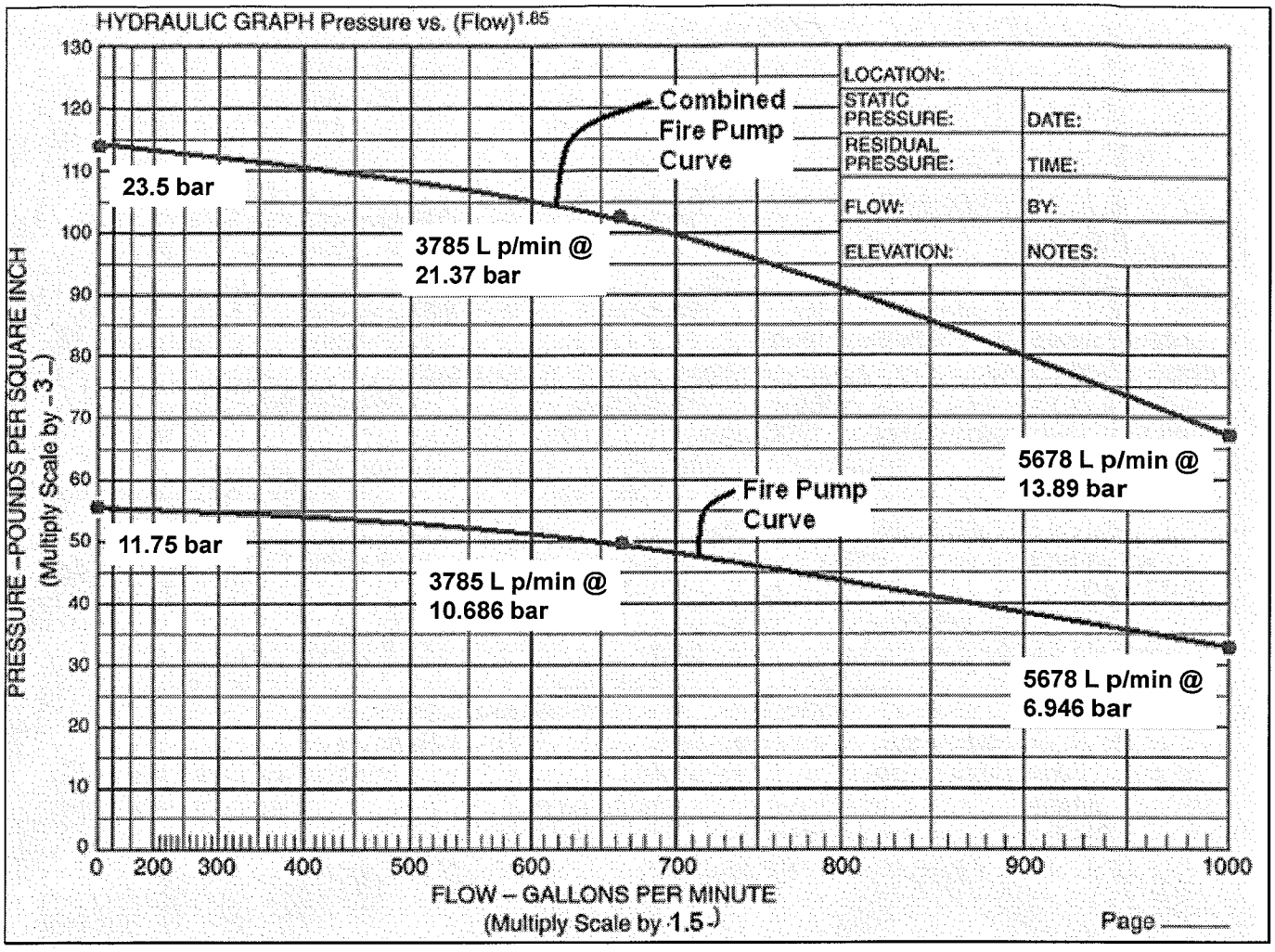

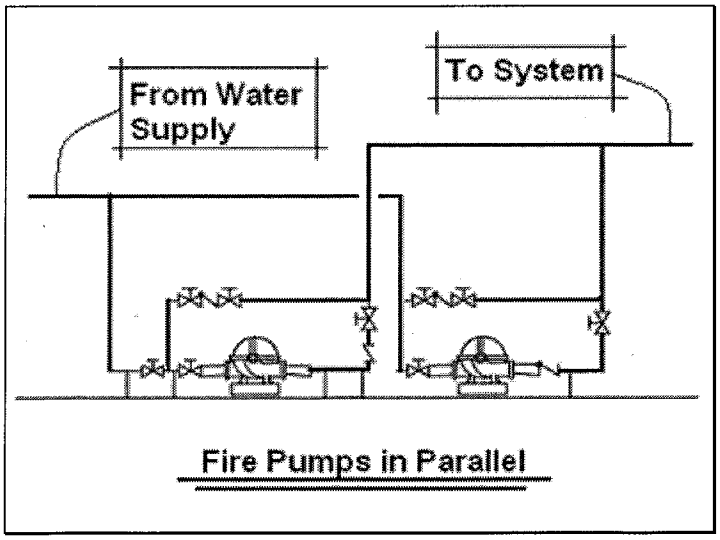

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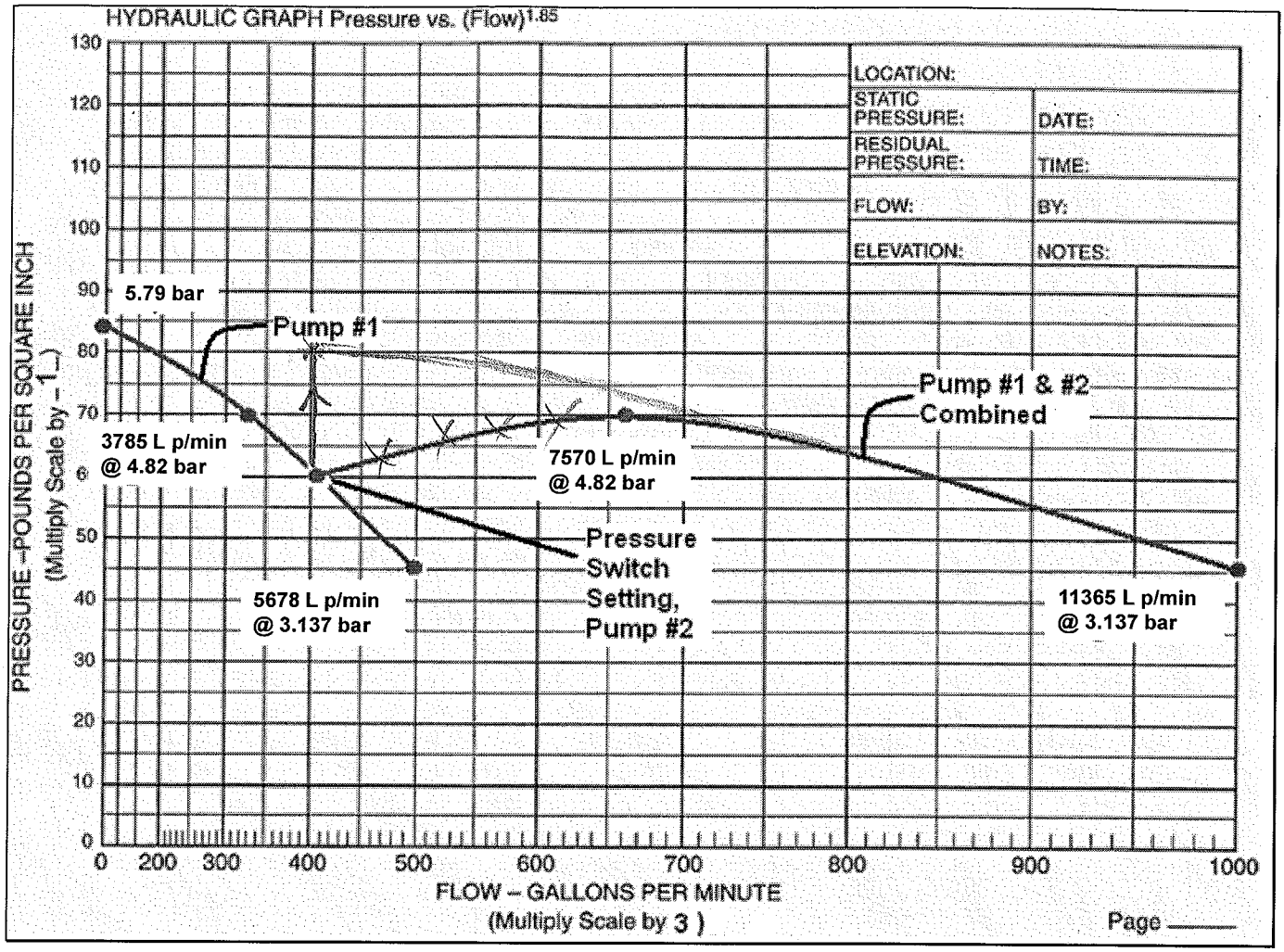
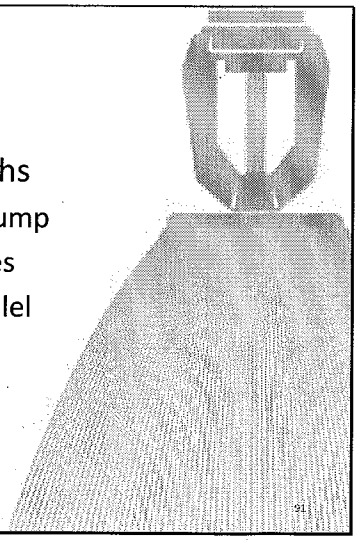


Wrap-Up

- Water Supply Graphs
  - City Water / Fire Pump
  - Fire Pumps in Series
  - Fire Pumps in Parallel



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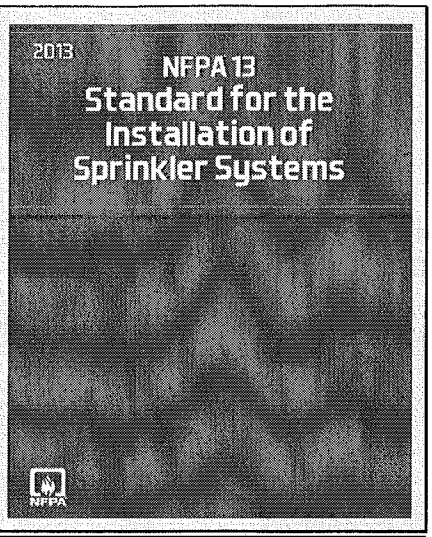
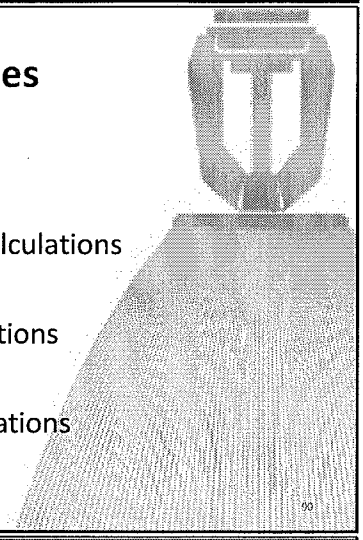
Hydraulic Calculations

Day 2



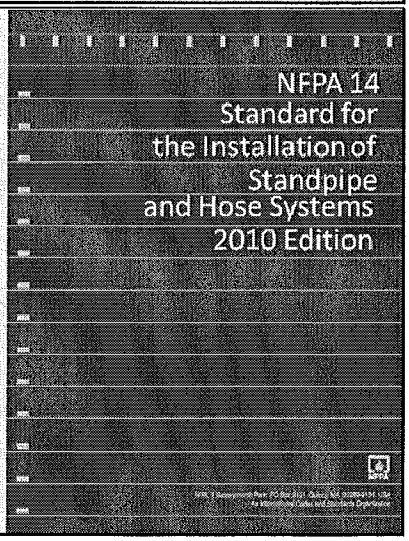
Day 2 Modules

- Standpipe System Calculations
- Rack Storage Calculations
- Practice Hand Calculations



Module 5

Standpipe System Calculations



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Standpipe System Calculations

- Minimum Flow Requirements
  - 946 L p/min (250 gpm) at each of the two top-most outlets
  - 946 L p/min (250 gpm) for each additional standpipe
- Maximum Flow
  - 4731 L p/min (1250 gpm) unsprinklered buildings
  - 3785 L p/min (1000 gpm) fully sprinklered buildings

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NFPA 14 – Design

7.10.1.1* Flow Rate

7.10.1.1.1 For Class I and Class III systems, the minimum flow rate for the hydraulically most remote standpipe shall be 1893 L/min (500 gpm) , through two 65 mm (2.5") outlets at one location, and the calculation procedure shall be in accordance with 7.10.1.2

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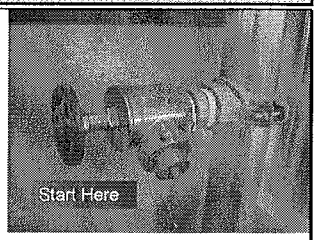
NFPA 14

Pressure Requirements



1. Calculations begin @ 65 mm (2.5") outlet with 6.9 Bar (100 psi)
2. Add Friction Loss (equivalent length fittings) for valve (9.5 m ft for angle vs. 21.3 m for globe)
3. Add friction loss for length between hose valve and standpipe connection
4. Add equivalent length for fittings (tee in SP)

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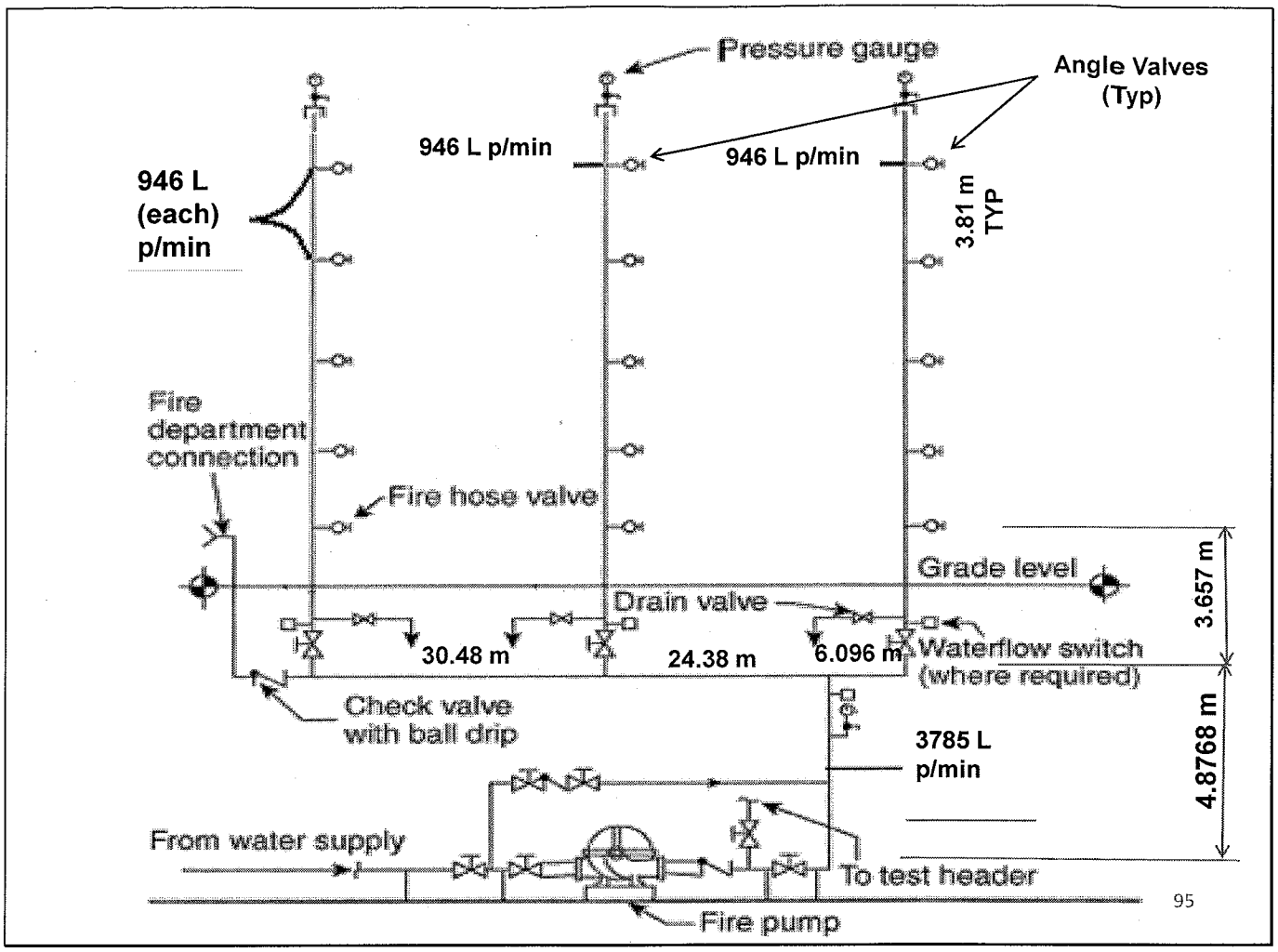

Activity 5.1

- Calculate the standpipe system on sketch 5.1
  - Select pipe size and calculate flow and pressure back to the fire pump using a combined fire pump/city water supply curve.

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Standpipe System Calculations

Activity 5.1 – Participant Directions

Group Size: Individual

Activity Objective: Participants will use handouts and lecture information to calculate a standpipe system as shown on sketch 5.1.

1. The standpipe system consists of three risers

2. The pipe type is schedule 10, black steel with grooved fittings.

3. The city water supply as shown below has already been adjusted to the suction flange of the fire pump:
Static: 6.2 bar
Residual 5.9 bar @ 3611 L/min

Fire Pump:
3785 L/min @ 5.5 bar
Churn pressure is 120%

Static = (4 × 3.8m) + 3.7m + 4.9m = 23.8m

Pipe length = (4 × 3.8) + 3.7m + (30.5m + 24.4m) + 4.9m
= 78.7m

$P_f = 6.05 \left[\frac{Q^{1.85}}{C^{1.85} d^{4.87}} \right] 10^5 = \left(\frac{(9.46)^{1.85}}{120^{1.85} 16.15^{4.85}} \right) 10^5$

$\left(\frac{F^{1.85}}{3.6 \times 10^{14}} \right) 10^5$

= 0.00032 bar/m

× [(4 × 3.8) + 3.7 + 3.05]

= 0.007 bar

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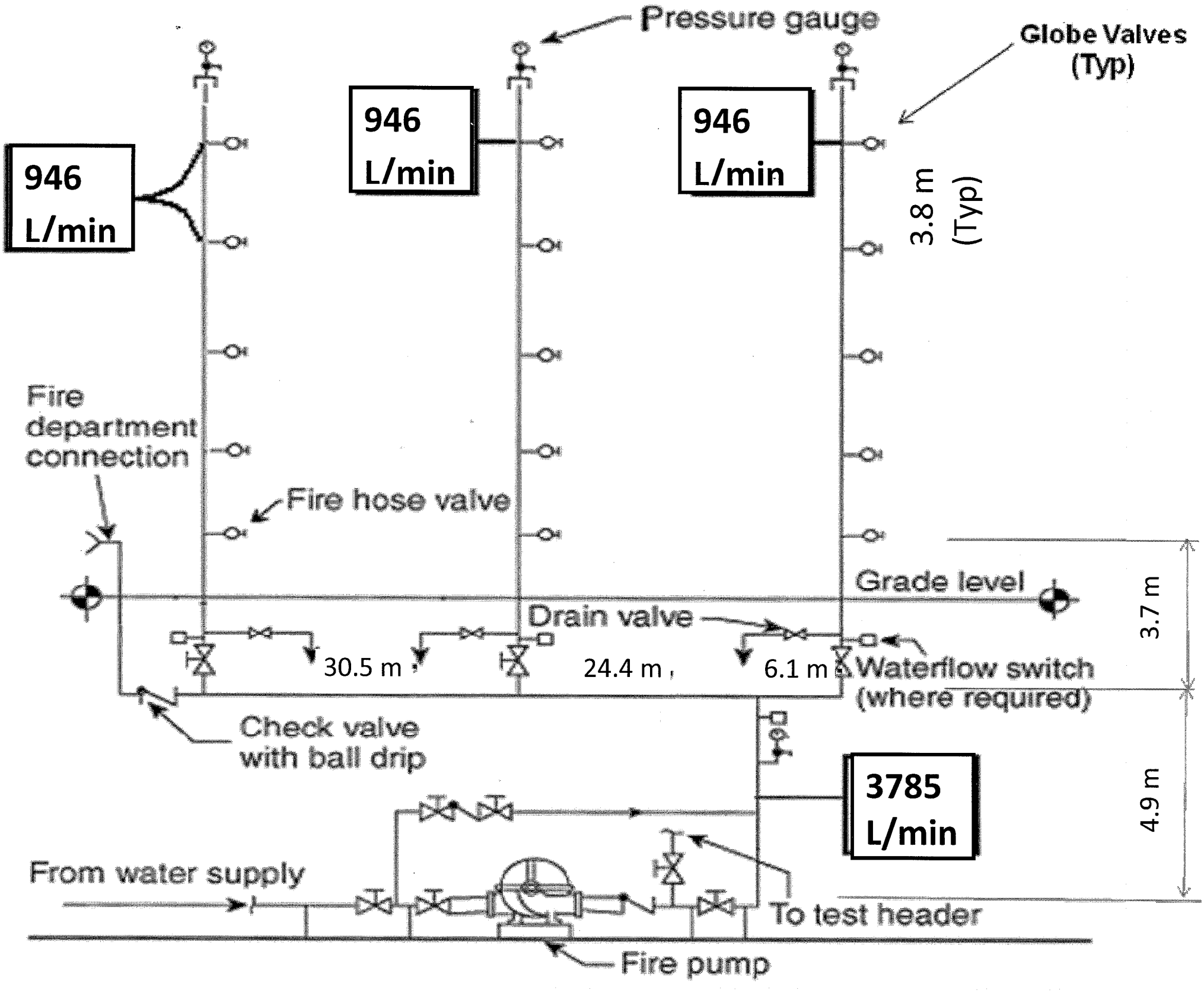
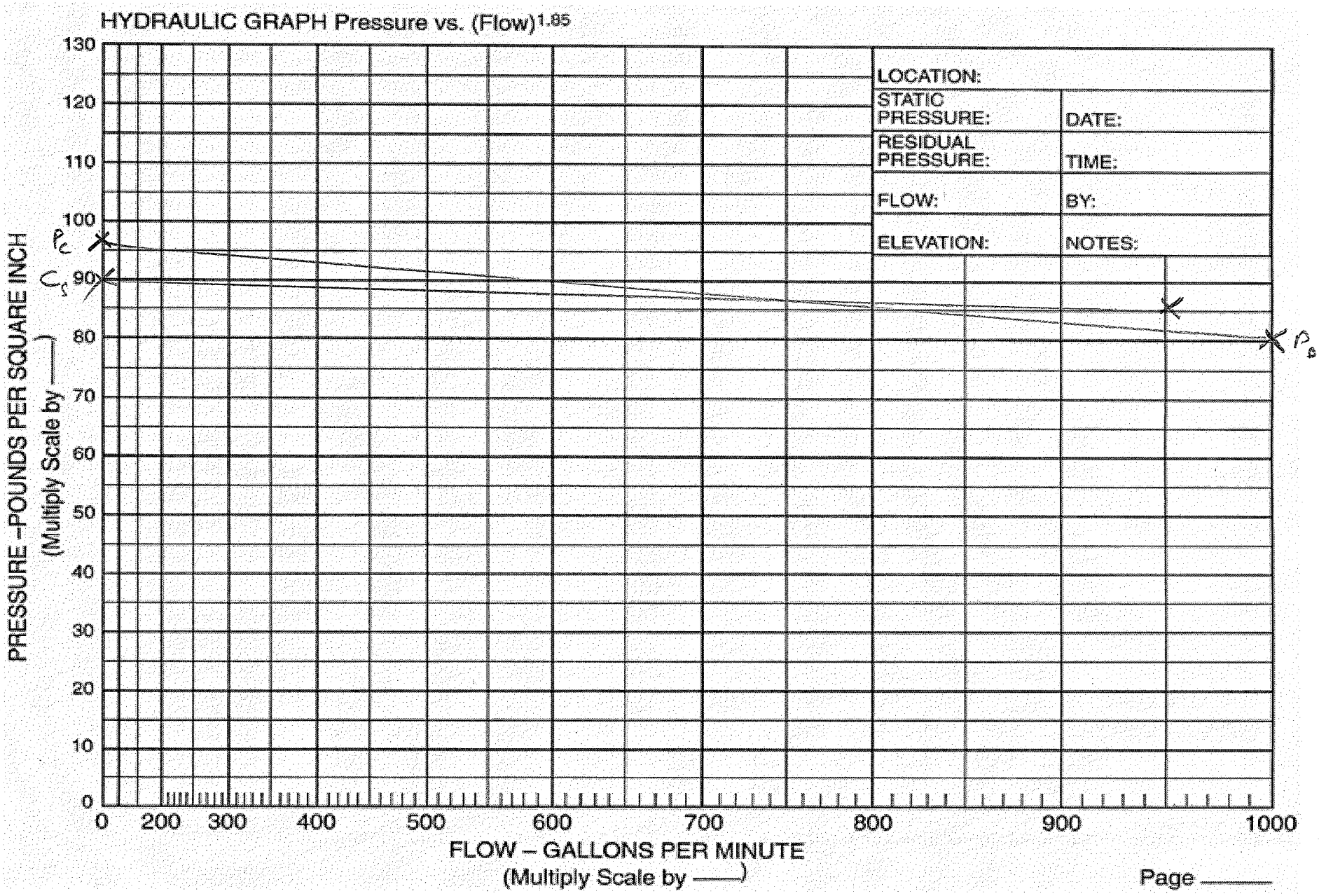
Sketch 5.1


Pressure gauge
Globe Valves (Typ)
946 L/min
946 L/min
946 L/min
3.8 m (Typ)
Fire department connection
Fire hose valve
Grade level
Drain valve
30.5 m
24.4 m
6.1 m
Waterflow switch (where required)
3.7 m
Check valve with ball drip
3785 L/min
4.9 m
From water supply
To test header
Fire pump



Page _____

h/o 5.1.2

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HYDRAULIC DESIGN INFORMATION SHEET

Name _____ Date _____

Location _____

Building _____ System No. _____

Contractor _____ Contract No. _____

Calculated by _____ Drawing No. _____

Construction: ☐ Combustible ☐ Noncombustible Ceiling Height _____ m (ft)

Occupancy _____

System Design

☐ NFPA 13 ☐ LT HAZ ORD HAZ ☐[1] ☐[2] ☐ EX HAZ ☐[1] ☐[2]

☐ NFPA 231 ☐ NFPA 231C Figure _____ Curv _____

☐ NFPA 15 ☐ Other (Specify) _____

☐ Specific ruling _____ Made by _____ Date _____

Area of sprinkler operation _____

Density _____

Area per sprinkler _____

Hose allowance L/min (gpm): Inside _____

Hose allowance L/min (gpm): Outside _____

Rack sprinkler allowance _____

System Type

☐ Wet ☐ Dry ☐ Deluge ☐ Preaction

Sprinkler or Nozzle

Make _____ Model _____

Size _____ *K*-Factor _____

Temperature rating _____

Calculation Summary

System L/min (gpm) required _____ kPa (psi) required _____ A1 base of riser

"C" factor used: Overhead _____ Underground _____

Total L/min (gpm) required _____ kPa (psi) required _____ Ref. PT. _____ System nos. operating _____

Water Supply

Water Flow Test

Date & time _____

Static kPa (psi) _____

Residual kPa (psi) _____

L/min (gpm) flowing _____

Elevation _____

Pump Data

Rated capacity _____

At kPa (psi) _____

Elevation _____

Tank or Reservoir

Capacity _____

Elevation _____

Well

Proof flow _____ L/min (gpm)

Location _____

Source of information _____

Commodity Storage

Commodity _____ Glass _____ Location _____

Storage height _____ Area _____ Aisle width _____

Storage method: Solid piled _____ % Palletized _____ % Hack _____

% Plastics _____

Rack

☐ Single row ☐ Conventional pallet ☐ Automatic storage ☐ Encapsulated

☐ Double row ☐ Slave pallet ☐ Solid shelving ☐ Nonencapsulated

☐ Multiple row ☐ Open

Flue Spacing in mm (in.)

Longitudinal _____ Transverse _____

Clearance from Top of Storage to Ceiling

_____ m (ft) _____ mm (in.)

Horizontal barriers provided _____

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HYDRAULIC CALCULATIONS

Contract Number _____ Sheet No. _____ of _____

Name & Location _____

Reference	Nozzle Ident. & Location	Flow in L/min (gpm)	Pipe Size mm (in.)	Pipe Fittings & Devices m (ft)	Equiv. Pipe Length m (ft)	Friction Loss bar/m (psi/ft)	Req. bar (psi)	Normal Pressure bar (psi)	Notes
1	SP-1	q Q 250	2½	THV 1T	Lgth. 0.5 Ftg. 42 Tot. 47.5	0.215	Pt 100 Pf 9.77 Pe	Pt Pv Pn	Stair #1
1	SP-1	q Q 250	6		Lgth. 12.5 Ftg. Tot.	0.003	Pt 109.77 Pf 0.038 Pe 5.41	Pt Pv Pn	
2		q 250 Q 500	6	GV T	Lgth. 49.5 Ftg. 33 Tot. 82.5	0.0109	Pt 114.85 Pf 0.9 Pe 21.43	Pt Pv Pn	
3		q 500 Q	6		Lgth. 100 Ftg. Tot. 100	0.190	Pt 137.18 Pf 1.9 Pe	Pt Pv Pn	
4		q 250 Q 750	6	1-T	Lgth. 2500 80 Ftg. 30 Tot. 110	0.230	Pt 139.08 Pf 2.53 Pe	Pt Pv Pn	Stair #2
5		q 250 Q 1000		T L GV OV	Lgth. 26 Ftg. 77 Tot. 103	0.392	Pt 141.61 Pf 6.04 Pe 6.93	Pt Pv Pn	Stair #3
FP		q 1000 Q			Lgth. Ftg. Tot.		Pt 152.58 Pf Pe	Pt Pv Pn	Assume loss of pump
		q Q			Lgth. Ftg. Tot.		Pt Pf Pe	Pt Pv Pn	
		q Q			Lgth. Ftg. Tot.		Pt Pf Pe	Pt Pv Pn	
		q Q			Lgth. Ftg. Tot.		Pt Pf Pe	Pt Pv Pn	
		q Q			Lgth. Ftg. Tot.		Pt Pf Pe	Pt Pv Pn	
		q Q			Lgth. Ftg. Tot.		Pt Pf Pe	Pt Pv Pn	
		q Q			Lgth. Ftg. Tot.		Pt Pf Pe	Pt Pv Pn	
		q Q			Lgth. Ftg. Tot.		Pt Pf Pe	Pt Pv Pn	
		q Q			Lgth. Ftg. Tot.		Pt Pf Pe	Pt Pv Pn	
		q Q			Lgth. Ftg. Tot.		Pt Pf Pe	Pt Pv Pn	

(NFPA 15)

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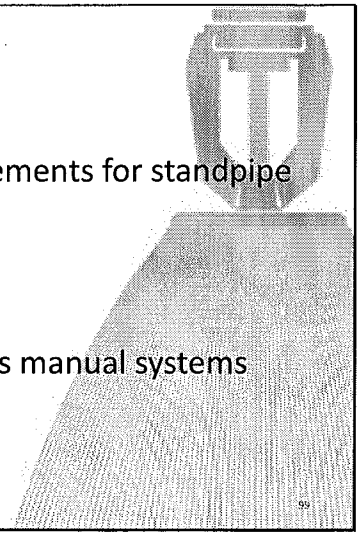
Wrap-Up



- Calculation requirements for standpipe systems
  - –Pipe type
  - –Automatic versus manual systems

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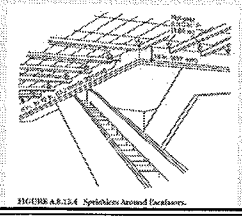
Module 6

Water Curtains & In-Rack Sprinklers





Module Learning Points

- Water Curtain Hydraulic Requirements
- Room Design Method
- Determine Commodity Classifications
- Select Density & Area of Operation
- Adjustments
- Calculations for Rack Sprinklers

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Water Curtains

- Floor openings protected by closely spaced sprinklers and draft stops (NFPA 13: 8.15.4.2)
- Sprinklers shall be spaced not more than 6 ft apart
- Not required around large openings 20 ft (6 meters)or more from opposite edges per 8.15.4.4

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Section 8.15.4.3 p. 13-85

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Water Curtain

- Sprinklers shall discharge at least 3 gpm / lineal ft (37 L/min per lineal meter)or not less than 15 gpm (56.8 L/m)
  (NFPA 13 - 11.3.3.1)
- The number of sprinklers calculated must correspond to the 1.2√remote area used in the area/density approach

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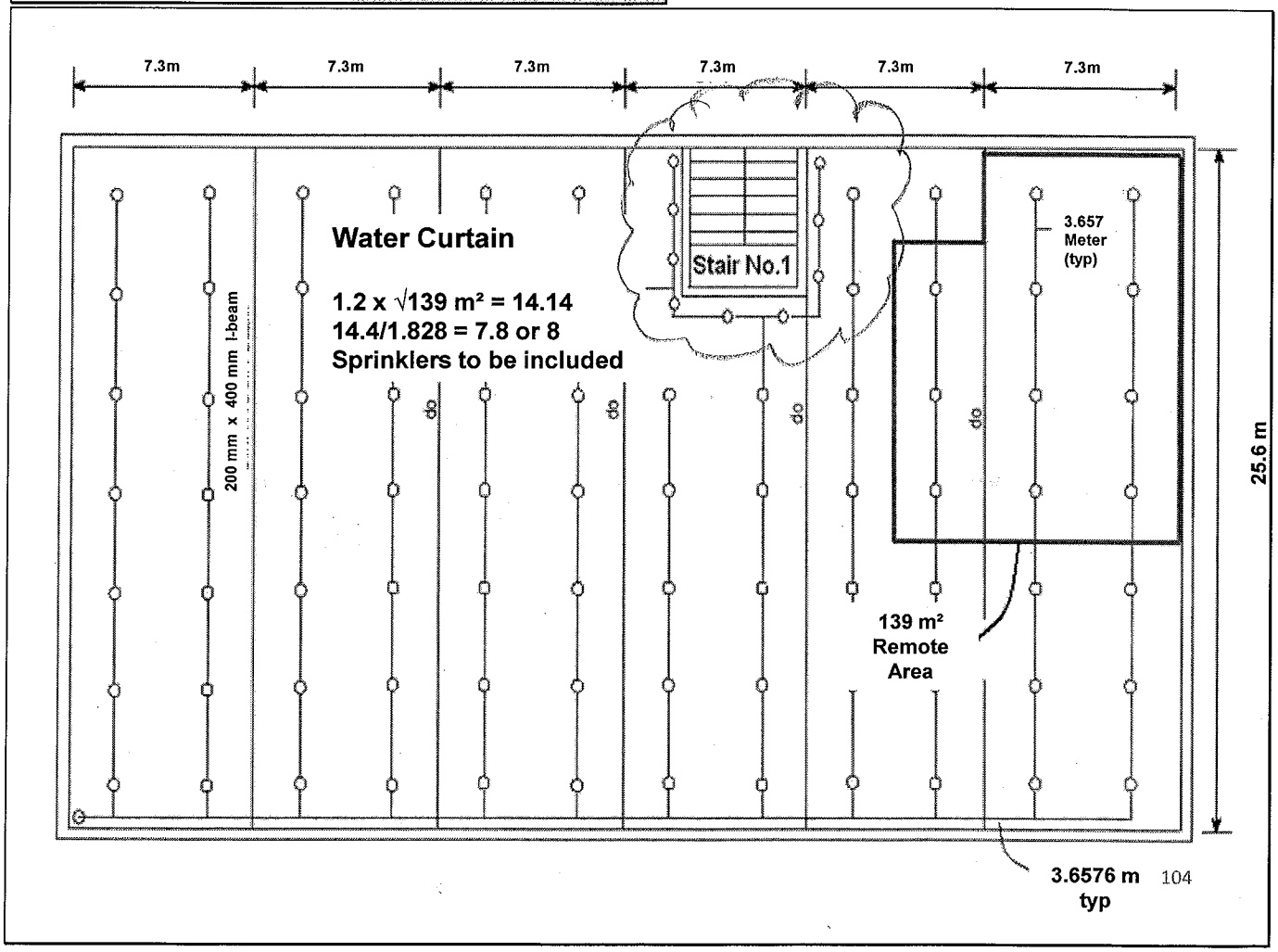
Section 11.3.3 – p. 125



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Room Design Method

- Based upon the room that creates the highest demand (NFPA 13: 11.2.3.3.1)
- For unprotected openings, calculations must extend to two sprinklers in the communicating space

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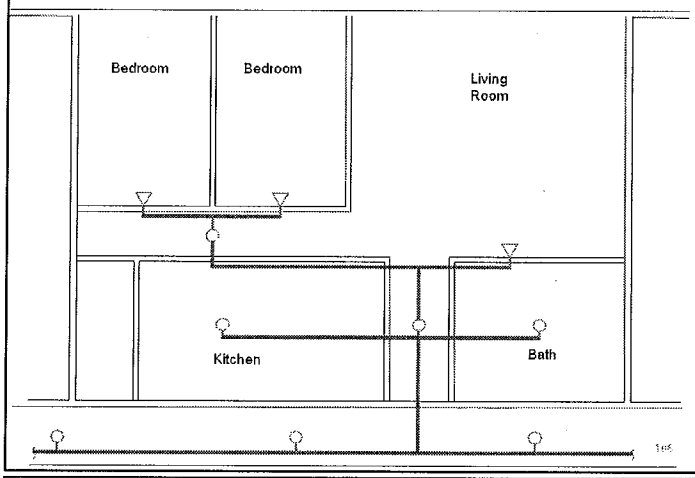
Section 11.2.3.3, p. 13-125

Room Design Method



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Section 11.2.3.3, p.13-120

Commodity Classifications

- Class I through IV
- Group A, B & C Plastics

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Section 5.6.1, p.13-25

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Table 16.2.1.3.2

Single or double row racks
- Storage height over 12 ft (3.7 m) up to and including 25 ft (7.6 m)
- Without solid shelves

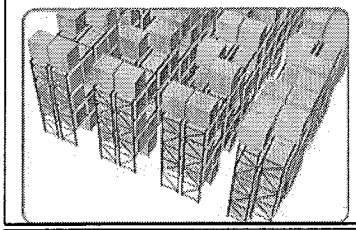
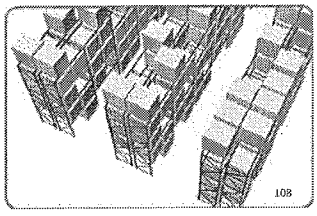
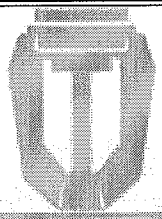



Table 16.2.1.3.2, p.13-150

Other Design Approaches

- Table 16.2.2.1 CMSA Sprinklers
- Table 16.2.3.1 ESFR Sprinklers



CMSA
- control mode sprinkler applied

CMSA vs Standard Sprinklers

With K 160 (K 11.2) Sprinklers, we calc 15 sprinklers @ 1.7 Bar (25 psi) vs 20 sprinklers
- 25% fewer sprinkler heads flowing water
- Better starting pressure with K-115 (8.0) standard spray:

- But we flow 5 fewer sprinklers so the total pressure demand is less
- K-240 sprinkler is more efficient... just as the K- 115 is more efficient than the K-80 sprinkler...



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ESFR vs SSU/SSP or CMSA

Nominal K-Factor	Orientation	Bar	Hose Stream Allowance
200	Upright or pendent	3.4	950 L p/min
240	Upright or pendent	2.4	950 L p/min
320	Pendent	1.7	950 L p/min
360	Pendent	1.0	950 L p/min

Table 16.2.3.1 pg 155

Rack Sprinklers

- Table 16.2.1.3.2 provides requirements for Class I through IV Commodities stored up to 25 ft (7.62 m) in height
  - Refers to Figures 16.2.3.1.2(a) through (g)

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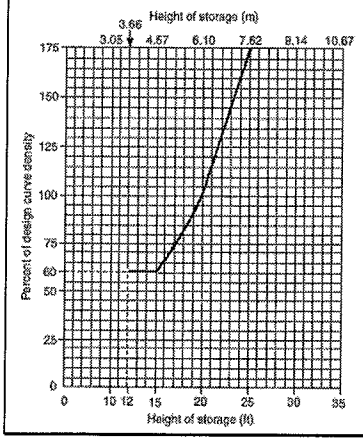
Table 16.2.1.3.2, p.13-145

Storage Height Modifier



Based on storage heights greater or less than 20 ft (7.62 m) high –

Figure 16.2.1.3.4.1 requires an adjustment in the **density** selected

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Figure 16.2.1.3.4.1, p.13-157

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Rack Sprinkler Criteria Example #1

- Sample Rack Sprinkler Criteria
  - Class III Commodity
  - Encapsulated
  - Storage height – 18 ft (5.48 m)
  - Roof Height – 25 ft (7.62 m)
  - Aisles – 4 ft (1.2 m) wide
  - High temp sprinklers

Rack Sprinkler Criteria Example #1

Using Table 16.2.1.3.2:

- Are rack sprinklers required?
- Which hydraulic criteria figure must be used?

- What curves must be used?
- Can the density be adjusted?
- Can the remote area be adjusted?

Table 16.2.1.3.2, p.13-150

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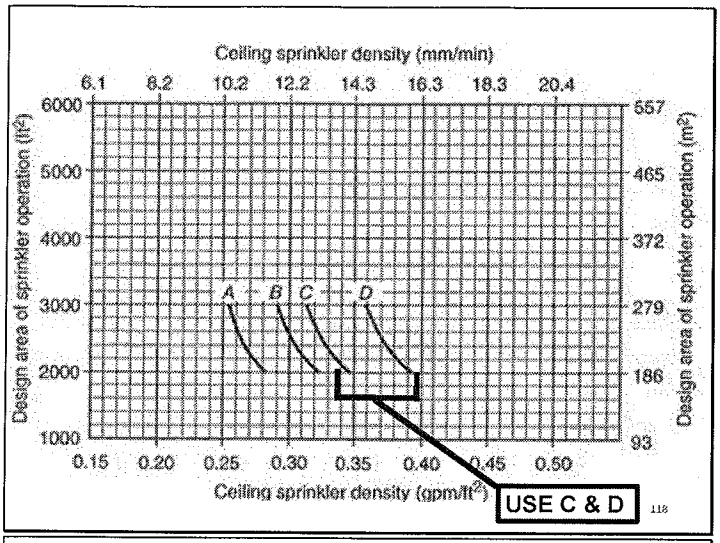

Figure 16.2.1.3.2(f)

Curve Legend

C- 4ft (1.22m) aisles with high temperature ceiling sprinklers and ordinary temperature in-rack sprinklers

D- 4ft (1.22m) aisles with ordinary temperature ceiling sprinklers and ordinary temperature in-rack sprinklers

Design Criteria Based upon Ceiling Sprinkler Temp Rating



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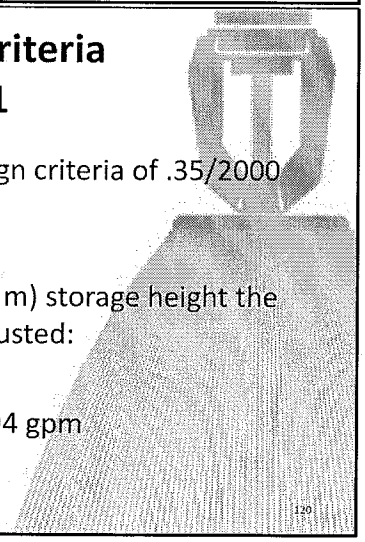
Figure 16.2.1.3.2, p.13-149

Rack Sprinkler Criteria Example #1

- From Curve C, a design criteria of .35/2000 gpm/ft² can be used
  - Due to 18 ft (5.48 m) storage height the density can be adjusted:

0.35 x 0.84 = 0.294 gpm



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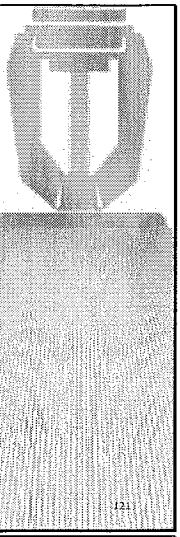
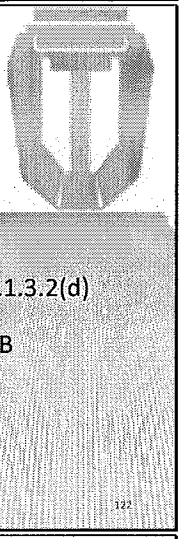
Rack Sprinkler Criteria Example #2

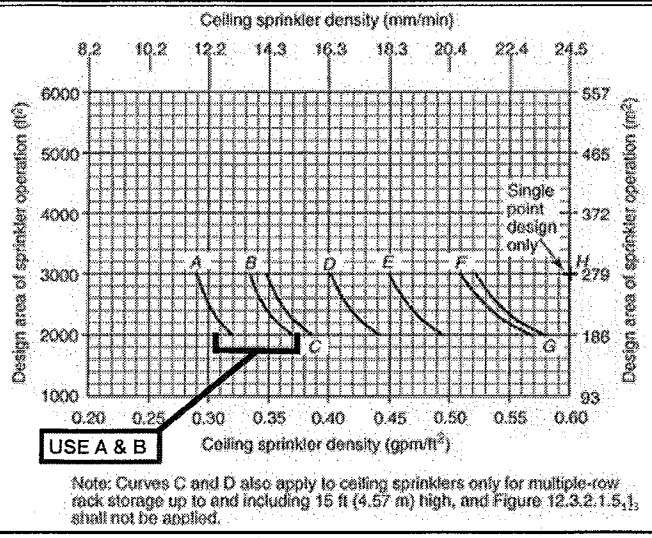
- Sample Rack Sprinkler Criteria
  - Class IV Commodity
  - Non-encapsulated
  - Storage Height – 23 ft (7.01 m)
  - Roof Height – 25 ft (7.62 M)
  - Aisles – 8 ft wide (2.4 m)
  - High Temp Ceiling Sprinklers



Rack Sprinkler Criteria Example #2

- Using Table 16.2.1.3.2:
  - Are rack sprinklers required? Yes
  - Which hydraulic criteria figure must be used? 16.2.1.3.2(d)
  - What curves must be used? A & B
  - Must the density be adjusted? No





Note: Curves C and D also apply to ceiling sprinklers only for multiple-row rack storage up to and including 15 ft (4.57 m) high, and Figure 12.3.2.1.5.1[13] shall not be applied.

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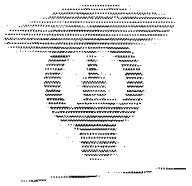
Figure 16.2.1.3.2(d)

Design Criteria Based upon Ceiling Sprinkler Temp Rating

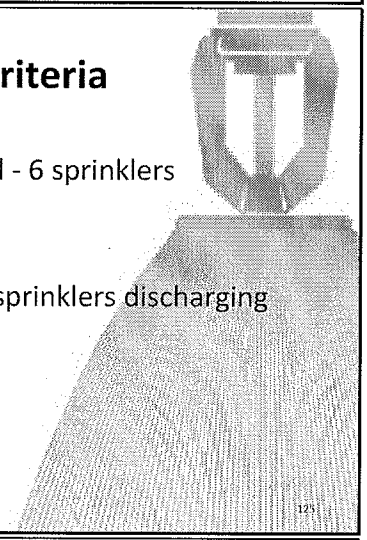


Curve	Legend
A	Single- or double-row racks with 8 ft (2.44 m) aisles with high temperature ceiling sprinklers and ordinary temperature in-rack sprinklers
B	Single- or double-row racks with 8 ft (2.44 m) aisles with ordinary temperature ceiling sprinklers and ordinary temperature in-rack sprinklers
C	Single- or double-row racks with 4 ft (1.22 m) aisles or multiple-row racks with high temperature ceiling sprinklers and ordinary temperature in-rack sprinklers

Figure 16.2.1.3.2, p. 13-142

Rack Sprinkler Criteria

- Class I, II & III, 1 level - 6 sprinklers discharging
- Class IV – 1 level - 8 sprinklers discharging



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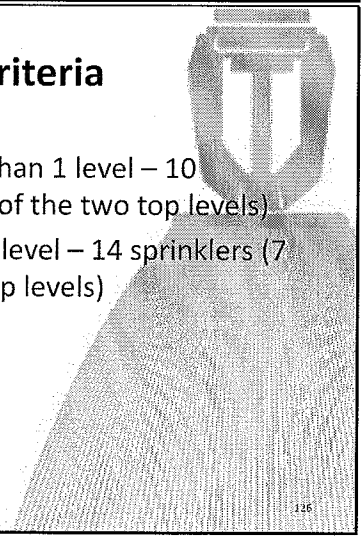
Section 16.2.4.3.1, p. 13-157

Rack Sprinkler Criteria

- Class I, II & III more than 1 level – 10 sprinklers (5 at each of the two top levels)
- Class IV more than 1 level – 14 sprinklers (7 at each of the two top levels)



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Rack Sprinkler Criteria

- Class I thru IV Storage up to and including 25ft in height:
  - 15 psi minimum pressure for all rack sprinklers
  - Q=K x √P
    - Q = 5.6 x √15 or Q = 21.7gpm
    - Q = 8.0 x √15 or Q = 31.0 gpm

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Section 16.2.4.4, p.13-158

Rack Sprinkler Criteria

- Hose Demand Applies
  - 0, 50 or 100 gpm (0, 189 or 379 L/min) for inside hose
  - 500 gpm (1893 L/p min) total outside hose
  - 90 minute duration – Class I, II & III
  - 120 minute duration – Class IV

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New Table 12.8.6.1 , p.13-129

Rack Sprinkler Criteria

- Rack sprinklers must be calculated as discharging simultaneously with ceiling sprinklers
- Both calculations (racks and ceiling sprinklers) must be balanced to within .5 psi (.034 bar) at the junction point

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Section 23.4241, p. 13-236
Section 23.8.2.and 23.8.3, p. 13-243

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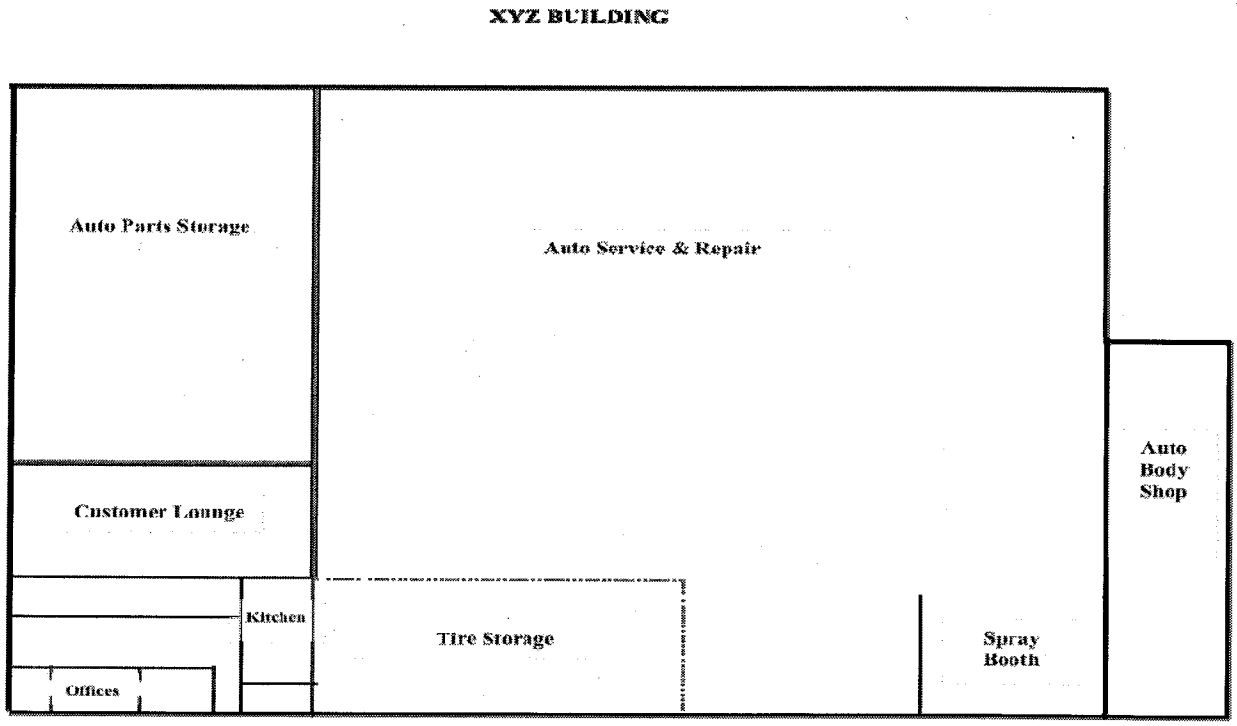
Module 7

Hydraulic Calculation Exercises



Figure 7.1



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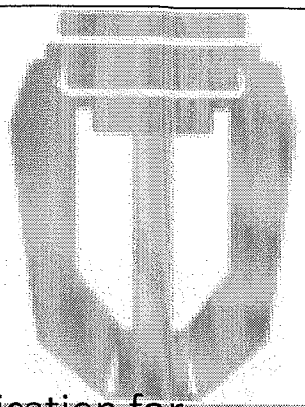
Activity 7.1



Occupancy Classifications

Using Figure 7.1 Identify the Occupancy Classification for the different areas

Offices LIGHT HAZARD

Customer Lounge LIGHT HAZARD

Auto Service and Repair ORDINARY GROUP 2

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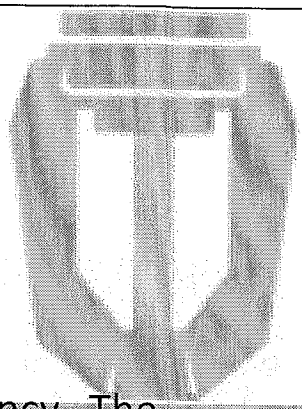
Activity 7.1



Water Supply

A building is identified as a light hazard occupancy. The selected area of the operation is 279 m^2.

What is the minimum flow required for the sprinkler system? 0.07 gpm/ft^2 2.8x L/min/m^2

What is the total water supply needed?

Q = AD = 3000 ft^2 x 0.07 = 210 gpm x 30 = ~~12,600~~ 6,300 gallon

279 x 2.8x = 795 lpm
+ 378.5 lpm = 35,205 l.
x 30 min

100 gpm x 30 + = 3000 gallon
9,300 gallon

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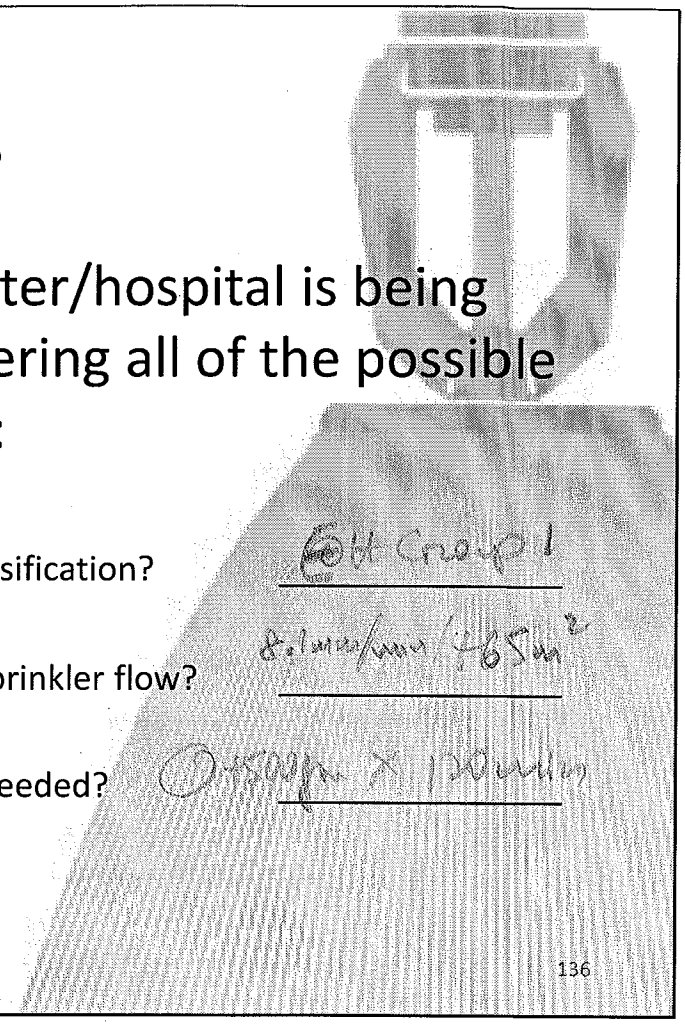
Activity 7.1



A full service medical center/hospital is being developed. Upon considering all of the possible occupancy classifications:

What is the highest likely occupancy classification? Ⓗ Group 1

What is the greatest possible required sprinkler flow? 8.1mm/min/465m²

What is the highest likely water supply needed? ① 4500gpm × 120min

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O2 policy fire not increasing its ~~[illegible]~~ severity

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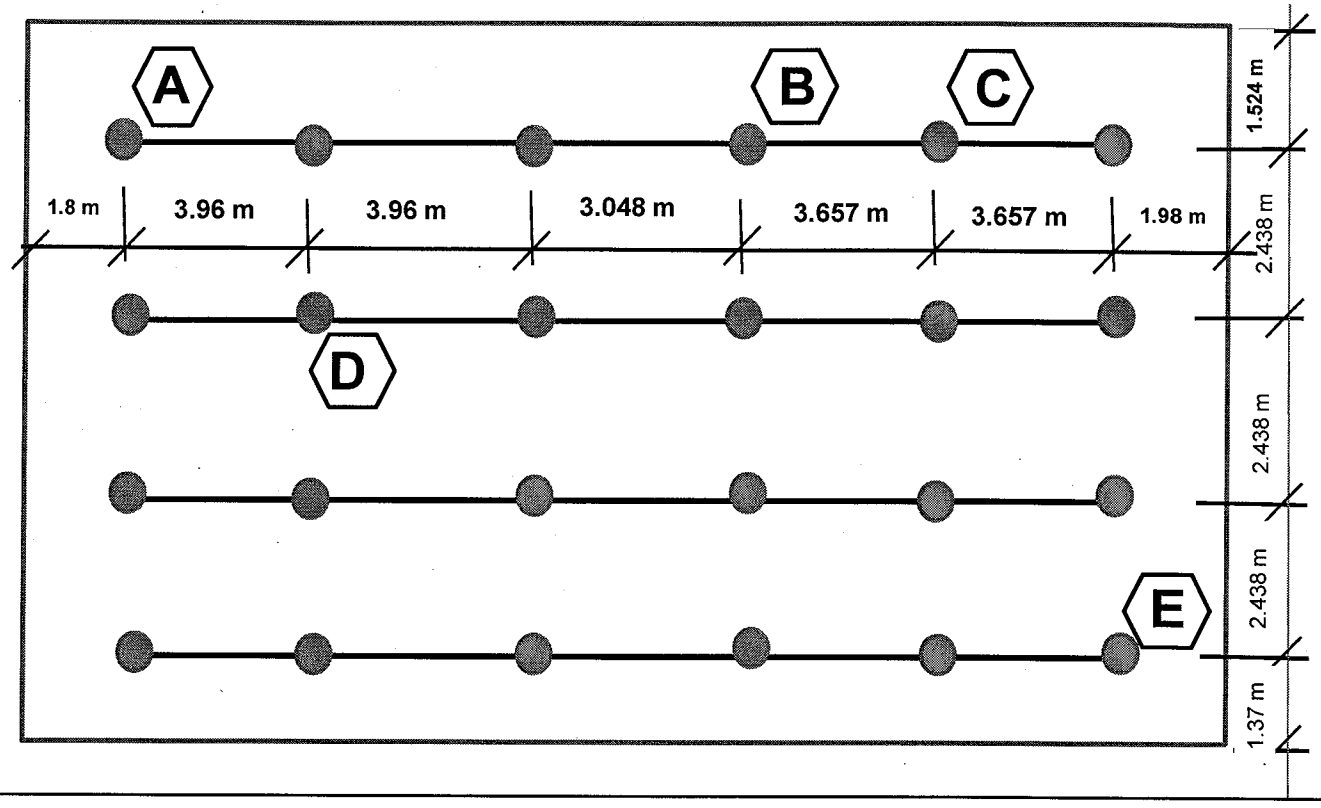
Figure 7.2
S x L = Protection Area



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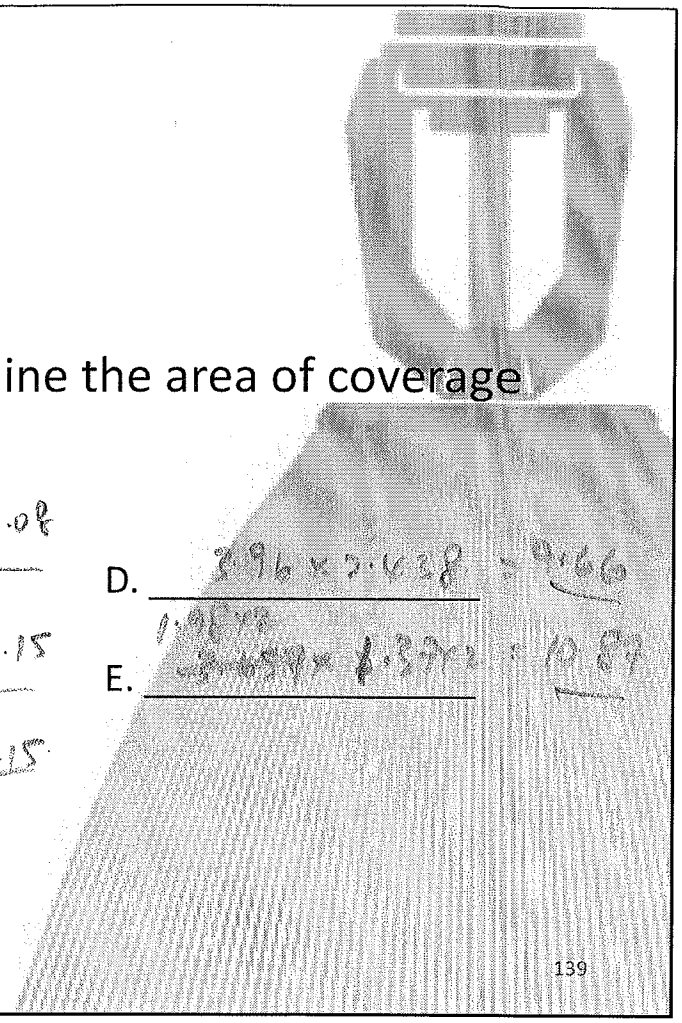
Activity 7.2



Area of Coverage

Using Figure 7.2, determine the area of coverage for sprinkler:

A. $3.96 \times 3.0 = 12.0$

B. $3.65 \times 3.0 = 11.15$

C. $3.65 \times 3.0 = 11.15$

D. $3.96 \times 3.0 = 12.0$

E. $3.96 \times 3.0 = 12.0$

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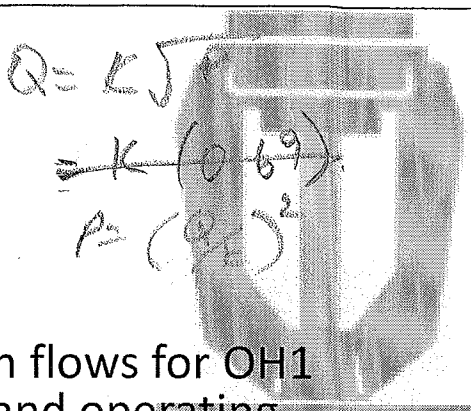
Activity 7.2



Sprinkler Pressure

Using Figure 7.2 and the minimum flows for OH1 Occupancies, calculate the flow and operating pressure for sprinkler:

	K= 80 Sprinkler	K= 115 Sprinkler
	A. 0.85	A. 0.41
	C. 0.73	C. 0.35
	E. 0.69	E. 0.33

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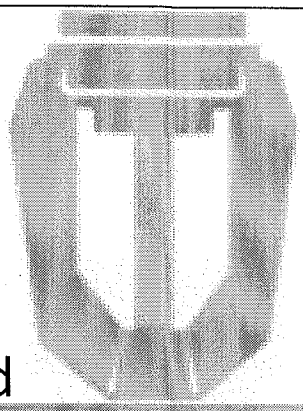
Activity 7.2



Minimum Sprinkler Flow

Using Figure 7.2, assuming a hazard classification of Ordinary Group 2, calculate the minimum flow required for sprinkler:

A. 97.848

B. 90.35

C. 90.35

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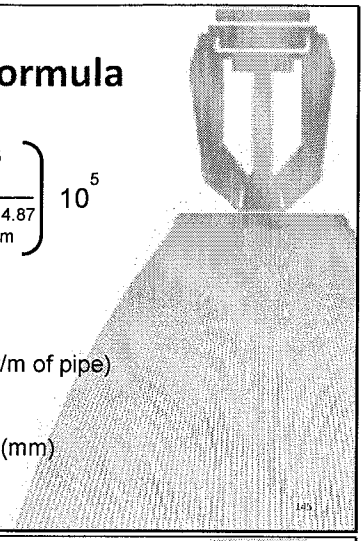
Hazen Williams Formula

$$P_m = 6.05 \left(\frac{Q_m^{1.85}}{C^{1.85} d_m^{4.87}} \right) 10^5$$

where:
P_m = frictional resistance (bar/m of pipe)
Q_m = flow (L/min)
C = friction loss coefficient
d_m = actual internal diameter (mm)



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C Values

Table 23.4.4.7.1 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 or stainless steel	150
Asbestos cement	140
Concrete	140

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

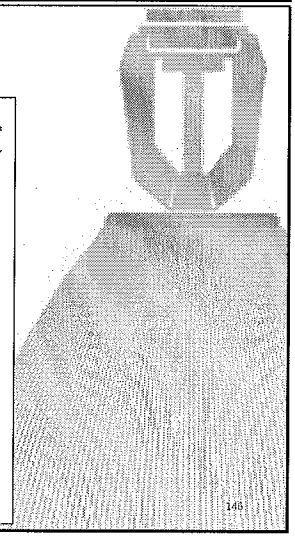

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Table A.6.3.2 Steel Pipe Dimensions

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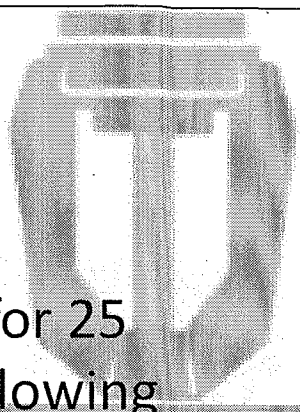
Activity 7.3



Calculate the friction loss per foot for 25 gpm of water flowing under the following conditions:

1 in. diameter Schedule 40 steel pipe in a wet sprinkler system

h_f table $\Rightarrow$ 0.199 psi/ft.

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$Q = 25$ gpm $= \frac{5}{8}$

$C = 120$

$d_m = 1.049$

$$P = \frac{4.52\,Q^{1.85}}{C^{1.85} d^{4.87}} \quad (\text{psi}).$$

$= 0.197$ psi/ft.

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Fittings

Table 23.4.3.1.1 Equivalent Schedule 40 Steel Pipe Length Chart

	Fittings and Valves Expressed in Equivalent Feet (Meters) of Pipe														
	¼ in.	⅜ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
Fittings and Valves	(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 (3.4)	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)
Swing check*	—	—	5 (1.5)	7 (2.1)	9 (2.7)	11 (3.4)	14 (4.3)	16 (4.9)	19 (5.8)	22 (6.7)	27 (8.2)	32 (9.8)	45 (13.7)	55 (16.8)	65 (20)

For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Note: Information on ½ in. pipe is included in this table only because it is allowed under 8.15.19.4 and 8.15.19.5.
*Due to the variation in design of swing check valves, the pipe equivalents indicated in this table are considered average.

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Equivalent Length Adjustments



NFPA 13, 23.4.1.3.1 requires modifiers be utilized for different C values and /or internal pipe diameter. The modifier for pipe diameter is a factor derived from the following formula:

$$Factor = \left\{ \frac{Actual\ Inside\ Diameter}{Schedule\ 40\ Steel\ Inside\ Diameter} \right\}^{4.87}$$

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P. 13-236

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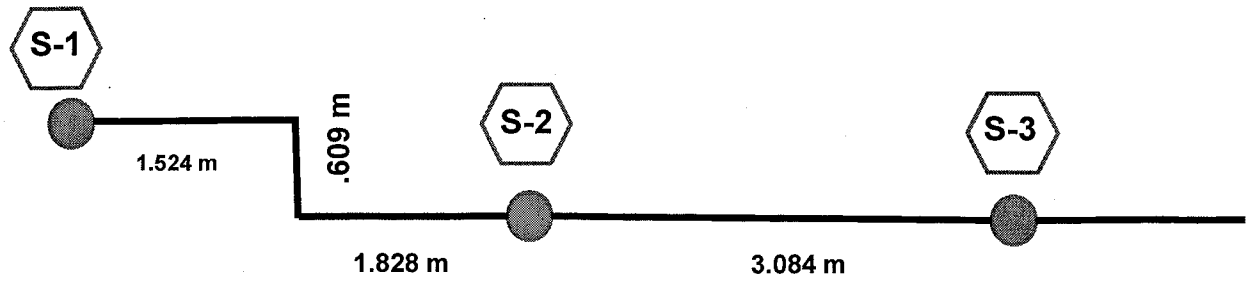
Figure 7.4



Pipe Size:	**1”**	**System Type:**	**Wet**
Pipe Type :	**Sched 40 steel**	**Area of Coverage:**	
Sprinkler Type:	**K= 80**		**S1 = 11.148 m²**
Density:	**6.1 mm/min**		**S2 = 11.148 m²**
			S3 = 11.148 m²

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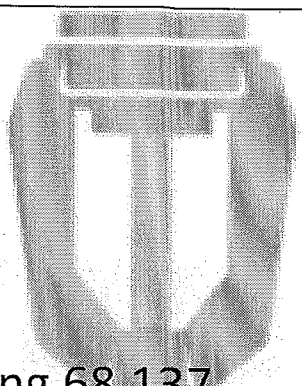

Activity 7.4.1

Refer to Fig 7.4

Sprinkler S1 has a K-factor of 80, is flowing 68.137 L/min, and requires a pressure of .712 bar. The friction loss per foot is .0073 bar/meter. As a result, 0.958 bar is needed for friction loss to move the 68.137 L/min from sprinkler S2 to S1. As such, the total pressure at sprinkler S2 is .808 bar

How much water will be discharged from sprinkler S2?

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$Q = K\sqrt{P} = 80 \times \sqrt{0.808} = 71.9$ L/min

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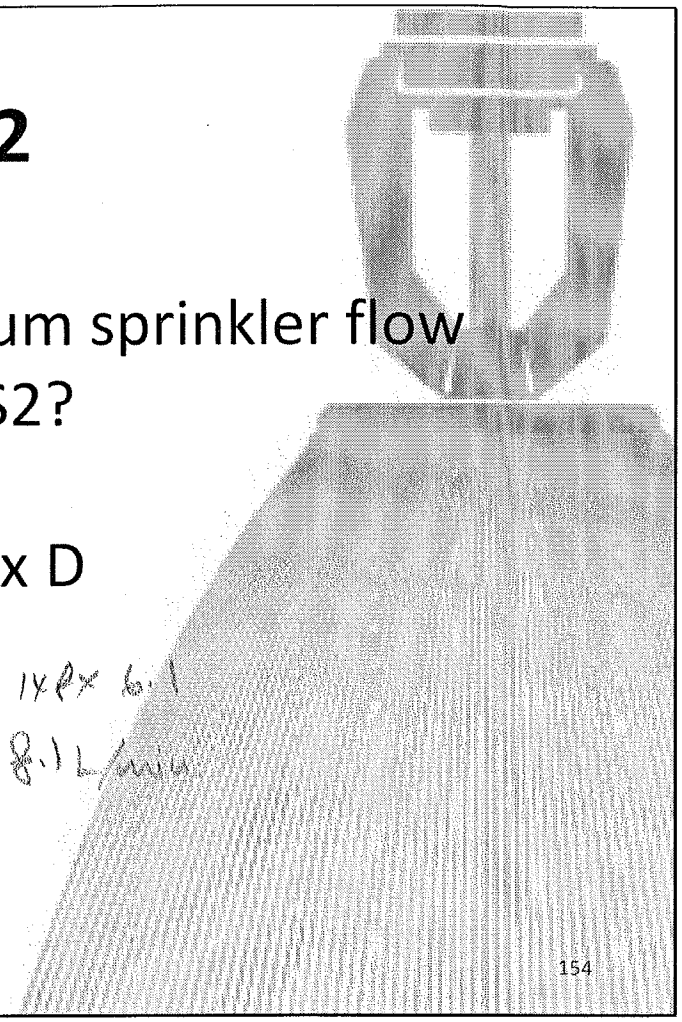
Activity 7.4.2

What is the minimum sprinkler flow required for S1 or S2?

$$Q = A \times D$$

= 11.1 × 6.1

= 68.1 L/min



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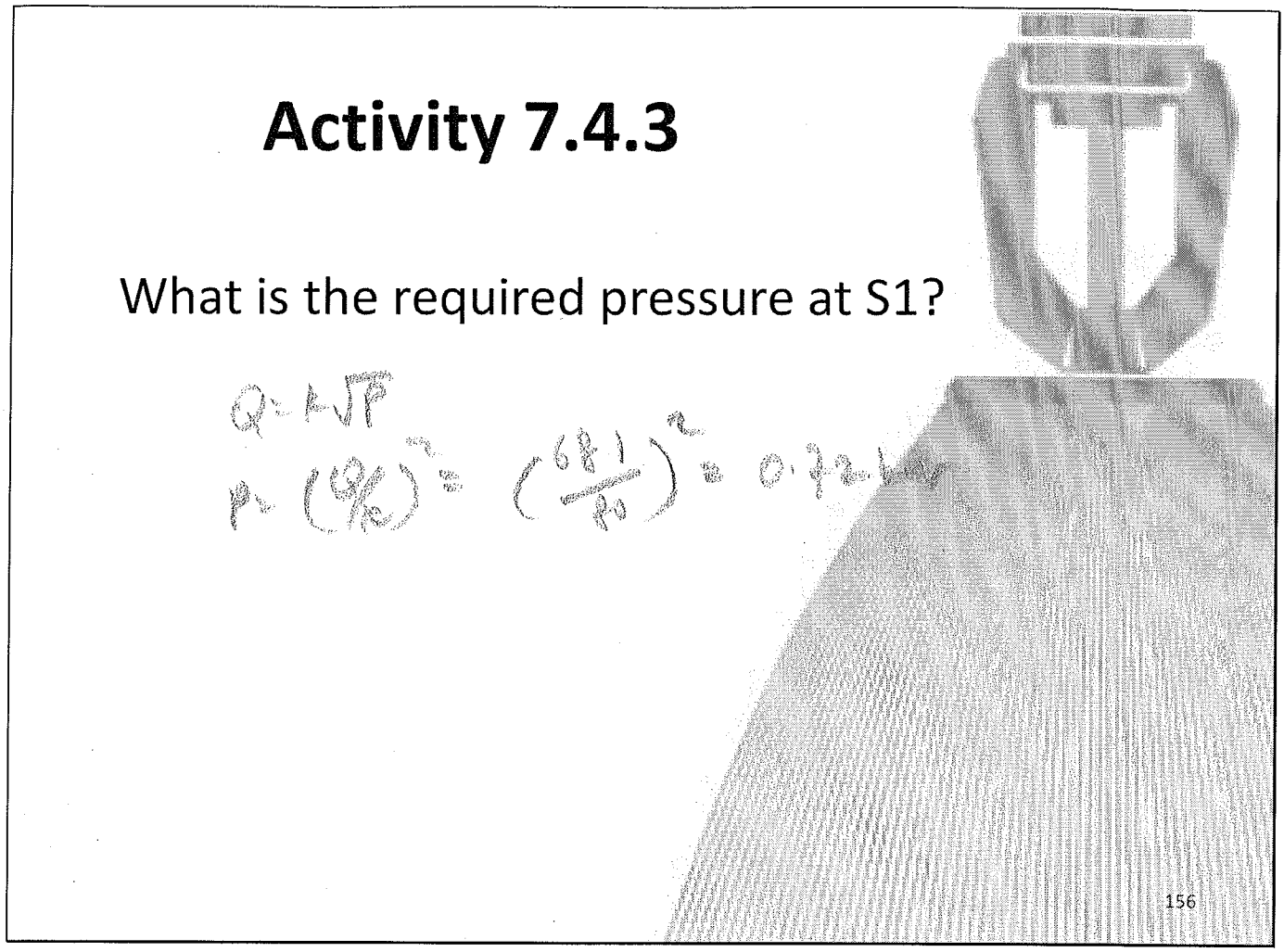
Activity 7.4.3

What is the required pressure at S1?



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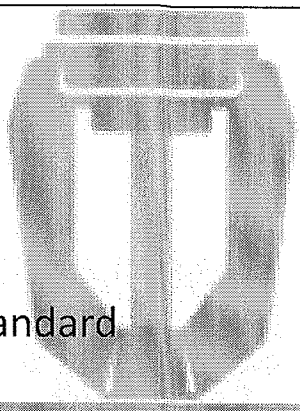

Activity 7.4.4

What is the equivalent length for the (2) 90° standard elbows?

Using Table 23.4.3.1.1 the equivalent length for (2) 1 in. standard 90° elbows is 4 ft.

There is no modification for Schedule-40 steel pipe.

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7.4.5

What is the total equiv. length for S1 to S2?

$L_T = L + L_E$

$= 3.96\,m + 4\,ft\,(1.2\,m)$

$= 5.16\,m.$

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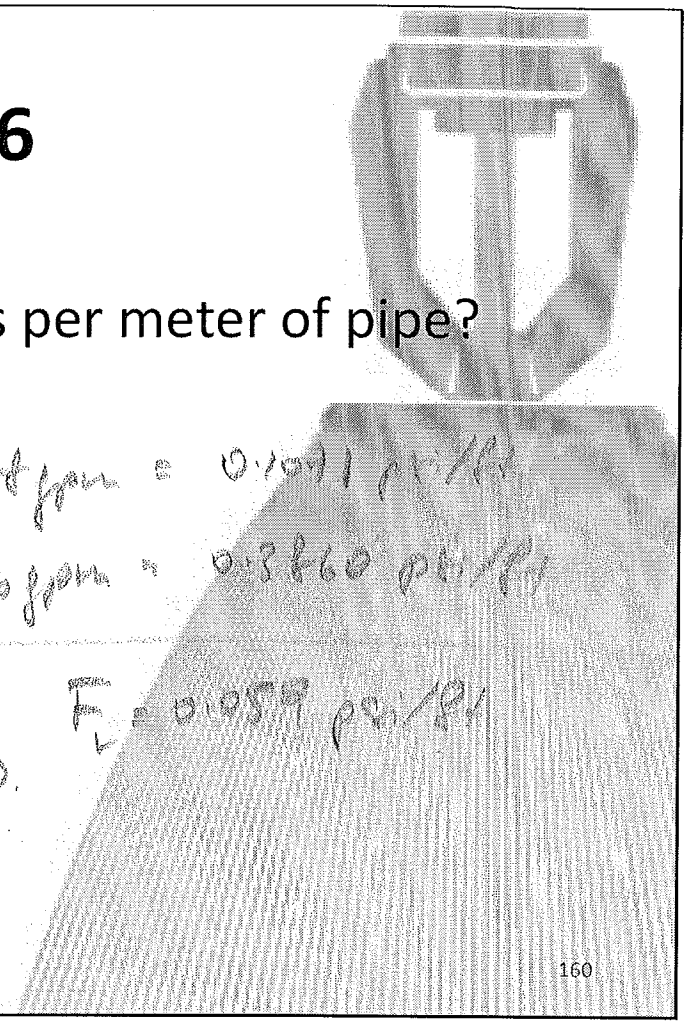
Activity 7.4.6

What is the friction loss per meter of pipe?



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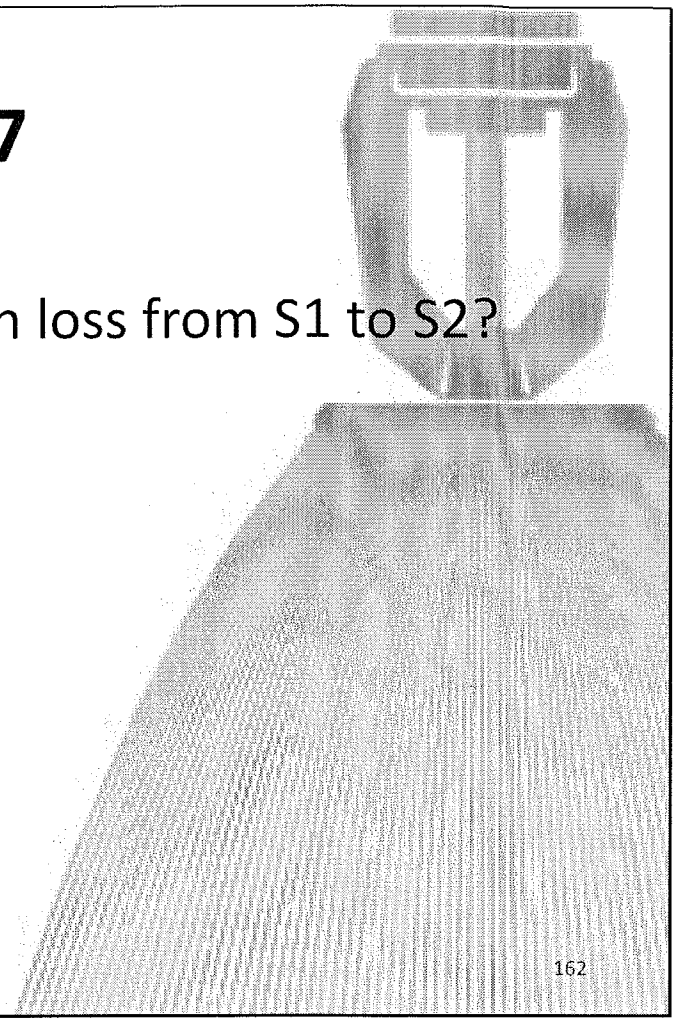
Activity 7.4.7

What is the total friction loss from S1 to S2?



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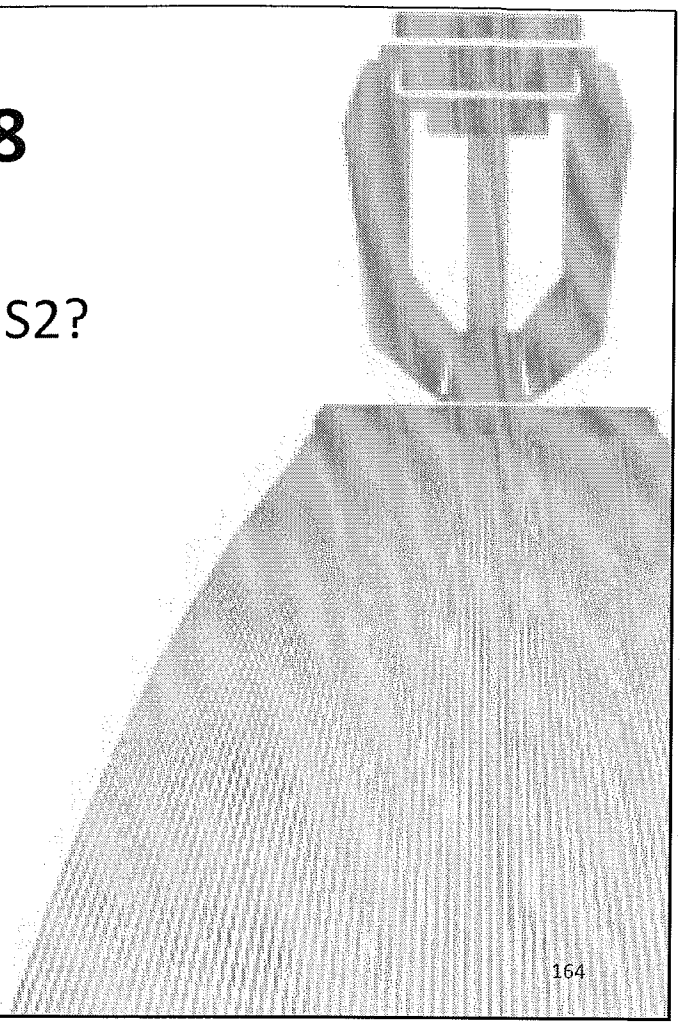
Activity 7.4.8

What is the pressure at S2?

$P_{S2} = P_{S1} + F_T$



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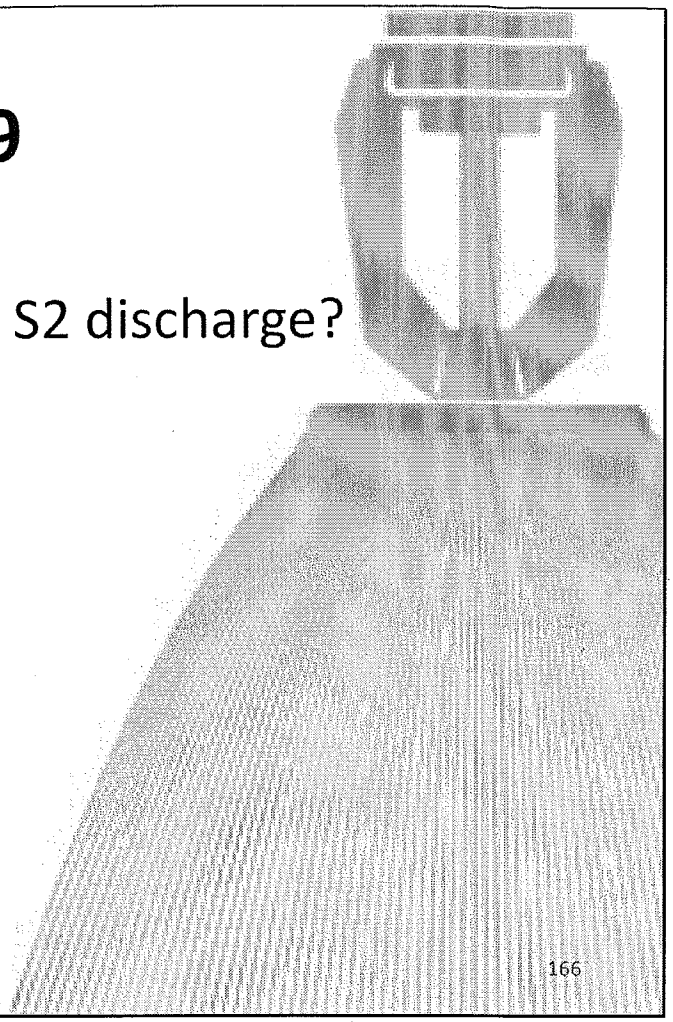
Activity 7.4.9

What flow will sprinkler S2 discharge?

$Q = k\sqrt{P}$



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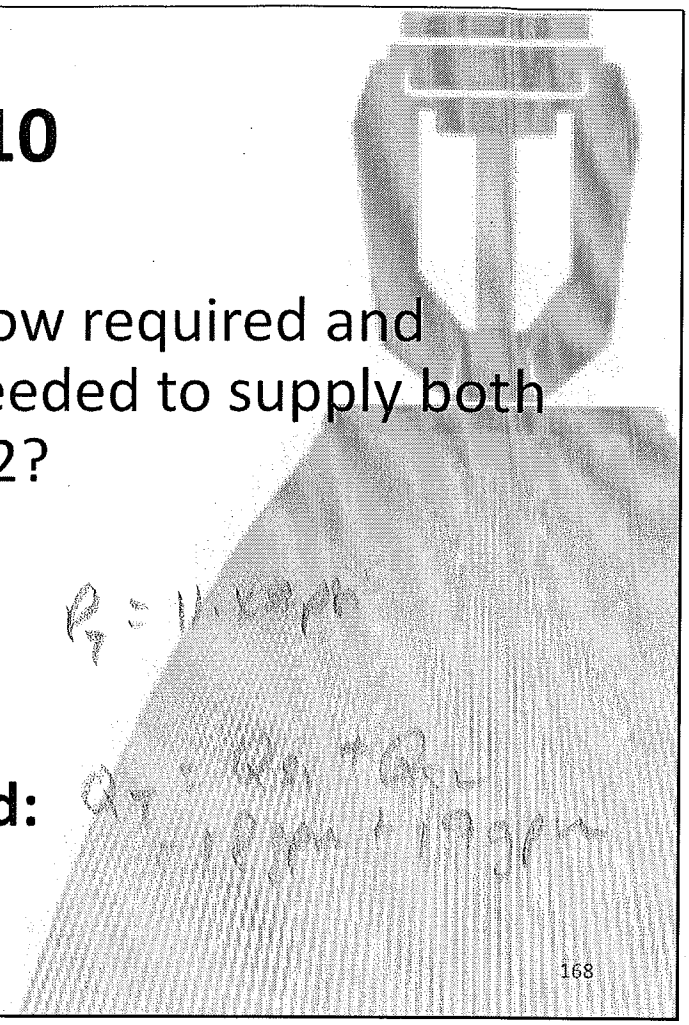
Activity 7.4.10

What is the total flow required and what pressure is needed to supply both sprinklers S1 and S2?

Pressure required:

Total flow required:



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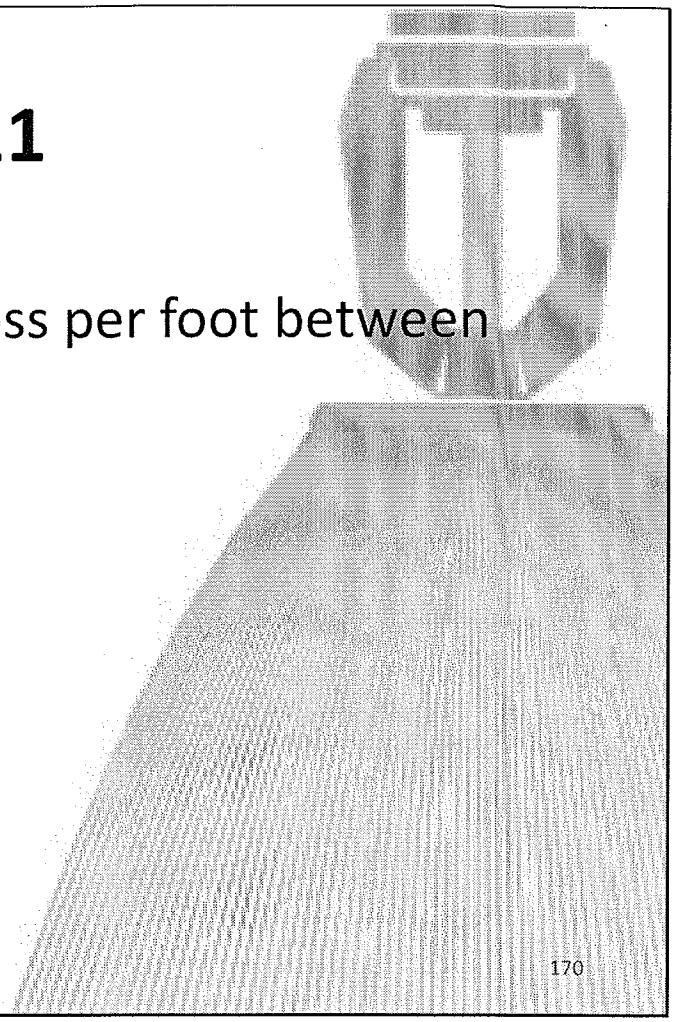
Activity 7.4.11



What is the friction loss per foot between S2 and S3?

$F_f = L_f \times F_L$

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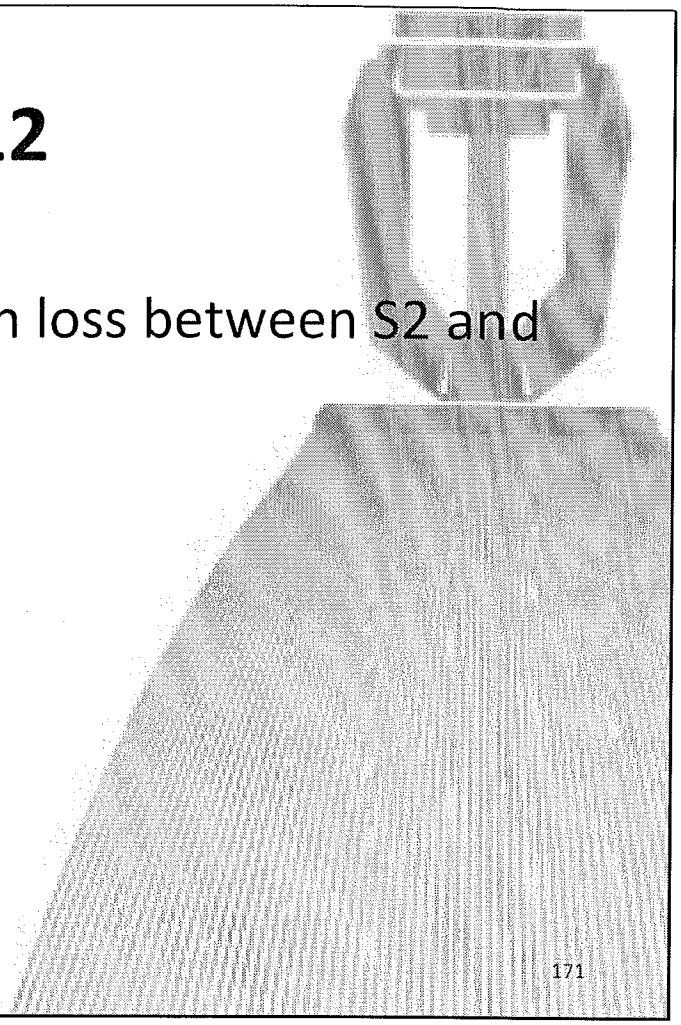
Activity 7.4.12

What is the total friction loss between S2 and S3?

$P_{S_1} = P_{E_1} + F_1$



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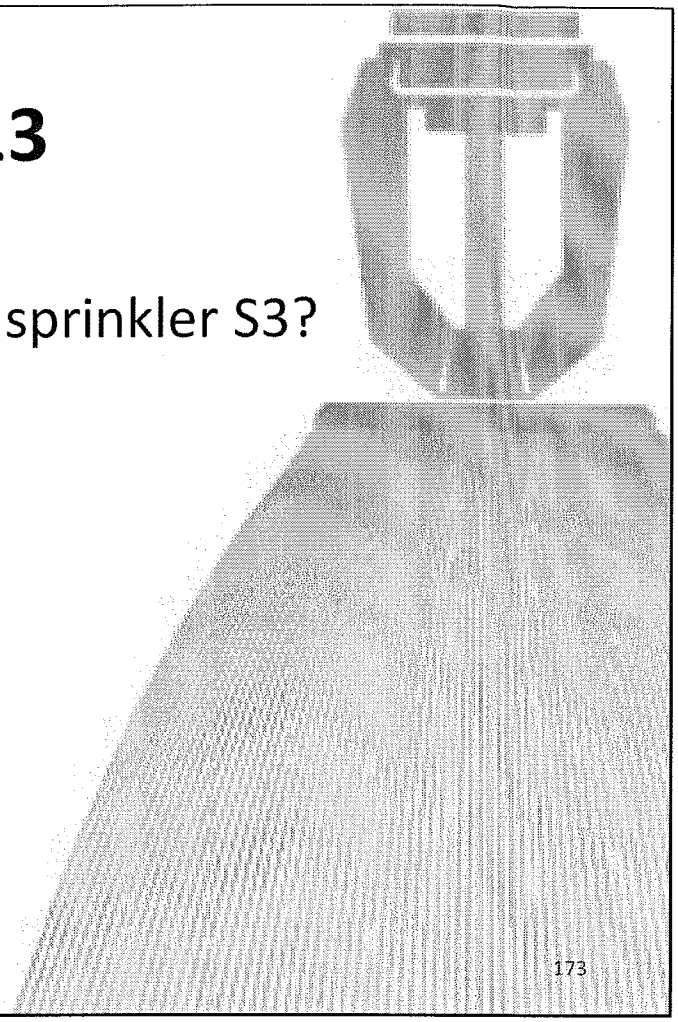
Activity 7.4.13

What is the pressure at sprinkler S3?



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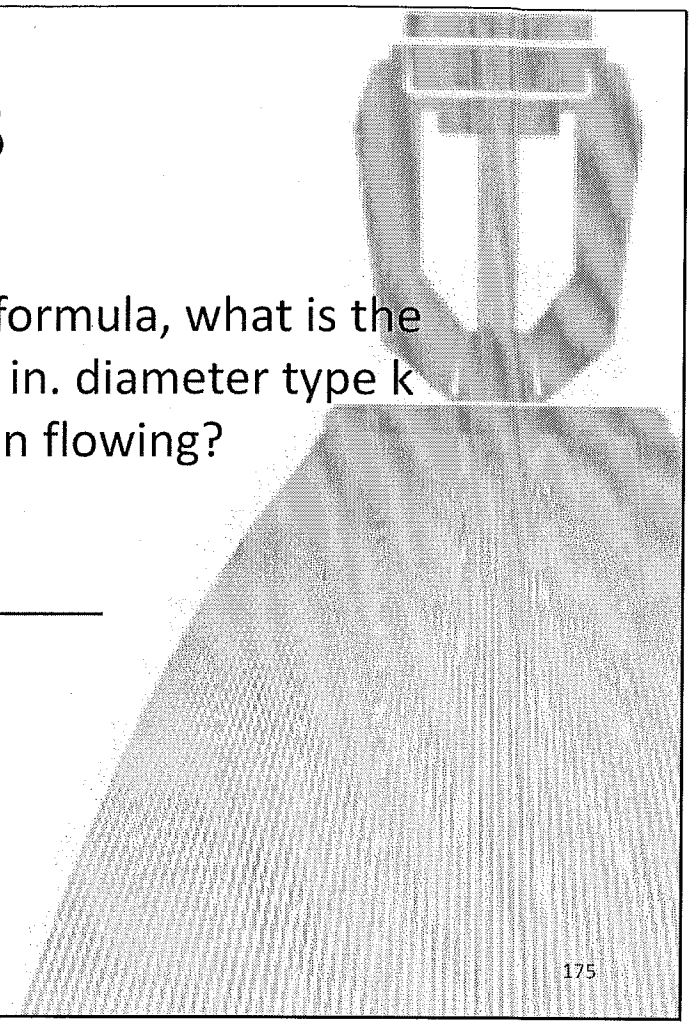
Activity 7.5



Using the Hazen-Williams formula, what is the friction loss per meter in 3 in. diameter type k copper tube with 175 L/min flowing?

_____

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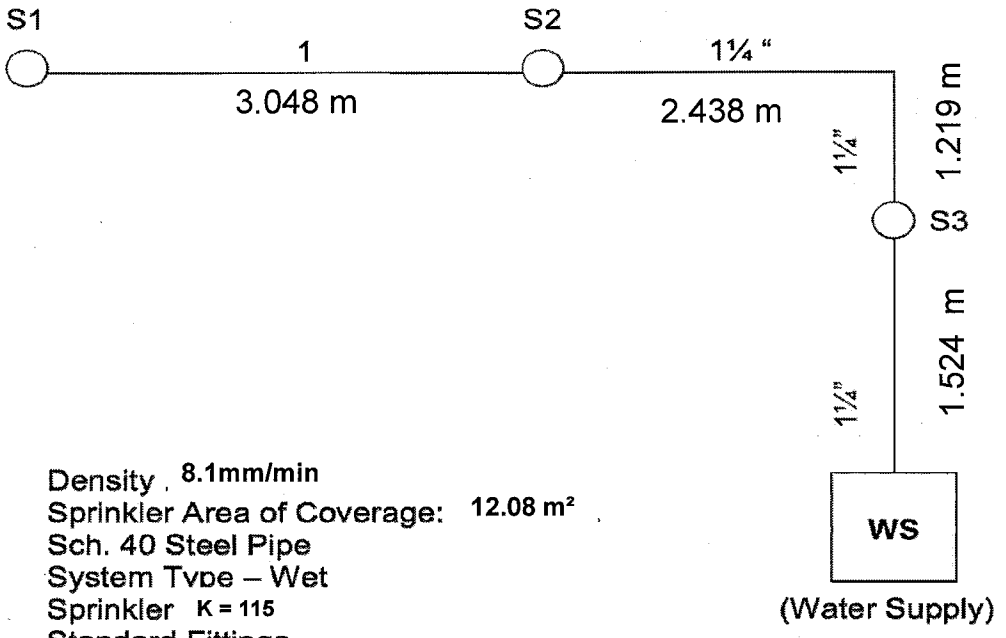
Hydraulic Calculations

Figure 2.3



Density . **8.1mm/min**
Sprinkler Area of Coverage: **12.08 m²**
Sch. 40 Steel Pipe
System Type – Wet
Sprinkler **K = 115**
Standard Fittings

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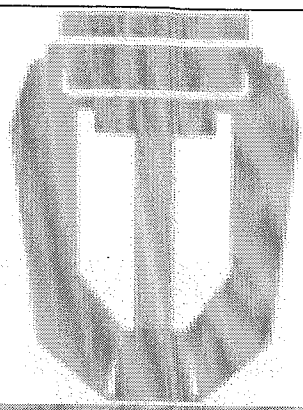
Activity 7.5



Using Fig 2.3 complete the following:

What is the minimum needed flow and pressure for sprinkler:

S1: _____

S2: _____

S3: _____

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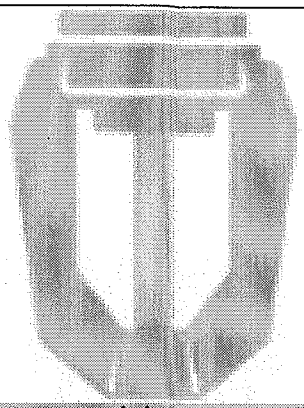
Activity 7.5



Using Fig 2.3 complete the following:

What is the actual flow and pressure for sprinkler:

S1: _____

S2: _____

S3: _____

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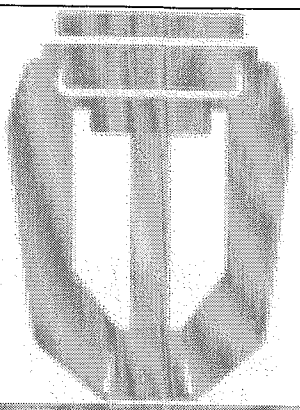

Using Figure 2.3

What is the total flow and pressure required at the water supply if the pipe from S3 to WS is increased to 1.5 in. diameter?

WS Q = _____

P = _____

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Activity 7.5

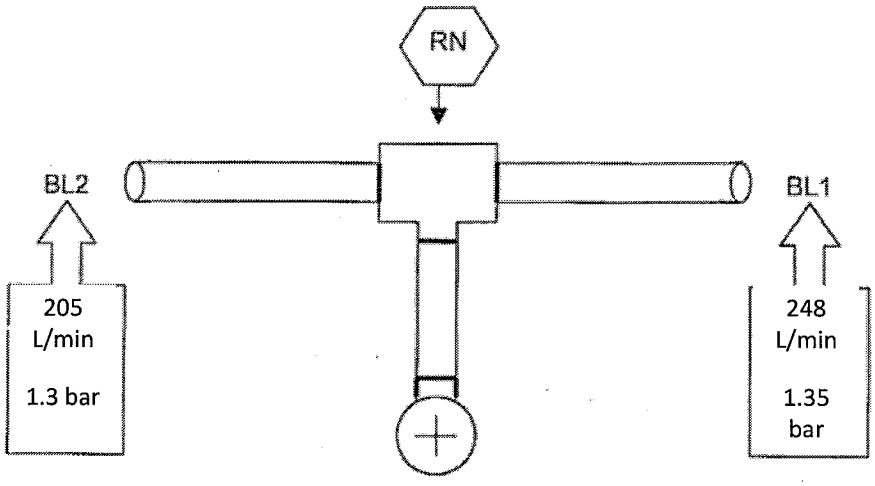

Figure 3.7

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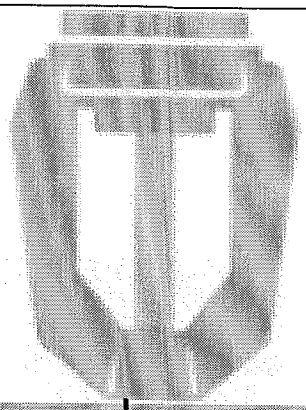
Activity 7.5



Example:

Using Figure 3.7, balance the pressure and flows at the top of the riser nipple (RN). The pressure and flow for BL1 is 1.35 bar @ 248 L/min. The pressure and flow for BL2 is 1.3 bar @ 205 L/min.

Determine K-factor for BL2
(lower of the two pressures)

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$Q = k\sqrt{P}$

$k = Q/\sqrt{P} = \frac{205}{\sqrt{1.3}} = 179.8$

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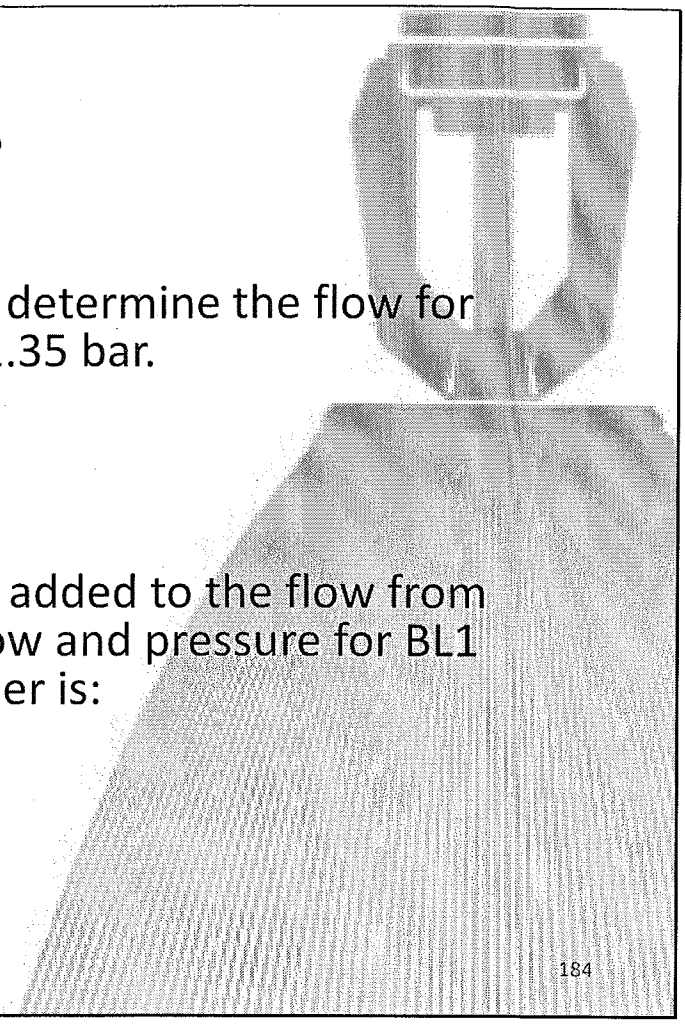
Activity 7.5



With the K-factor of **179.82** determine the flow for BL2 at the BL1 pressure of 1.35 bar.

The adjusted flow for BL2 is added to the flow from BL1. The total combined flow and pressure for BL1 and BL2 at the top of the riser is:

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$Q = k\sqrt{P}$

$= 179.8\sqrt{1.35}$

$= 208.93$ L/min

$\Rightarrow$ 460 L/min @ 1.3 bar

Adjusted flow for BL2 is added to the flow from BL1. Total combined flow and pressure for BL1 and BL2 at the top of the riser is

460 L/min @ 1.3 bar

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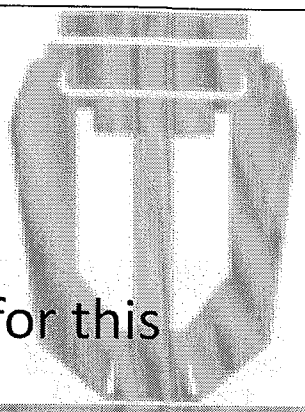
Activity 7.5



Refer to the following information for this exercise:

Two branch lines meet at the junction point at the top of a riser nipple. Branch line number 1 (BL1) has a demand of 227 L/min at 1.2 bar. Branch line number 2 (BL2) has a demand of 175 L/min at 1 bar.

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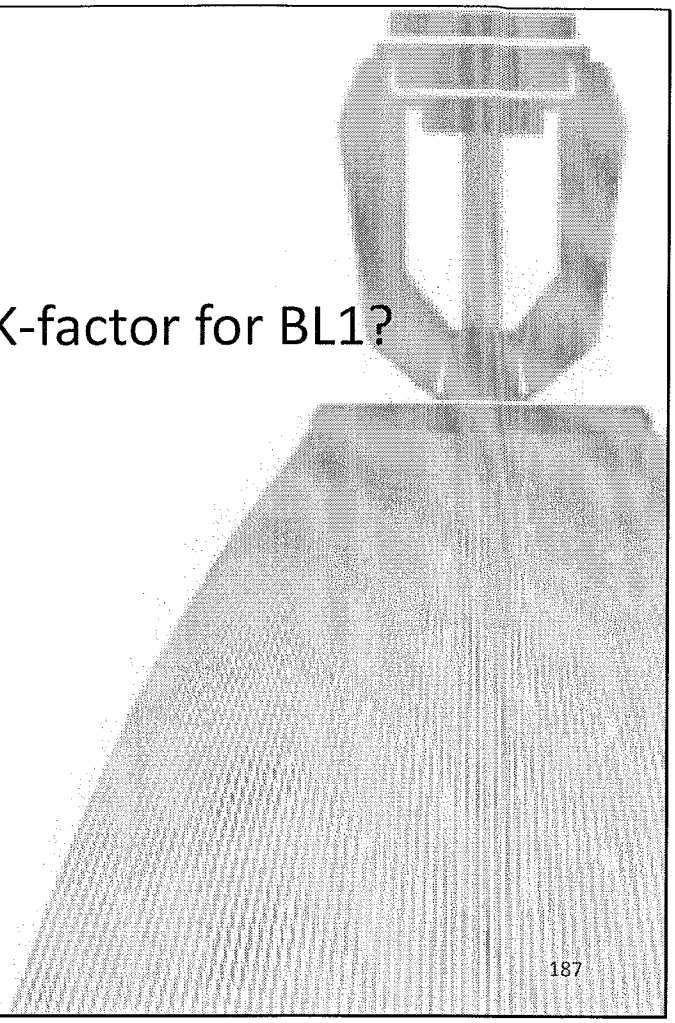
Activity 7.5

What is the equivalent K-factor for BL1?

_____



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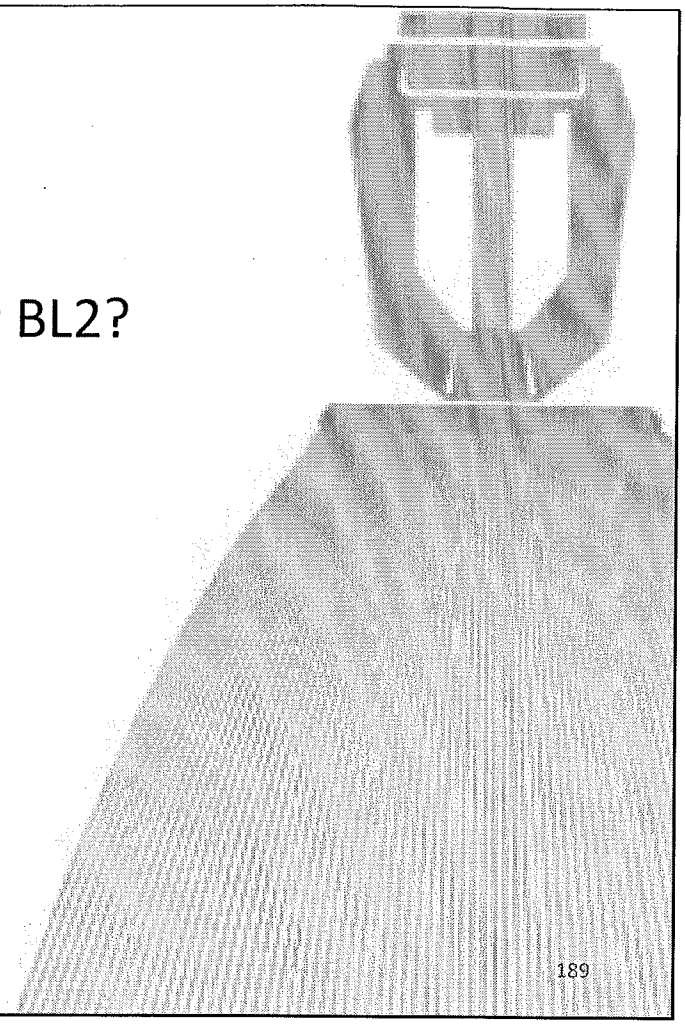
Activity 7.5

What is the K-factor for BL2?

K = _____



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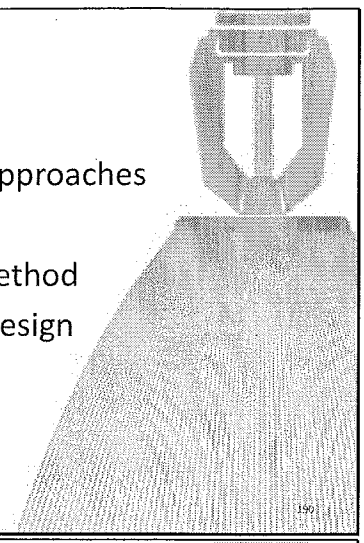
Wrap-up

- Hydraulic design approaches
  - –Water Curtain
  - –Room Design Method
  - –Rack Sprinkler Design



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Seminar Conclusion

- Hydraulic Calculations
  - –Manual Calculations
    - Better understanding
    - Time consuming, tedious
  - –Computer Calculations
    - Quick, efficient



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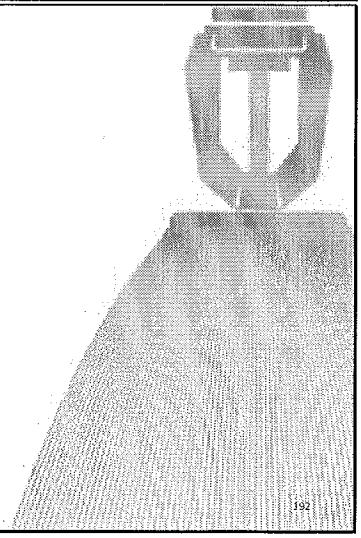
Q & A

- Fill out evaluations
- THANK YOU!



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