Fire Protection Hydraulics and Water Supply Analysis

FPST 2483 Unit 06
Analysis of Looped and Gridded systems

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Module objective

- Upon completing this module, the student should be able to:
  - Use the try and error method for a simple loop;
  - Apply the split flow formula.
  - Use equivalent length in complex loops
  - Understand and use Hardy-cross method in loop calculations

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Friction Loss in Loops and Grids

- Why loop is important?
  - Multiple supplies of water
  - Balance of forces
- Simple Loops
- Complex Loops
- Piping Systems

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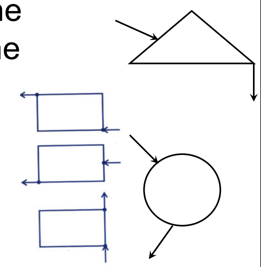
Simple Loops

- There is exactly one inflow point and one outflow point.
- Exactly two paths exist between the inflow and outflow points.



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Simple Loops

Additional Concepts:

- **Total flow** in must equal flow out
- Total flow must equal sum of two paths
  $Q_t = Q_1 + Q_2$
- **Friction loss** must be equal in each path
- The total friction loss equals one path, not sum of two paths
  $P_{ft} = P_{f1} = P_{f2}$

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What goes in comes out.

- The 'total" friction loss across a loop is <u>not</u> the sum of losses in the two legs, but only the loss in either leg.
- In order to solve for friction loss in simple loops, the flow split must first be established.
  - Many methods are possible; all based upon energy balance across the loop.
  - Two methods will be presented

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Trial and Error

A. An estimate of the flow split is made and friction loss calculated for each leg.

B. If the loss is equal in each leg, the solution has been reached.

Pf within 0.5psi

C. If the loss is not equal, the flows must be adjusted and tried again

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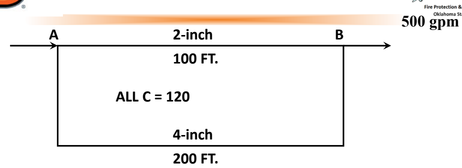
Example



ALL SCHEDULE 40 STEEL

First Try

$$Q_1 = 150 \rightarrow P_{f1} = \frac{4.52 \times 150^{1.85}}{120^{1.85} \cdot 2.067^{4.87}} = .199 \times 100 = 19.9 \text{ psi}$$

$$Q_2 = 350 \rightarrow P_{f2} = \frac{4.52 \times 350^{1.85}}{120^{1.85} \cdot 4.026^{4.87}} = .037 \times 200 = 7.4 \text{ psi}$$

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Example 1 Continued

Second Try

$$Q_1 = 75 \rightarrow P_{f1} = .055 \times 100 = 5.5 \text{ psi}$$

$$Q_2 = 425 \rightarrow P_{f2} = .053 \times 200 = 10.6 \text{ psi}$$

Third Try

$$Q_1 = 100 \rightarrow P_{f1} = .093 \times 100 = \boxed{9.3 \text{ psi}}$$

$$Q = 400 \rightarrow P = .048 \times 200 = \boxed{9.6 \text{ psi}}$$

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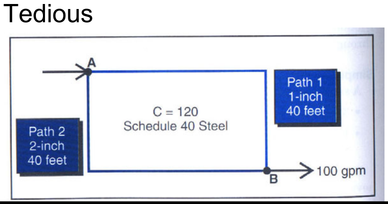
Method I: try and error

- Educated guesses
- Multiple calculations
- 0.5 psi is close enough
- Slow & Tedious



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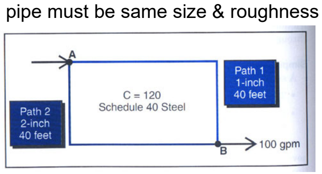
Method II

- Solution reached directly using the split flow formula

$$Q_1 = \frac{Q_t}{1 + \left(\frac{L_1}{L_2}\right)^{0.54}}$$

- No consideration for pipe size and roughness
- All pipe must be same size & roughness



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Method II

- If pipe does not have the same diameter and roughness, it must be converted to equal size & roughness by adjusting length of pipe.

$$P_T = \frac{4.52 Q^{1.85} L}{C^{1.85} D^{4.87}}$$

$$Q_1 = \frac{Q_t}{1 + \left(\frac{L_1}{L_2}\right)^{0.54}}$$

$$L_e = L_1 \cdot \frac{D_e^{4.87}}{D_1^{4.87}} \cdot \frac{C_e^{1.85}}{C_1^{1.85}}$$

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Split flow formula

Derivation

$$Q_1 = \frac{Q_T}{1+\left(\frac{L_1}{L_2}\right)^{0.54}}$$

$$Q_1 + Q_1 \cdot \left(\frac{L_1}{L_2}\right)^{0.54} = Q_T$$

$$Q_1 \cdot \left(\frac{L_1}{L_2}\right)^{0.54} = Q_2$$

$$Q_1 \cdot L_1^{0.54} = Q_2 \cdot L_2^{0.54}$$

$$Q_1^{1.85} \cdot L_1 = Q_2^{1.85} \cdot L_2$$

$$P_T = \frac{4.52 Q^{1.85} L}{C^{1.85} D^{4.87}}$$

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Notes about Method II

- Always use actual internal diameter (Appendix A) in calculations, so you need to know the material and/or schedule type.
- Change one branch to match another branch. Do not change both, you will get lost by doing so.
- Conservations of energy (pressure loss) and matter (mass) are fundamental rule in these manipulations.

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Summary

- Loops and grids are composed of segments of simple pipes.
- Hand calculation is useful to understand the algorithm in computer software.
- Method I: try and error
- Method II: split-flow formulation with equivalent length
- Method III: Hardy-cross method (next lecture)

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