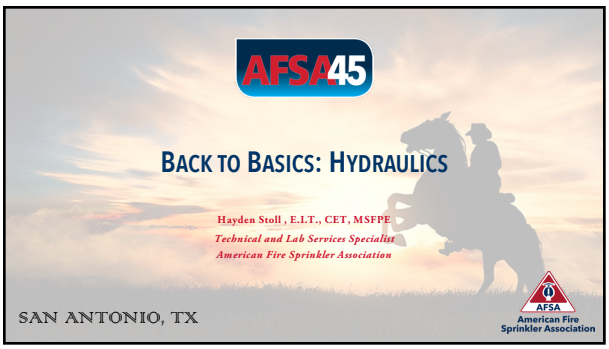
AFSA45
BACK TO BASICS: HYDRAULICS
Hayden Stoll , E.I.T., CET, MSFPE
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SAN ANTONIO, TX
AFSA
American Fire Sprinkler Association

1

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AMERICAN FIRE SPRINKLER ASSOCIATION
Hayden Stoll is a technical services specialist for the American Fire Sprinkler Association (AFSA). He earned his Bachelor of Science from the University of Maryland-College Park in fire protection engineering. He has experience with design engineering applied to fire protection systems, as well as inspection, testing, and maintenance of fire protection systems for the National Park Service including private hydrant maintenance and conducting risk and life safety analyses for historic buildings. He also has experience installing and maintaining fire protection systems for Strickland Fire Protection, a Pye-Barker Company.
AFSA
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Email: hstoll@firesprinkler.org | Phone: 214-349-5965

2

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The authority on fire, electrical, and building safety
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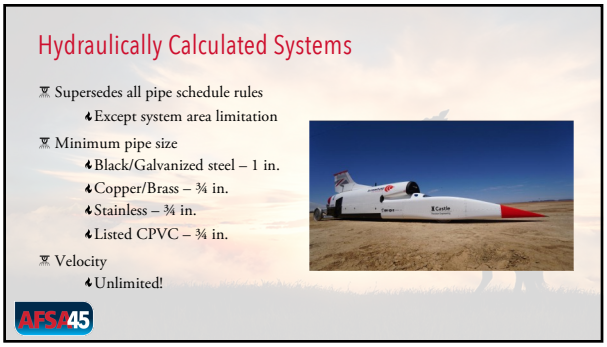
Hydraulically Calculated Systems
Supersedes all pipe schedule rules
Except system area limitation
Minimum pipe size
Black/Galvanized steel – 1 in.
Copper/Brass – ¾ in.
Stainless – ¾ in.
Listed CPVC – ¾ in.
Velocity
Unlimited!
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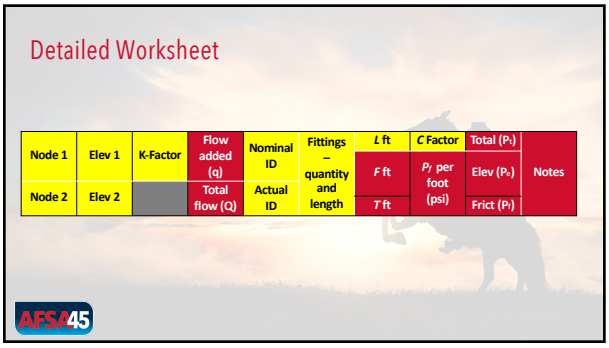
4


Detailed Worksheet
Node 1
Elev 1
K-Factor
Flow added (q)
Nominal ID
Fittings – quantity and length
L ft
C Factor
Total (Pt)
F ft
Pf per foot (psi)
Elev (Pe)
Notes
Node 2
Elev 2
Total flow (Q)
Actual ID
T ft
Frict (Pf)
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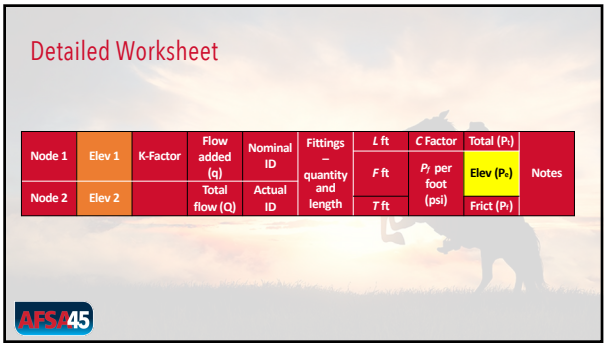
5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Elev 1
K-Factor
Flow added (q)
Nominal ID
Fittings – quantity and length
L ft
C Factor
Total (Pt)
F ft
Pf per foot (psi)
Elev (Pe)
Notes
Node 2
Elev 2
Total flow (Q)
Actual ID
T ft
Frict (Pf)
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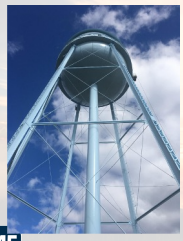
6

Elevation Pressure



$$\Delta P = 0.433h$$

- Where:
  - ΔP is the change in pressure in psi
  - h is the height between two reference points in ft

h = Elev 1 – Elev 2

7

Detailed Worksheet

Node 1 / Node 2	Elev 1 / Elev 2	K-Factor	Flow added (q) / Total flow (Q)	Nominal ID / Actual ID	Fittings – quantity and length	L ft / F ft / T ft	C Factor	Total (P_t) / Elev (P_e) / Frict (P_f)	Notes
1	15 ft								
2	12 ft							1.3 psi	

$\Delta P = 0.433h$

$h = E_1 - E_2 = 15\text{ ft} - 12\text{ ft} = 3\text{ ft}$

$\Delta P = 0.433(3\text{ ft}) = 1.299 = 1.3\text{ psi}$

8

Detailed Worksheet

Node 1 / Node 2	Elev 1 / Elev 2	K-Factor	Flow added (q) / Total flow (Q)	Nominal ID / Actual ID	Fittings – quantity and length	L ft / F ft / T ft	C Factor	Total (P_t) / Elev (P_e) / Frict (P_f)	Notes

9

Calculating Friction Loss

- Hazen-Williams equation:

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

- Where,
  - p is the pressure loss per foot (psi/ft)
  - Q is the flow (gpm)
  - C is the friction loss coefficient
  - d is the actual internal diameter (in.)

Section 28.2.2.1.1

10

Calculator Friendly Arrangement

p = 4.52 × Q^1.85 ÷ C^1.85 ÷ d^4.87

11

C Values

Hazen-Williams C Values	
Unlined cast or ductile iron	100
Black steel (dry systems including preaction)	100
Black steel (wet systems including deluge)	120
Black steel (dry system including preaction) using: nitrogen, vacuum pressure, or vapor corrosion inhibitors†	120
Galvanized steel (dry systems including preaction)	100
Galvanized steel (wet systems including deluge)	120
Galvanized steel (dry system including preaction) using nitrogen, vacuum pressure, or vapor corrosion inhibitors†	120
Plastic (listed) all	150
Cement-lined cast- or ductile iron	140
Copper tube, brass or stainless steel	150
Asbestos cement	140
Concrete	140

Table 28.2.4.8.1

12

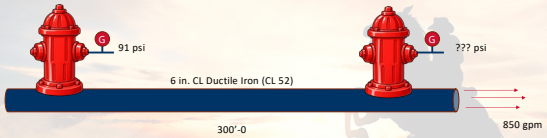
Internal Diameters of Pipe

- Underground pipe
  - Annex of "Installation of Underground Piping"
- Aboveground pipe
  - Annex of "Installation of Piping, Valves and Appurtenances"

Table A.6.2.3 and Table A.16.3.2

13

Example



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Calculating Friction Loss

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

$$p = \frac{4.52 \; x \; 850^{1.85}}{140^{1.85} \; x \; 6.16^{4.87}}$$

$$p = 0.018 \text{ psi/ft}$$

Flow was given:

$Q = 850$ gpm

C Value for Cement Lined Ductile Iron:

$C = 140$

Actual Internal Diameter for 6 in. CL Ductile Iron

$d = 6.16$ in.

15

Pipe and Equivalent Length of Fittings

- Hazen-Williams results in psi/ft
- Need to multiply by total length of pipe + fittings

16

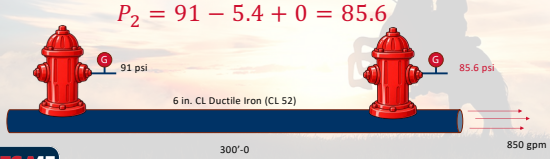
Example

$$P_f = p \; x \; (L + L_f)$$

$$P_f = 0.018 \; x \; (300 + 0) = 5.4 \text{ psi}$$

$$P_2 = P_1 - P_f + P_e$$

$$P_2 = 91 - 5.4 + 0 = 85.6$$



17

Pipe and Equivalent Length of Fittings

- H-W results in psi/ft
- Need to multiply by total length of pipe + fittings

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Calculating Friction Loss

- Includes
  - Pipe
  - Fittings
  - Valves
  - Meters
  - Flow switches
  - Strainers
  - Elevation changes

Section 28.2.4.8

19

How to Calculate Fittings

- Tee or cross
  - Where the flow changes direction
  - Equivalent length based on the step the fitting is included
- Standard elbow
  - Abrupt 90-degree turn
  - Screw-type
- Reducing elbow
  - Based on the smallest outlet

Section 28.2.4.8

20

Detailed Worksheet

Node 1	Elev 1	K-Factor	Flow added (q)	Nominal ID	Fittings – quantity and length	*L* ft	*C* Factor	Total (P_t)	Notes
Node 2	Elev 2		Total flow (Q)	Actual ID		*T* ft	P_f per foot (psi)	Frict (P_f)	

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Equivalent Lengths of Fittings

Fittings and Valves Expressed in Equivalent Feet of Pipe

Fittings and Valves	¾ in.	1 in.	1-1/4 in.	1-1/2 in.	2 in.	2-1/2 in.	3 in.	3-1/2 in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
45º elbow	---	1	1	1	2	2	3	3	3	4	5	7	9	11	13
90º standard elbow	1	2	2	3	4	5	6	7	8	10	12	14	18	22	27
90º long-turn elbow	0.5	1	2	2	2	3	4	5	5	6	8	9	13	16	18
Tee or Cross	3	4	5	6	8	10	12	15	17	20	25	30	35	50	60
Butterfly	---	---	---	---	---	6	7	10	---	12	9	10	12	19	21
Gate	---	---	---	---	---	1	1	1	1	2	2	3	4	5	6
Flow Switch	---	---	6	9	10	14	17	22	---	30	---	16	22	29	36
Swing Check	---	---	5	7	9	11	14	16	19	22	27	32	45	55	65

Values above based on Schedule 40 pipe with a C Value of 120*

Table 28.2.3.1.1

22

Pipe and Equivalent Length of Fittings

- Pipe is **NEVER** adjusted
- Fittings have an equivalent length
  - Listed in manufacturer's data sheet
  - Table in NFPA 13
- Based on Sch. 40 pipe
- Based on *C* Value of 120

C Value Multiplier				
Value of C	100	130	140	150
Multiplying Factor	0.713	1.16	1.33	1.51

$$Factor = \left(\frac{100}{120}\right)^{1.85} = 0.713$$

$$Factor = \left(\frac{d_{actual}}{d_{40}}\right)^{4.87}$$

Section 28.2.3.1.3

23

Equivalent Length Example

What is the total equivalent length of pipe and fittings for a hydraulic calculation step for a dry pipe sprinkler system that includes 10 ft of 2 in. Schedule 10 black steel pipe, 1 TEE (changes direction), and 2 90-degree ELs?

$$Factor = \left(\frac{d_{actual}}{d_{40}}\right)^{4.87}$$

$$Factor = \left(\frac{2.157}{2.067}\right)^{4.87}$$

$$Factor = 1.23$$

C Value
Table 28.2.3.2.1
0.713

2 in. pipe @10 ft No adjustments = 10 ft
2 in. TEE @ 10 ft × 1 × 1.23 × 0.713 = 8.8 ft
2 in. EL @ 5 ft × 2 × 1.23 × 0.713 = 8.8 ft

Total equivalent length = 27.6 ft

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Node Analysis

$$Q = K\sqrt{P} \qquad P = \left(\frac{Q}{K}\right)^2 \qquad K_n = \frac{Q}{\sqrt{P}}$$

$Q = 5.6 \times \sqrt{10\ psi}$

$Q = 5.6 \times 3.16$

$Q = 17.71$ gpm

$P = \left(\frac{22\ gpm}{5.6}\right)^2$

$P = (3.93)^2$

$P = 15.434$ psi

$K_n = \frac{100\ gpm}{\sqrt{25\ psi}}$

$K_n = \frac{100\ gpm}{5}$

$K_n = 20$ gpm x psi$^{-1/2}$

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Balancing Hydraulic Junction Points

- Balanced within 0.5 psi
- Highest pressure
- Combined (adjusted) flows
- Use of K-Factors permitted

Section 28.2.2.4

26

Hydraulic Balancing Process

- Identify the lower pressure node (N_{LP})
  - Find the K_n for that node
  - Balance flow up to the pressure of the higher pressure node (N_{HP})
- Add the adjusted flow of the N_{LP} to the unadjusted flow of the N_{HP}
- Use pressure from N_{HP}

$$K_n = \frac{Q}{\sqrt{P}}$$

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

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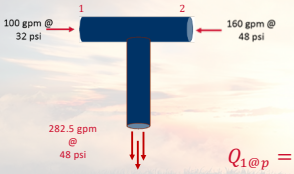
Hydraulic Junction Points

Example 1



$$Q_c = Q_{1@p} + Q_2$$

$$K_1 = \frac{Q_1}{\sqrt{P_1}}$$

$$K_1 = \frac{100\ gpm}{\sqrt{32\ psi}} = 17.678$$

$$Q_{1@p} = K_1\sqrt{P_2}$$

$$Q_{1@p} = 17.678\sqrt{48\ psi} = 122.5\ gpm$$

$$Q_c = 122.5 + 160\ gpm = 282.5 \text{ gpm}$$

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K-Factors for Branch Lines

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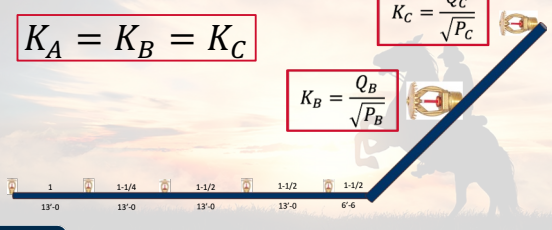
K-Factors for Branch Lines

$$K_A = K_B = K_C$$

$$K_C = \frac{Q_C}{\sqrt{P_C}}$$

$$K_B = \frac{Q_B}{\sqrt{P_B}}$$



30

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✓ Attend full seminar
✓ Complete survey 1 of 2 ways:
✓ Survey link is emailed to attendees with scanned badges
✓ Event app by EventsAir
• Login to app
• Navigate to seminar survey
✓ Surveys close 10/31/26
Thank you!
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hstoll@firesprinkler.org
AFSA45
Scan QR code to submit questions for Ask the Experts!

31

2027 Training Schedule

WEBINARS

1/6	Updates to NFPA 20
1/20	Calculating Pressure Reducing Hose Valves
2/3	Consumer Alert: Nitrogen in Sprinkler Systems
2/17	Reviewing Hydraulic Calculations
3/3	Updates to NFPA 13, 2028 Ed.
3/17	Updates to NFPA 13R & 13D, 2028 Eds.
4/7	Topic Coming Soon
4/21	NFPA 25: Roles & Responsibilities
5/5	Standpipe Flow Test Procedures
5/19	Storage 101
6/2	NFPA Technical Meeting - Voting Guide
6/16	Topic Coming Soon
6/30	Topic Coming Soon
7/7	Updates to NFPA 14, 2027 Edition
7/21	Adjacent Hazards & Design Methods
8/4	Acceptance Testing
8/18	Modifications to Existing Systems
9/22	Topic Coming Soon
10/6	Seismic 101
10/20	Proposed Updates to NFPA 25, 2029 Ed.
11/3	Evaluating Fire Pump Flow Tests
11/17	Top 10 Tech Reviews
12/1	Designing Water Storage Tanks
12/15	Pump Room Layout

PROGRAMS

Feb 9 - Mar 5 Apr 20 - May 14 Aug 3 - Aug 27** Oct 26 - Nov 19	Beginning Design School*
Apr 26 - May 7 Nov 1 - 12	Intermediate Design School*
Feb 8 - 10** Apr 12 - 14 Jul 12 - 14 Oct 11 - 13	Sprinkler Hydraulics Calculations Workshop
Apr 19 - 21 Oct 18 - 20	Advanced Hydraulics Calculations Workshop
Feb 11** Apr 30 Jul 23 Sep 24	Introduction to the Fire Sprinkler Industry
Mar 1 - 3 May 17 - 19 Aug 16 - 18 Oct 18 - 20**	NFPA 25 Essentials Workshop
Jun 7 - 10 Sep 20 - 23	Experienced Inspector Skills Lab
Mar 4 - 5 May 20 - 21 Aug 19 - 20 Oct 21 - 22**	NFPA 25 Fire Pump Workshop
Spring Summer Fall	ITM Inspector Development Program* *This program is 20 months.*

** Hybrid course **At General Air Products Lab, Exton, PA*

AFSA46

September 8-11	Manchester Grand Hyatt San Diego, CA

For More Details Visit:
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Dates subject to change. Programs subject to minimum registrations.

rev 9/14/2026

Virtual Instruction Path (VIP)

for Sprinkler Fitting Apprentices

Level 1 - Begins January 2027

Level 2 - Begins February 2027

Level 3 - Begins January 2027

Level 4 - Begins March 2027

www.firesprinkler.org/VIP

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HANDS-ON WORKSHOPS FOR 2027

FEATURING AFSA'S TRAINING LAB

NFPA 25 Essentials Workshop

Mar | May | Aug | Oct

Description: Understand roles, responsibilities, and NFPA 25 ITM procedures through hands-on testing of wet systems, dry systems, and fire pumps.

NFPA 25 Fire Pump Workshop

Mar | May | Aug | Oct

Description: Develop practical NFPA 25 fire pump ITM skills, including no-flow and full-flow testing, water supply graphing, and performance evaluation.

Introduction to the Fire Sprinkler Industry

Feb | Apr | Jul | Sep

Description: This course is designed for those new to the industry. An introductory, wide-ranging 8-hour course that provides a broad overview of core fire sprinkler industry concepts for those new to the field.

Experienced Inspector Skills Lab NEW

Mar | Sep

Description: Take your ITM expertise beyond the basics. Designed for experienced technicians, this course combines focused classroom instruction with hands-on system lab training to strengthen your application of current NFPA 25 inspection, testing, and maintenance requirements. Refine fire sprinkler testing practices, improve documentation, deliver more consistent service, and help reduce liability while reinforcing knowledge commonly covered on certification exams.

Learn more about AFSA's fire sprinkler lab featuring functional risers, a spray room, fire pumps, and an interactive classroom.

firesprinkler.org/lab