Fire Protection Hydraulics and Water Supply Analysis

FPST 2483 Chapter 6

Intro to Hardy-Cross Method

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Module objective

- Upon completing this module, the student should be able to:
  - Understand the principles in Hardy-cross method
  - Follow the procedure in Hardy-Cross method
  - Solve problems

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Complex Loops

- Method 2 will NOT work
- A traditional approach to manually solving for the flow split and friction loss in complex systems is known as the Hardy Cross technique
- This is a tedious iterative approach presenting many possibilities for mistakes

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Important Considerations

- Hardy Cross is an approximate method. Answers may be rounded to the nearest 10 gpm.
- Initial step is always drawing a flow diagram showing pipe lengths and sizes and all flow inputs and outputs.
- In labeling assumed flows around the loop, clockwise flows are considered to be positive and counter clockwise flow is considered to be negative.

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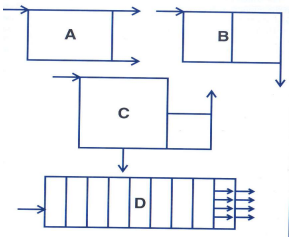
Complex Loops

One or more of the following:

- More than one inflow point
- More than one outflow point
- More than two paths between input and output



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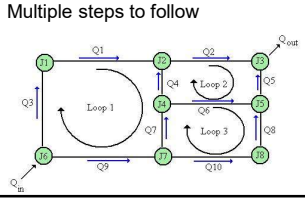
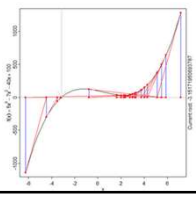
Hardy Cross Method

- Hardy Cross's method/technique, also known as the moment distribution method, works on the principle of balancing circuit pressure drop by correcting assumed flows.
- Developed in early 1900's
- Used to determine flows in complex systems
- Multiple steps to follow





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Who is Hardy Cross?

- **Hardy Cross,** (b. Feb. 10, 1885, Nansemond County, Va., U.S.—d. Feb. 11, 1959, Virginia Beach, Va.), U.S. professor of civil and structural engineering whose outstanding contribution was a method of calculating tendencies to produce motion (moments) in the members of a continuous framework, such as the skeleton of a building.
- Cross was appointed professor of structural engineering at the University of Illinois, Urbana, in 1930; seven years later he became full professor at Yale, retiring in 1951. Among other honours, he received the Institution of Structural Engineers' (British) gold medal.

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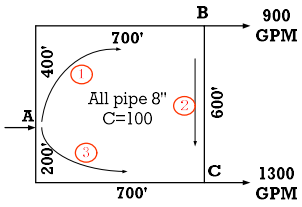
Hardy Cross

- Step 1
- Make *a line drawing of system*, all in points and outpoints, pipe diameters, C factors, and lengths



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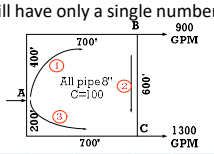
Hardy Cross

- Step 2
  - *Number each pipe line* with an Arabic numeral, each pipe of different flow, C factor or diameter must be numbered. A pipe common to two loops will have only a single number.
  - Copy information down in the right order.



LINE NO	SIZE (inches)	C-Factor	LENGTH (feet)	Q (gpm)	Pf (PSI)	1.85Pf Q	CORREC-TION	Q GPM	Pf (PSI)
1	8	100							
2	8	100							
3	8	100							

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Hardy Cross

- Step 3
  - Number Each Loop, including any imaginary loops
    - If Using the Nomograph, convert all pipes to *an equivalent length of 8 inch pipe with a C of 100*. This allows the nomograph to be used.
  - Copy all data to Hardy Cross worksheet
  - Every pipe must be shown in two loops (imaginary loops are used in multi-loop systems)

LINE NO	SIZE (inches)	C-Factor	LENGTH (feet)	Q (gpm)	Pf (PSI)	1.85Pf Q	CORREC-TION	Q GPM	Pf (PSI)
1	8	100	1100						
2	8	100	600						
3	8	100	900						

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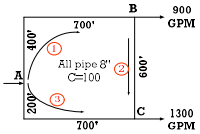
Hardy Cross

- Step 4
  - Estimate flows in every pipe (guess the first one in first iteration)
  - The flow exiting must equal flow entering
  - *Conservation of matter*

LINE NO	SIZE (inches)	C-Factor	LENGTH (feet)	Q (gpm)
1	8	100	1100	1000
2	8	100	600	100
3	8	100	900	-1200



Flows must be shown as positive or negative
Clockwise are positive
Counter-clockwise are negative
Each pipe will never have the same sign in two loops

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Hardy Cross

- Steps 5/6/7/8
  - With all data entered
  - *Calculate* friction loss from Hazen Williams formula or chart
    - Note: Hazen Williams is in PSI, but chart below requires it to be in feet if using the nomograph
  - Showing negative or positive results
  - Add up friction loss values for each loop

$$Pf = \frac{4.52 \times Q^{1.85} \times L_e}{C^{1.85} \times D^{4.87}} = \_\_\_\_ \text{ psi}$$

LINE NO	SIZE (inches)	C-Factor	LENGTH (feet)	Q (gpm)	Pf (PSI)	1.85Pf Q	CORREC-TION	Q GPM	Pf (PSI)
1	8	100	1100	1000	14.1				
2	8	100	600	100	0.11				
3	8	100	900	-1200	-16.1				
					-1.89				

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Hardy Cross

- Steps 7/8
  - Find NH/Q via the nomograph, or simply calculate 1.85*Pf/Q.
  - The values of 1.85*Pf/Q should all be summed

LINE NO	C Factor	SIZE INCHES	LENGTH FEET	Q GPM	Pf (PSI)	1.85Pf Q	CORREC-TION	Q GPM	Pf (PSI)
1	100	8	1100	1000	14.1	.03			
2	100	8	600	100	0.12	0.002			
3	100	8	900	-1200	-16.1	.025			
					-1.89	.057			

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Hardy Cross

- Step 9
  - The sum of friction loss divided by 1.85Pf/Q
  - Step 9 is for systems without multiple loops.
    - This results in *a "correction" factor* which is added to each pipe. Steps 7, 8, & 9 repeated until the sum of the friction loss, Pf is less than or equal to 1.0 psi

LINE NO	C Factor	SIZE INCHES	LENGTH FEET	Q GPM	Pf (PSI)	1.85Pf Q	CORREC-TION	Q GPM	Pf (PSI)
1	100	8	1100	1000	14.1	.03	+30	1030	
2	100	8	600	100	0.12	0.002	+30	130	
3	100	8	900	-1200	-16.1	.025	+30	-1170	
					-1.89	.057	-33		

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Hardy Cross

- Step 10 (Next Week!)
  - Double correction is needed for multiple flows/loops
  - Create correction factor for each loop
  - Create a 2nd correction factor for pipes in a second loop keeping sign (+ or -).
  - *Repeated in all loops until the sum of the friction loss Pf is less than or equal to 1.0 psi in ALL loops*

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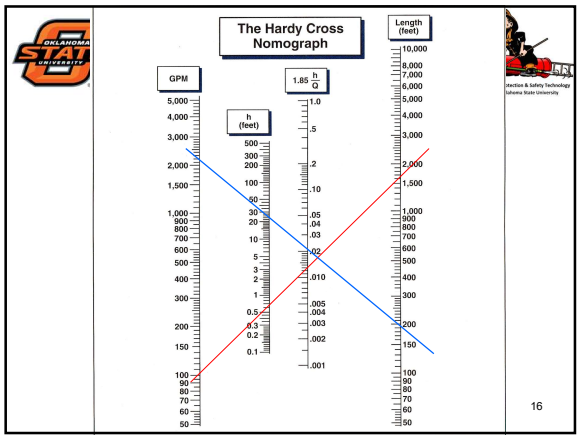

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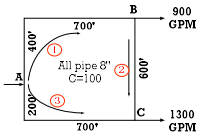
Finish the first problem

Total Friction loss between:
Points A-B?
Points A-C?



LINE NO	C Factor	SIZE INCHES	LENGTH FEET	Q GPM	Pf (PSI)	1.85Pf Q	CORRECTION	Q GPM	Pf (PSI)
1	100	8	1100	1000	14.1	.03	+30	1030	14.9
2	100	8	600	100	0.12	0.002	+30	130	0.2
3	100	8	900	-1200	-16.1	.025	+30	-1170	-15.4
					-1.89	.057	-33		-0.3

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Hardy Cross

- ***Don't get discouraged***
- Understanding manual method will help in gathering data for programs.
- Computer programs are repeating the hand-calculation steps, faster and more efficient.

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Summary

- Assume flows
- Calculate friction loss around paths
- Compare friction loss values
- If friction losses are not the same, calculate a correction factor for the flows. If friction losses are the same (within 1 psi) or the correction factor is less than 1 gpm, go to Step 9.
- Apply correction factor to flows
- Repeat steps as necessary
- End; record final flows and fiction loss

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